Environmental Science and Pollution Research (2021) 28:41663–41674
https://doi.org/10.1007/s11356-021-13684-1

RESEARCH ARTICLE

Renewables as a pathway to environmental sustainability targets in the era of trade liberalization: empirical evidence from Turkey and the Caspian countries

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Received: 19 January 2021 / Accepted: 24 March 2021 / Published online: 30 March 2021

Abstract

The quest for improved environmental quality through low-carbon emission has been explored in this study in the wake of the growing call for a transition to renewable energy use amidst widening trade relations between Turkey and the countries in the Caspian region including Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan. This study draws strength from the United Nations Sustainable Development Goals (UN-SDGs) and their impact by 2030. These SDGs encompass pertinent targets on responsible energy consumption (SDG-12), access to clean and affordable energy (SDG-7), and climate change action (SDG-13). Empirical evidence from the dynamic ordinary least squares (DOLS) technique corroborated by the fully modified ordinary least squares (FMOLS) technique shows that a percent rise in renewable energy consumption level significantly abates carbon emission among these countries by about 0.26% while growing globalization vis-à-vis a percent increase in openness to trade significantly hampers environmental quality via inducement of carbon emission level by 0.32%. Extended findings from the Granger causality analysis corroborate the significance of the long-run coefficients with regard to the double-edged benefits of renewable energy consumption in enhancing both environmental quality and income levels through lower carbon emission and sustainable economic growth stimulations among the countries. The study confirmed the inverted U-shape relation between income growth and environmental deterioration, thus validating the EKC hypothesis for Turkey and the Caspian countries. This suggests that both blocs are still at the scale stage of their growth trajectory, where the emphasis is focused on increasing income level relative to environmental sustainability. As such, important policy measures were provided in the concluding section of this study.

Keywords Environmental sustainability · Renewable energy · CO_2 emission reduction · Trade · Turkey and Caspian countries · EKC

JEL classification C32 · C33 · Q43 · Q50 · Q56

Responsible Editor: Philippe Garrigues

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Introduction

Turkey and the Caspian countries have enjoyed agelong ties cutting across socioeconomic, political, and in some cases cultural values. While the former has a huge market for energy import, the majority of the countries in the latter region are mainly net exporters of energy from hydrocarbon given their substantial amount of oil reserves. In economic terms, Turkey and the Caspian countries are close trading partners partly due to the cooperation on energy issues and also the geographical proximity (Demirbaş 2002; Aras and Akpinar 2011).

Geographically, Turkey is close to the Caspian region with some Caspian countries like Azerbaijan and Iran being Turkey's neighboring countries at its eastern borderline.

Table 1 Natural gas import from selected Caspian countries (million Sm^3) 2008–2018

Countries	Russia		Iran		Azerbaijan	
Years	Amount	Share (%)	Amount	Share (%)	Amount	Share (%)
2008	23,159	62.01	4113	11.01	4580	12.26
2009	19,473	54.31	5252	14.65	4960	13.83
2010	17.576	46.21	7765	20.41	4521	11.89
2011	25,406	57.91	8190	18.67	3806	8.67
2012	26,491	57.69	8215	17.89	3354	7.3
2013	26,212	57.9	8730	19.28	4245	9.38
2014	26,975	54.76	8932	18.13	6074	12.33
2015	26,783	55.31	7826	16.16	6169	12.74
2016	24,540	52.94	7705	16.62	6480	13.98
2017	28,690	51.93	9251	16.74	6544	11.85
2018	23,642	46.95	7863	15.61	7527	14.95

Source: Energy Market Regulatory Authority (EPDK 2018)

Generally, the Caspian countries are famous for their rich endowment with oil deposits as these countries, namely, Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan have an estimated 299.4 thousand million barrels of proved oil reserves representing about 17.3% of the total global proved oil reserves as at the end of 2018 (British Petroleum (BP) 2019). Turkey on the other hand has a huge demand for energy import and consumption considering the economic expansion that has positioned the country among major rapidly emerging economies in the world.

Turkey has been dealing with a trade deficit due to the huge import bills of which a substantial chunk goes to energy import from abroad (Oğulata 2003; Yurdakul and Cevher 2015). Besides, Erşen and Çelikpala (2019) have observed that getting an affordable and reliable flow of energy supply in a bid to ensure energy security is a major challenge to the Turkish economy. They further noted that the country's oil and gas demand accounts for up to three-quarters of the total primary energy supply with over 92 and 99% dependence on import, respectively. Thus, countries in the Caspian region among other oil-rich countries have become the major strategic partners in Turkey's bid to achieving energy security (Ediger and Durmaz 2016).

Countries in the Caspian region alone account for a significant proportion of Turkey's energy import at about 46.8 and 77.51% of the nation's total oil and natural gas import, respectively (EPDK 2018; EPDK 2019).

