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INVESTIGATING THE IMPACT OF TECHNOLOGICAL INNOVATION AND RENEWABLE ENERGY ON ENVIRONMENTAL POLLUTION IN THE SELECTED COUNTRIES WITH HIGH POLLUTION

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ABSTRACT

The extensive consumption of non-renewable energies as well as the widespread increase in economic activities in recent decades has had caused great environmental impacts. These impacts include the Earth temperature increase, climate change, sea level rising, and finally international disputes exacerbation. Some countries have made extensive efforts in recent years to make greater use of the potential of renewable energies for technological innovation. These efforts are in line with increasing the benefits of using these energies and new technologies and comply with international agreements to reduce the Earth temperature. In this paper, panel quantile regression model was examined to evaluate the effects of technological innovation and renewable and non-renewable energy consumption on CO2 emission rate in 15 countries with high CO2 emissions during 1990–2016**.** The results of the present study revealed that renewable energies and technological innovations had significant and negative effects on CO2 emissions. The effect of non-renewable energies on CO2 emissions was positive and significant.

JEL Classification: C32, O52, Q43, Q50

INTRODUCTION

There has been a growing consensus among, energy and environmental thinkers over the last decades on the threatening effects of climate change on human life and environmental quality for future generations (Sadorsky, 2009; Danish et al., 2017; Filho et al., 2018). Extensive studies have indicated that reducing greenhouse gas emissions is essential to reduce climate changes (Perez et al., 2017; Lu et al., 2017). The environmental issues have been incorporated into political decisions, especially the decisions related to growth and development policies. Natural resources have been considered as inputs needed for production and environmental quality as a welfare criterion. The association of environmental issues with economic variables and development theories and experiences is under investigation at a large level (Valeria, 2006). The studies conducted over the last years on the factors affecting the greenhouse gas emissions have focused on renewable energies and new technologies (Zhang and Cheng, 2009; Yu and Du, 2018). Following industrial revolution, especially in recent decades, with the use of more energy, the average productivity of the production factors has been increased, but the use of energy has caused more damage to the environment due to its polluting effects. The environmental consequences of global warming and climate change and greenhouse gas emissions have caused increasing concerns on renewable energy consumption and people tendency for using renewable energy has been increased as one of the most important characteristics of renewable energy is reducing carbon dioxide emissions and contribution to protect the environment (Zhang, 2011; Mayer & Kent, 2007). The consumption of renewable energies as created energy sources can reduce the growing concerns about greenhouse gas emissions, high price, volatile energy and dependency on external energy sources (Khoshnevis Yazdi and Shakouri, 2017). Additionally, investment in research and development expenditure and changes in technology can reduce CO2 emissions (Jones, 2002). Therefore, technological innovations play a key role in reducing energy consumption and improving energy efficiency (Sohag and Begum, 2015). Moreover, to explain the effect of innovation on carbon dioxide emissions, growth models have been also used, as innovation indirectly affects greenhouse gas emissions through increased production and capital and energy consumption (Kumar et al., 2012).

Challenging approaches have been raised on the effects of technological innovation on the environment in recent years. Endogenous growth literature suggests that technological innovation can have a positive effect on the environment in the long term. According to economists reasoning, technological innovation, leads to increased investment, directly and indirectly, by reducing the cost of information and exchanges, increasing the productivity of production factors, increasing savings and improving the flow of allocation of the resources. As a result, it has positive effects on the environment. In contrast to this perspective, some economists believe that technological innovation can cause damage environment. They argue that if technological innovation improves resources allocation and increases savings efficiency, the savings rate might decrease, leading to a credit crisis and it will damage the environment by reducing investment (Dogan, 2016). Hence, examining the relationship requires empirical investigation. Environmental pollution is one of the most challenging issues in today's world. Many researchers have discussed on this issue. Various methods, approaches and examples have provided contradictory results, and investigations in this area continue. Accordingly, the aim of this study was to evaluate the effects of technological innovation and renewable energies on environmental pollution in the countries with high levels of pollution based on the classification of International Renewable Energy Agency (IRENA) using quantile regression during 1990-2016.

