International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2017, 7(6), 96-102.

The Relationship between Economic Growth, Renewable Energy, and CO_2 Emissions: Evidence from Panel Data Approach

Majid Mahmoodi*

Faculty of Management, Economics and Accounting, Velayat University, Iranshahr, Iran. *Email: m.mahmoodi@velayat.ac.ir

ABSTRACT

The aim of the present study is to examine the relationship between economic growth, renewable energy (RE) and carbon dioxide emission (CO_2) for a panel of 11 developing countries over the period 2000–2014. The panel cointegration and panel vector error correction model causality is employed to examine the long-run and causal relationships between the variables. The results of Kao and Pedroni panel cointegration test indicate the existence of long-run relationship between economic growth, RE and CO_2 emissions. Also the panel causality results indicate bidirectional causality between RE and CO_2 emission, bidirectional causality between gross domestic product (GDP) and CO_2, and unidirectional causality from GDP to RE. Furthermore, the results of panel dynamic ordinary least squares estimates show the positive impact of economic growth on CO_2 emissions and negative impact of RE on CO_2 emissions.

Keywords: Economic Growth, Renewable Energy, CO_2 Emissions, Panel Data
JEL Classifications: C33, O44, Q20

1. INTRODUCTION

Along with industrialization and technological progress in the past decade, the use of energy sources such as oil, natural gas and coal, has been increased in different countries. So that we can say, energy is fundamental and basic infrastructure for industrial and economic activities in each country.

Energy is an important production factor, and in fact is the engine of economic growth. Therefore, the relationship between energy consumption and economic growth attracted the attention of economists and policy-makers in recent decades. In particular that, the volatility of energy price in recent decades has an obvious effect on world economy. But in the last two decades, the reliance on traditional energy sources has created great concern. One of which is the limited and finishing realization of traditional energy sources and fossil fuels. And the other is the adverse environmental impact, greenhouse gas emissions and global warming. Among the greenhouse gases, carbon dioxide (CO_2) has the greatest effects on global warming. According to the international energy outlook (IEA 2016) estimates, total world energy consumption and CO_2 emissions are expected to increase 48% and 34%, respectively, between 2012 and 2040.

Nowadays, growth and sustainable economic development have been considered to protect the quality of environment and to respect the right of access to natural sources for future generations. Therefore, this has led us to an alternative for traditional energy sources. Renewable energy (RE) resources such as solar, wind, hydropower, and geothermal energy are the best alternative to traditional energy sources. Considering to the RE sources can improve our movement in order to achieve the sustainable economic development. So, researchers, governments and international organizations attempt to increase RE production and mitigate the adverse environmental impacts and global warming. To meet this goal, various policies have been adopted by different countries such as carbon taxes, feed-in tariffs, premium payments, quota systems, auctions and cap and trade systems (De Arce et al., 2016). These incentives reduced the production costs of RE and in many countries RE has become competitive with conventional energy (Koçak and Şarkgüneşi, 2017).

In past decades, many studies have been done on the relationship between energy consumption and economic growth. But in recent years, considering the aforementioned issues, the relation between RE consumption, economic growth and CO_2 emissions have been more interested. However, studies based on the RE are limited and there are no common consensuses among the different studies, so studying in this topic is still interested. The lack of common consensus can be due to the different countries, time periods, data sources and econometric method have been used in different studies. The aim of this study is to examine the relationship between economic growth, RE and CO_2 emissions for a panel of 11 developing countries over the period 2000–2014 by employing the panel-vector error correction model (VECM) causality and panel dynamic ordinary least squares (DOLS) estimator. To this end, the rest of the paper is organized as follows: Section 2 presents the literature review of empirical studies, Section 3 discusses the model and data, Section 4 presents the methodology and empirical results and finally Section 5 presents conclusion.

2. LITERATURE REVIEW

Zoundi (2017) investigates short and long-run impacts of RE on CO_2 emissions for a panel of 25 selected African countries, over the period 1980–2012 by using panel cointegration method. CO_2 emissions are found to increase with economic growth. The estimations results reveal that RE, with a negative effect on CO_2 emissions, is an efficient substitute for the traditional energy sources.