Taking a look at Table 1, over the years, gas import to Turkey primarily comes from countries in the Caspian region with Russia, Iran, and Azerbaijan accounting for 46.95, 15.61, and 14.95% of the total natural gas import, respectively, in 2018. Furthermore, from Table 2, as at the end of 2018, the region is also very crucial to Turkey's energy sustainability as 25.21, 18.37, 3.14, and 0.08% of the total oil import come from Russia, Iran, Kazakhstan, and Azerbaijan, respectively. The remaining oil and gas supplies have been accounted for by other oil-rich countries.

Turkey being home to some 83.4 million people (World Development Indictors, WDI 2019) with a fast-growing emerging economy status has a challenge of meeting up with its domestic energy demand, and the country still has a substantial reliance on fossil fuel consumption for its energy needs. Greenhouse gas (GHGs) increased the most in Turkey among other Organization for Economic Co-operation and Development (OECD) countries over the last decade (OECD 2019). This is despite Turkey's growing effort in recent times to increase energy efficiency by decoupling GHGs emissions through investment in renewable energy sources[1].

The nexus between globalization vis-à-vis trade openness proxy and carbon emission has shown substantially mixed results in the literature; however, the rise in renewable energy consumption is often found to be beneficial to the global quest for achieving low-carbon emission based on a larger proportion of the findings from extant studies (Shahbaz et al. 2017;

Table 2 Amount of petroleum import from selected Caspian countries (tons) 2018

Countries	Total import	Share (%) of total import
Russian Federation	9,758,156.107	25.21
Iran	7,109,530.987	18.37
Kazakhstan	1,214,449.967	3.14
Azerbaijan	30,263.600	0.08
Total	18,112,400.66	46.8

Source: Energy Market Regulatory Authority (EPDK 2019). The total import is a combination of all forms of petroleum products which may include crude oil, diesel types, fuel oil types, aviation fuels, marine fuels, and other products

[1] See Figs. 2 and 3 in the Appendix for the trend in Carbon emission and renewable energy consumption in Turkey and countries in the Caspian region.

Alola 2019; Destek and Sarkodie 2019; Liu and Hao 2018; Alola et al. 2019a; Nathaniel and Khan 2020; Destek et al. 2018). The survey of the literature also shows that the case of Turkey has received attention compared to the countries in the Caspian region as far as energy-related studies are concerned (Ozturk and Acaravci 2013; Shahbaz and Sinha 2019; Destek and Aslan 2017; Cetin et al. 2018; Destek and Sinha 2020). The membership role of Turkey among the Organization for Economic Co-operation and Development (OECD) countries gives Turkey a better chance of being addressed especially when the bloc has been studied unlike the other countries in this present study that are not member countries to the organization[2]. Likewise, the case of Russia has gotten some attention alongside four other emerging economies in a group that is commonly referred to as the BRICS countries (Haseeb et al. 2018; Aydin and Turan 2020; Adedoyin et al. 2020a). However, to the best of the authors' knowledge, the literature remained scanty on the Caspian region especially for other countries like Azerbaijan, Kazakhstan, and Turkmenistan which have received little or no attention in the extant studies. Meanwhile, the importance of the region in the global energy market deserves to be given adequate attention in the quest for a sustainable environment given the dynamics of trade and energy consumption in our globalized world. Hence, this study explores the impacts of trade openness and transition to renewable energy use on the environmental quality of Turkey and the countries in the Caspian region, thus providing a contemporary insight into the environmental sustainability of the countries in this bloc. This study is distinct from the previous in terms of, first, scope by augmenting the traditional environmental Kuznets curve (EKC) setting for the case of Turkey and the Caspian region which has received less documentation in the extant literature. Second, the carbon-income function is tested while incorporating renewable energy consumption and trade liberalization to explore the nature of trade between the investigated countries if dirty or clean. Studies of this kind are worthwhile given the pertinent role of green trade, responsible energy consumption, and environmental sustainability across the globe. To ascertain the soundness of coefficients and empirical results, we explore the battery of panel estimators like the dynamic ordinary least squares (DOLS) technique corroborated by the fully modified ordinary least squares (FMOLS) method and panel Granger causality test to investigate the direction of causality flow among the highlighted variables.

The study is organized into 4 sections starting with the extended introduction that encapsulates some extant studies in "Introduction". The empirical approach and results were detailed out in the second section. "Empirical results and discussion" presents the results and discussion of the empirical findings, while the fourth section provides a summary of the study with suggestions for policymakers.