Review of literature

Two different approaches have been used in natural resources research in the last few decades. The first approach considers the effect of natural resources on economic growth. Many researchers have investigated the relationship between energy consumption and economic growth (Cheng, 1995; Stern, 2004; Lee & Chang, 2007).The second approach considers the effects of natural resources and macroeconomic variables on the quality of environment (Grossman and Kruger, 1991; Zhang & Cheng, 2009; Choi et al., 2011; Lin et al., 2016). One of the main causes of global warming is greenhouse gas emissions, which have a direct relationship with the energy consumption of countries. Ecological economists such as Ayers and Nair (1984) argue that in the biophysical model of growth, energy is the only and the most important growth factor. They argue that workforce and capital are the intermediary factors that need energy to be used. However, some neoclassical economists, such as Berndt and Denison (2011) argue that energy has an indirect effect on economic growth through its impact on workforce and capital and does not directly affect economic growth. These economists argue that energy is an intermediary input and capital and land are the basic factors of production.

However, uncontrolled and excessive use of energy, especially fossil fuels, to meet the goal of economic growth has increased environmental pollution. Non-renewable energies are consumed in human daily activities, but burning large quantities of these non-renewable energies increases carbon dioxide in the atmosphere. Annually, more than 3 billion tons of carbon dioxide is released due to burning of non-renewable energy, which significantly exceeds the recyclability through nature, and these gases remain in the atmosphere for a long time, leading into global warming. The global temperature has been increased by 1.02 ° C during the years 1900-2015. This increase in temperature has resulted in climate change. The natural disaster caused by climate change can lead into human harm and death. Reports suggest that if humans do not take any action about greenhouse gas emissions by 2030, the global average temperature will probably increase by 4 ° C.

Meyer and Kant (2007) have stated that the average efficiency of production factors has been increased after the industrial revolution, especially in recent decades due to increased energy use and it has caused more environmental degradation due to its pollutant effects, so that the energy sector is the primary cause of environmental change. Thus, it can be stated that energy policy and environmental policy are closely related. Moreover, distribution of the imported goods to a country requires a transportation network for imports distribution and this transportation network is fueled by energy. In addition, imported goods can affect energy consumption depending on the composition of the goods. Sustainable imported goods such as cars, refrigerators, etc. are major energy users, and an increase in these types of imported goods will increase the demand for energy, and increasing energy consumption will in turn have a positive effect on CO_2 production (Sadorsky, 2010).

In addition, recent biomedical studies have shown that developing countries are most vulnerable to increased climate change and environmental hazards, and if an appropriate action is not taken, they will have higher consequences than predicted. The environmental consequences of global warming and climate change and greenhouse gas emissions have increased concerns about renewable energy consumption, and people have showed greater tendency for using renewable energy, as the most important characteristics renewable energy is reducing CO_2 and contributing to environment protection. Consumption of renewable energies as generated energy sources can reduce the increasing concerns about greenhouse gas emissions, high prices, volatile energy and dependency on external energy sources (Khoshnevis Yazdi and Shakouri, 2017). In international trade, countries also seek strategic policies to achieve their business goals. It is believed that adopting strict environmental policies reduces the competitiveness of firms in the country; while, these policies in practice have improved the performance of companies in some countries and created a competitive advantage for them.

Porter and Vonderlinde (1995) have presented numerous case studies in which a strict environmental policy has led into lower production costs. The idea that strict environmental business policy improves the performance of the whole firm is known as the Porter's hypothesis and it is called as the green strategy. Moreover, as a result of the expansion of trade, the volume of economic activities (including polluting activities) has been expanded and the use of resources and energy has been increased inappropriately. In addition, expansion of trade and increased competitive pressures between domestic firms and foreign competitors reduce the strictness of environmental policies and even delay the passing and implementation of national environmental rules in the face of free trade process and increase greenhouse gas emissions (Panayotou, 1999). Additionally, population growth, poverty and environmental degradation in developing countries have created a vicious cycle. Hence, this vicious cycle has severely affected the quality of people's lives and has made the effort of developing countries to achieve sustainable development fruitless. Water, soil, air, and living creatures are the four most important and needed natural resources that meeting human needs depends on them.

