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ORIGINAL PAPER

Analysis of the impact of renewable energy consumption and economic growth on carbon dioxide emissions in 12 MENA countries

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Abstract

This paper examines the impact of renewable energy consumption, economic growth, foreign direct investment inflows and trade on carbon dioxide emissions for a panel of 12 Middle East and North Africa countries over the period 1980–2012 using the recent Panel Vector Autoregressive model with multi-domain analysis framework. The results from Granger causality test reveal a bidirectional causality relationship between the candidate variables supporting the feedback hypothesis. The findings show that economic growth leads to environmental degradation while renewable energy, international trade and foreign direct investment inflows lead to decreases carbon dioxide emissions. A serious shift toward using more renewable energy resources, international trade and foreign direct investment inward is recommended to improve the environmental quality and attain the sustainable growth in the region.

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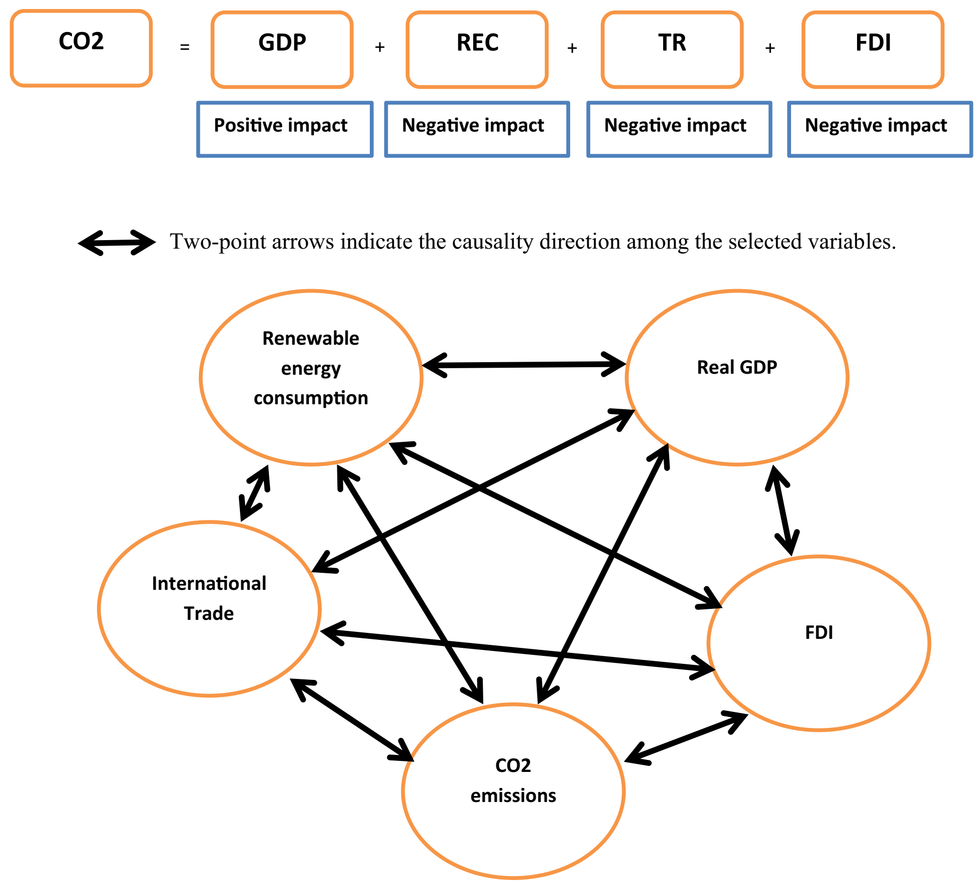
Graphical abstract



Keywords Renewable energy · Economic growth · CO_2 emissions · Panel vector error correction model · Middle East and North Africa

Introduction

In recent years, change in climate is due to massive use of polluting energy sources (fossil fuels). This change caused impacts on human and natural condition. If the greenhouse gases (GHG) emissions continue its increase, then it will cause further warming and long-lasting changes in all components of the climate arrangement. The carbon dioxide (CO_2) emissions growth rates cause many problems on the health of the population and on the quality of the environment (Ben Jebli 2016). Several sciences have taken into consideration the dangerous effects caused by CO_2 emissions. The impact of emissions on the environmental quality is the topical subject developed by academic and scientific researchers ((UNFCCC) 2014). The World Bank has played an essential role in supporting efforts to decline the pollution rate and to endorse low level of emissions growth. The efforts of the World Bank are mainly focused

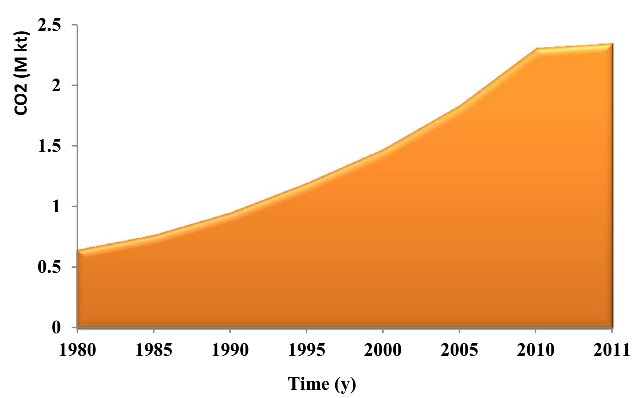


Fig. 1 The evolution of CO_2 emissions (M kt) in the MENA region over the period 1980–2011

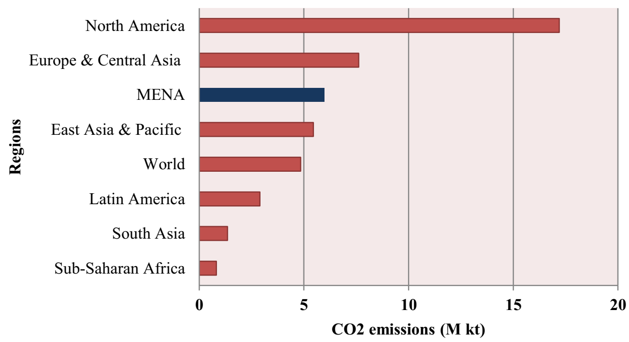


Fig. 2 Per capita CO_2 emissions by region (M kt) in 2011

on enhancing countries to use clean energy generation by giving financial incentives (World Bank 2013).

It is worth noting that the Middle East and North Africa (MENA) region has around 57% of the world's proven oil reserves and 41% of natural proven gas reserves (World Bank 2017). About 85% of all GHG emissions in this region are mainly derived from energy production and consumption. CO_2 emissions (measured in Millions kilotons, M kt) have increased largely in MENA countries since 1980 (see Fig. 1).

