RESEARCH ARTICLE

Examining the roles of renewable energy consumption and agriculture on CO_2 emission in lucky-seven countries

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Abstract

Environmental degradation has become an important global issue due to the extraordinary increase in greenhouse gas emissions in recent years. Therefore, identifying the main determinants of environmental degradation is one of the primary agenda items of researchers and policymakers. In the literature, many social, economic, and sectorial factors related to the main determinants of CO_2 emissions have been studied. Although these studies provide very important information about the causes of CO_2 emissions and environmental degradation, some deficiencies remain in the related literature. The agricultural sector activities, which are an important sector at a global level and have significant potential impacts on CO_2 emissions, have not been adequately studied. In order to fill this gap, the effects of agriculture and renewable energy on CO_2 emissions were examined for lucky-seven countries during the period 1995–2014. The results of panel cointegration reveal the presence of long-run nexus among the variables. While the findings indicate that agriculture increases CO_2 emissions, renewable energy is a very important catalyst in reducing CO_2 emissions in lucky-seven countries. We also found that economic growth and energy consumption enhance CO_2 emissions and trade openness decreases. Panel VECM results indicate that variables are the causes of CO_2 emission in the long run. Also, we find that economic growth is the cause of CO_2 emissions in the short run.

Keywords CO_2 emissions · Renewable energy · Agriculture · Panel cointegration · Lucky-seven countries

Introduction

The extraordinary acceleration of technological advances has rapidly increased people's well-being and quality of life, especially in the past few decades. Moreover, environmental issues caused by increased greenhouse gas emissions threaten the life quality of societies (Waheed et al. 2018). The Intergovernmental Panel on Climate Change (IPCC) (2014) stated that environmental problems such as greenhouse gas problems and climate change are one of the most important threats to the future of public welfare and human existence. Especially the global population problems, the acceleration of globalization and the increase in the use of energy consumption (ENE) have increased the level of carbon dioxide emissions (CO_2), which is one of the most important reasons for environmental degradation. Data from BP Statistical Review (2019) reveals the dangerous increase in CO_2. While the CO_2 was 11,193.9 million tons in 1965, it increased three times in 2018 and reached 33,890.8 million tons. The increase in CO_2 and the environmental problems created by it seem to continue to increase pressure on governments and policymakers to stop environmental degradation.

The environmental problems make the creation of sustainable low carbon economies an important goal (Goh and Ang 2018; Zhu et al. 2016). Undoubtedly, reducing CO_2 and improving environmental quality necessitates identifying the main determinants of CO_2. For example, agricultural activities (AGR) cause CO_2. The most important reason for CO_2 from the agricultural sector is the intensive use of energy in agricultural activities. The use of agricultural equipment and machinery is one of the important causes of ENE (Sebri and Abid

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2012). AGR activities such as heating, cooling, drying, and packaging and transportation for agricultural purposes need a significant amount of energy (Bayrakci and Kocar 2012). In this context, supplying the energy need in the agricultural sector through fossil fuels, which is the main source of CO_2, increases the level of CO_2. Additionally, the use of chemical fertilizers carried out within the framework of AGR, methane gas emitted by animal husbandry, and the destruction of forests to create agricultural land are other factors that increase CO_2 (Rafiq et al. 2016; Jebli and Youssef 2017b). AGR causes between 14 and 30% of world greenhouse gas emissions (Reynolds and Wenzlau 2012; Vermeulen et al. 2012).

The intensive use of fossil-based energy sources in the agricultural sector causes serious environmental and economic problems. It is stated that CO_2 from the AGR can be reduced with some measures and practices (IPCC 2014). In this context, using animal fertilizer instead of chemical fertilizer, converting agricultural residues into energy, and integrating renewable energy (REN) into AGR can be important factors in reducing agricultural CO_2 (Liu et al. 2017; Jebli and Youssef 2017a). Integrating REN into both AGR and other sectors is critical in reducing CO_2, protecting from excessive fluctuations in oil prices, ensuring energy security, and reducing foreign dependency in energy (Apergis et al. 2010; Burke and Stephens 2018). In this context, solar energy, biomass energy, geothermal energy, wind energy, and hydropower are important catalysts for the improvement of environmental quality by integrating REN sources such as biological activities, reducing CO_2, and protecting agricultural areas (Bayrakci and Kocar 2012).