Rapid population growth will result in reduced crop yields and water scarcity. Soil erosion, deforestation and water quality decline are the side effects of increasing the number of humans. In general, population pressure leads into environmental degradation and poverty and leave unpleasant effects on the environment. The excessive and uncontrolled population increase will increase the carbon dioxide emissions through factors such as more consumption, expansion of public transportation, increased energy consumption and CO_2 emissions. Energy consumption in the transportation sector accounts for about 27% of global energy demand and 22% of total carbon dioxide emissions (International Energy Agency, 2012). Transportation is the fastest growing sector in the world in terms of energy consumption and CO_2 emissions. Therefore, reducing the share of CO_2 emissions from the transportation sector is a major challenge in achieving climate change goals (Yang et al., 2015). As economies have largely shifted from factor-driven growth to technological-based innovation in new approaches to growth, investigation of the effect of these technological changes on the environment has become an interesting topic for researchers (Yu and Du, 2018). The impact of technological innovation on CO_2 emissions varies at different levels of economic development.

With regard to technological innovations, it has been stated that this variable plays a major role in reducing fossil fuels (Tang and Tan, 2013).

Some researchers have shown that research and development expenditures have had a positive effect on economic growth (Lotz, 2015; Fang, 2011). Investment in research and development and technological change can reduce CO2 emissions (Jones, 2002). Thus, technological innovations play a key role in reducing energy consumption and improving energy efficiency (Sohag and Begum, 2015). In the opposite approaches, to explain the impact of innovation on carbon dioxide emissions, growth models are also used, as innovation indirectly affects greenhouse gas emissions through increased production and capital and energy consumption (Kumar et al., 2012). In general, technological technologies are able to improve the models of evaluation, management and reducing the hazards for environment and provide opportunities for the production of new and healthy products. New technologies in environmental protection play a key role in new ways of producing and reducing energy consumption. It also reduces greenhouse gas emissions and production of wastes through the process of green production. It also reduces the raw material consumption and is considered a strategy to protect the environment and natural resources and achieve sustainable development (Lee and Cheng, 2009). Financial development also results in economic growth through level effect, efficiency effect, and increased investment. The level effect states that the optimal financial system shifts resources from inefficient to efficient projects. The efficiency effect suggests that financial development is a good method to increase liquidity and asset diversification to allocate financial resources for profitable projects.

An increase in investment results in economic growth by increasing domestic products and an increase in economic growth leads to an increase in energy demand. An increase in demand for energy sources can result in increased greenhouse gas emissions. In empirical studies, Abdouli (2016) evaluated the effect of economic growth, direct investment inflows, open trade, and energy consumption on the environment in 17 MENA countries using static and dynamic panel data during 1990–2013. The results showed that Kuznets curve of environment exists. The study also revealed that foreign direct investment increases environmental pollution and energy consumption increases carbon dioxide emissions. In a study on the sustainable development of an economy - energy - environment system under a dynamic system: A case study of the Chinese states, Zhou et al (2017) concluded that long term development is not sustainable in the selected Chinese states, but can be achieved through energy structure adjustment. They also found that an increase in investment in environmental protection can enhance the sustainable growth rather than over-consumption of energy and gross domestic production.

In his research entitled “CO2 emissions, renewable and non-renewable energy consumption and economic growth: evidence from developing countries”, Katsuya used the Panel Data Model of 42 developing countries during 2002-2011 to investigate the relationship between carbon dioxide emissions, renewable and non-renewable energy consumption and economic growth. The results revealed that renewable energy consumption has a reverse effect and non-renewable energy consumption has a direct effect on the long-term economic growth of the studied countries. Lin et al (2017) tested the spatial effects of foreign direct investment on sulfur dioxide emissions in Beijing-Tianjin and Hebi regions of northern China during 1990–2015. The results show that foreign direct investment has a significant positive effect on sulfur dioxide emissions and air quality in local cities is influenced by the process of investment in the surrounding area. Yu and Du (2018) investigated the effect of technological innovation on carbon dioxide emissions in China during 1997 to 2015. The carbon dioxide trend during 2016-2030 has been also predicted. The research results revealed that technological innovation is an effective factor in reducing greenhouse gas emissions. Based on other results, carbon dioxide trends will be decreased by 2030 due to technological growth and stricter environmental laws.