The associated environmental problems are worsened through heavy subsidies on petroleum products which promote excessive and inefficient use of fossil fuels (Farzanegan and Markwardt 2012). In this context, energy subsidies in 20 largest non-OECD countries reached $310*10^{12}$ USD in 2007 (IEA 2008). Eleven countries out of the total of 20 countries in the world that financially supported the gasoline consumption were from the MENA region (Brown 2011). As assessed by the World Bank (2012), fuel subsidies alone are 2 to 7.5 times larger than the public spendings on health in Morocco, Yemen and Egypt. In 2007, Iran was the largest fossil fuel subsidizer in the world with USD $56*10^{12}$ per year, followed by Russia with USD $51*10^{12}$ per year. China, Saudi Arabia, India, Venezuela, Indonesia, Egypt and Ukraine represent the other large subsidizers, with annual subsidies exceeding USD $10*10^{12}$ yearly (IEA 2008). The under-pricing of petroleum products in the MENA region is considerable. According to the World Bank (2012), the gasoline price gaps between the price of gasoline in Yemen, Bahrain, Egypt, Saudi Arabia, Iran, Kuwait, Libya, Qatar and Algeria and the average world price of gasoline were 81%, 90%, 62%, 95%, 58%, 87%, 97%, 89% and 77% per liter in 2008. The massive subsidies distort the price system and cause an inefficient allocation of resources. The high energy intensity of production and excessive use of fossil fuels is a natural significance of such subsidies (Farzanegan and Markwardt 2012). The existence of cheap energy hampers investments in clean technology and energy efficient means of transportation (Von Moltke et al. 2004; Ellis 2010). The IEA (2010) stresses that the removal of fossil fuel subsidies is a crucial part of the overall mitigation of climate change for the MENA region. According to the Carbon Dioxide Information Analysis Center (CDIAC 2011), six Middle Eastern countries ranked among the top twenty emitting nations based on CO_2 per capita in 2011 (global ranking in parentheses): Qatar (1), Kuwait (4), Oman (7), United Arab Emirates (9), Saudi Arabia (10) and Bahrain (11). The MENA region reliance on oil and gas, as well as their energy-intensive industrial projects that promote the use of domestically produced hydrocarbons, have also left a mark on the region's carbon footprint. These problems have considerably risen since the 1960s alongside rapid rates of urbanization, energy-intensive industrialization and rising living standards (World Bank 2016) (Fig. 2).

It is worth noting that there are no more studies that have investigated the dynamic causal links between renewable energy consumption, economic growth, foreign direct investment (FDI), international trade (TR) and CO_2 emissions for the case of MENA countries. Sustainable development is urgently needed for all MENA countries. The energy used in economic activities may enable social and economic development, but it can have a negative impact on the environment leading to climate changes at the global scale (Alshehry and Belloumi 2017). Conventional energy consumption may contribute to the connection between CO_2 emissions and economic growth via two channels. Conventional energy consumption may lead directly to an increase in CO_2 emissions. Conventional energy use may lead to an increase in economic activities, and it is positively related to CO_2 emissions. The replacement of a part of conventional energy by renewable energy can release the negative effects caused by the overuse of fossil fuels in MENA countries (Fig. 3).

Our study attempts to fill the gap by examining the impact of economic growth and renewable energy consumption on CO_2 emissions using the recent Panel Vector Autoregressive (PVAR) approach developed by Abrigo and Love (2015) to investigate the dynamic relationships

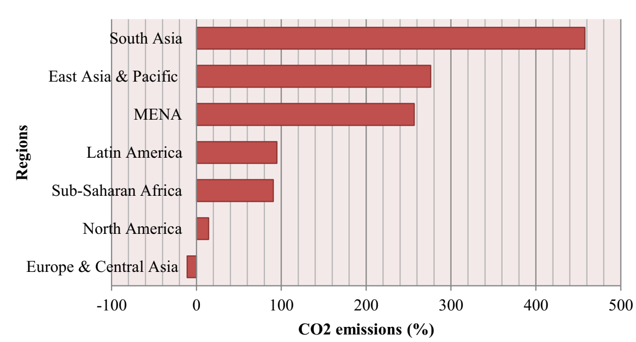


Fig. 3 Regional trend in CO_2 emissions growth (%) over the period 1980–2012

among the variables under investigation for the case of 12 MENA countries over the period 1980–2012. FDI inflows and TR are included as control variables. It is expected that economic growth has positive effect on CO_2 emissions because the majority of MENA countries are still in the low growth regime where there is an increasing linear relationship between economic growth and pollution. Renewable energy consumption is expected to be beneficial for environment because it is a clean energy and its substitution to fossil fuels leads to less pollution. The literature investigating the FDI-CO_2 emissions nexus has not yet reached a consensus. FDI inflows effects on environment are decomposed into technique, scale and composition effects (Pazienza 2015). These techniques define the role played by the transfer and the diffusion of technology and the progress of economic activities in the reduction of pollution degree (for more details see (Pazienza 2015). The effect of TR on CO_2 emissions is ambiguous. It also depends on the net impact of all effects (Ertugrul et al. 2016). *Scale effect* implies that economic growth resulting from TR leads to high levels of energy consumption and more CO_2 emissions. *Composition effect* leads countries to change their composition of production by producing less polluted goods. *Technique effect implies that* TR leads to the transfer of environmentally friendly technologies and energy efficient production technologies among countries, which cause reductions in CO_2 emissions.

MENA region is chosen for two basic reasons. Environmental quality has worsened in the recent decades in this region due to the extensive use of fossil fuels. Most of the MENA countries use hugely fossil fuel energy without taking into account the necessary preconceptions to avoid the growth of CO_2 emissions. Several indicators are directly correlated with CO_2 emissions growth, and it is important to look for the input of these variables in the progress of emissions. Renewable energy resources (mainly solar and wind energies) are important in MENA countries that can lead to overcome environmental pollution in the region, and even in the world.

Compared to the previous works on MENA countries, the present paper considers the case where renewable energy is used for production. Only top renewable energy consumer's countries of the region are selected. The empirical analysis employs a new technique of estimation of PVAR model developed by Abrigo and Love (2015). This technique permits for lag selection and Granger causality, can add exogenous variables, and can generate impulse responses and variance decompositions. The econometric equation model integrates the variables of FDI inflows and TR as control variables.

Section 2 discusses some literature review, while Sect. 3 presents the data and methods used. In Sect. 4, we present the results and discussion. Section 5 concludes the paper.