Ozturk and Acaravci (2016) examined the long-run and causal relationship between economic growth, carbon emissions, energy consumption, foreign trade ratio, and employment ration in Cyprus and Malta over the 1980–2006 years, by employing autoregressive distributed lag (ARDL) bounds testing approach and error correction based Granger causality models. The empirical finding indicates the existence of long-run relationship between the variables only for Malta. The results of Granger causality test show that the causality runs from carbon emissions, energy consumption, foreign trade ratio, and employment ratio to economic growth but not vice versa in Malta.

Dogan and Ozturk (2017) studied the impact of real income, RE consumption and non-renewable energy consumption on CO_2 emissions for the USA over the period 1980–2014 years by considering environmental Kuznets Curve (EKC) model. The results of Gregory-Hansen cointegration test indicate that CO_2 emissions, the real income, the quadratic real income, renewable and non-renewable energy consumption are cointegrated. The long-run estimates of ARDL model indicate that increases in RE consumption mitigate environmental degradation whereas increases in non-renewable energy consumption contribute to CO_2 emissions. In addition, the EKC hypothesis is not valid for the USA.

Hassine and Harrathi (2017) examined the causal relationship between RE consumption, real gross domestic product (GDP), trade and financial development for the Gulf Cooperation Council countries over the 1980–2012 years. The empirical finding indicates bidirectional causality in both short and long-run between output and exports. While, there is no evidence of causality in the short-run between output and RE consumption or private sector credit and between exports and RE consumption or private sector credit. Moreover, the long-run estimated results indicate that there is evidence of a statistically significant impact of RE consumption, exports and private sector credit on output.

The study of Leitao (2014) attempted to investigate the relation between economic growth, carbon dioxide emissions, RE and globalization for Portugal over the 1970–2010. The results indicate that CO_2 emissions and RE are positively correlated with economic growth. Furthermore, the overall index of globalization has a positive effect on growth. The results of Granger causality show a unidirectional causality between RE and economic growth.

Apergis and Payne (2015) analyzed the long-run and causal relationship between RE consumption per capita, real GDP per capita, carbon dioxide emissions per capita, and real oil prices for a panel of South American countries from 1980 to 2010 period. The results of long-run estimate indicated positive and significant impact of real GDP per capita, CO_2 emissions per capita and oil price to RE. Furthermore, the empirical finding of panel causality test indicates bidirectional relationship between the variables. The error correction terms (ECT) in each of the equations are statistically significant, indicating that shocks to any one of the equations will be temporary in nature returning to the long-run equilibrium.

Jebli and Youssef (2015) examined the relation between economic growth, renewable and non-renewable energy, per capita CO_2 emissions and international trade for Tunisia over the 1980–2009 years. The empirical finding of ARDL bound testing and vector error correction Granger causality method indicates the existence of a short-run unidirectional causality from trade, GDP, CO_2 emission and non-renewable energy to RE consumption. The results of long-run estimate reveal that negative impact of RE consumption to the CO_2 emissions.

Sebri and Ben-Salha (2014) examined the causal relationship between economic growth, RE, trade openness and CO_2 emissions for BRICS countries over the 1971–2010 periods. Empirical finding of ARDL bounds testing and VECM reveal the bidirectional causality between economic growth and RE. Furthermore, the results indicate the significant effect of trade openness and CO_2 emission in promoting the RE consumption.

Omri et al. (2015) examined the causal relationship between nuclear energy, RE, economic growth and CO_2 emission for a panel of 17 developed and developing countries by employing panel data models over the 1990–2011 years. The results indicate mixed direction of causality for different countries.

Aliprandi et al. (2016) presented a model to simulating the operational characteristics of a national grid similar to the Italian one, with relevant shares of wind and photovoltaic energy, and estimate CO_2 emissions with a level of penetration. The results show that the reduction of CO_2 emissions is lower than expected considering the amount of energy produced from renewable sources, and is related to the level of RE penetration and the season of the year; in summer the reduction is slightly greater, because of the higher production by combined cycle gas turbines and the consequent decrease of that generated by the more pollutant coal power plants.

López-Menéndez et al. (2014) attempts to study the impact of economic growth on CO_2 emissions for a panel data set of 27 European Union countries during the 1996–2010 periods by estimation of an EKC. Empirical finding reveal the significant impacts of renewable energies on CO_2 emissions, suggesting the existence of an extended EKC.

Bölük and Mert (2014) investigated the EKC hypothesis by considering the relationship between CO_2 emissions, income, RE and fossil fuel energy consumption for panel of 16 European Union countries over the 1990–2008 years. The results show that RE consumption contributes around 1/2 less per unit of energy consumed than fossil energy consumption in terms of greenhouse gas emissions in EU countries.