RESEARCH DATA AND METHODOLOGY

The research variables are listed in Table 1.

Table 1. The variables and their sources

Variable	Variable definition	source
CO2 emissions (CO2)	Total CO2 due to energy consumption (based on tons)	EIA (2019)
Gross domestic product (PGDP) per capita	Real GDP per capita (constant in USD 2010)	WDI (2018)
Foreign trade (TR)	Trade in percentage of GDP	WDI (2018)
Technological Innovation Index (TECH)	Technological Innovation Index (Total Applied Inventors) based on person	WDI (2018)
non-renewable energy consumption (NRE)	Total energy consumption (oil, gas, coal) (non-renewable) based on tons	**BP-statistical review (2019)**
Total renewable energy (RE) consumption	The total consumption of renewable energy based on tons	**BP-statistical review (2019)**
Financial development (Fina)	Internal credits to the private sector as a percentage of GDP	WDI (2018)
(POP) Total population	Population size	WDI (2018)

In econometric studies, standard methods (such as ordinary least squares, instrumental variables, and generalized method of moments) have been generally used. They explain the mean effect of explanatory variables on the distribution of the dependent variable. In this study, quantile regression method was used to investigate the factors affecting the greenhouse gas emissions. It was first introduced by Koenker and Bassett (1974) and developed in subsequent studies (Koenker and Bassett, 1999; Koenker and Hallock, 2001). This method gradually became a comprehensive method for statistical analysis of linear and nonlinear response variable models in different fields. The main reason to use quantile regression is to provide a model with a detailed and comprehensive look at response variable evaluation to allow for interference of independent variables not only in the data center of gravity, but in all parts of the distribution, especially in the initial and final spectrum. Moreover, this method does not have limitation of assumptions of ordinary regression, heterogeneity variance, and the effective presence of outliers in estimating the stable coefficients. This method is stronger than ordinary least squares (OLS) regression compared to outliers and abnormal distribution and enables estimation of the effect of influential factors in different urban distribution points (Koenker and Hallock, 2001). The quantile regression can be expressed as equation 1.

$$q\left(\frac{CO_{2it}}{\Omega_t}\right) = \theta_{0t} + \theta_{1t}NRE_{it} + \theta_{2t}RE_{it} + \theta_{3t}TECH_{it} + \theta_{4t}TR_{it} + \theta_{5t}POP_{it} + \theta_{6t}PGDP_{it} + \theta_{7t}Fina_{it} + \mu_{it} \quad (1)$$

In equation (1), $q\left(\frac{CO_{2it}}{\Omega_t}\right)$is the conditional Quantile of Co2 and Ωt contains the information at time t. Equation (1) can be rewritten as Equation 2:

$$Co2_{it} = +X_{it}\theta_t + \varepsilon_{it} \quad (2)$$

In equation (2), X represents a spectrum of variables affecting Co2. Unlike the OLS method which is based on minimizing the sum of squares of residuals, the quantile method uses the minimization of the sum of the absolute values of harmonic residuals to estimate the model parameter (Kuenker and Machado, 1999), called as Least Absolute Deviations (LAD).

The selected countries for the study

The sample studied in this study included 15 countries selected from the International Renewable Energy Agency (IRENA) countries during the period 1990 to 2016, which are among the countries with the highest CO2 emissions.

Table 2: The list of the studied countries

Iran	Turkey	Germany	Malaysia
China	Indonesia	Egypt	Finland
India	Thailand	Bangladesh	Russia
Japan	Peru	Philippine	

Descriptive statistics of the research variables

To provide an overview of the important characteristics of the calculated variables, the following table presents some of the concepts of descriptive statistics of these variables, including mean, median, standard deviation, minimum and maximum, and distribution of variables.