Literature review

The impacts of renewable energy consumption, economic growth, FDI and TR on CO_2 emissions have been investigated in various empirical studies (see Table 1). Bhattacharya et al. (2017) suggest that, from 85 developed and developing countries, both renewable energy deployment and institutions play a significant role in stimulating economic growth and reducing CO_2 emissions. For a panel of 25 selected African countries, Zoundi (2017) recommend that CO_2 emissions are found to increase with income per capita. Ito (2017) suggest that, for a panel of 42 developed countries, non-renewable energy consumption leads to a negative impact on economic growth for developing countries. In the long run, renewable energy consumption positively contributes to economic growth. Previous studies have been examined in order to highlight the contribution of each variable to the evolution of CO_2 emissions, but by considering different sets of variables under consideration. In the previous empirical studies, different statistical approaches and econometric methods are used (two steps generalized method of moments (GMM), fixed effect regression, PVAR, autoregressive distributed lag (ARDL) model, Granger causality, etc.) either for the case of panel or time series. From the previous empirical studies, the findings are different and depend mainly on the methodologies, periods, sample sizes and countries.

The directions of both short and long-run causalities among the variables under consideration have been examined in many studies. Table 1 summarizes some previous empirical studies and presents their contributions according to the methodology, variables, samples and the period used.

Growth–pollution nexus

The relationship between the environmental quality indicators and economic growth has been extensively investigated. For the case of Algeria, Bouznit and Pablo-Romero (2016) considered the ARDL approach to examine the validity of the Environmental Kuznets Curve (EKC) hypothesis over the period 1970–2010. The results showed that the EKC hypothesis is validated and that increasing economic growth in Algeria has increased emissions. Ahmad and Du (2017) used the ARDL bound approach to investigate the dynamic association between energy production, CO_2 emissions and economic growth in Iran. Although the production of energy positively has contributed to economic growth, CO_2 emissions are positively linked to economic growth. Using a dynamic panel model based on the GMM technique, Jalil (2014) investigated

Table 1 Summary of some previous studies

Authors	Sample	Period	Methodology	Main findings
Growth–pollution nexus				
Bouznit and Pablo-Romero (2016)	Algeria	1970–2010	ARDL	Environmental Kuznets curve (EKC) is confirmed. Income has not yet reached the required level
Ahmad and Du (2017)	Iran	1971–2011	ARDL-fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS)	There is a positive relationship between CO_2 emissions and economic growth
Akbostanci et al. (2009)	Turkey	1968–2003 (time series) and 1992–2001 (panel data)	Cointegration- time series and panel data	EKC is not supported for both time series and panel data
Jalil (2014)	18 MENA countries	1971–2009	GMM technique	Gross domestic product (GDP), energy consumption, foreign direct investment and agriculture production have significant impacts on CO_2 emissions in the region
Ang (2008)	Malaysia	1971–1999	Multivariate cointegration	Causality is running from economic growth to energy consumption in both short and long run
Wang (2012)	98 countries	1971–2007	Dynamic panel threshold model	EKC is not supported. Economic growth negatively affects CO_2 emissions
Apergis (2016)	15 countries	1960–2013	Panel, time series and time-varying approaches of cointegration.	EKC hypothesis holds in 12 out of the 15 countries
Renewable energy–pollution nexus				
Bhattacharya et al. (2017)	85 developed and developing countries	1991–2012	System GMM and fully modified OLS	Renewable energy sources play a significant role for CO_2 emissions.
Zoundi (2017)	25 African countries	1980–2012	Panel cointegration approach	No evidence of a total validation of EKC. Renewable energy use negatively affects CO_2 emissions.
Sadorsky (2009)	G7 countries	1980–2005	Panel cointegration approach-FMOLS and DOLS	CO_2 emissions have a positive impact on renewable energy consumption
Apergis and Payne (2014)	Seven Central American countries	1980–2010	Panel cointegration with structural breaks	CO_2 emissions affect renewable energy consumption.
Dogan and Ozturk (2017)	USA	1980–2014	EKC model- structural break-ARDL model	Renewable energy consumption mitigates environmental degradation.
Ben Jebli and Ben Youssef (2015)	North Africa countries	1971–2008	Panel cointegration approach-Granger causality test	Short-run unidirectional causality running from CRW to CO_2 emissions.
Foreign direct investment–pollution nexus				
Omri et al. (2014)	54 countries	1990–2011	Dynamic simultaneous-equation panel data	Bidirectional causality between FDI and CO_2 emissions for all panels

Table 1 (continued)

Authors	Sample	Period	Methodology	Main findings
Ren et al. (2014)	18 China's industrial panel data	2000–2010	Two-step GMM estimation	FDI inflows further aggravate China's CO_2 emissions
Zhu et al. (2016)	The Association of South East Asian Nations (ASEAN-5)	1981–2011	Fixed effect panel quantile regression	The effect of FDI on carbon emissions is negative
Neequaye and Oladi (2015)	27 developing countries	2002–2008	Fixed effects model	FDI is significant in determining emissions in developing countries
Trade–pollution nexus				
Shahbaz et al. (2017)	105 high income, middle and low income	1980–2014	Vector error correction model (VECM), Westerland and Granger causality tests	Trade openness impedes environmental quality.
Ben Jebli et al. (2016)	OECD countries	1980–2010	EKC- Panel cointegration techniques	Trade openness affects negatively emissions.
Ertugrul et al. (2016)	10 developing countries	1971–2011	ARDL bounds tests	Trade increases CO_2 emissions in Turkey, India, China and Indonesia, while it has no effect on the environment in Thailand, Brazil and Korea

the determinants of CO_2 emissions in 18 MENA countries over the period 1971–2009. Their results showed that real GDP, fossil fuel energy consumption, FDI and agriculture production had significant effects on CO_2 emissions.

Renewable energy–pollution nexus

Various empirical studies have examined the role that the renewable energy consumption may contribute to the mitigation of CO_2 emissions in the world. Empirical studies have found that renewable energy use can decrease in CO_2 emissions (see Table 1). Table 1 reports some studies that investigated the renewable energy–pollution nexus. Apergis and Payne (2014) examine the determinant of renewable energy for a panel of seven Central American countries. The results from their estimation suggest that a long-run cointegrated relationship exists between renewable energy consumption per capita, real GDP per capita, carbon emissions per capita, real coal prices and real oil prices with the respective coefficients positive and statistically significant. Ben Jebli and Ben Youssef (2015) employed the Granger causality test and the panel cointegration approach for a group of North Africa countries over the period 1971–2008. Their findings revealed the existence of a unidirectional short-run causality running from renewable energy consumption to CO_2 emissions. For a panel data set of 17 OECD countries, Bilgili et al. (2016) use panel FMOLS and DOLS estimations. The results revealed that renewable energy consumption yields negative impact on CO_2 emissions. Bölük and Mert (2015) use the ARDL approach to examine the potential of renewable energy sources in reducing the impact of GHG emissions in Turkey. The results show that the coefficient of electricity production from renewable sources with respect to CO_2 emissions is negative and statistically significant in the long run.

