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Research Article

EMPIRICAL FINDINGS ON THE RELATIONSHIP BETWEEN RENEWABLE ENERGY PRODUCTION, EXPORT DIVERSIFICATION AND CO_2 EMISSIONS IN TRANSFORMATION ECONOMIES

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ABSTRACT

In order to contribute to the ongoing discussions on the environment-economy relationship, the relationship between renewable energy consumption, export diversification, economic growth and CO_2 emission in the countries considered as transformation economies was investigated in the period between 1997 and 2014 in the current study. In the study, IPS, LLC unit root tests, Pedroni and Kao cointegration tests, and FMOLS and DOLS coefficient estimation methods, which are frequently used in the literature, were used. As a result of the analyses, it was concluded that renewable energy consumption, economic growth and export diversification have negative effects on CO_2 emissions, while trade openness has a positive effect. In the Dumitrescu-Hurlin causality test results, a bidirectional causality relationship was found between renewable energy production and trade openness and CO_2 emissions. Within the scope of these results, it is considered important to implement incentive policies for export diversification and renewable energy production in countries of transformation economy. Given the positive effect of trade openness on CO_2 emissions, it is considered necessary to reduce the share of sectors polluting the environment in trade and to increase the share of sectors that do not have a negative impact on the environment.

Keywords: CO_2 emissions, Renewable energy production, Export diversification, Trade openness, Economic growth.

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

INTRODUCTION

The rise in living standards causes countries to switch from agricultural production to an industrialized system in order to achieve high economic growth rates, resulting in an increase in environmental pollution. The quality of the environment is affected by both local and international economic factors. In this connection, countries take various measures related to international trade in order to make their systems less sensitive to macroeconomic shocks of open economies and to control economic and environmental sustainability. In this context, they adopt export diversification and trade openness to reduce dependency on various export products and achieve sustainable economic growth. Through these policies implemented, both the scope of the products and services to be exported can be expanded and an increase in economic gains can be accomplished. However, in recent years, the impact of this situation on the environment has also been considered to be important (Li et al., 2021; Can et al., 2021; Shahzad et al., 2021). The development in the industry has increased the demand for energy, which is the most important input of mass production. The resulting energy demand has been tried to be met from fossil fuels such as coal, oil and natural gas. Therefore, there has been a significant increase in greenhouse gas emissions and accordingly environmental degradation has accelerated (Okumus and Bozkurt, 2020; Bilgili et al., 2016). In this regard, it is considered that the pressure on the environment can be reduced as a result of increasing renewable energy production and that environmental degradation can be stopped by meeting the energy need with these resources.

It is argued that the effect of economic factors on environmental pollution differs according to the development level of countries. In this context, there are studies such as the ones conducted by Acaravci and Ozturk (2010) and Bese and Kalayci (2021) pointing out that there is an inverted U-shaped relationship between economic growth and environmental pollution in developed economies. However, in the study by Okumus and Bozkurt (2020), it is stated that economic growth in low-income countries increases environmental degradation and it is argued that the Environmental Kuznets Curve (EKC) is not valid. It has been stated that this may be due to the inability to reach the point where the relationship between environmental pollution and economic growth will begin to improve. In this connection, the relationship between renewable energy production, export diversification, trade openness, economic growth and CO_2 emissions in 12 countries, which are considered as economies of transformation from a planned economy to a free market economy, is examined in this study. These countries' integration into the global economic structure later than other countries and their rapid industrialization within the framework of economic growth targets put pressure on the environment.

The relationship between the environment and economic growth has been examined by many researchers in countries with different income groups. However, in the current study, the relationship between the environment and economic growth in the transformational economies that joined the global economic structure in the 90s is examined. In a significant part of the studies examining the relationship between environmental pollution and economic growth, the effect of energy consumption on environmental pollution has been examined and thus investigating the effect of energy production on environmental pollution in the current study is believed to contribute to the literature. In addition, although there are studies examining the effect of export diversification on economic growth in the literature, the very limited number of studies examining the relationship between export diversification and environmental pollution in terms of transformation economies makes the current study different from other studies.