In the environmental economy literature, it has been observed that specific factors such as economic growth (GDP), ENE, foreign direct investments (FDI), trade openness (OPE), income distribution (GINI), institutional quality (IQ), population (POP), and urbanization (URB) are used to determine the determinants of CO_2 and other pollutants (see Halicioglu 2009; Apergis and Payne 2009; Uzar and Eyuboglu 2019; Zakaria and Bibi 2019; Dogan and Inglesi-Lotz 2020; Uzar 2020). It is seen that other descriptors of CO_2 and other pollutants are finance (FIN), tourism (TOU), and higher education (EDU) (see Shahbaz et al. 2013; Katircioglu 2014; Katircioglu et al. 2020). The use of many socioeconomic and sectorial variables in the disclosure of CO_2 and other pollutants indicates that an intense effort is made to identify the main determinants of environmental degradation. Although these studies provide important contributions to explain the main determinants of environmental degradation, some deficiencies in the literature stand out. As mentioned above, although AGR and REN have significant potential effects on CO_2, the number of studies testing the empirical linkages among AGR, REN, and CO_2 is almost nonexistent (see Rafiq et al. 2016; Jebli and Youssef 2017a; Liu et al. 2017; Waheed et al. 2018). Therefore, it is very important to

reveal the relationship between the AGR and REN and to analyze the effects of these variables on CO_2.

This study aims to examine the effects of the AGR and REN consumption on CO_2 in the lucky countries that cover the period of 1995–2014. In addition, GDP, ENE, and OPE are included in the model to prevent the omitted variable bias problem. Thus, it is aimed to comprehensively determine the basic determinants of CO_2. In the literature, the countries called new emerging market countries or lucky sevens are Malaysia, Indonesia, India, Kenya, Mexico, Colombia, and Poland. Bremmer (2015) and Bakirtas and Akpolat (2018) stated that seven countries have come to the forefront in the academic analysis due to improvements in governance quality in recent years, an increase in economic growth rates, and a potential for sustainable high economic growth in the future. Thus, it has become an important question how rapid economic growth and developments in the governance area will affect the quality of the environment in these countries. The acceleration of economic growth has the potential to increase CO_2 by increasing ENE in these countries. In this context, expanding the use of REN in these countries can be thought to play an important role in reducing the environmental costs of the growth process. In addition, since these countries have a significant agricultural economy, determining the impact of the agriculture sector on CO_2 provides a strong research motivation.

It is expected that the study contributes to the literature in some aspects. Firstly, although many factors are used in the literature to explain CO_2, the impact of the AGR on CO_2 has been neglected. This study examines the effects of AGR and REN consumption on CO_2, as the main independent variable. In this framework, the study enriches the environmental economy literature by providing fresh evidence for the linkages among AGR, REN, and CO_2. Secondly, there is almost no study in the literature that examines lucky-seven countries. As far as the authors know, Bakirtas and Akpolat (2018) examined the nexus between ENE, GDP, and URB in this country group, while Eyuboglu and Uzar (2020) tested the linkages between savings and investments. Therefore, this study is the pioneer attempt to examine the determinants of CO_2 by using AGR and REN as the main explanatory variables in lucky-seven countries. In this context, the findings of the study will provide important information in designing AGR and REN policies for policymakers in lucky-seven countries. Finally, the second-generation panel data methodology is used in the study. Ignoring the cross-sectional dependence (CD) and heterogeneity (HG) will cause the results to be biased.

The remainder of the study is structured as follows. "Literature review" summarizes agriculture-energy and CO_2 literature. "Data and methodology" explains the data and methodology. "Findings" reports the findings. Finally, "Conclusion and policy implications" summarizes the study and gives policy implications.

Literature review

The determinants of CO_2, which is an important indicator in the environmental economics literature, have been examined with different countries, periods, variables, and econometric methodologies. Earlier studies in the literature generally focused on the effect of GDP and ENE on CO_2 and other pollutants. In this context, the first attempt was carried out by Grossman and Krueger (1991). Grossman and Krueger (1991) examined the trade-off between GDP and various environmental indicators and found that there is an inverse U nexus between the variables. Following this pioneering study, Shafik and Bandyopadhyay (1992) provided strong evidence of an inverse-U nexus between income level and different environmental indicators similarly to Grossman and Krueger (1991). After these studies, interest in the impact of GDP and ENE on CO_2 has started to increase. Say and Yücel (2006) examined the effect of GDP and ENE on CO_2 in Turkey. Findings indicated that both factors positively affect CO_2. Soytas et al. (2007) examined the impact of GDP and ENE on CO_2 in the US. The findings approve the validity of the Environmental Kuznets Curve (EKC) hypothesis in the US and show that ENE causes CO_2. Apergis and Payne (2009) investigated the impact of GDP and ENE on CO_2 in 6 Central American Countries. The findings approve the reverse U-shaped nexus between GDP and CO_2 and show that EN increases CO_2. Arouri et al. (2012) pointed out that ENE is an important determinant of CO_2 in 12 Middle East and North African countries, while there is no strong evidence for the validity of the EKC.