Foreign direct investment–pollution nexus

Zhu et al. (2016) investigated the impacts of FDI, economic growth and energy consumption on CO_2 emissions in five countries of ASEAN group using a panel quantile regression technique that takes into consideration the unobserved individual heterogeneity and distributional heterogeneity. The results showed that FDI affects negatively CO_2 emissions, except at the fifth quantile, and its impact becomes statistically significant at higher quantiles. Neequaye and Oladi (2015) used a fixed effects model to examine the impact of FDI inflows and environmental aid disbursements on CO_2 emissions for a panel of developing countries. The authors concluded that attracting more FDI could be a good way to improve the quality of the environmental situation.

Trade–pollution nexus

Shahbaz et al. (2017) explored the relationship between CO_2 emissions, TR and economic growth for a panel of 105 countries (high-, middle- and low-income countries) using panel cointegration approach. Their results showed that TR obstructs the quality of the environment of the selected countries. Ben Jebli et al. (2016) examined the dynamic causal relationships between renewable and non-renewable energy consumption, TR (imports or exports) and CO_2 emissions for a panel of 25 OECD countries over the period 1980–2010. The results indicated the existence of a long-run association among the variables. The results from FMOLS and Dynamic ordinary least squares (DOLS) long-run elasticities revealed that increasing TR leads to decrease in CO_2 emissions. Ertugrul et al. (2016) investigated the relationship between CO_2 emissions, TR, real income and energy consumption for the top ten CO_2 emitters. The authors considered the ARDL bounds to cointegration approach using annual data for the period of 1971–2011. The results revealed that TR is one of the main determinants of CO_2 emissions. TR increases CO_2 emissions in Turkey, India, China and Indonesia. It has no impact on CO_2 emissions in Thailand, Brazil and Korea. Halicioglu and Ketenci (2016) discussed the impact of international TR on CO_2 emissions for the case of transition countries using the ARDL approach to cointegration and GMM method. The results indicated the presence of the long-run relationship between the two variables and the impact of TR on CO_2 emissions varies from country to country.

Several empirical analyses have mentioned the role that renewable energy consumption can play in the reduction of CO_2 emissions and in the motivation of the economic productivity. These results depend on several factors such as the selected period of time, selected countries, integrated variables and technique of estimation. There is no general rule proving that the use of renewable energy contributes to the decrease in CO_2 emissions because technically the result is due to several factors mentioned above. The growth of CO_2 emissions must be tested for each case and we can achieve several consequences in terms of sign of impact or in term of causality direction.

The present study differs from the results presented in Table 1 by considering the case of MENA countries to investigate the impact of renewable energy consumption, economic growth, FDI and TR on CO_2 in the 12 MENA countries. The study employs PVAR approach, a recent empirical technique. The empirical analysis chooses the best consumers of renewable energy in the continent. To our knowledge, there is no study examining the causal links between these variables and especially for the MENA selected countries.

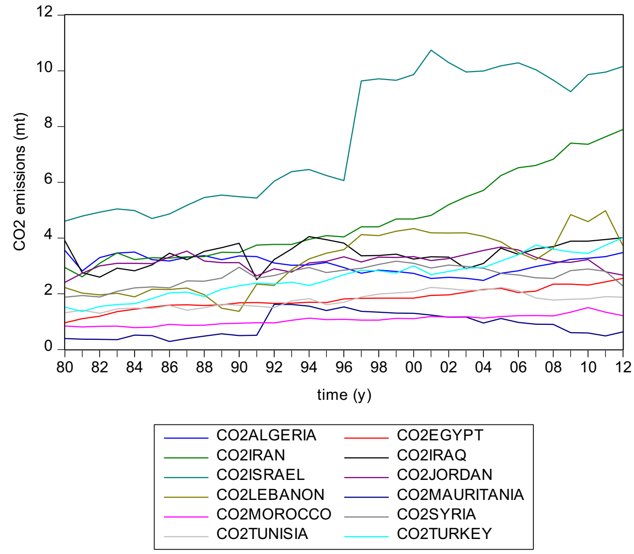


Fig. 4 per capita CO_2 emissions plot (mt)

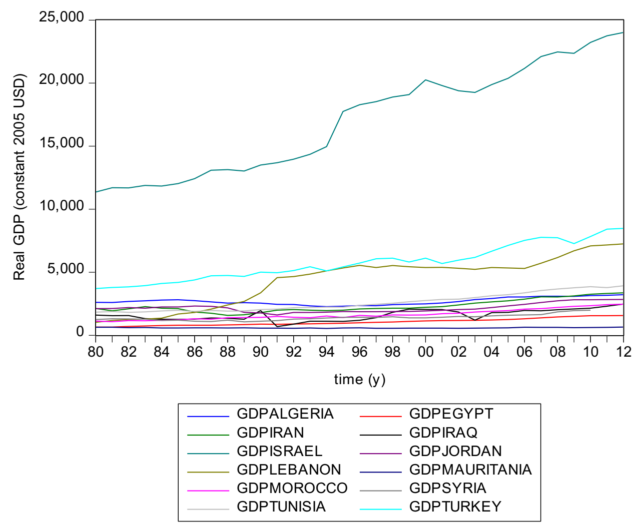


Fig. 5 Per capita GDP plot (constant 2005 USD)

Data and methods

Data and descriptive statistics

This study covers the period of 1980–2012. The data used are obtained from the World Development Indicators online database of the World Bank (2017) and US Energy Information Administration (EIA 2017) for 12 MENA countries. The selected MENA countries investigated are: Algeria–Egypt–Iran–Iraq–Israel–Jordan–Lebanon–Morocco–Mauritania–Syria–Tunisia–Turkey. The data used are for the variables of GDP per capita (in constant 2005 USD), CO_2 emissions per capita (in metric tons, mt), renewable energy consumption (REC) expressed as the share of consumption from renewable energy sources in total energy consumption, TR measured as the sum of imports and exports divided by GDP, and FDI inflows expressed as a share of GDP. All the variables are transformed into their natural logarithm forms to obtain consistent results and more stationary behavior by overcoming the heteroscedasticity problem between the variables (Vogelvang 2005; Shahbaz et al. 2012; Salahuddin et al. 2017). Data on GDP per capita, CO_2 emissions per capita, TR, and FDI are obtained from Word Bank (World Bank 2017) World Development Indicators online database. Data on renewable energy consumption are obtained from the US Energy Information Administration (2017).