Data and empirical approach

For empirical analysis, this study critically examines three variables that are related to the subject matter of the study including the level of carbon emission among the countries, openness to trade, and the level of renewable energy use. As such, relevant data were obtained on the level of carbon dioxide emitted into the environment (CO_2, in metric tons per capita) and were represented by $LnCO_2$. For trade openness (*LnOPEN*), the summation of total import and export as a fraction of individual countries' gross domestic product (GDP) was utilized, and the total amount of renewable energy use (*LnRGER*) as a percentage of the total final energy consumption in each country between 1992 and 2016 was also obtained for the empirical analysis. To further access the impact of income levels alongside the amount of renewable energy consumption on the environmental quality of the panel countries, the real per capita income levels for each country were also incorporated into the model specification in Eq. (1). The incorporation of the income variable makes it possible to simultaneously examine the validity of the popular environmental Kuznets curve (EKC) hypothesis for the panel study (Sarkodie and Strezov 2019; Sinha and Shahbaz 2018; Usman et al. 2019; Sinha et al. 2017; Zhang 2019; Erdogan et al. 2020; Adedoyin et al. 2020b).

$$LnCO_{2it} = LnRGER_{it} + LnOPEN_{it} + LnINC_{it} + LnINC_{it}^2 + \varepsilon_{it} \quad (1)$$

From Eq. (1), *LnINC* represents the real per capita income level (current US$), and $LnINC^2$ captures the square value of the real per capita income for the countries, while other variables remain as earlier defined for country *i* in given time *t*. All the understudied variables were presented in natural logarithm, and the data were sourced from the World Bank Development Indicator (World Development Indictors, WDI 2019).

We present the statistical summary of individual country data in Table 3 showing descriptive statistics like the mean, the maximum and minimum values, and the standard deviations, before proceeding to explore the corresponding panel unit root properties of the variables in "Unite root properties of variables."

[2] The OECD is an organization established to strengthen economic corporation and development following the 14th of December 1960 Paris convention between 20 founding member countries including, Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, UK, and the USA. Turkey became a member since 2 August 1961 and has been playing active roles in the organization until date. See OECD (2008) for more information about the OECD.

Table 3 Descriptive statistics of individual variables

Country	CO_2 emissions	Renewable energy consumption	Trade openness	Income
Azerbaijan				
Mean	0.615959	0.348112	1.938490	2.015560
Maxi	0.881877	0.648334	2.148603	6.093284
Mini	0.529972	−0.141425	1.743112	1.325419
Std. Dev.	0.083526	0.191098	0.092292	1.352952
Iran				
Mean	0.776155	−0.032299	1.631591	2.364860
Maxi	0.925399	0.184165	1.735922	3.511538
Mini	0.572159	−0.358139	1.465802	1.511019
Std. Dev.	0.122047	0.135304	0.068075	0.606724
Kazakhstan				
Mean	1.068436	0.209335	1.913952	2.365805
Maxi	1.202496	0.443053	2.174166	6.627587
Mini	0.892287	0.062132	1.724683	1.468568
Std. dev.	0.101165	0.108257	0.089235	1.404377
Russia				
Mean	1.083388	0.554627	1.724054	3.030080
Maxi	1.387360	0.606177	2.043665	7.034008
Mini	1.005493	0.508906	1.419240	2.055241
Std. Dev.	0.091049	0.026918	0.106216	1.328155
Turkey				
Mean	0.543880	1.229841	1.646672	2.752098
Maxi	0.669267	1.389357	1.740128	4.946541
Mini	0.432572	1.064753	1.483958	1.929332
Std. Dev.	0.077582	0.110456	0.072860	0.994917
Turkmenistan				
Mean	0.975773	−1.450325	1.960127	2.515730
Maxi	1.103773	−0.497890	2.231108	8.341123
Mini	0.838337	−2.753388	1.719723	1.283354
Std. Dev.	0.089964	0.695244	0.148354	2.070528

Source: Author's computation. Maxi, Mini, and Std. Dev. represent the maximum, minimum, and standard deviation values, respectively

Unite root properties of variables

Appropriate unit root tests were conducted on the variables that were adopted for the study following the importance of the test as observed in extant studies (Paramati et al. 2017; Aslan et al. 2018; Rahman and Velayutham 2020; Nwaka and Onifade 2015; Munir et al. 2020; Onifade 2015; Udemba et al. 2019; Onifade et al. 2020a). Accordingly, three major unit root test outputs were reported in the study based on the findings from Im et al. (IPS, Im et al. 2003), Levin et al. (LLC, Levin et al. 2002), and Breitung (2000) unit root test techniques. The combination of all the approaches has been argued to be of benefits when there is a need to ensure the robustness of the test results as that would be critical to the empirical methodology that would be eventually adopted in the study (Kose et al. 2020; Udemba 2020). Table 4 shows the results of the unit root test conducted for all variables at the level and first difference with respect to individual intercepts and trends.

The result presented in Table 1 shows the significance of the various test statistics using their probability values as denoted by the corresponding asterisk superscripts. To corroborate the results from the initial three test approaches, the chi-square statistics for the Fisher-PP test (Phillips and Perron 1988) was also reported to harness the nonparametric benefits. The unit root results support the stationarity condition of all variables at the same level of integration. In other words, there is evidence to support the stationarity of all variables combined at least in their first difference.