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

In the introduction part of the study, brief information about the subject is given. Secondly, recent studies on the variables used within the scope of the model created in the literature section are presented. In the third section, information about the data, model and methodology is given, and in the fourth section, the empirical results obtained from the analyses are presented. In the conclusion part, policy recommendations are made within the context of the results obtained.

LITERATURE

There are many studies with different perspectives on the relationship between environmental pollution and the economy. It is seen that most of these studies have focused on the relationship between environmental pollution and economic growth. In addition, many factors such as financial development, globalization, foreign direct investments, etc., which are considered to be effective on the environment, have been examined. In this section, studies that include the variables in the model created within the scope of the current study will be discussed, and firstly, brief information will be given about the studies that have examined the relationship between export diversification and environmental pollution in recent years.

Gozgor and Can (2016), one of the studies examining the relationship between export diversification and environmental pollution, examined the relationship between economic growth, energy consumption and export diversification and CO_2 emissions in the period between 1971 and 2010. The findings of the study revealed that the EKC hypothesis is supported and that energy consumption and export diversification increase CO_2 emissions in the long run. Apergis et al. (2018) analyzed the relationship between economic growth and export diversification and CO_2 emissions in the period 1962 – 2010 in their study for 19 developed countries with the ARDL bounds test. The results obtained in the analyses showed that the EKC is valid and export diversification has a negative effect on CO_2 emissions. Bashir et al. (2020) examined the relationship between energy intensity and carbon intensity and export diversification for the period 1990 – 2015 for 29 OECD member countries. As a result of the study, in which three different indicators of export diversification were used, it was determined that export diversification increased energy efficiency and also had a positive effect on environmental pollution. Dogan et al. (2020) analyzed the relationship between economic growth, trade openness, urbanization, export quality, energy consumption and CO_2 emissions between 1971 and 2014 for 63 developed and developing countries with second-generation analysis methods. In the study, it was seen that economic growth and energy consumption have a positive and significant effect on CO_2 emissions. In the study, it was also determined that urbanization and export quality negatively affect the environment. Shahzad et al. (2020) conducted a study for the same study period and for the same countries to examine the effect of export diversification, wide and dense margins on CO_2 emissions. The empirical findings obtained in the study using the GMM showed that export diversification, wide margin and dense margin indicators reduce CO_2 emissions in both developing and developed countries.

When the studies examining the relationship between energy and environmental pollution are reviewed, it is seen that the effect of renewable and non-renewable energy consumption on environmental pollution has generally been examined in the literature. Apergis and Payne (2009), one of the few studies examining the relationship between energy production and environmental pollution, investigated the relationship between CO_2 emissions and energy consumption and pro-

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

duction for 6 Central American countries in the period from 1971 to 2004. In the long-term results obtained, it was determined that energy consumption increases CO_2 emissions, and there is an inverted U-shaped relationship between energy production and CO_2 emissions. Moreover, in the study, it was concluded that there is a bidirectional causality relationship between energy consumption and production and CO_2 emissions. Mahmoodi (2017) examined the relationship between economic growth, renewable energy and CO_2 emissions in the period between 2000 and 2014 for 11 developing countries. In the study, it was concluded that there is a bidirectional causality relationship between renewable energy and CO_2 emissions and between economic growth and CO_2 emissions. In addition, the results showed that economic growth has a positive effect while renewable energy has a negative effect on CO_2 emissions. Bekun et al. (2019), who examined the relationship between renewable and non-renewable energy consumption, economic growth, natural resource rent and CO_2 emissions in 16 European Union member countries for the period 1996-2014, used the PMG-ARDL method in their analysis. In the study, it was revealed that natural resource rent, economic growth and non-renewable energy consumption have an increasing effect on CO_2 emissions. It is stated that the effect of renewable energy consumption on CO_2 emissions is positive and may be beneficial in reducing the environmental pollution. Baye et al. (2021) investigated the main factors driving renewable energy production for 32 Sub-Saharan African countries using panel data from 1990 to 2015. In the study, evidence was presented that CO_2 emissions have a negative effect on renewable energy production, while economic growth, trade liberalization, natural resource rent and urbanization have positive effects on renewable energy consumption.

