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ABSTRACT

This paper examines the nexus between CO_2 emissions, energy consumption and economic growth using simultaneous-equations models with panel data of 14 MENA countries over the period 1990-2011. Our empirical results show that there exists bidirectional causal relationship between energy consumption and economic growth. However, the results support the occurrence of unidirectional causality from energy consumption to CO_2 emissions without any feedback effects, and there exists bidirectional causal relationship between economic growth and CO_2 emissions for the region as a whole. The study suggests that environmental and energy policies should recognize the differences in the nexus between energy consumption and economic growth in order to maintain sustainable economic growth in MENA region.

Keywords: Carbon dioxide emissions, Energy consumption, Economic growth.

1. Introdution

The nexus between environmental pollutant, energy consumption and economic growth has been the subject of considerable academic research over the past few decades. According to the Environmental Kuznets Curve (EKC) hypothesis, as output increases, carbon dioxide emissions increase as well until some threshold level of output was reached after which these emissions begin to decline. The main reason for studying carbon emissions is that they play a focal role in the current debate on the environment protection and sustainable development. Economic growth is also closely linked to energy consumption since higher level of energy consumption leads to higher economic growth. However, it is also likely that more efficient use of energy resources requires a higher level of economic growth.

In literature, the nexus between environment–energy–growth has attracted attention of researchers in different countries for a long time. Roughly, we can categorize past studies in this field into three strands. The first focuses on the validity of the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis postulates that the relationship between economic development and the environment resembles an inverted U-curve, i.g. Ang (2007), Saboori et al. (2012). That is, environmental pollution levels increase as a country growth, but begin to decrease as rising incomes pass beyond a turning point. This hypothesis was first proposed and approved by Grossman and Krueger (1991). Dinda (2004) offer extensive review surveys of these studies. Further examples consist of Friedl and Getzner (2003) and Managi and Jena (2008). However, a higher level of national income does not necessarily warrant greater efforts to contain the CO_2 emissions. Recently, Jaunky (2010) investigated the Environment Kuznet's Curve (EKC) hypothesis for 36 high-income economies (including Bahrain, Oman and UAE) over the period 1980–2005. Unidirectional causality running from GDP per capita to CO_2 emissions per capita has been identified in both the short-and long-run. However, Holtz-Eakin and Selden (1995) establish a monotonic rising curve and an Nshaped curve have found by Friedl and Getzner (2003). On the other hand, Richmond and Kaufman (2006) concluded that there is no significant relationship between economic growth and CO_2 emissions.

The second strand of researches focuses on the nexus between energy consumption and economic growth. This nexus suggests that higher economic growth requires more energy consumption and more efficient energy use needs a higher level of economic growth. Since the pioneer work of Kraft and Kraft (1978), Granger causality test approach has become a popular tool for studying the relationship between economic growth and energy consumption in different countries, e.g. Stern (1993), Belloumi (2009), Pao (2009) and Ghosh (2010). However, Belloumi (2009) has used a VECM Model and showed that, in Tunisia, there is a causal relationship between energy consumption and income over the period of 1971-2004. Similarly, Altinay and Karagol (2004) investigated the causal relationship between electricity consumption and real GDP in Turkey over the period of 1950–2000. They showed that both used tests have yielded a strong evidence for unidirectional causality running from the electricity consumption to income. This implies that the supply of electricity is vitally important to meet the growing electricity consumption, and hence to sustain economic growth in Turkey.

Finally, most previous studies have shown that economic growth would likely lead to changes in CO_2 emissions. It has also found that energy consumption is often a key determinant of CO_2 emissions. It is therefore worthwhile to examine the nexus between economic growth, energy and CO_2 emissions by considering them simultaneously in a modeling framework. In this strand, Ang (2007) and Soytas et al. (2007) initiated this combined strand of research. Recent works include Halicioglu (2009) and Zhang and Cheng (2009) for a single country study. Halicioglu (2009) and Zhang and Cheng (2009) extended the above mentioned multivariate framework further by including the impacts of foreign trade and urban population, respectively into the nexus, in order to address omitted variable bias in econometric estimation. Also, based on panel error-correction model (PECM), Arouri et al. (2012) have tested the relationship between CO_2 emissions, energy consumption, and real GDP for 12 Middle East and North African Countries (MENA) over the period 1981–2005. They showed that the real GDP exhibits a quadratic relationship with CO_2 emissions for the region as a whole. The econometric relationships derived in this study suggest that future reductions in carbon dioxide emissions per capita might be achieved at the same time as GDP per capita in the MENA region continues to grow.