Figures 4, 5, 6, 7 and 8 show the variation of each variable for the sample of 12 MENA countries over the period 1980–2012. Figure 4 presents the tendency of CO_2 emissions per capita. Israel has the biggest value of per capita CO_2 emissions with 10.73 mt in 2001, while Mauritania has the smallest value with 0.29 mt in 1986. According to Fig. 4, we can conclude that Israel takes the initial place, followed by Iran, Lebanon and Iraq in the fourth place. Mauritania has the lowest level of pollution and takes the last place. Figure 5 reveals the evolution of per capita real GDP over the selected period and shows that Israel has the biggest value of per capita real GDP with 24,018.16 constant 2005 USD in 2012. Mauritania has the lowest level of per capita real GDP with 540.18 constant 2005 USD in 1994. Figure 6 reports the evolution of FDI across time for all selected countries. According to Fig. 6, Mauritania has the biggest share of FDI (share of GDP) with 37.26% in 2005, while Jordan has the lowest share with −0.59% in 1993. The tendency of TR (the sum of imports and exports divided by GDP) variable across time for the MENA countries is reported in Fig. 7 and indicates that Mauritania has the biggest level with 80.75% in 2012. Iran has registered the lowest level of TR with 6.88% in 1986. Regarding the evolution of per capita REC, Fig. 8 reports that Syria has the biggest share of REC with 0.64% in 1980, while Israel has the lowest level with $0.14*10^{-3}$% in 1990.

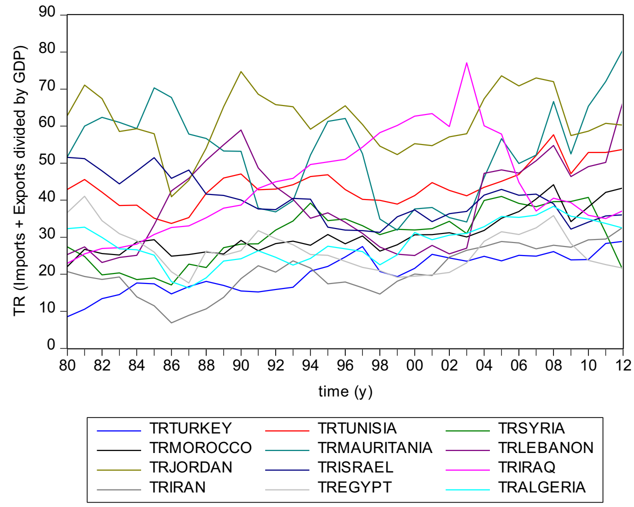


Fig. 7 Trade plot (as the sum of imports and exports divided by GDP)

Panel unit root tests

The initial step of the empirical study is to examine the stationarity of the different series using various unit root tests. This is the mainly necessary stride in the econometric

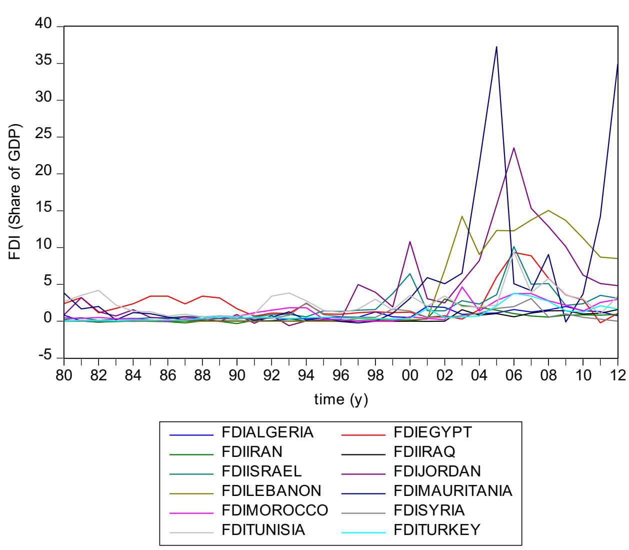


Fig. 6 FDI plot (share of GDP)

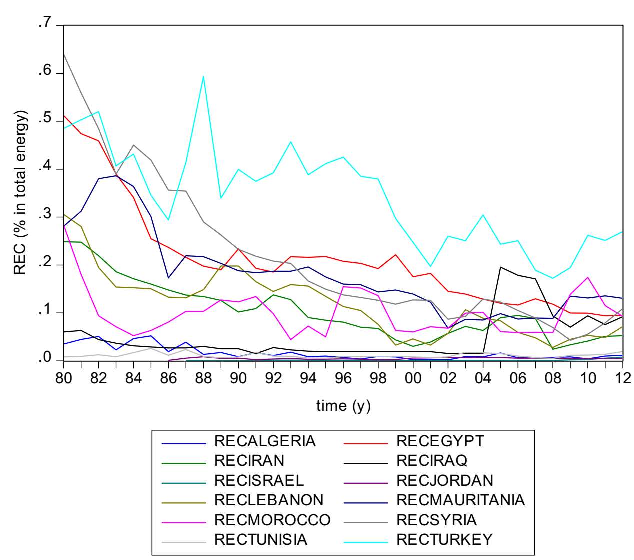


Fig. 8 Per capita REC (the share of consumption from renewable energy sources in total energy consumption)

investigation of time series since the use of non-stationary variables gives spurious results. For this reason, this study uses the Levin et al. (2002) and the Im et al. (IPS 2003) panel unit root tests.

The difference between the Levin et al. (2002) test and the Im et al. (IPS 2003) test is that the latter test supposes the estimated coefficient is cross-sectionally heterogeneous. Both panel unit root tests suppose the independence across cross sections and they are denominated as the first generation unit root tests. On the other hand, the dependence in cross sections can occur because of externalities, disregarded common factors, economic and regional associations (Kasman and Duman 2015). The second-generation unit root tests deal with the issue of the dependence in cross sections. These tests are suggested by Pesaran (2007), which are based on the Cross-Sectional Augmented Dickey–Fuller (CADF). The CIPS critical values for different deterministic parameters are simulated and tabulated by Pesaran (2007).

The results of these panel unit root tests are shown in Table 2. The variables are integrated if the null hypothesis is rejected. Levin et al. (2002), Im et al. (2003) and Pesaran (2007) tests statistics are computed for the variables in levels and first differences. The results from these tests are reported in Table 2. It is shown that all the selected variables are stationary after the first difference, whereas the level outcomes provide the existence of a unit root. All series are integrated of order one (I (1)).