In studies on the relationship between trade openness and environmental pollution, Al-Mulali (2015) examined the relationship between ecological footprint and energy consumption, urbanization, industrial development, political stability and trade openness for 14 MENA countries in the period 1996-2012 using FMOLS method. In the study, as a result of the analyses conducted with FMOLS method, it was concluded that energy consumption, urbanization, industrial development and trade openness have positive effects on environmental pollution, while political stability has a negative effect. Mahmood et al. (2019) investigated the relationship between trade openness and CO_2 emissions between 1971 and 2014 for Tunisia. In the study, in which the validity of the EKC hypothesis was also tested, the results of the analysis supported the validity of the EKC. In addition, in the study, it was tested whether trade openness has an increasing (positive) effect on CO_2 emissions. Dauda et al. (2020) examined the relationship between innovation and CO_2 emissions for 9 countries in Africa between 1990 and 2016 on both a panel and country basis. In the study, it was stated that the relationship between innovation and CO_2 emissions is in an inverted U shape. Furthermore, it was seen that renewable energy consumption and human capital also reduce CO_2 emissions. Investigating the effect of renewable and non-renewable energy consumption and trade openness on environmental pollution in 24 OECD countries, Destek and Sinha (2020) used annual data from 1980 to 2014. In the study, in which second-generation panel data analysis methods were used, it was concluded that the Environmental Kuznets Curve hypothesis is not valid for the OECD countries and that renewable energy consumption and trade openness have a reducing effect on environmental pollution, and that non-renewable energy consumption has an increasing effect. In the study by Adebayo and Kirikkaleli (2021), the relationship between globalization, economic growth, technological innovation, renewable energy consumption and CO_2 emissions in the period 1990Q1 - 2015Q4 in Japan, which is the third largest economy in the world, was investigated. Empirical results revealed that globalization, economic growth and technological innovation have

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

an increasing (positive) effect on CO_2 emissions in the short and long term. It was seen that renewable energy consumption reduces CO_2 emissions both in the short and long term.

In the study of Li et al. (2021), which is the study drawn on in the creation of the model used in the current study, the relationship between renewable energy production, economic growth, export diversification, trade openness and CO_2 emissions in China between 1989 and 2019 was examined. The results obtained in the study, in which FMOLS, DOLS and CCR methods were used, showed that export diversification and renewable energy production have negative effects on CO_2 emissions, whereas trade openness and economic growth have positive effects on CO_2 emissions.

DATA, MODEL AND METHODOLOGY

In the current study, the relationship of renewable energy production, economic growth, export diversification and trade openness with CO_2 emissions is examined for Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Moldova, North Macedonia, Russia, Ukraine, Uzbekistan, which are considered to be transformation economies, for the period between 1997 and 2014. The study of Li et al. (2021) is followed in the determination of the variables used in the study and in the creation of the model. The model constructed in this direction is as follows;

$$lnCO2_{it} = \beta_0 + \beta_1 lnRENO_{it} + \beta_2 lnGDPPC_{it} + \beta_3\, lnEXDİV_{it} + \beta_4 lnOPEN_{it} + \vartheta_t \quad (1)$$

In the model, $lnCO_2$ represents per capita carbon emission, lnRENO, rate of renewable energy production in total electricity production, lnGDPPC, per capita real national income, lnEXDIV, export diversification index, lnOPEN, the rate of trade in GDP, and ϑ_t , error term. All the series used were included in the analysis by taking their natural logarithm. The data for the CO_2 emission, economic growth (lnGDPPC), renewable energy production (lnRENO) and trade openness (lnOPEN) variables used in the study were obtained from the World Bank WDI (World Development Indicators) database, and the data for the export diversification (lnEXDIV) variable were obtained from the International Monetary Fund (IMF) database.