Table 1 summarizes some previous findings on the linkages between CO_2 emissions, energy consumption, and economic growth including the method used, the techniques and main findings. More than 15 studies are considered in a wide range of countries, including MENA countries, France, Turkey, India, Malaysia and others. The number of studies dealing with the nexus between CO_2 emissions, energy consumption, and economic growth seems considerably fewer than those dealing with causality between energy consumption and real GDP.

The results of studies on the relationship between CO_2 emissions, energy consumption, and real GDP differ from country to another and vary depending to the used methodology. It is difficult to succinctly clarify these variations. First, some studies found that CO_2 emissions can influence the GDP and/or energy consumption. For example, Soytas and Sari (2009) and Ang (2007) found this relationship for Turkey; and Arouri et al. (2012) for MENA countries. These results imply that more CO_2 emissions lead to economic growth. Second, if the relationship goes from energy consumption to GDP and/or CO_2 emissions, then GDP and/or CO2 emissions can increase through more energy consumption. For example, Belloumi (2009) found this relationship for Tunisia; and Ozturk and Acaravci (2010) for Turkey. Finally, some studies showed the causality relationship goes from GDP to energy consumption and/or CO_2 emissions. For example, Halicioglu (2009) found this relationship for Turkey; and Lotfalipour et al. (2010) for Iran.

Table 1
Summary of the existing empirical studies on the relationships between CO_2 emissions, energy consumption, and economic growth.

Study	Countries	Periods	Methodologies	Causality relationship
CO_2 emissions and GDP nexus				
Holtz-Eakin and Selden (1995)	130 countries	1951–1986	EKC hypothesis	Monotonic rising curve
Richmond and Kaufman (2006)	36 nations	1973–1997		No relationship
Saboori et al. (2012)	Malaysia	1980–2009	EKC hypothesis	C → Y (in the long-run) Inverted-U shape curve (in the long and short-run)
Energy consumtion and GDP nexus				
Stern (1993)	United States	1947–1990	Multivariate VAR model	E → Y
Yuan et al. (2007)	China	1963–2005	Johansen–Juselius, VECM	E → Y Y → E
Belloumi (2009)	Tunisia	1971–2004	Johansen–Juselius, VECM	E ↔ Y (in the long-run) E → Y (in the short-run)
Ghosh (2010)	India	1971–2006	ARDL bounds test, Johansen–Juselius, VECM	Miscellaneous
CO_2 emissions, Energy consumption and GDP nexus				
Ang (2007)	France	1960–2000	EKC hypothesis,Johansen Juselius, VECM, ARDL bounds test.	E → Y
Soytas et al. (2007)	United States	1960–2004	EKC hypothesis, Granger causality test	E → C
Apergis and Payne (2009)	6 central American countries	1971–2004	EKC hypothesis, panel VECM	C ↔ Y ; E → C Y → C Inverted U-shaped curve
Halicioglu (2009)	Turkey	1960–2005	ARDL bounds test, Johansen–Juselius, VECM	C ↔ income ; C → E C ↔ square of income
Soytas and Sari (2009)	Turkey	1960–2000	Granger causality test	C↔ E (in the long-run)
Zhang and Cheng (2009)	China	1960–2007	Toda–Yamamoto procedure	Y → E E → C
Chang (2010)	China	1981–2006	Johansen cointegration VECM	Miscellaneous
Lean and Smyth (2010)	5 Asean countries	1980–2006	Panel cointegration EKC hypothesis, panel VECM	C → E Inverted U-shaped curve
Lotfalipour et al. (2010)	Iran	1967–2007	Toda-Yamamoto method	Y → C (in the long-run)
Ozturk and Acaravci (2010)	Turkey	1968–2005	ARDL bounds test, VECM	C → Y (in the long-run)
Arouri et al. (2012)	12 MENA countries	1981–2005	Panel unit root tests and cointegration	E ↔ C (in the long-run)