Pao and Tsai (2011) studied the impact of economic growth and financial development on environmental degradation for a panel of BRIC countries (Brazil, Russian Federation, India, and China) by using a panel cointegration approach over the 1980 and 2007 period. The result indicates bidirectional causality between CO_2 emissions and foreign direct investment (FDI) and unidirectional causality from GDP to FDI. Additionally, there exists output-emissions and output-energy consumption bidirectional causality, while there is unidirectional causality from energy consumption to CO_2 emission.

Apergis and Payne (2014) studied the determinants of RE consumption per capita for a panel of seven Central American countries over the period 1980–2010. The empirical finding reveal a long-run cointegration relationship between RE consumption per capita, real GDP per capita, CO_2 emissions per capita, real coal prices, and real oil prices with the respective coefficients positive and statistically significant.

The study of Apergis et al. (2010) examined the causal relationship between CO_2 emissions, nuclear energy consumption, RE consumption, and economic growth for a panel of 19 developed and developing countries over the period 1984–2007. The results of panel Granger causality tests suggest that in the short-run nuclear energy consumption plays an important role in reducing CO_2 emissions whereas RE consumption does not contribute to reductions in emissions. This may be due to the lack of adequate storage technology to overcome intermittent supply problems as a result electricity producers have to rely on emission generating energy sources to meet peak load demand.

Jebli et al. (2015) use panel cointegration techniques to investigate the short- and long-run relationship between CO_2 emissions, GDP, RE consumption and international trade for a panel of 24 sub-Saharan Africa countries over the period 1980–2010. Short-run Granger causality results reveal that there is a bidirectional causality between emissions and economic growth; bidirectional causality between emissions and real exports; unidirectional causality from real imports to emissions; and unidirectional causality runs from trade (exports or imports) to RE consumption. There is an indirect short-run causality running from emissions to RE and an indirect short-run causality from GDP to RE. The long-run estimates suggest that the inverted U-shaped EKC hypothesis is not supported for these countries; exports have a positive impact on CO_2 emissions, whereas imports have a negative impact on CO_2 emissions.

Menyah and Wolde-Rufael (2010) examined the causal relationship between nuclear and RE, economic growth and CO_2 emissions for the US over the 1960–2007 period. The results show a unidirectional causality from nuclear energy consumption to CO_2 emissions, but no causality from RE to CO_2 in this time period.

3. MODEL AND DATA

According to relative literature on the relationship between RE, economic growth and CO_2 emissions, we use the following regression model:

$$LCO_{2it} = \alpha_0 + \alpha_{1i} LY_{it} + \alpha_{2i} LRE + u_{it} \quad (1)$$

Where LCO_2 is the total CO_2 emissions from fuel combustion (million tonnes of CO_2), LY is the real GDP of constant 2010 U.S. dollars, LRE is the total renewable electricity net generation (Billion Kilowatt-hours) as a proxy for RE. The data sources of LCO_2, LY and LRE respectively are the International Energy Agency (EIA), World Development Indicators (WDI) and U.S. Energy Information Administration (EIA), all variable presented in natural logarithmic form.

Baltagi (2005) points out several benefits of employing panel data: Controlling for individual heterogeneity and giving more informative data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency. With respect to these benefit this study used panel data of CO_2 emission, RE and GDP for a panel of 11 developing countries including: Albania, Bulgaria, Croatia, Indonesia, India, Iran, Malaysia, Pakistan, Poland, Thailand, and Turkey over the 2000–2014 period.

Table 1 report some descriptive statistics of CO_2 emissions, GDP and RE for all countries included in present study over the period 2000–2014. The highest means of CO_2 emissions (1333.19), real GDP (1367.28), and RE (129.89) are in the India, while the lowest means of CO_2 emissions (3.72) and real GDP (10.21) are in Albania and lowest mean of RE (3.99) is in Bulgaria. Furthermore, according to the standard deviation, India is the highest volatility country in CO_2 emissions (382.04), real GDP (436.10), and RE (41.74).