Panel cointegration test

This study applies the Pedroni (2004) panel cointegration test to investigate the beingness of a level relationship among the

Table 4 Unit root test results

Statistics	Levels				
Variables	$LnCO_2$	$LnRGER$	$LnOPEN$	$LnINC$	$LnINC^2$
LLC	−12.6091***	1.55160*	−4.16103***	−22.8283***	−41.1610***
Breitung	−0.66922	−2.06414**	−2.06750**	2.06478	2.20992
IPS	−6.07792***	−1.40258*	−4.18460***	−22.3801***	−52.6025***
Fisher-PP	29.0717***	20.4868*	25.4478***	26.9420***	57.2377***
First difference					
LLC	−6.49315***	−6.84635***	−11.0748***	−4.78992***	−21.4637***
Bg	−1.88608**	−3.64641***	−2.48159***	−2.09485**	−0.34539
IPS	−7.61611***	−6.63804***	−10.2608***	−3.74768***	−15.0392***
Fisher-PP	145.280***	334.783***	141.650***	18.3646	17.1327

Source: Author's computation. Variables are given in natural logarithm and ***, **, and * indicate the statistical significance of coefficients at 1, 5, and 10% levels, respectively

variables. The application of the Pedroni (2004) test has received attention in contemporary studies (Behera and Dash 2017; Dogan and Ozturk 2017; Asongu et al. 2020; Dogan and Inglesi-Lotz 2020). This technique helps to ascertain the presence of level relationship among variables in the panel of a study based on the statistical significance of certain tests' statistics combined under two subdivisions namely the panel statistics and the group statistics with respect to both the within and between dimensions of a panel distribution.

From the cointegration test outputs in Table 5, the presence of level relationship among variables is supported by the rejection of the null hypothesis of no cointegration following the statistical significance of the PP and ADF statistics for both the within and between statistical dimensions at a conventional 5% significance level.

Dynamic ordinary least square (DOLS) regressions

Having established the underlaying unit root properties and the presence of cointegration relationship among the variables in the panel of the study as rightly detailed in "Unite root properties of variables" and "Panel cointegration test," respectively, the panel long-run coefficient estimates were obtained through the dynamic ordinary least square (DOLS) methodology. Given a simple panel regression model involving two variables say A_i and B_i as shown in Eq. (2), Pedroni (2001) introduced both leads and lag dynamics into the model specification to obtain a typical panel dynamic operator for the ordinary least square as shown in Eq. (3).

$$A_{it} = \gamma_i + \alpha_i B_{it} + \sum_{j=-k}^{K} \delta_{ik} \Delta B_{i,t-k} + \varepsilon_{it} \quad (2)$$

$$\phi_i = \left(N^{-1} \sum_{i=1}^{N} \left[\sum_{t=1}^{T} P_{it} P_{it}^{*} \right]^{-1} \left[\sum_{t=1}^{T} \left(P_{it} P_{it}^{**} \right) \right] \right) \quad (3)$$

From Eq. (3), N and i denote the cross-sectional data and its number of observations, respectively, while T and t represent the time series data and its corresponding number of observations accordingly. P_{it} is equivalent in value to $2(K+1)1$ and P_{it}^{**} is equal to $\left(B_{it} - B_i^{O}\right)$, where B_i^{O} represents the average of B_i and $\Delta B_{i,\ t-k}$ stands for the differential value of B_i, while ϕ_i represents the dynamic ordinary least square estimator. The estimates from the adopted DOLS technique were reported alongside the estimates from a fully modified ordinary least square (FMOLS) estimator. This is done to benefit from the unique properties of these estimation techniques that make it possible to obtain more robust results over the choice of the conventional ordinary least square (OLS) approach that is prone to producing spurious outputs (Liu and Hao 2018; Paramati et al. 2018; Çoban et al. 2020; Nathaniel and Bekun 2020).

Table 5 Cointegration test

	Stat	Prob.	Stat	Prob.
Alternative hypothesis: common AR coefficients (within dimension)				
Panel v-statistic	0.592636	0.2767	0.611488	0.2704
Panel rho-statistic	0.197889	0.5784	0.164893	0.5655
Panel PP-statistic	−2.022447	0.0216	−2.285087	0.0112
Panel ADF-statistic	−1.594875	0.0554	−2.378898	0.0087
Alternative hypothesis: individual AR coefficients (between dimension)				
Group rho-statistic	1.005479	0.8427		
Group PP-statistic	−1.981965	0.0237		
Group ADF-statistic	−2.267655	0.0117		

Source: Author's computation

Empirical results and discussion

The results of the estimations from the DOLS regression are presented in Table 6 for both pooled and group estimations. To corroborate the output of the DOLS estimates, the corresponding estimated coefficients from the FMOLS approach were also provided in the result section.