The panel data method, which was obtained by combining time series data and cross-section data, was used as an econometric method in the study. In panel data models, there are N units and T observations corresponding to each unit (Tari, 2010; Bostan et al., 2016). In this direction, economic inferences can be made by using more information. In this way, more information usage and economic inferences can be made, and since it gives cross-section and time series data together, the number of observations and degrees of freedom increase and the possibility of multicollinearity errors between explanatory variables decreases. In addition, panel data analysis models allow for suggesting economic policies for a certain group instead of suggesting an individual economic policy (Hsiao, 2003). Another advantage of analyses made with panel data is that it includes effects other than explanatory variables that cannot be observed throughout the units or time in the model. Panel data models are classified according to whether these effects are fixed or random. If these effects are found in the deterministic part of the model, it is expressed as the fixed effects model, and if they are found in the random part, it is expressed as the random effects model. In this context, models can contain more information and variables, so reliable predictions can be made (Baltagi, 2011). In addition to these advantages, panel data models have some inadequacies. Problems such as model specification errors, measure-

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

ment errors and especially data collection problems may occur (Gulmez and Yardimcioglu, 2012).

In panel data analysis, first of all, stationarity should be investigated. In this connection, the stationarity of the variables was examined by using the Levin, Lin and Chu (2002), Im, Peseran and Shin (2003) unit root tests. Although individual unit root tests have limited power against alternative hypotheses with extremely persistent deviations from equilibrium, LLC is considered a powerful panel unit root test that allows different unit root tests to be applied for each cross-section. For the LLC unit root test to be applied, the series must form a balanced panel (Baltagi, 2005; Yildirim, 2019). The Im, Peseran and Shin (IPS) panel unit root test, which is another test used to investigate stationarity, allows the coefficients to be heterogeneous by removing the requirement that the autoregressive coefficient of the cross-section units should be homogeneous, which is the basic assumption of the LLC unit root test.

After applying unit root tests, the long-term relationship between the series is examined with cointegration tests. In the current study, the cointegration relationship between the variables was investigated with Pedroni and Kao cointegration tests. The Pedroni cointegration test consists of seven different tests, four pooled in the "within" dimension and three in the "between" dimension. The first three of the tests in the "within" dimension consist of non-parametric tests (Ogul, 2022). The fact that the variables used in the study are stationary at the I(1) level enables the Pedroni and Kao cointegration tests to be applied.

After determining the cointegration relationship between the variables, the direction and coefficient of the cointegration relationship between the variables were analyzed with the coefficient estimators FMOLS (2000) (Fully Modified Ordinary Least Squares) and DOLS (2001) (Dynamic Ordinary Least Squares). The FMOLS and DOLS estimators were first applied for time series by Philips and Hansen (1990). However, this method was adapted to panel data by Pedroni (2000). The FMOLS estimator includes a semi-parametric correction method against the estimation problems that may be caused by the long-term correlation between stochastic shocks and the cointegration equation. The use of this method offers great advantages such as the avoidance of deviations due to endogeneity and autocorrelation correction (Kilinc et al., 2020; Kartal, 2022). The DOLS coefficient estimator, on the other hand, combines the precursors and lags of the first differences of the independent variables. Thus, the endogenous feedback effects from the dependent variable to the independent variables can be eliminated. In this context, the estimates obtained with the DOLS method can give more reliable results than the Panel OLS estimator in terms of eliminating the endogeneity problems between the independent variables and error terms and overcoming the autocorrelation problems in the error terms (Songur and Yalman, 2013).

Finally, the Dumitrescu and Hurlin (2012) panel causality test was used to determine the causality relationship between the variables. The Dumitrescu-Hurlin causality test, which is based on the Granger causality method, can be used in panel data and can reveal the causality relationship between the variables. The Dumitrescu-Hurlin causality test can show that the causality relationship which is valid for any country within the scope of panel data is also valid for different countries and it can give more effective results with the increase in the number of observations. In addition, the Dumitrescu-Hurlin causality test can also provide consistent results when the time (t) dimension is bigger or smaller than the cross-section (n) dimension (Celik and Unsur, 2020).

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

EMPIRICAL FINDINGS

In this part of the study, there are findings related to the model established to analyze the relationship between CO_2 emissions, renewable energy production, per capita income and trade openness in countries of transition economy. Before the evaluation of the findings obtained, the descriptive statistics for the dependent and independent variables in the model are presented in Table 1.