4. METHODOLOGY AND EMPIRICAL RESULTS

The econometric methodology of this paper follows four steps. First, we test for a panel unit root. Prompted by the existence

Table 1: Descriptive statistics

Country	Descriptive statistics	CO_2 (million tonnes of CO_2)	GDP (billions of constant 2010 U.S. $)	RE (billion Kilowatt-hours)
Albania	Mean	3.72	10.21	4.80
	Maximum	4.10	12.76	7.67
	Minimum	3.10	6.96	2.76
	SD	0.28	2.00	1.28
Bulgaria	Mean	45.18	45.57	3.99
	Maximum	51.00	52.81	7.33
	Minimum	39.30	32.77	1.70
	SD	3.16	7.34	1.66
Croatia	Mean	18.46	57.21	6.43
	Maximum	21.20	65.55	9.84
	Minimum	15.10	46.79	4.23
	SD	1.80	5.33	1.71
India	Mean	1333.19	1367.28	129.89
	Maximum	2019.66	2133.77	195.46
	Minimum	890.43	811.54	72.00
	SD	382.04	436.10	41.74
Indonesia	Mean	343.39	661.38	19.70
	Maximum	436.53	942.33	26.78
	Minimum	255.31	453.41	15.00
	SD	51.21	160.02	4.16
Iran	Mean	444.86	396.07	11.11
	Maximum	556.09	485.33	18.18
	Minimum	312.16	281.92	3.70
	SD	81.14	67.92	4.62
Malaysia	Mean	166.70	228.87	7.70
	Maximum	220.51	314.33	14.11
	Minimum	115.02	162.52	5.13
	SD	33.11	48.912	2.51
Pakistan	Mean	121.88	160.15	27.24
	Maximum	137.83	206.17	31.95
	Minimum	95.95	117.55	17.00
	SD	16.02	28.84	4.64
Poland	Mean	295.60	425.66	8.13
	Maximum	308.30	535.59	19.87
	Minimum	279.00	326.20	2.50
	SD	8.78	74.529	5.98
Thailand	Mean	204.09	303.76	9.89
	Maximum	247.44	381.67	15.72
	Minimum	152.28	217.71	6.50
	SD	29.49	54.00	2.87
Turkey	Mean	244.87	666.56	44.05
	Maximum	307.11	871.81	68.72
	Minimum	182.56	471.67	24.00
	SD	41.64	131.28	13.08

SD: Indicates standard deviation. GDP: Gross domestic product, RE: Renewable energy

of unit roots in the series, long-run cointegration relationship between variables was tested by using the panel cointegration test. Conditional on finding cointegration, the causal link between variables have been explored by employing the Granger causality test. At the fourth and final step we estimate the long-run cointegration by using panel DOLS estimator.

4.1. Panel Unit Root Test

Several panel unit root tests have been presented for understanding stationary properties of panel data. We have employed the tests proposed by Levin et al. (LLC, 2002), Im et al. (IPS, 2003) and Fisher-type test proposed by Maddala and Wu (1999) and Choi (2001) to test the null hypothesis of the existence of a unit root.

Following Dickey and Fuller (1979, 1981), Levin and Lin (1993), and Levin et al. (2002) considered a panel extension of the null hypothesis that each individual time series in the panel contains a unit root against the alternative hypothesis that all individual series are stationary (Hsiao, 2003).

The test of Im et al. (IPS, 2003) allow for a heterogeneous coefficient of y_{it-1} and propose an alternative testing procedure based on averaging individual unit root test statistics. IPS suggests

Table 2: Panel unit root tests

Variable test	LCO_2		LY		LRE	
	Levels	1st differences	Levels	1st differences	Levels	1st differences
LLC (2002)	−1.35	−7.94***	−0.84	−6.03***	−0.61	−10.05***
IPS (2003)	0.60	−6.16***	1.37	−3.85***	0.48	−8.03***
ADF-Fisher	20.74	76.70***	26.22	55.63***	25.65	97.24***
PP-Fisher	27.72	98.92***	29.78	62.92***	31.19	128.61***

*** and **denote statistical significance at the 1 and 5% levels

an average of the ADF tests when u_{it} is serially correlated with different serial correlation properties across cross-sectional units.

Maddala and Wu (1999) and Choi (2001) proposed a Fisher-type test of unit root, which combines the P-values from unit root tests for each cross-section i to test for unit root in panel data. The Fisher test is nonparametric and distributed as Chi-square with 2° of freedom.

The result of panel unit root tests presented in Table 2 and indicates the existence of unit roots in level for LCO_2, LY and LRE. But the results of panel unit root tests in the first difference indicate that all variables are become stationary after first difference. In other words, data series are integrated of order one I (1).