From Table 6, the two approaches eventually produced relatively similar coefficients with regard to the statistical significance and corresponding signs of the estimated coefficients. The combination of both the pooled and group estimates from the DOLS reveals that all variables do significantly impact the environmental quality of Turkey and the Caspian countries as the variables show a significant impact on the level of carbon emission for the countries in the study. In precise terms, openness to trade among the countries hampers environmental quality as a 1% rise in trade openness is expected to stimulate carbon emission by approximately 0.32%. This result supports the conclusion of Shahbaz et al. (2017) that trade openness impedes a sustainable environment in a globalized world with more environmental deteriorating effects in lower and middle-income countries based on their empirical study of over a hundred countries that were grouped into three major income levels. The finding from this current study is not unexpected considering that a substantial share of the trade sector in the majority of the Caspian countries is accounted for by economic activities in their energy industries which are predominantly driven by the vast hydrocarbon reserves across the region. These hydrocarbon reserves in the region do not only impact the share of export in the trade sector of all countries in the study but also have direct impacts on the level of overall energy consumption among these countries. Also, larger volumes of oil production are required to support targeted export growth and to sustain domestic energy consumption which is predominantly fossil fuel-based among these countries. On the part of Turkey, oil and gas imports significantly account for a significant share of the entire import bill for sustaining the huge energy demand in the domestic market. Hence, the current study for the Turkey–Caspian bloc confirms that trade can hamper the environmental quality and similar findings have been documented in other economies in the different bloc (Wu et al. 2016; Zhang et al. 2019). In the case of China, for instance, Yunfeng and Laike (2010) have also observed that foreign trade hampers environmental quality as their study reveals that manufacturing activities to meet export target account for about 10.03 to 26.54% of China's annual CO emissions.

Table 6 DOLS and FMOLS pooled and grouped estimation results

Variables	*DOLS* Coefficients	*FMOLS* Coefficients
Pooled estimates		
Explained var (CO_2)		
LnRGER	−0.258344***	−0.101518***
LnOPEN	−0.040161	0.291140***
LnINC	0.767413***	0.267818**
$LnINC^2$	−0.133969**	−0.043608**
Grouped estimates		
Explained var (CO_2)		
LnRGER	−0.077761	0.066770
LnOPEN	0.318116***	0.587588***
LnINC	0.309912**	−0.136783***
$LnINC^2$	−0.091510**	0.011974

Source: Author's computation. Variables are given in natural logarithm and ***, **, and * indicate the statistical significance of coefficients at 1, 5, and 10% levels, respectively

On the other hand, a percent rise in the level of renewable energy source use is expected to significantly abate carbon emission in these countries by about 0.26%, thus aiding environmental quality improvement for the countries in the panel study. The pooled estimates from the FMOLS approach also corroborate the DOLS results considering the signs and significance of the coefficients. This present finding buttresses the results from the panel of other countries where related studies have been conducted even though the adopted methodology were different in some cases (Zhang 2019; Paramati et al. 2017; Alola et al. 2019b; Zafar et al. 2019; Bekun et al. 2019; Adedoyin et al. 2020b; Asongu et al. 2020; Destek and Aslan 2017; Onifade et al. 2021). Furthermore, the income component of the study reveals that an initial income level among the countries exerts a positive and significant impact on the level of carbon emission while the case is different as income level grows. As per capita income level doubles among the countries, carbon emission is expected to be abated over time, and this relationship is found to be significant as the negative and positive coefficient estimates of INC and INC^2 were statistically significant in both models under the DOLS. Hence, the validity of the environmental Kuznets curve (EKC) hypothesis for Turkey and the Caspian countries is established. The validity of EKC shows that as income levels rise among the countries due to expansion in

Table 7 Granger causality results

F-Statistics					
Variables	*LnCO*$_2$	*LnRGER*	*LnOPEN*	*LnINC*	Causality
LnCO$_2$	_	0.23697	0.62310	2.53839*	*CO2→INC*
LnRGER	4.61499**	_	2.67961*	9.53011***	*RGER→CO2, INC, OPEN*
LnOPEN	0.10316	1.06916	_	28.3120 **	*OPEN→INC*
LnINC	13.6994***	10.3869***	14.0441***	_	*INC→CO2, RGER, OPEN*

Source: Author's computation. Variables are given in natural logarithm and ** and * indicate the statistical significance of coefficients at 1 and 5% levels, respectively

economic activities, the detrimental effects of carbon emission into the environment would initially increase, but this effect will later be offset as a rise in income level is sustained at a certain threshold over time. This finding further supports the argument for the validity of the EKC especially for the specific cases of Turkey and Russia as documented in some extant studies relating to the OECD and BRICS economies, respectively (Pata 2018; Destek and Sarkodie 2019; Haseeb et al. 2018; Fotourehchi 2020).

Granger causality test

After establishing a cointegration relationship and having known the nature of interaction among variables in the model of the study by examining the statistical impacts of the included explanatory variables on the explained variable (carbon emissions level), the causality nexus among these variables was also examined to strengthen the general conclusions regarding the estimated models following the relevance of causality test in extant studies (Rahman and Velayutham 2020; Munir et al. 2020; Udemba 2019; Onifade et al. 2020b; Taiwo et al. 2020; Fotourehchi 2020). We report the outputs of the Pairwise Granger Causality test in Table 7.