Model specification

This study uses the recent PVAR approach developed by Abrigo and Love (2015). The useful tool corresponds to a mixture econometric method linking the traditional panel model, which takes into consideration unobserved individual heterogeneity to the vector autoregressive (VAR) model, which regards all the series as endogenous in the system. The main benefit of the PVAR methodology consists in the grouping of the conventional VAR method which deals with the problem of endogeneity with panel data approach that allows for unobserved individual heterogeneity. A further benefit consists in the possibility of raising the number of pertinent observations through introducing fixed effect, leading to a better consistency of the assessment (Abrigo and Love, 2015).

The initial stage of the modeling process is to estimate the optimal lag and moment as well as the model selection criteria based on the J-statistic of over-identifying restrictions proposed by Hansen (1982). The result of the J-statistic test is then compared to some other tests, which are based on the information criterion (the Akaike information criteria (AIC), the Bayesian information criteria (BIC) and the Hannan-Quinn information criteria (HQIC)). The selected model is the one that provides the lowest computed values. The next stage of the PVAR approach is to carry the panel Granger causality tests by examining the causal directions between per capita real GDP, CO_2 emissions, REC, TR and FDI.

The further step in PVAR model is to compute the coefficients using system GMM method after removing the country fixed effects, which would generate biased parameters, using the forward mean differencing (i.e., the Helmert procedure). The principal advantage of the PVAR is to permit the assessment of the impact of the orthogonal shocks. It implies the effect of a shock of one covariate on another, while maintaining all other covariates invariants. This is carried out by the utilization of panel impulse-response functions (IRF). The last step consists on estimating the variance decompositions in order to reveal the importance of the shock in indicating the deviations of variables in the PVAR model through reporting the percentage of the movement in one variable that is explicated by the shock to another variable, accrued over time.

Table 2 Panel unit root tests results

Variables	IO	LLC	IPS	CIPS
GDP	I (0)	− 0.764 (0.222)	0.82818 (0.7962)	1.435 (0.924)
ΔGDP	I (1)	− 4.018*** (0.000)	− 6.823*** (0.000)	− 9.066*** (0.000)
REC	I (0)	− 0.818 (0.126)	− 0.416 (0.338)	0.284 (0.612)
ΔREC	I (1)	− 7.987*** (0.000)	− 8.083*** (0.000)	− 11.907*** (0.000)
CO_2	I (0)	− 0.414 (0.339)	0.102 (0.540)	0.174 (0.529)
ΔCO_2	I (1)	− 9.698*** (0.000)	− 10.738*** (0.000)	− 12.972*** (0.000)
TR	I (0)	− 0.151 (0.439)	− 0.848 (0.198)	0.696 (0.757)
ΔTR	I (1)	− 5.051*** (0.000)	− 7.091*** (0.000)	− 9.837*** (0.000)
FDI	I (0)	− 1.304 (0.102)	− 1.414 (0.098)	0.361 (0.754)
ΔFDI	I (1)	− 6.802*** (0.000)	− 9.908*** (0.000)	− 4.448*** (0.000)

"IO" and "CIPS" denote the order of integration and the Pesaran unit root tests, respectively. Panel unit root tests include intercept and trend. *** denotes statistical significance at the 1% level. Values in parenthesis are probabilities

Results and discussion

The results of the tests of the estimation of the PVAR's optimal lags and model selection criteria are shown in Table 3. They indicate that the row in line with the first lag contains the low values, and it is the optimal lag. The optimal model is supposed to incorporate the variables from the period t to period $t-1$.

The next analysis is focusing on PVAR Granger causality tests among the aforementioned variables. The results from these tests are reported in Table 4. It is worth mentioning that all the null hypotheses are rejected at the 1% significance level, referring to the probabilities and the chi-square statistics. According to the PVAR Granger causality results, the causality presents a strong evidence for two ways causality between all the underlying variables. There is a bidirectional causality between GDP and CO_2, GDP and REC, GDP and TR, GDP and FDI, CO_2 and REC, CO_2 and TR, CO_2 and FDI, REC and TR, REC and FDI and between FDI and TR.

The empirical outcomes show that the causal link between economic growth and CO_2 emissions is bidirectional. Any change in the evolution of economic activities in the region could lead to environmental degradation and any increase in the degree of pollution will affect economic growth. This finding conforms to that found by Al-Mulali (2012) for the case of 12 Middle Eastern countries, Tang and Tan (2015) for the case of Vietnam country and Antonakakis et al. (2017) for the case of high-income countries. It is not similar to that of Dogan and Seker (2016a) for the case of the European Union, to the findings of Ben Jebli et al. (2016) for a panel of 25 OECD countries, and to the results of Esso and Keho (2016) for a sample of 12 Sub-Saharan African countries.

A bidirectional causality occurs between CO_2 emissions and REC. This implies that the renewable energy deployment can considerably improve the environmental quality and any harmful changes in CO_2 emissions cause the increase in renewable energy use. This result is similar to that of Apergis and Payne (2015) for a panel of 11 South American countries and Al-MulaliU et al. 2015 for the case of Latin America and Caribbean countries and Dogan and Seker (2016b) for the case of top renewable energy countries. This effect is not similar to that of Menyah and Wolde-Rufael (2010) for the case of the USA and Ben Jebli and Ben Youssef (2017) for the case of North Africa countries. The results provide a strong confirmation for a bidirectional causality between CO_2 emissions and international trade. This means that more international trade is an efficient channel for disseminating clean technologies that use renewable energy as a main source of production and that may contribute to pollution reduction. This result is consistent with the finding obtained by Shahbaz et al. (2013) for the case of Indonesia but contradicts with the result of Dogan and Turkekul (2016) for the case of the USA; Kasman and Duman (2015) and Dogan and Seker (2016a) for the case of European Union countries and Cerdeira Bento and Moutinho (2016) for the case of Italy.