4.2. Panel Cointegration Test

On the basis of the panel unit root test results, which imply that the data series are non-stationary in level, at the second step, we proceed to test for the existence of a long-run relationship between variables by using panel cointegration test. Granger (1981) showed that when if some series are integrated of order one (they become stationary after first differencing), but a linear combination of them is already stationary without differencing, they are said to be cointegrated, which implies the existence of a long-run relationship between the series.

Several tests are proposed to examine the existence of cointegration in panel data. We use Pedroni (1999, 2004) and Kao (1999) panel cointegration test.

Pedroni (1999) considers the following time series panel regression:

$$y_{i,t} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \ldots + \beta_{Mi} x_{Mi,t} + e_{i,t} \quad (2)$$

For t=1,…,T; i=1,…,N; m=1,…,M

Where T refers to the number of observations over time, N refers to the number of individual members in the panel, and M refers to the number of regression variables. Pedroni presented seven statistics for testing the null hypothesis of no cointegration versus cointegration in panel data. Four statistics called panel cointegration statistics, which are based on pooling along what is commonly referred to as the within-dimension. In addition to them, three statistics called group-mean panel cointegration statistics, which are based on pooling along what is commonly referred to as the between-dimension.

Kao (1999) introduced parametric residual-based panel cointegration. He expanded four DF-types and one ADF-type tests for testing the null hypothesis of no cointegration. The tests are based on the spurious least squares dummy variable panel regression equation with one single regressor.

Table 3 presented the results of Pedroni panel cointegration tests and reveals the existence of cointegration relationship between RE, economic growth and CO_2 emissions. The results of Kao panel cointegration test presented in Table 4 and support the existence of cointegration between the series.

4.3. Panel Causality Test

The finding of cointegration implies that there exists a causal relationship between the series, but it does not indicate the direction of causality. Engle and Granger (1987) show that if non-stationary variables are cointegrated, a vector autoregression (VAR) in first differences will be misspecified, because of the removed long-run information in the first differencing, but a VECM can avoid this shortcoming. In addition, unlike the usual Granger causality test, VECM can identify sources of causation and can distinguish between a long-run and a short-run relationship in the series.

We specify a model with a dynamic error-correction representation. This means that the VAR model is augmented with one period lagged ECT, which is obtained from the estimated residuals of the cointegrated model. A tri-variate panel-VECM for examining the causality between CO_2 emissions, economic growth and RE can be written as follows:

$$\Delta LCO_{2it} = c_{1i} + \sum_{i=1}^{k} \alpha_{1ik} \Delta LCO_{2it-k} + \sum_{i=1}^{k} \beta_{1ik} \Delta LY_{it-k} + \sum_{i=1}^{k} \gamma_{1ik} \Delta LRE_{it-k} + \varphi_{1i} ECT_{t-1} + \varepsilon_{it} \quad (3)$$

$$\Delta LY_{it} = c_{2i} + \sum_{i=1}^{k} \alpha_{2ik} \Delta LCO_{2it-k} + \sum_{i=1}^{k} \beta_{2ik} \Delta LY_{it-k} + \sum_{i=1}^{k} \gamma_{2ik} \Delta LRE_{it-k} + \varphi_{2i} ECT_{t-1} + \varepsilon_{it} \quad (4)$$

$$\Delta LRE_{it} = c_{3i} + \sum_{i=1}^{k} \alpha_{3ik} \Delta LCO_{2it-k} + \sum_{i=1}^{k} \beta_{3ik} \Delta LY_{it-k} + \sum_{i=1}^{k} \gamma_{3ik} \Delta LRE_{it-k} + \varphi_{3i} ECT_{t-1} + \varepsilon_{it} \quad (5)$$

Where Δ is the first difference operator; ECT_{t-1} is the lagged ECT; k is the lag length; and ε_{it}, υ_{it} and $\in_{it}$ are the serially uncorrelated error term.