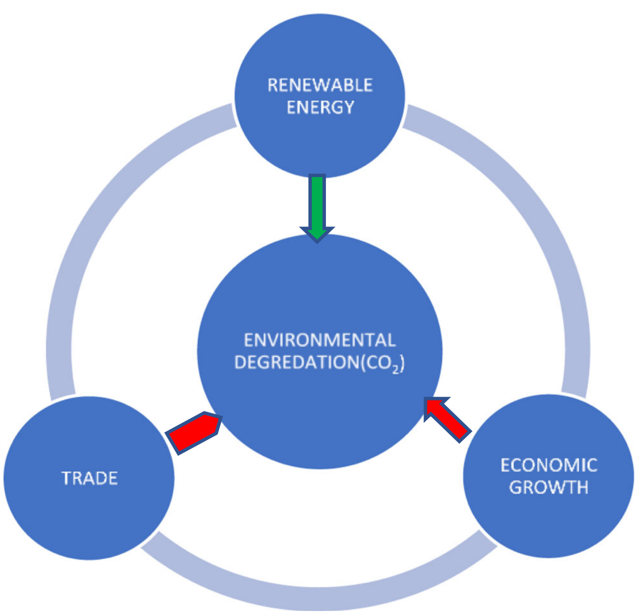


Fig. 1 Abstract scheme of analysis. Graphical legend: the red highlighted arrow indicates positive nexus while green shows an inverse relationship with CO_2 emission

From Table 7, at a 5% significance level, renewable energy consumption is found to be Granger causing carbon emission level in the countries that are included in the panel study. Thus, buttressing the interplay depicted in Fig. 1. On the other hand, trade openness was only statistically significant in Granger causing the income level among the countries. Also, there is a significant bidirectional causality from countries' per capita income levels to renewable energy consumption and globalization vis-à-vis the level of openness to trade in the countries that are included in the panel study. This causality nexus corroborates the long-run coefficients on the double-edged significance of renewable energy consumption in enhancing environmental quality through lower carbon emission and the enhancement of income level through economic growth stimulations among the countries. Liu and Hao (2018) have noted that this kind of nexus is likely obtainable in energy trading and importing economies such as in the case of Turkey and the Caspian countries as observed in this present study.

Finally, there is a piece of evidence in support of the possibility of carbon emission having a causal effect on the per capita income level of the countries in the study but only at a 10% significance level. While this evidence comes at a higher significance level compared to the conventional 5% level, it is, however, important to state that this is still a signal that caution should be taken by the policymakers with regard to the adoption of carbon emission control policy as the implementation of such policies has the potential of being detrimental to the goal of enhancing sustainable income level for the population.

Conclusions and policy implications

The dynamic interaction between the prospect for a paradigm shift to renewable energy and environmental degradation was examined in this study. Thus, the study provides a timely insight into the impacts of such nexus on environmental quality vis-à-vis the level of carbon emission in the wake of growing trade relations among countries. The study focuses on the case of Turkey and the countries in the Caspian region including Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan. Estimates from the dynamic ordinary least squares (DOLS) technique corroborated by the results of the fully modified ordinary least squares (FMOLS) show that a rise in renewable energy consumption level significantly enhances environmental quality among the countries while growing globalization vis-à-vis increasing openness to trade significantly hampers environmental quality as it positively influences carbon emission level among the countries. Additionally, the findings from the Granger causality analysis corroborate the significance of the long-run coefficients with regard to the double-edged impacts of renewable energy consumption in enhancing both environmental quality through lower carbon emission and the enhancement of income level through economic growth stimulations among the countries. The study confirmed the inverted U-shape relation between income and environment deterioration, thus validating the EKC hypothesis for the panel countries.

Based on the foregoing findings, deliberate efforts must be made to stimulate renewable energy use in a decisive bid toward enhancing environmental quality among the countries in the study. While this must be done for all countries in the study, more emphasis should be placed on the cases of Russia, Turkey, and Iran considering that these three countries combined account for the most carbon emission in the bloc. Also, these countries account for approximately 90% of the population demographics of the entire study with about 144.3 million, 83.4 million, and 82.9 million people, respectively (World Development Indictors (WDI) 2019). As such, appropriate energy conservation policy measures in these three countries would go a long way in helping the entire region to reach a minimal carbon emission threshold over time. It is soothing to know that these countries have started making some gradual efforts toward alternative green energy as the growth rate per annum of renewable energy generation between 2007 and 2017 was about 47.3% in Turkey, 8.8% in Russia, and 8.8% in Iran (British Petroleum (BP) 2019). However, the present level of investment in green energy is still substantially low given that all the countries in the present study still account for less than 2% of the total share of the global renewable energy generation in 2018 (British Petroleum, BP 2019).

Furthermore, although our study confirms that trade openness worsens environmental quality for the panel country, nevertheless, this is not an indicator that anti-trade campaign policies should be encouraged among the countries since it is very clear from the causality results that trade openness is of critical importance to economic growth in the region as its granger causes income levels among the countries. On the contrary, while the world still enjoys the benefits of global trade relations, the countries in the study should put in place workable policy measures to harness the benefits of technology transfer and foreign direct investment (FDI) in the alternative green energy sector as some of these countries currently enjoy FDI in their hydrocarbon driven energy sector.