The literature that started with Grossman and Krueger (1991) has gradually expanded over time. Then, more specific variables and sectors have been used to explain CO_2. For example, Halicioglu (2009) used international trade, GDP, and ENE in explaining CO_2 increase in Turkey. Findings showed that all three variables positively affect CO_2. Tang and Tan (2015) focused on the impact of FDI on CO_2 in Vietnam. Findings denoted that FDI is an important determinant of CO_2 along with the level of production and ENE. Dogan and Seker (2016) examined the impact of REN on CO_2 in the European Union (EU) countries. They found that REN is an important catalyst in reducing CO_2. Dong et al. (2018) examined the effect of POP growth on CO_2 in 128 countries and found a positive relationship. Uzar and Eyuboglu (2019) examined whether GINI affects CO_2 in Turkey. The study concluded that improvements in GINI reduce CO_2. Ali et al. (2019) analyzed the impact of URB on CO_2 in Pakistan. They found that URB increases CO_2. Zakaria and Bibi (2019) examined the impact of IQ indicators on CO_2 in the South Asian region. The study pointed out that IQ is an important factor in curbing CO_2 in South Asia.

In addition to such social and economic indicators, it appears that some variables such as FIN, TOU, and EDU come to the forefront in explaining CO_2. Shahbaz et al. (2013) focused on the impact of financial development (FD) on emissions in South Africa. The findings showed that FD is a factor that reduces CO_2. Similarly, Charfeddine and Kahia (2019) focused on the effect of the financial sector and REN on CO_2 in MENA countries. The findings indicated that both the financial sector and REN had a weak impact on CO_2. Moreover, Katircioglu (2014) and Eyuboglu and Uzar (2019) used the TOU as the main explanatory variable in explaining CO_2. While Katircioglu (2014) found negative linkages between TOU and CO_2 in Singapore, Eyuboglu and Uzar (2019) found a positive nexus in Turkey.

Studies to explain CO_2 are generally focused on specific socioeconomic factors and some sectors. However, the AGR has been analyzed in very few studies. Rafiq et al. (2016) stated that the impact of the AGR on the environment has been carefully followed by experts such as ecology, agriculture, and the environment, but the energy and environmental economists are unfamiliar with the subject. The insufficient number of studies examining AGR, REN, and CO_2 has also overlooked the importance of REN usage in the AGR. Moreover, this deficiency may make it difficult to establish appropriate economic policies. As far as the authors know, there are very few studies in the literature that investigate the linkages among AGR, REN, and CO_2.

Rafiq et al. (2016) tested the effect of AGR, OPE, and ENE on CO_2 in 53 countries during the period 1980–2010. The results denoted that REN decreases and non-renewable energy (NREN) enhances CO_2. It is concluded that agricultural and service sector activities reduce CO_2. Jebli and Youssef (2017a) analyzed the linkages among REN, AGR, and CO_2 in Tunisia covering the period 1980–2011. The results denoted that REN diminishes CO_2 and AGR increases the CO_2. Results also showed that the EKC hypothesis is not valid in Tunisia. They also found bidirectional causality between AGR and CO_2. Liu et al. (2017) tested the impact of REN and AGR on CO_2 in ASEAN-4 countries during the period 1970–2013. Results indicated that REN and AGR diminish CO_2. Also, it is explored that NREN positively affects CO_2. They found causality from AGR to CO_2 and bi-directional causality between CO_2 and REN. Jebli and Youssef (2017b) analyzed the linkages among REN, AGR, GDP, and CO_2 in five North African countries during the 1980–2011 period. According to the results, while GDP increases CO_2, AGR decreases CO_2 in the long-run. In contrast to other studies, it is concluded that REN increases CO_2. Causality results showed that CO_2 and AGR are the causes of each other. Also, it is determined that the causality is from REN to CO_2 and AGR in the long run. Waheed et al. (2018) tested the trade-off among REN, AGR, forestation, and CO_2 in Pakistan covering the period 1990–2014. The results show that forestation and REN reduce CO_2. VECM results denote that REN, AGR, and forestation are the causes of CO_2. Qiao

et al. (2019) examined the linkages among AGR, GDP, and REN in G20 countries. They explored that AGR has a positive effect while REN has a negative effect on CO_2. Aydoğan and Vardar (2020) analyzed the linkages among AGR, REN, CO_2, and GDP in E7 countries spanning the period 1990–2014. They found a positive nexus among CO_2, GDP, NREN, and AGR and a negative relationship between CO_2 and REN.

Table 1 summarizes studies on REN, AGR, and CO_2 nexus. In this context, in four out of seven studies, AGR increases CO_2 and decreases in three of seven. In six studies, REN decreases CO_2 and increases it in only one study. Therefore, similar to the literature in the energy and environmental economy, a consensus could not be achieved in the relationship between REN, AGR, and CO_2. Also, two studies focused on one country, while the other five focused on country groups. In this context, our study focuses on lucky-seven countries that are based on AGR and their economic growth process is gradually increasing. Therefore, empirical evidence to be obtained will provide important information for policymakers in the development of lucky-seven countries in the development of agricultural and environmental policies.