The direction of panel causations can be identified by testing for the significance of the coefficient of dependent variables in Eqs. (3–5). We test H_0:β_{1ik}=0 ∀i, k and H_0:γ_{1ik}=0 ∀i, k to determine short-run Granger causality from GDP and RE to CO_2 emissions, respectively; H_0:α_{2ik}=0 ∀i, k and H_0:γ_{2ik}=0 ∀i, k to determine short-run Granger causality from CO_2 emissions and RE to GDP; and H_0:α_{3ik}=0 ∀i, k and H_0:β_{3ik}=0 ∀i, k to indicate short-run Granger causality from CO_2 emissions and GDP to RE. Finally, for long-run causality, we test H_0:φ_i=0 ∀i, k, in each Eq. (3–5). (Notice: The null hypothesis implies no Granger causality).

Lag-length selection using Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ) indicated one lags for this panel. The results of panel causality are displayed in Table 5.

Empirical finding of panel causality in short-run indicates unidirectional causality from GDP to RE, unidirectional causality from RE to CO_2 emission, and bidirectional causality between GDP and CO_2 emissions. Furthermore, there is evidence of long-run causality in any of the VECM vectors.

Table 3: Pedroni panel cointegration test

Statistics type	Statistic value
Panel v-statistic	4.02***
Panel ρ-statistic	−10.49**
Panel non-parametric (PP) t-statistic	−4.49
Panel parametric (ADF) t-statistic	−122.07***
Group ρ-statistic	−12.12***
Group non-parametric t-statistic	−4.69***
Group parametric t-statistic	−3.80***

***,** and *denote statistical significance at the 1, 5 and 10% levels, respectively

Table 4: Kao panel cointegration test

Statistics type	Statistic value
DF_ρ	−1.39*
DF_t	−3.19***
DF_{ρ^*}	−5.69***
DF_{t^*}	−3.78***
ADF	−1.97***

***,**and *denote statistical significance at the 1, 5 and 10% levels, respectively

Table 5: Panel-VECM causality

Dependent variable	Source of causation (independent variables)			
	Short-run			Long-run
	ΔLCO_2	ΔLY	ΔLRE	ECT
ΔLCO_2	-	7.93***	24.67***	4.24**
ΔLY	11.86***	-	0.39	167.28***
ΔLRE	0.62	3.08*	-	29.36***

Table reports F statistics. ***,**and *denote statistical significance at the 1, 5 and 10% levels, respectively. ECT: Error correction term, VECM: Vector error correction model

Table 6: Panel DOLS long-run estimates, dependent variable: LCO_2

Variable	Coefficient	t-statistic
LY	0.80***	12.43
LRE	−0.09***	−2.7
R^2=0.99, adjusted R^2=0.99		

***,** and *denote statistical significance at the 1, 5 and 10% levels, respectively. DOLS: Dynamic ordinary least squares

4.4. Panel DOLS Estimates

The last step is to estimate the regression equation (1). Given our variables are cointegrated, we estimate the long-run relationship using the DOLS estimator proposed by Kao and Chiang (2000). Monte Carlo results of Kao and Chiang illustrate the OLS estimator has a non-negligible bias in finite samples and results of DOLS estimator are better than the conventional OLS estimator. Table 6 presents the results of DOLS estimation of cointegration relationship. The estimated coefficients are statistically significant at the 1% levels and imply a 1% increase in GDP increase CO_2 emissions by 0.80%, and a 1% increase in RE decrease CO_2 emissions by 0.09%.

5. CONCLUSION

In recent years, the relationship between RE consumption, economic growth and CO_2 emissions have been interested among the researchers. However, studies based on the RE are limited and there are no common consensuses among the different studies, so studying in this topic is still required.

Therefore, the aim of present study is to examine the relationship between economic growth, RE and CO_2 emission for a panel of 11 developing countries over the period 2000–2014. Firstly, panel unit root tests were performed and indicated that all variables are integrated of order one. Furthermore, Panel cointegration tests support the existence of cointegration between variables.

In the next step, panel-VECM causality framework used to reveal the direction of causality between the series. Empirical finding of causality in short-run indicates unidirectional causality from GDP to RE, unidirectional causality from RE to CO_2 emissions, and bidirectional causality between GDP and CO_2 emissions. Furthermore, the significance of ECT indicates the existence of long-run causality in all three vectors of error correction model. Finally, panel DOLS long-run estimates of cointegration relationship show that positive and statistically significant impact of GDP on CO_2 emissions and negative and statistically significant impact of RE on CO_2 emissions and environmental quality. Some policy implication can be proposed with respect to these results. For instance, we can mitigate the adverse impact of traditional energy source by substitute it with RE resources, without any worrying about the decline in economic growth.

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