Table 3: The descriptive statistics of the research variables

variables	mean	SD	max	min	probability J-b
CO2 emissions (CO2)	68.236	10.248	6.947	80.10	000.0
Gross domestic product per capita (PGDP)	68.11569	89.15167	70.49363	48.399	000.0

Foreign trade (TR)	80.61	72.39	40.220	67.15	000.0
Technological Innovation Index (TECH)	71.43018	4.127750	00.120498	00.21	000.0
non-renewable energy consumption (NRE)	62.281	32.475	2.3047	10.6	000.0
Total renewable energy consumption (RE)	31.1	16.2	06.14	000143.0	000.0
Financial development (Fina)	62.66	24.50	29.221	31.97	000.0
Total population (POP)	234000000	3830000000	13800000000	4986431	000.0
Number of observations	405	405	405	405	405

Source: The research findings

Based on the results of descriptive statistics of research variables, it can be stated that all variables have abnormal distribution according to Jarque-Bera test results. In addition, computational dispersion criteria show that the data have large dispersion. Reliability of the research variables means that the mean and variance of the variables and the covariance of the variables have been constant in different years. If the research variables are not reliable, either in time series data or in the panel data, it will cause the problem of false regression. In this study, Levin-Lin- Chu tests was used to evaluate the reliability of variables. The reliability results of the research variables are shown in Table (4).

Table 4: The results of the reliability test of the research variables (Lin-Levin-Chu Method)

variables	Level / first difference	Test statistic	Probability	tationary or non-stationary
CO2	level	71.2	99.0	non-stationary
	difference	94.-13	00.0	stationary
PGDP	level	64.23	00.1	non-stationary
	difference	39.-5	00.0	stationary
TR	level	60.-1	06.0	non-stationary
	difference	15.-16	00.0	stationary
TECH	level	04.13	00.1	non-stationary
	difference	34.-9	00.0	stationary
NRE	level	91.6	00.1	non-stationary
	difference	22.-11	00.0	stationary
RE	level	92.11	1/00	non-stationary
	difference	11.-2	01.0	stationary
POP	level	07.1	85.0	non-stationary
	difference	34.-4	00.0	stationary
Fina	level	83.3	99.0	non-stationary
	difference	56.-8	00.0	stationary

Based on the results of the Lin-Levin- Chu test, the research variables are non-static and become static with one time of differentiation. The results of the Fisher co-integration test are presented in Table (5).

Table 5: Fisher co-integration test results

hypothesis	Test statistic	Probability	Fisher maximum eigenvalues test statistic	Probability
Lack of co-integration	0.1444	00.0	7.238	00.0
Maximum one co-integration relationship	9.533	00.0	4.452	00.0
Maximum two co-integration relationship	2.465	00.0	3.233	00.0
Maximum three co-integration relationship	1.298	00.0	3.189	00.0
Maximum four co-integration relationship	4.178	00.0	7.116	00.0
Maximum five co-integration relationship	9.151	00.0	76.99	00.0

Source: The research findings

The results of the co-integration test suggest the rejection of the null hypothesis that states there is no co-integration in the Fisher co-integration test. The results of the quantile regression estimates are presented in Table 6.

Table 6: The results of quantile regression estimates

variable	Q20	Q40	Q50	Q60	Q80
PGDP	0.0000826 (0.30)	0.000286 (1.64)	0.00079 (3.88)	0.000773 (4.68)	0.000779 (4.56)
TR	0.0377 (10.73)	0.063 (2.98)	0.0349 (9.18)	0.145 (5.32)	0.030 (2.55)
TECH	-0.000706 (-5.58)	-0.000753 (-7.59)	-0.000664 (-8.19)	-0.000746 (-7.81)	-0.000975 (-5.05)
NRE	0.178 (16.32)	0.163 (17.03)	0.167 (16.26)	0.172 (15.55)	0.160 (10.58)
RE	-0.081 (-2.31)	-0.062 (-2.56)	-0.026 (-1.57)	-0.031 (-1.97)	-0.0099 (-0.81)
POP	0.000342 (4.56)	0.000133 (3.56)	0.000563 (4.11)	0.0006548 (3.56)	0.000154 (4.21)
FINA	0.009 (1.34)	0.007 (2.27)	0.004 (1.03)	0.0006 (1.09)	0.000 (1.11)