Table 1. *Descriptive Statistics for the Variables*

Variables	$lnCO_2$	lnRENO	lnGDPPC	lnEXDIV	lnOPEN
Mean	0.151	2.615	8.084	1.135	4.398
Median	0.175	2.810	8.078	1.104	4.374
Maximum	1.629	4.605	9.370	1.800	5.062
Minimum	-1.271	-2.635	6.805	0.533	3.582
Std.Error	0.661	1.578	0.597	0.278	0.301
Skewness	-0.064	-1.518	0.110	0.205	-0.176
Kurtosis	2.450	5.761	2.491	2.874	2.706
Number of observations	216	216	216	216	216

Source: Author's calculations

In order to reach correct results in panel data analysis, the series must be stationary. Thus, the stationarity of the series should be tested in order to establish a meaningful relationship between dependent and independent variables and to reach correct results. Table 2 shows the results of the panel unit root tests of Levin, Lin, Chu (2002), Im, Pesaran, and Shin (2003), which are frequently used unit root methods in studies using panel data analysis.

Table 2. *Panel Unit Root Test Results*

Level	LLC		IPS	
	With Constant and Trend			
	t-statistics	Probability	t-statistics	Probability
lnCO2	2.649	0.996	-0.140	0.442
lnRENO	3.569	0.999	-1.789**	0.036
lnGDPPC	1.236	0.891	0.736	0.769
lnEXDİV	3.209	0.999	0.654	0.743
lnOPEN	2.601	0.995	0.726	0.766
Difference Values				
ΔlnCO2	-7.928***	0.000	-9.189***	0.000
ΔlnRENO	-12.174***	0.000	-3.491***	0.000
ΔlnGDPPC	-6.114***	0.000	-3.379***	0.000
ΔlnEXDİV	-12.293***	0.000	-1.915**	0.027
ΔlnOPEN	-9.846***	0.000	-1.459*	0.072

Note: Δ: Shows the first difference of series. ***Significant at the level of 1%, **Significant at the level of 5%, *Significant at the level of 10%.

Source: Author's calculations

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

When the results of the unit root tests are examined, it is seen that all the variables except the lnRENO variable in the IPS unit root test results have unit root at the level. However, since all the variables in the model were required to be stationary, unit root tests were applied by taking the difference of all the variables. It was concluded that all the variables applied difference operation are stationary at the first difference.

After the stationarity of the series was determined, the cointegration relationship of the series was examined with the Pedroni and Kao cointegration tests. In the Pedroni cointegration test results shown in Table 3, it is seen that four tests out of seven different tests are significant. Thus, the H_0 hypothesis of the Pderoni cointegration method "there is no cointegration between the series" is rejected. In order to support the results of the Pedroni cointegration method, the Kao cointegration test was also applied in the study, and it was seen that there was a cointegration relationship between the variables in the results of this method.

Table 3. *Panel Cointegration Test Results*

Pedroni Panel	**With Constant-Without Trend**		**Weighted**	
Cointegration Test	**t-statistics**	**Probability**	**t-statistics**	**Probability**
Panel v-statistics	0.307	0.379	-0.109	0.543
Panel rho- statistics	0.585	0.720	0.772	0.780
Panel PP- statistics	-3.964***	0.000	-4.692***	0.000
Panel ADF- statistics	-3.875***	0.000	-4.228***	0.000
Group rho- statistics	2.091	0.981		
Group PP- statistics	-5.988***	0.000		
Group ADF- statistics	-4.104***	0.000		
Kao Panel Cointegration Test	**t-statistics**	**Probability**		
ADF	-3.134***	0.000		

Note: ***Significant at the level of 1%, **Significant at the level of 5%, *Significant at the level of 10%.

Source: Author's calculations

The coefficient and direction of the cointegration relationship obtained with the Pedroni and Kao Cointegration tests were analyzed by using the FMOLS (Fully Modified Ordinary Least Square) and DOLS (Dynamic Ordinary Least Squares) estimators and the results are presented in Table 4. In the results of both methods applied, it was determined that the renewable energy production (lnRENO), economic growth (lnGDPPC) and export diversification (lnEXDIV) variables have negative effects on CO_2 emissions. In the other result obtained, it was seen that trade openness increases CO_2 emissions.