Table 4 Results of the PVAR Granger causality tests

Null hypothesis			
GDP $\nrightarrow$ CO_2	REC $\nrightarrow$ CO_2	TR $\nrightarrow$ CO_2	FDI $\nrightarrow$ CO_2
9.845***	12.859***	32.994***	24.342***
(0.002)	(0.000)	(0.000)	(0.000)
Null hypothesis			
GDP $\nrightarrow$ REC	CO_2 $\nrightarrow$ REC	TR $\nrightarrow$ REC	FDI $\nrightarrow$ REC
292.733***	113.576***	150.660***	6.961***
(0.000)	(0.000)	(0.000)	(0.008)
Null hypothesis			
CO_2 $\nrightarrow$ GDP	REC $\nrightarrow$ GDP	TR $\nrightarrow$ GDP	FDI $\nrightarrow$ GDP
120.972***	21.319***	108.252***	25.248***
(0.000)	(0.000)	(0.000)	(0.000)
Null hypothesis			
CO_2 $\nrightarrow$ TR	REC $\nrightarrow$ TR	GDP $\nrightarrow$ TR	FDI $\nrightarrow$ TR
71.724***	56.973***	239.472***	7.198***
(0.000)	(0.000)	(0.000)	(0.005)
Null hypothesis			
CO_2 $\nrightarrow$ FDI	REC $\nrightarrow$ FDI	TR $\nrightarrow$ FDI	GDP $\nrightarrow$ FDI
144.785***	6.774***	6.756***	7.419***
(0.000)	(0.009)	(0.006)	(0.009)

Chi-square statistics are reported with respect to short-run changes in the independent variables. H_0: $\nrightarrow$ indicates no Granger causality relationships. *** denotes the statistical significance at 1% level; Probabilities are presented in parenthesis

Table 3 The PVAR's optimal moment (lag) and model selection criteria

Lag	CD	J	J p value	MBIC	MAIC	MQIC
1	0.56131	80.927	0.299	−333.181***	−69.072***	−175.368***
2	0.65857	53.031	0.358	−223.041	−46.968	−117.833
3	0.41309	27.866	0.314	−110.170	−22.133	−57.565

CD is the coefficient of determination, which captures the percentage of variation explained by the panel VAR model. J is the statistic of over-identifying restrictions proposed by Hansen (1982). *** denotes the optimal lag and model selection

Table 5 PVAR model of CO_2 results

	Dependent variable: CO_2		
	Coefficient	Statistic	P-value
$CO_{2(t-1)}$	−0.031	−1.08	0.281
$GDP_{(t-1)}$	0.163	3.14	0.002^{***}
$REC_{(t-1)}$	−0.089	−3.59	0.000^{***}
$TR_{(t-1)}$	−0.094	−5.74	0.000^{***}
$FDI_{(t-1)}$	−0.007	−4.93	0.000^{***}
Hansen's *J* test		166.101	0.549

Five-variables VAR model is estimated by system GMM. Country-time and fixed effects are removed prior to estimation. "***" indicates significance at 1% level

The bidirectional causality found between CO_2 emissions and FDI means that the characteristics of FDI inflows in the selected MENA countries are considered as not clean FDI. The foreign investors who are intended to maximize their profit, are exposed to bring with them capital that damages the quality of the environment rather than their own sophisticated technologies to invest in the MENA region. This result is in line with that of Hakimi and Hamdi (2016) for the case of Tunisia and Morocco and with Abdouli and Hammami (2017) for a panel of 17 MENA countries, but contradicts some other studies like Seker et al. (2015) for the case of Turkey and Abbasi and Riaz (2016) for the case of Pakistan. Both of these two studies found a unidirectional causality from FDI to CO_2 emissions.

The results of the PVAR model of CO_2 emissions are reported in Table 5. It is worth remembering that all the candidate variables used in the VAR specification model are changed into the growth form. It appears that economic growth lagged by one period has a positive and significant impact on CO_2 emissions at the 1% significance level. A 1% increase in economic growth increases the CO_2 emissions by approximately 0.163%. This result provides strong evidence that, because of the fast growing of the population in the MENA countries, economic activities of the region have been improved. This improvement can be explained mainly by the expansion of energy demand, which is essentially derived from the excessive exploitation of non-renewable energy sources. The great usage of energy has considerably contributed to the growth of CO_2 emissions. More growth of economic activities causes more CO_2 emissions, and then environmental worsening. The opening effect is dominant in MENA countries. They are still in the primary phase of development where there is an increasing linear relationship between CO_2 emissions and economic growth.

The estimation results show that the coefficient of REC has a negative and statistically significant impact on CO_2 emissions at the 1% significance level. A 1% increase in REC reduces CO_2 emissions by around 0.089%. This implies

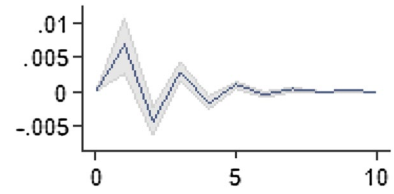


Fig. 9 Response of CO_2 to GDP shock

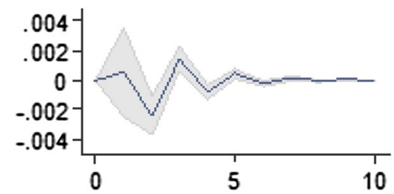


Fig. 10 Response of CO_2 to REC shock

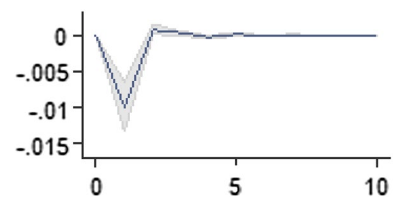


Fig. 11 Response of CO_2 to TR shock

that renewable energy plays an important role to improve the environmental quality and to mitigate GHG emissions. The same result is observed for the variable TR lagged by one period. In fact, a 1% increase in TR decreases CO_2 emissions by around 0.094%. Given that TR can increasingly move CO_2 emissions through three kinds of effects (i.e., scale, composition and technique effects), the finding of the present study provides strong evidence that increasing TR contributes to the environmental degradation reduction. This can be explained by the fact that the impact of both technique and composition prevails scale effect. In other words, MENA countries have made a significant progress in the invention of new technologies and take advantage from technology spillovers through enhancing TR.

The CO_2 emissions variable is affected by the lagged coefficient of FDI inflows, which is found to be negative and statistically significant. A 1% increase in FDI drops-off CO_2 emissions by approximately 0.007%. This implies that the magnitude of the FDI effect on CO_2 emissions is negligible due to the dominance of unclean FDI in the region. The net impact of composition, scale and technique effects is very low. This conforms to the literature investigating the FDI-CO_2 emissions nexus that has not yet reached a consensus.