Data and methodology

The goal of the study is to analyze the effect of REN and AGR on the CO_2 in Colombia, India, Indonesia, Kenya, Malaysia, Mexico, and Poland during the period 1995–2014, using Kao (1999), Fisher-type Johansen (1999) and Westerlund (2007) and Panel VECM causality tests. In this study, we employ the longest available data. The data for Poland is not available before 1995, and the data for CO_2 are not available after 2014. To avoid the omitted variable bias problem, ENE, GDP, and OPE are included in the model. Thus, our model can be expressed as follows:

$$CO_{2_{it}} = f\left(ENE_{it}, REN_{it}, AGR_{it}, GDP_{it}, OPE_{it},\right) \qquad (1)$$

In the equation, CO_2, ENE, REN, AGR, GDP, and OPE indicate CO_2 (metric tons per capita), energy use (kg of oil equivalent per capita), renewable energy consumption per capita, agriculture value added (% of GDP), GDP per capita

(constant 2010 US$), and trade openness (sum of export and import to GDP), respectively. The annual panel data are taken from WDI. This study utilizes the logarithmic values of the data.

Before detecting unit root characteristics of the variables, it is crucial to examine CD and HG in panel data. Thus, we first tested whether CD exists within the panel data by applying Breusch and Pagan (1980) and Pesaran et al. (2008) tests. The H_0 hypothesis of these tests denotes that there is no CD.

To test for whether or not slope coefficients are homogenous, we used Pesaran and Yamagata's Swamy test (Pesaran and Yamagata 2008). In the test, H_0: $\beta_i = \beta$ for all individual, against the HG.

In case that a panel data has CD and HG, the conventional panel unit root tests give unreliable results. Thus, we used Pesaran's (2007) CIPS test which is taking CD into account. The H_0 hypothesis of the CIPS test is the unit root and the alternative hypothesis is no unit root. If the test statistic is upper than the critical value, we can reject the null hypothesis. Due to the fact that all of the variables are integrated in the order of one, the cointegration nexus among the variables is examined by employing Kao (1999), Fisher-type Johansen (1999), and Westerlund (2007) cointegration tests. The Kao cointegration tests involving panel data are based on the Engle-Granger (1987) two-step (residual-based) cointegration tests, whereas the Fisher test is a combined Johansen test. The Kao analyzes the asymptotic null distribution of residual-based cointegration test in panel data by applying Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests.

Maddala and Wu (1999) stated that Fisher-type Johansen (1999) estimates better than Engle-Granger two-step procedure tests. It gives more robust results in the long run. The test statistic is easy to compute and it is a non-parametric test that does not assume homogeneity in the coefficients (Lee and Chiu 2011: 2113; Ouedraogo 2013:641).

The Westerlund (2007) tests avoid the problem of common factor restriction and are designed to test the H_0 hypothesis of no cointegration by inferring whether the error-correction term in a conditional error-correction model is equal to zero. Westerlund (2007) panel cointegration considers CD and HG in the panel. The test estimates statistics on group and panel

Table 1 Studies on REN, AGR, and CO_2 nexus

Authors	Countries	Period	AGR-CO_2	REN-CO_2
Rafiq et al. (2016)	Low, Middle and High-Income Countries	1980–2010	(−)	(−)
Jebli and Youssef (2017a)	Tunisia	1980–2011	(+)	(−)
Liu et al. (2017)	ASEAN-4	1970–2013	(−)	(−)
Jebli and Youssef (2017b)	5 North African Countries	1980–2011	(−)	(+)
Waheed et al. (2018)	Pakistan	1990–2014	(+)	(−)
Qiao et al. (2019)	G20	1990–2014	(+)	(−)
Aydoğan and Vardar (2020)	E7	1990–2014	(+)	(−)

tests. If slope coefficients are heterogeneous G_t and G_a; if slope coefficients are homogenous P_t and P_a results should be taken into account. Also, bootstrap values should be considered in the case of CD.

The H_0 hypothesis of no cointegration is evaluated against the alternative hypothesis of cointegration among the variables in all three cointegration tests. The long-run effects are estimated by FMOLS and DOLS suggested by Pedroni (2000, 2001).