Lastly, while we strongly recommend that suitable emission standard should be set up for the region, we also recognize the need to put individual countries' differences into consideration as the consequences of environmental degradation might vary across the countries in the panel study due to differences in the level of technology and environmental control capacities among other issues. Although the larger countries in the panel namely Russia, Turkey, and Iran have bigger roles in the level of carbon emission into the environment in the region, however, the adverse effect of the deteriorating environment might be more pronounced among the other countries namely Turkmenistan, Azerbaijan, and Kazakhstan with regard to their income levels, level of environmental investments, and their general infrastructural capacity development. As such, both inward FDI on green energy and technology transfer is strongly encouraged among the countries in the study and from other advanced economies beyond the region.

The present study investigates and compliments the frontiers of knowledge on the EKC debate while accounting for the pertinent of trade liberalization and renewable energy for Turkey and the Caspian countries in a balanced panel setting. However, we suggest that further study can investigate the theme while accounting for demographics covariates like population, urbanization, and political regime into the EKC framework via disaggregated data.

Appendix

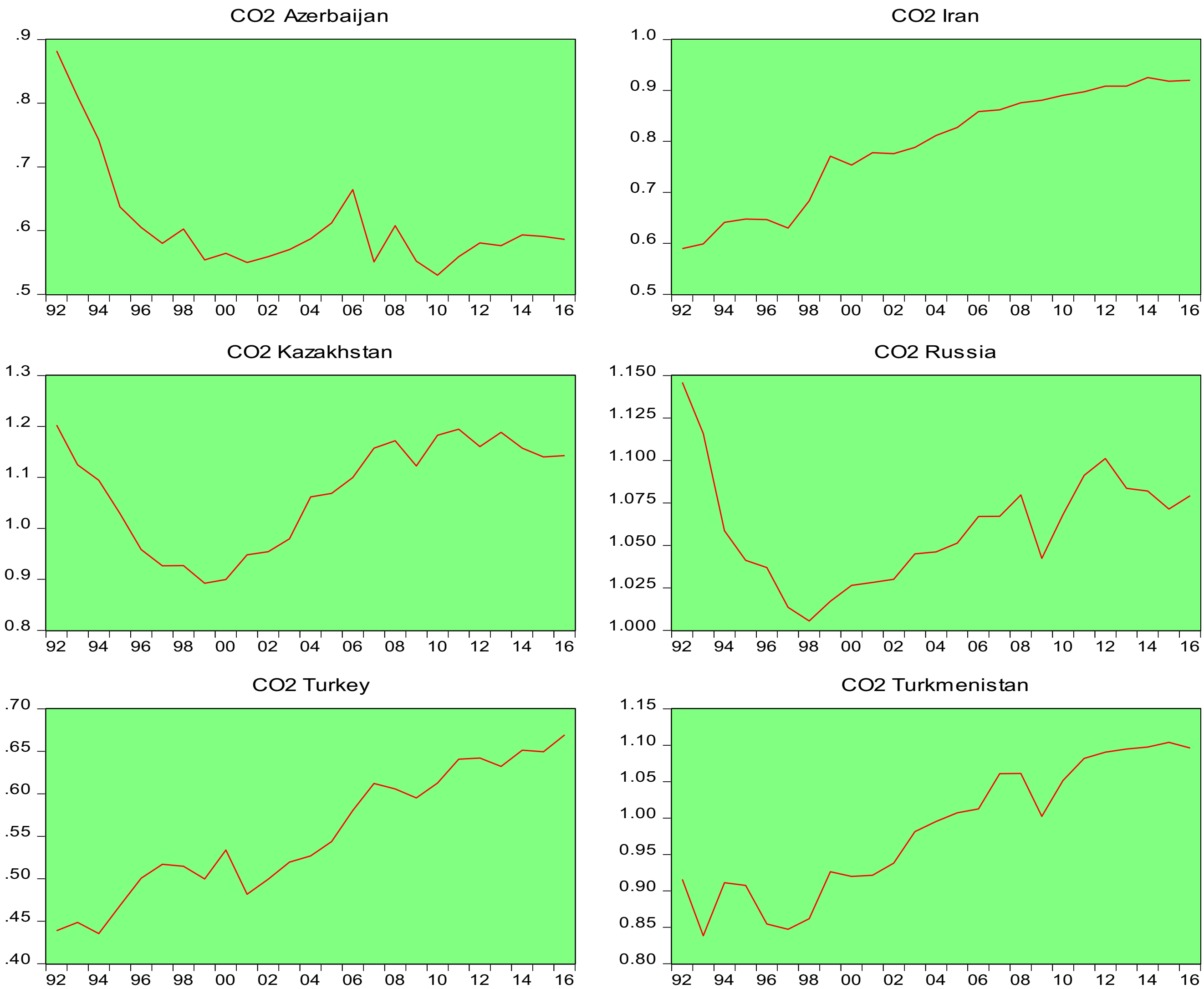
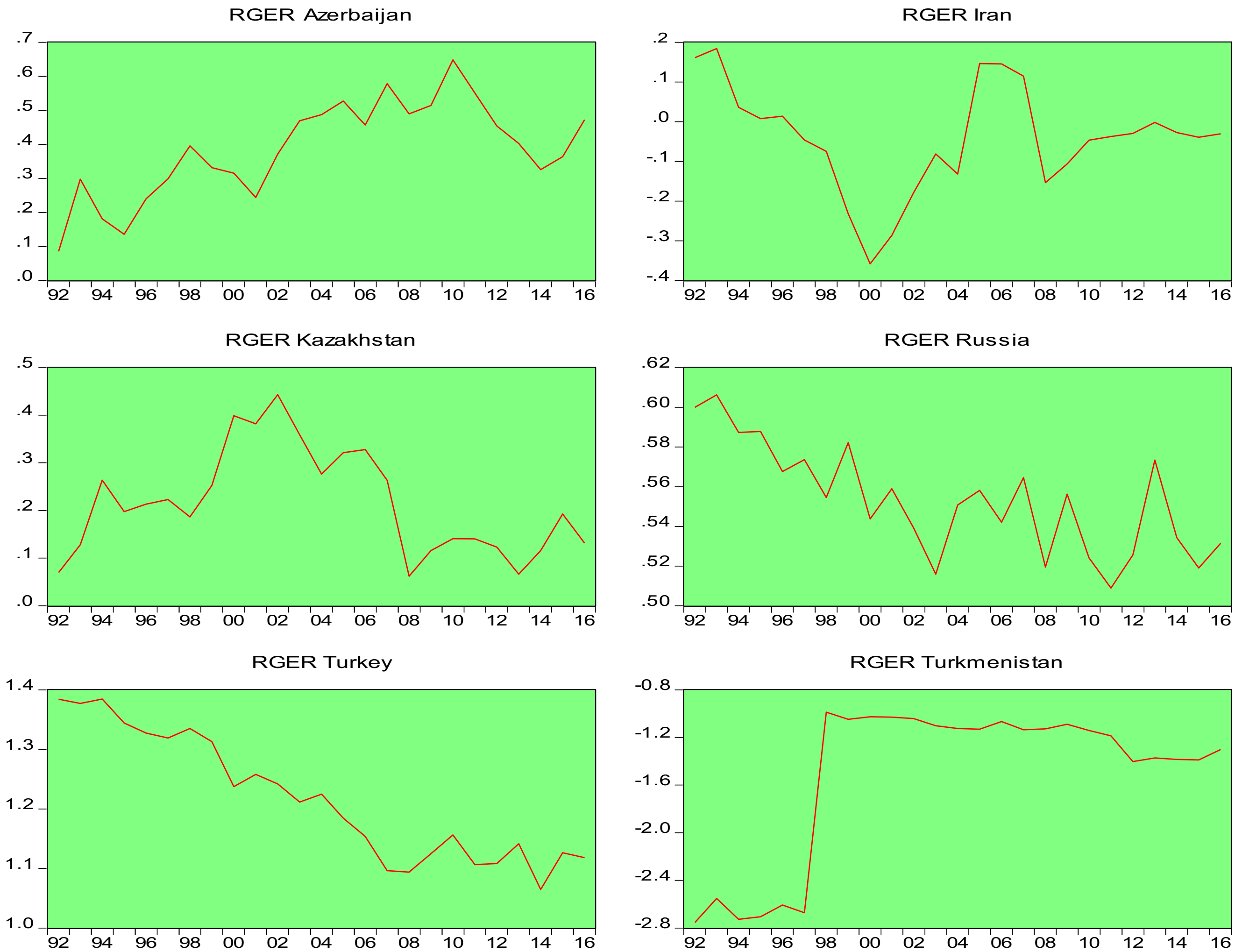