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

Table 4. *Results of FMOLS and DOLS Coefficient Estimators*

Model	$lnCO2_{it} = \beta_0 + \beta_1 lnREN_{it} + \beta_2 lnGDPPC_{it} + \beta_3\, lnEXDİV_{it} + \beta_4 lnOPEN_{it} + \vartheta_t$			
Method	**FMOLS**		**DOLS**	
Variable	**Coefficient**	**Probability**	**Coefficient**	**Probability**
lnRENO	-0.319***	0.000	-0.294***	0.000
lnGDPPC	-0.630***	0.000	-0.602***	0.000
lnEXDİV	-0.747***	0.000	-0.570***	0.000
lnOPEN	0.310***	0.003	0.260**	0.011

Note: ***Significant at the level of 1%, **Significant at the level of 5%, *Significant at the level of 10%.

Source: Author's calculations

When the results obtained by FMOLS and DOLS methods are compared with the literature, it is seen that export diversification has a negative effect on CO_2 emissions and this result is consistent with the studies of Apergis et al., (2018), Bashir et al., (2020) and Shahzad et al., (2020). On the other hand, it is seen that this result is not compatible with the study of Gozgor and Can (2016) and it is thought that the reason for this may be due to the use of a single country and time series analysis methods in the study of Gozgor and Can (2016). It is also seen that trade openness has a positive effect on CO_2 emissions and this result concurs with the studies by Al- Mulali (2015), Mahmood et al., (2019), Adebayo and Kirikkaleli (2021).

After examining the long-term cointegration relationship between the variables on a panel and country basis, the causality relationship between the variables was analyzed with the Dumitrescu-Hurlin (2012) causality test.

Table 5. *Dumitrescu-Hurlin Granger Causality Test Results*

Null (H_0) Hypothesis	**Wald Statistics**	**Z-bar Statistics**	**Probability**
$lnRENO \nrightarrow lnCO2$	5.113***	3.016	0.002
$lnCO2 \nrightarrow lnRENO$	5.685***	3.664	0.000
$lnGDPPC \nrightarrow lnCO2$	7.836***	6.096	0.000
$lnCO2 \nrightarrow lnGDPPC$	3.174	0.824	0.409
$lnEXDİV \nrightarrow lnCO2$	3.194	0.847	0.396
$lnCO2 \nrightarrow lnEXDİV$	4.118*	1.892	0.058
$lnOPEN \nrightarrow lnCO2$	6.668***	4.774	0.000
$lnCO2 \nrightarrow lnOPEN$	8.772***	7.153	0.000

Note: ***Significant at the level of 1%, **Significant at the level of 5%, *Significant at the level of 10%.

Source: Author's calculations

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

When Table 5 showing the results of Dumitrescu-Hurlin (2012) causality method is examined, it is seen that there is a bidirectional causality relationship between renewable energy production and CO_2 emissions. In other results, it is seen that there is a one-way causality relationship between economic growth to CO_2 emissions, and a one-way causality relationship between CO_2 emissions to export diversification. In addition, a bidirectional causality relationship is seen between trade openness and CO_2 emissions.

CONCLUSION

Since the reduction of climate change and environmental pollution is an ongoing debate in current studies, the effect of various factors on CO_2 emissions has been investigated. In the international arena, it is accepted that in addition to the accomplishment of economic growth targets, it is necessary to act together and produce solution-oriented policies for the protection of the environment.

In the current study, the relationship between export diversification, renewable energy production and trade openness and CO_2 emissions, whose separate effects have been examined in the literature, was investigated. In the study, countries that joined the free market economy later than other countries and rapidly industrialized were selected, and the years 1997-2014 were chosen as the research period in order to conduct balanced panel data analysis. First-generation panel data analysis methods were used in the study. In the analyses made with FMOLS and DOLS methods, it was determined that the renewable energy production (lnRENO), economic growth (lnGDPPC) and export diversification (lnEXDIV) variables have negative effects on CO_2 emissions. In the other result obtained, it is seen that trade openness increases CO_2 emissions.

In light of the findings, it can be said that it would be beneficial to evaluate renewable energy production and export diversification policies together. Countries need to act together to prevent rising CO_2 emissions due to increased trade openness. Developing countries should focus on reducing pollution as well as developing policies to increase environmentally friendly energy production and support technology transfers.

Eurasian Research Journal
Autumn 2022
Vol. 4, No. 4.

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