The direction of the short-run and long-run panel causality nexus between the variables is investigated by the panel-based vector error correction model (VECM). The VECM causality used in the current study is based on the following model:

$$
\begin{bmatrix} \Delta CO2_{it} \\ \Delta ENE_{it} \\ \Delta REN_{it} \\ \Delta AGR_{it} \\ \Delta GDP_{it} \\ \Delta OPE_{it} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \end{bmatrix} + \sum_{p-1}^{q} \begin{bmatrix} b_{11,p} b_{12,p} b_{13,p} b_{14,p} b_{15,p} \\ b_{21,p} b_{22,p} b_{23,p} b_{24,p} b_{25,p} \\ b_{31,p} b_{32,p} b_{33,p} b_{34,p} b_{35,p} \\ b_{41,p} b_{42,p} b_{43,p} b_{44,p} b_{45,p} \\ b_{51,p} b_{52,p} b_{53,p} b_{54,p} b_{55,p} \\ b_{61,p} b_{62,p} b_{63,p} b_{64,p} b_{65,p} \end{bmatrix} \begin{bmatrix} \Delta CO2_{it-1} \\ \Delta ENE_{it-1} \\ \Delta REN_{it-1} \\ \Delta AGR_{it-1} \\ \Delta GDP_{it-1} \\ \Delta OPE_{it-1} \end{bmatrix} \quad (2)
$$
$$
+ \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \\ c_6 \end{bmatrix} ect_{it-1} + \begin{bmatrix} \mu_{1it} \\ \mu_{2it} \\ \mu_{3it} \\ \mu_{4it} \\ \mu_{5it} \\ \mu_{6it} \end{bmatrix}
$$

where Δ is the first-difference operator, t is the time from 1995 to 2014, i is the cross-sections (1, 2, 3, 4, 5, 6, 7), ect and μ are the lagged ECT and the error term, a is the fixed country effect, b is the coefficient of short-run causal effect, and c is the long-run adjustment coefficient, respectively (Liu et al. 2017: 1241).

Findings

Table 2 indicates the summary of statistics. The logarithmic averages of CO_2, ENE, REN, AGR, GDP, and OPE are 0.7258, 6.9050, 0.0062, 2.2432, 8.2063, and 4.0968, respectively.

The results of the Breusch and Pagan (1980) and Pesaran et al. (2008) tests are denoted in Table 3. Results indicate that the H_0 hypothesis of cross-sectional independence is rejected. Also, we can reject the H_0 hypothesis of the Swamy test thus decide that the panel data is heterogeneous.

Then, we employ the CIPS panel unit root test because of the existence of CD and HG. The findings of CIPS are reported in Table 4. When the test is employed to the first differences of the variables, the H_0 hypothesis is rejected for CO_2, ENE, REN, AGR, GDP, and OPE.

The cointegration nexus among CO_2, ENE, REN, AGR, GDP, and OPE is investigated by Kao, Fisher-type Johansen, and Westerlund cointegration tests.

Table 5 reports the results of Kao's (1999) residual panel cointegration tests, which also reject the null of no

cointegration at the 1% significance level. In other words, variables are cointegrated.

Table 6 shows Fisher-type Johansen cointegration test results. The trace and max-eigen statistics show that there are at least four cointegrating vectors at the 0.05 level. In other words, CO_2, ENE, REN, AGR, GDP, and OPE tend to move together in the long run.

We also apply the Westerlund (2007) panel cointegration test to analyze the nexus between the variables in the long run. This test takes into account both the issues of CD and HG. The findings are reported in Table 7. G_a and G_t test statistics indicate that the H_0 hypothesis of no cointegration can be rejected because their p values are lower than 0.10. In other words, variables are cointegrated.

After the determination of the cointegration nexus among variables, Pedroni (2000) FMOLS and Pesaran (2006) DOLS is employed to reveal the long-run coefficients. The estimations are presented in Table 8. According to FMOLS and DOLS estimators, REN negatively affects CO_2 in the long run. Findings are consistent with Rafiq et al. (2016), Liu et al. (2017), Jebli and Youssef (2017a), Waheed et al. (2018), Qiao et al. (2019), and Aydoğan and Vardar (2020). The findings show that the use of REN is very important instead of NREN. Widespread usage of REN indicates that CO_2 will reduce environmental problems. The AGR enhances CO_2 according to both FMOLS and DOLS estimators in the long run. The findings are similar to Jebli and Youssef (2017a), Waheed et al. (2018), Qiao et al. (2019), and Aydoğan and Vardar (2020). The results imply that fossil fuel use in the AGR sector is common in lucky-seven countries. Therefore, a raise in the AGR sector's production increases CO_2 by raising the use of fossil fuels. Thus, the use of REN becomes more important, given the impact of the AGR sector on environmental pollution.

The causal nexus among CO_2, ENE, AGR, REN, GDP, and OPE are investigated by VECM. Table 9 denotes the results of VECM. We reveal that four out of five ECTs are significant and negative (CO_2, ENE, AGR, and OPE equations). These results suggest that AGR, ENE, REN, GDP, and OPE are causes of CO_2 in the long run. Also, CO_2, REN, AGR, GDP, and OPE are Granger causes of ENE; CO_2, ENE, REN, GDP, and OPE are Granger causes of AGR; CO_2, ENE, REN, AGR, and GDP are Granger causes of OPE in the long run. Moreover, it is found that GDP is the cause of CO_2 in the short run. Also, we find that REN is the cause of AGR in the short run. Moreover, the change in GDP affects the ENE and OPE in the short run.