Fig. 2 Trend of carbon emission in Turkey and countries in the Caspian region



RGER represents renewable energy consumption level (% of total final energy consumption)

Fig. 3 Trend of renewable energy consumption in Turkey and countries in the Caspian region. RGER represents renewable energy consumption level (% of total final energy consumption)

Acknowledgements Author gratitude is extended to the prospective editor(s) and reviewers that will/have spared time to guide toward a successful publication.

Authors' contributions The first author (Dr. Stephen Taiwo Onifade) was responsible for the conceptual construction of the study's idea. The second author (Prof. Dr. Savaş Erdoğan) alongside the first author handled the extended introduction/literature section. The third author (Dr. Festus Victor Bekun) managed the data gathering and preliminary analysis, while Prof. Dr. Mehmet Alagöz was responsible for proofreading and manuscript editing. The author(s) read and approved the final manuscript.

Data Availability The data for this present study are sourced from the World Development Indicators (https://data.worldbank.org/). The current specific data can be made available upon request, but all available and downloadable at the aforementioned database and weblink.

Declarations

Ethical approval The authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript. The authors of this article also assure that they follow the springer publishing procedures and agree to publish it as any form of access article confirming to subscribe access standards and licensing.

Consent to participate Not applicable.

Consent for publication Applicable.

Competing interests The authors declare no competing interests.

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