The IRF determine the effect of shock resulting from the independent variable on the dependent variable. The results make strong evidence that the response of CO_2 emissions attributable to forecast error resulting in economic growth is positive and statistically significant (See Fig. 9). This finding robustly supports our initial vision that economic growth is strongly related to environmental pollution. The outcome does not show similarity in the response of CO_2 emissions down to forecast error resulting in REC, TR and FDI. The results indicate that the three above-mentioned variables (REC, TR and FDI) have negative and statistically significant impacts on CO_2 emissions, suggesting that they can be main factors in reducing pollution levels in MENA region (See Figs. 10, 11 and 12). The results are explained by the fact that MENA countries have oriented toward more TR regime which can seriously curb environmental degradation through implementing environmental reforms. These reforms can affect the level of CO_2 emissions through two channels, i.e., the direct channel in which TR reforms affect the distribution of resources between more or less polluting sectors (the composition effect) and the indirect effect through which TR reforms have an economic activity that has an impact on CO_2 emissions. The negative impact of FDI on emissions is the consequence of substantial rise in FDI inflows in MENA region which led to improve energy efficiency, so that the production of goods and services results in less environmental pollution. The demand for renewable energy has increased considerably in the MENA countries. This increase can be attributed to concerns about globing warming and fossil fuels depletion. According to these results, we conclude that regional countries, whose environments are very intensive in terms of CO_2 emissions and energy use, as several MENA countries have taken concrete measures and developed strategies to produce clean energy on a large scale.

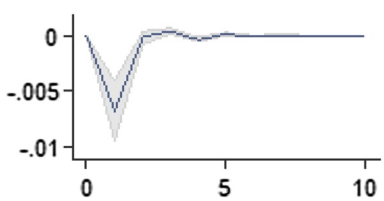


Fig. 12 Response of CO_2 to FDI shock

Table 7 PVAR stability condition results

Eigenvalue		Modulus
Real	Imaginary	
−0.5474856	0	0.5474856
−0.1794672	0	0.1794672
−0.0431288	−0.1678818	0.1733332
−0.0431288	0.1678818	0.1733332
0.1079890	0	0.1079890

The forecast error variance decomposition indicates the percentage of the deviation in variable attributable to its own shock against shock to the additional variable. The findings from the analysis of variance decomposition are presented in Table 5. This study allows a forecast horizon of 10 years. Interesting fact, at the forecast horizon of 1 year (y), approximately 92% of the primary step variance forecasting in CO_2 emissions per capita is explained by its own innovations and GDP, REC and TR explain the remaining 8%. In the long term, the response to shocks resulting from own innovations decreases to about 70.23%, while the response of CO_2 emissions to the shocks in GDP, REC, TR and FDI are anticipated to increase and reach around 29.77% from the second year forecasting horizon. Among the 29.77% of the variance, about 14.06% of variance is attributed to the shocks in GDP, and approximately 12.10% variations are due to REC while the rest 2.37% and 1.24% are attributed to the shocks in TR and FDI. The results mainly reinforce that the

Table 6 The forecast error variance decomposition of CO_2 emissions

Period	Impulse variable				
	CO_2	GDP	REC	TR	FDI
0	0	0	0	0	0
1	0.9230341	0.0644181	0.0094087	0.0031391	0
2	0.7835413	0.1060115	0.0976997	0.0127134	0.0000342
3	0.7461857	0.1282027	0.1098484	0.0238806	0.0018827
4	0.7064051	0.1370028	0.1205174	0.0238155	0.0122594
5	0.7035742	0.1395251	0.1207519	0.0237757	0.0123731
6	0.7027238	0.1402778	0.1208270	0.0237631	0.0124082
7	0.7024682	0.1405039	0.1208495	0.0237594	0.0124190
8	0.7023917	0.1405717	0.1208561	0.0237584	0.0124222
9	0.7023686	0.1405921	0.1208581	0.0237580	0.0124232
10	0.7023618	0.1405981	0.1208587	0.0237579	0.0124234

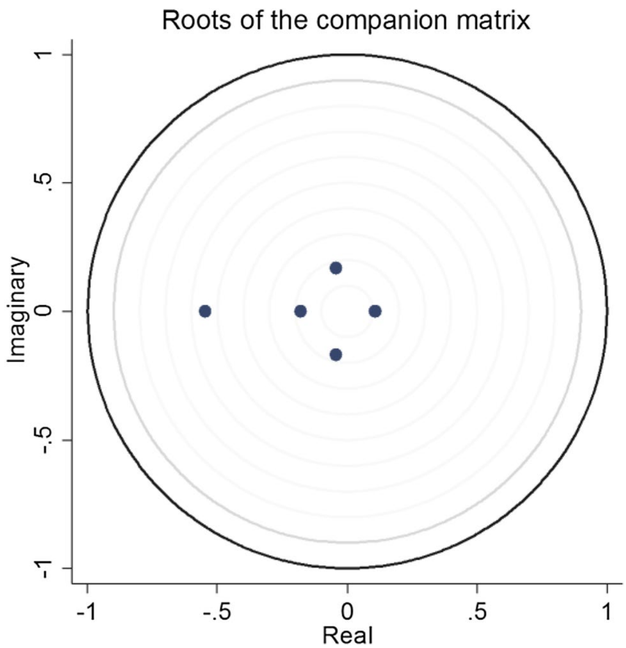


Fig. 13 The unit circle results

economic growth as well as renewable energy consumption are likely to have a high-expected impact on CO_2 emissions in the future. The expected impacts of TR and FDI appear to be weak (Table 6).

In order to check for the robustness of the model, we check the stability condition of the estimated PVAR through computing the modulus of each eigenvalue. According to Hamilton (1994) and Lütkepohl (2005), the stability of the VAR model exists if all modulus are strictly less than one, and all the eigenvalues stay inside the unit circle. The results of the eigenvalues and modulus are reported in Table 7 and Fig. 13. They show that the PVAR estimates satisfy the stability condition.

Conclusion and policy implications

The present study examines the impact of renewable energy, economic growth, FDI and TR on CO_2 emissions for a panel of 12 MENA countries over the period 1980–2012 by employing PVAR model with multi-domain analysis framework. PVAR Granger causality results support the feedback hypothesis confirming the existence of bidirectional causality between all the investigated variables.

Granger causality test shows a bidirectional causality interaction between all the selected variables supporting the feedback hypothesis. The empirical outcomes mentioned that economic growth leads to increase emissions level and suggested that renewable energy consumption, international trade and foreign direct investment inflows contribute to the reduction of emissions level.

MENA region should encourage the exploitation of renewable energy as well as the adoption of clean technologies using renewable energy in the production processes. This could be helpful for stimulating economic growth because of the great potential of renewable energy sources in the region. This implies that investing in renewable energy could permit countries to avoid a situation of energy infrastructure enclose into carbon-intensive development models and vulnerable to climate. Investing in renewable energy resources such as solar and wind energy could offer opportunities for MENA countries to reduce the use of fossil fuels energy. Governments should encourage cooperation projects aiming at the reduction of pollution level. MENA government should promote international trade by adopting clean technologies by means of technology spillovers to decrease in CO_2 emissions. More international trade is an effective strategy for transferring renewable energy technologies and contributing to increase the use of renewable energy sources. This would contribute to improve the environmental quality in the MENA region.

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