Results and discussion

This study examines the effects of AGR and REN on CO_2 by controlling GDP, ENE, and OPE from 1995 to 2014 in lucky-

Table 2 Summary statistics

	CO_2	ENE	REN	AGR	GDP	OPE
Mean	0.7258	6.9050	0.0062	2.2432	8.2063	4.0968
Median	0.5409	6.6694	0.0058	2.3952	8.5612	3.9987
Maximum	2.2203	7.9954	0.0102	3.3584	9.5532	5.3954
Minimum	− 1.6199	5.9570	0.0022	0.9103	6.4334	3.0986
Std. Dev.	1.0935	0.6826	0.0025	0.7793	0.9743	0.5401
Skewness	− 0.4420	0.2190	0.3381	− 0.3068	− 0.4786	0.9217
Kurtosis	2.2665	1.4881	1.720	1.7405	1.6768	3.4552
Observations	140	140	140	140	140	140

seven countries. Firstly, in the study, the CD and HG are examined and it is determined that there are CD and HG between the variables. Afterward, integration levels of the variables are tested by the CIPS unit root test that takes into account the CD and HG. CIPS test results indicated that the variables are stationary in their first differences. Then, the cointegration nexus among the variables are tested by employing Kao (1999), Fisher-type Johansen (1999), and Westerlund (2007) tests. All three tests confirmed a long-run cointegration relationship between the variables. After determining that the variables are cointegrated, the long-run effects of independent variables on CO_2 were estimated by FMOLS and DOLS estimators. All three tests confirmed the cointegration nexus among the variables. After determining that the variables are cointegrated, the long-run effects of ENE, REN, AGR, GDP, and OPE on CO_2 are estimated by FMOLS and DOLS estimators.

Results of FMOLS and DOLS estimators showed that ENE, REN, AGR, GDP, and OPE statistically significantly affect CO_2 in the long run. AGR, which is our main independent variable, positively affects CO_2 compared with both estimators. One percent increase in AGR increases CO_2 by 0.241–0.244% in lucky-seven countries. These results are similar to Jebli and Youssef (2017a), Waheed et al. (2018), Qiao et al. (2019), and Aydoğan and Vardar (2020). Since these studies are carried out for countries with different characteristics, it is difficult to generalize these results for lucky-seven countries. The long-run positive linkages between AGR and CO_2 in lucky-seven countries can be explained in several ways. The results indicate that fossil fuel use is high in the

agricultural sector in this country group. In the agricultural sector, activities such as water pumping, heating, drying, processing, and packaging and transportation of agricultural products are carried out intensely with fossil fuels, which cause to enhance CO_2 in the agricultural sector. Considering that the agricultural sector is large and fossil fuel use is common in these countries, it is possible to say that the increase in agricultural activities rapidly increases CO_2. According to Renewable Global Status Report (2019), although there are positive developments related to REN investments in all countries in the last year, the results indicate that the integration of REN into the agriculture sector is insufficient. Also, the fact that important agricultural activities such as fertilization are based on chemicals and the destruction of forest areas to create new agricultural lands may explain the effect of AGR on CO_2.

REN, our other main independent variable, negatively affects CO_2. One percent enhancement in REN use diminishes CO_2 by 0.388–0.412% in lucky-seven countries. Our results

Table 3 CD and HG tests

CD tests	Statistic	p values
Breusch-Pagan LM	126.54	0.000
Bias-corrected scaled LM	16.32	0.000
Homogeneity test	**Statistic**	**p values**
$\widetilde{\Delta}$	3.645	0.000
$\widetilde{\Delta}_{adj}$	3.864	0.000

Table 4 CIPS test

Variables	Intercept			Intercept and trend		
	t bar	Z[t bar]	p values	t bar	Z[t bar]	p values
CO_2	− 1.747	− 0.043	0.483	− 2.579	− 0.783	0.217
ENE	− 1.619	0.285	0.612	− 2.332	− 0.137	0.445
REN	− 1.308	1.085	0.861	− 1.971	− 0.809	0.791
AGR	− 2.439	− 1.822	0.034	− 2.399	− 0.313	0.377
GDP	− 2.567	− 2.151	0.016	− 2.243	0.098	0.539
OPE	− 1.985	− 0.655	0.256	− 2.653	− 0.977	0.164
$\Delta CO2$	− 2.948	− 3.129	0.001	− 3.132	− 2.231	0.013
ΔENE	− 2.461	− 1.877	0.030	− 3.192	− 2.389	0.008
ΔREN	− 2.871	− 2.243	0.003	− 2.828	− 1.887	0.076
ΔAGR	− 2.816	− 2.790	0.002	− 3.117	− 2.193	0.014
ΔGDP	− 2.580	− 2.183	0.015	− 2.780	− 1.294	0.098
ΔOPE	− 3.028	− 3.335	0.000	− 3.151	− 2.281	0.011