Source: The research findings (the numbers in parentheses are t statistic)

The estimated results for the variables of technological innovation, renewable energy and non-renewable energy are as follows:

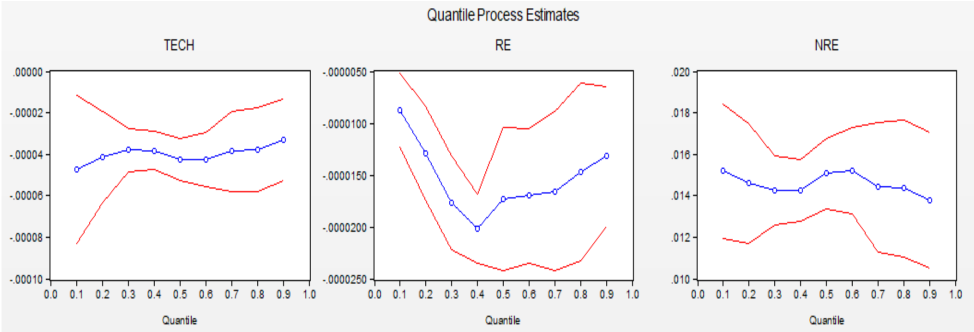

Chart 1: The results of the effects of technological innovation (TECH), renewable energies (RE) and non-renewable energies (NRE) on CO2 in different quantiles

The effect of non-renewable energies on CO2 emission was positive and significant in all quantiles studied and had the highest coefficient of estimate in the coefficients studied. Moreover, the effect of renewable energies on different quantiles has been largely remained unchanged. According to the estimation results in the different quantiles, the effect of GDP on CO2 emission in different quantiles is positive, but this effect is stronger in higher quantiles. The effect of technological innovations on CO2 emissions has also had a negative and significant impact on all the quantiles studied, which had a decreasing trend at first but again an increasing trend over time. Technological innovation allows for the introduction of new capital goods that may have a greater role in production than the existing capital goods.

Technological innovation with higher production efficiency enables more production with less use of production resources which can reduce carbon dioxide emissions. The effect of renewable energies on CO2 emissions was also negative and significant. This effect has also been increased at high quantiles, indicating its importance in high emissions. Although the effect of population on CO2 emissions was positive and significant in the quantiles studied, it was small in value. Finally, the effects of financial development on different quantiles were not significant. Using Newey and Powel test (1987), symmetry for the investigated quantiles was calculated in Table 7.

Table 7: Symmetry results for the investigated quantiles

The test of symmetry between the quantiles	Technological innovation (TECH)		Renewable energies (RE)	
	Statistic	Probability	Statistic	Probability
0.2- 0.8	0.098	0.031	-0.825	0.73
0.3- 0.7	0.054	0.00	-1.543	0.11
0.4- 0.6	0.076	0.18	-1.87	0.24

Source: The research findings

Given the computational probability value, in the quantiles investigated for technological innovation, the null hypothesis on the symmetry of results was rejected. In other words, with increasing CO2 emission volume, the effect of technological innovation variable has not been increased. Opposite results were obtained for the variable of renewable energies. Given the computational probability value in the quantiles studied for renewable energies, the null hypothesis on the symmetry of results was confirmed. In other words, with CO2 emission amount increase, the effect of the renewable energies variable was increased.

CONCLUSION AND RECOMMENDATION

Over the last decades, sustainable economic growth has become an important goal for most of the world's economies. Achieving this goal requires stabilizing or reducing greenhouse gas emissions. This requires transition from polluting energy-based economic activities to technology-based sustainable economic activities with fewer environmental impacts. The role of renewable energies and technological innovations in greenhouse gas emissions has been shown in extensive empirical studies. The results of this study also showed that renewable energies and technological innovations had negative effects on CO2 emissions. Technological innovations play a major role in reducing carbon dioxide emissions as an essential element in improving energy efficiency and reducing energy consumption. Technological developments have been a major factor of CO2 reduction, and the replacement of non-renewable energy with renewable energy for countries with relatively higher CO2 emissions has become a necessity. Appropriate policies for development of renewable energy production can also be considered as a strategy to reduce environmental pollution.

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