Δ shows the first differences. Critical values of CIPS are − 2.210, − 2.340, and − 2.600 for intercept and − 2.740, − 2.880 and − 3.150 for intercept and trend

Table 5　Kao cointegration test

	t Statistic	p values
ADF	−4.374461	0.0000
Residual variance	0.004426	
HAC variance	0.002372	

Table 7　Westerlund ECM

Model $CO_{2it} = f(ENE_{it}, REN_{it}, AGR_{it}, GDP_{it}, OPE_{it})$

Statistics	Value	Z value	Robust p values
G_a	−2.681	−1.256	0.000
G_t	−6.106	1.936	0.022
P_t	−6.661	−1.377	0.000
P_a	−4.177	1.282	0.200

G_t and G_a are the group mean statistics. P_t and P_a are panel mean statistics

are consistent with Rafiq et al. (2016), Dogan and Seker (2016), Liu et al. (2017), Waheed et al. (2018), Qiao et al. (2019), and Aydoğan and Vardar (2020). This result is compatible with the theoretical and empirical literature. Because REN, which is characterized as eco-friendly and ecological, is a sustainable energy source that can be reproduced with the use of existing resources. According to the Renewable Global Status Report (2019), lucky-seven countries have taken some important steps in REN production recently. Especially Poland, Indonesia, and Malaysia have started to make significant investments in REN capacity in recent years. In this context, changing the energy composition in favor of REN will be an important catalyst in reducing CO_2 in lucky-seven countries.

FMOLS and DOLS denote that CO_2 is mostly affected by GDP and ENE in the lucky-seven countries. The two variables increase CO_2 by 0.608–0.615% and 0.535–0.730%, respectively. Lucky-seven countries have very high economic growth rates in recent years. Therefore, increasing growth increases energy demand. Although REN capacity has increased in these countries in recent years, the energy portfolio is still based on fossil resources. Therefore, GDP increases CO_2 and the growth process based on high ENE in all sectors becomes an important determinant of CO_2. Moreover, the results also point out that energy efficiency is still not high in lucky-seven countries. Therefore, promoting the use of REN instead of NREN sources and increasing energy efficiency at the unit production level will reduce the environmental costs of GDP in lucky-seven countries. The increase in the governance quality of these countries in recent years has created hope for the reduction of environmental costs of the process of economic growth (Bremmer 2015; Bakirtas and Akpolat 2018).

Finally, OPE negatively affects CO_2 in lucky-seven countries. One percent increase in OPE reduces CO_2 by 0.113–

0155%. OPE can affect CO_2 through scale, composition, and technical effects. If the effect of the OPE on CO_2 is positive the scale effect is valid. If the effect of OPE on CO_2 is negative, the composition and technical effects are valid. The findings indicate that the commercial integration process positively affects the environment in lucky-seven countries. In this context, the inclusion of these countries in commercial globalization creates a positive impact on the environment, especially by using widespread technology instead of traditional and dirty methods in the production process.

VECM causality results show that AGR, ENE, REN, GDP, and OPE are causes of CO_2 in the long run. In other words, any change in independent variables affects CO_2 in lucky-seven countries. Also, CO_2, REN, AGR, GDP, and OPE are Granger causes of ENE; CO_2, ENE, REN, GDP, and OPE are Granger causes of AGR; CO_2, ENE, REN, AGR, and GDP are Granger causes of OPE in the long run. Moreover, it is found that GDP is the cause of CO_2 in the short run. We find that REN is the causes of AGR in the short run. Moreover, the change in GDP affects the ENE and OPE in the short run.

Conclusion and policy implications

Environmental degradation has become an important global problem due to the extraordinary increase in greenhouse gas emissions in recent years. For this reason, researchers and policymakers make a special effort to stop environmental degradation. In this context, attempts to explain the main determinants of CO_2 are gradually increasing. In the environmental economy literature, social, macroeconomic, and sectorial factors come to the fore in explaining CO_2.

Although all these studies have contributed to the discovery of the main causes of CO_2 and environmental degradation, it is possible to say that there are still some deficiencies in the related literature. In this context, the impact of AGR, which is one of the important sectors and potentially having an environmental impact, on CO_2 has been neglected except for a very few studies. This gap in the literature requires a comprehensive study of the potential effects of the AGR on CO_2.

Table 6　Fisher-type Johansen cointegration test

No. of CE(s)	Trace test	p values	Max-eigen test	p values
None	43.77	0.000	60.81	0.000
At most 1	271.7	0.000	196.2	0.000
At most 2	137.9	0.000	112.8	0.000
At most 3	51.74	0.000	51.75	0.000
At most 4	25.22	0.032	28.98	0.010
At most 5	10.61	0.716	12.61	0.444

Table 8 Long-run coefficients

Model: $CO_{2it} = f(ENE_{it}, REN_{it}, AGR_{it}, GDP_{it}, OPE_{it})$	FMOLS		DOLS	
	Coefficient	Prob.	Coefficient	Prob.
ENE	0.535	0.002	0.730	0.005
REN	− 0.388	0.000	− 0.412	0.005
AGR	0.244	0.003	0.241	0.044
GDP	0.615	0.000	0.608	0.000
OPE	− 0.113	0.059	− 0.155	0.084

Within the framework of this motivation, the effects of AGR and REN on CO_2 are analyzed with FMOLS and DOLS estimators cover the period 1995–2014 in lucky-seven countries. These countries, which have come to the forefront in economic analysis with their rapidly raising growth performance and governance quality in recent years, have been preferred due to some unique conditions. Considering that these countries will continue their rapid economic growth and development processes, how the impact of this process on the environment will have gained importance. In addition, since these countries have a significant agricultural economy, determining the impact of the AGR on CO_2 provides a strong research motivation.

Findings show that AGR is an important and positive determinant of CO_2 in lucky-seven countries. Fossil-based energy sources used in agricultural activities, chemical fertilizer use, and destruction of forest areas are the main factors explaining the positive impact of the AGR on CO_2. Another important finding from the study is that the use of REN is a very important catalyst in reducing CO_2. REN, which can be produced repeatedly with the use of existing resources, has less CO_2 than other types of energy. Empirical findings pointed out that GDP and ENE are an important determinant of CO_2 in lucky-seven countries. In this context, the increasing energy requirements of GDP and failure to achieve energy efficiency have revealed this result. Finally, OPE decreases CO_2 by using clean technology instead of traditional and dirty methods in lucky-seven countries.

Some policy suggestions can be made within the framework of the results obtained. It does not seem possible to reduce CO_2 with the existing agricultural activities in lucky-seven countries. In this framework, policymakers are faced with the pressure of both maintaining the agricultural production volume that contributes significantly to economic growth and reducing the environmental impacts of the agricultural production process. In this context, animal fertilizer should be expanded in agricultural activities instead of chemical fertilizer. Additionally, the conversion of agricultural wastes such as grain dust, wheat straw, and hazelnut shells into energy will reduce the use of fossil fuels in AGR and reduce CO_2. Therefore, the conversion of agricultural waste into energy should be encouraged in these countries. In this framework, governments should implement supports such as subsidies, tax breaks, and credit facilities for farmers. Another policy proposition is that unconsciously transformed forest lands into agricultural lands. In this context, new environmental legislation should be created, the destruction of forests and the creation of illegal agricultural areas should be prevented. Integrating renewable energy sources such as solar energy, biomass energy, geothermal energy, wind energy, and hydropower into the agricultural production process is also very critical. In this framework, the government can pay agricultural producers free of charge in exchange for the use of renewable energy. All these policies can reduce both agricultural production and the negative environmental impacts of the sector. In addition, R&D activities should be supported in promoting the use of REN. Increasing investments in clean

Table 9 VECM

Dependent variables	Short run						Long run
	ΔCO_2	ΔENE	ΔAGR	ΔREN	ΔGDP	ΔOPE	ECT
ΔCO_2	-	− 0.236	0.003	0.121	0.497*	0.050	− 0.011**
ΔENE	− 0.019	-	0.200	0.891	0.363***	− 0.023	− 0.011***
ΔAGR	0.061	0.487**	-	− 0.589***	− 0.008	0.103	− 0.014**
ΔREN	− 0.001	− 0.001	0.123	-	0.001	0.007	0.001
ΔGDP	0.001	− 0.200*	0.006	0.928	-	0.010	0.002
ΔOPE	− 0.009	0.103	− 0.047	− 0.504	0.654**	-	− 0.015**

***Significance at 1%, ** at 5%, * at %10

technologies will make the production process more environmentally friendly and effective in these countries in the long run. In this framework, governments can give priority to FDI that produces REN systems and provide energy efficiency, especially in agricultural and other sectors, through subsidies, tax reductions, and land support. All these policies will increase the share of clean energy in the energy portfolio in lucky-seven countries and reduce the environmental costs of economic growth.

The Covid-19 process, which influenced the whole world especially at the beginning of 2020, revealed the importance of the agricultural sector. In this process, it has been understood that it is important to maintain the continuity of the agricultural supply chain at the national and global levels to secure the food supply and mitigate the negative effects of the pandemic on the economy. In this context, the countries need to ensure continuity in the supply chain in the agricultural sector to secure the food supply. At the same time, policy measures should be taken to reduce the negative environmental impacts of agricultural activities. Future studies can test the effect of AGR and REN on CO_2 for individual countries using time series methods. In addition, future studies need to investigate more technical aspects regarding the integration of REN use into the agricultural sector. Undoubtedly, reducing and expanding the REN use costs of the agricultural sector will be very important for both public health and CO_2 reduction.

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