Note :
Y, C and E indicate GDP per capita, carbon dioxide emissions, and energy consumption, VAR represents vector auto regressive model, VECM refers to the vector error correct model, ARDL denotes the auto regressive distributed lag procedure and EKC refers to the environmental Kuznets curve.
→ and ↔ indicate unidirectional causality and feedback hypothesis, respectively.

Compared to previous studies (see table1), this paper used simultaneous equations based on structural modeling to study of the nexus between energy consumption, CO2 emissions and economic growth in the Middle East and North Africa (MENA) region. As we can see, about the emerging economies, our literature review generally indicates that little attention has paid to smaller emerging economies, particularly in MENA region. This region has some of the largest energy reserves in the world. Yet, while the region is trying to industrialize and modernize its economies, there are the challenges of the carbon emissions. Moreover, energy consumption is the most significant source of pollution and, in terms of particulate matter concentrations; MENA represents the second most polluted region in the world – after South Asia – and the highest CO_2 producer per dollar of output. The model allows examining at the sometime the interrelationship between CO_2 emissions, energy consumption, and economic growth in case of 14 MENA countries over the period 1990-2011 estimated by the GMM-estimator. However, to the best of our knowledge, none of the empirical studies have focused to investigating the nexus between energy-environment-growth via the simultaneous-equations models. Specifically, this study uses three structural equation models, which allows one to simultaneously examine the impact of (i) CO_2 emissions and energy consumption on economic growth, (ii) CO_2 emissions and economic growth on energy consumption, (iii) economic growth and energy consumption on CO_2 emissions.

The rest of the paper is organized as follows. Section 2 describes the data and the econometric methodology. Section 3 presents the results and discussion. Section 4 concludes this paper with some policy implications.

2. Econometric methodology and data

2.1. *The econometric modeling*

The objective of this paper is to analyze the interrelationship between CO_2 emissions, energy consumption and economic growth for 14 MENA countries using annual data over the period of 1990–2011. These three variables are in fact endogenous. As mentioned earlier, most existing literature generally suppose that economic growth would likely lead to changes in CO_2 emissions. It has also established that energy consumption is often a key determinant of carbon emissions. It is therefore worth investigating the interrelationships between the three variables by considering them simultaneously in a modeling framework.

For this purpose, we employ the Cobb–Douglas production function to investigate the three-way linkages between CO_2 emissions, energy consumption and economic growth including capital and labor as additional factors of production. Ang (2008), Sharma (2010), Menyah and Wolde-Rufael (2010), and Shahbaz et al. (2012), among others, include the energy and CO_2 emissions variables in their empirical model to examine the impact of these two variables on economic growth. While they find generally that emissions and energy stimulate economic growth. The general form of the Cobb-Douglas production function is as follows:

$$Y_{it} = AE^{\alpha it} C^{\alpha it} K^{\alpha it} L^{\alpha it} e^{uit} \quad (1)$$

The logarithmic transformation of Eq. (1) is given by:

$$\ln(Y_{it}) = \alpha_0 + \alpha_{1i}\, ln(E_{it}) + \alpha_{2i}\, ln(C_{it}) + \alpha_{3i}\, ln(K_{it}) + \alpha_{4i}\, ln(L_{it}) + \pi_{it} \quad (2)$$

Where $\alpha_0 = \ln(A_0)$; the subscript i=1, ….., N denotes the country and t=1, …..., T denotes the time period. Variable Y is real GDP per capita; E, C, K and L denote per capita energy consumption (ENC), per capita CO_2 emission, the real capital and labor respectively. A is for the level of technology and e is the residual term assumed to be identically, independently and normally distributed. The returns to scale are associated with energy consumption, CO_2 emissions, capital and labor and, are shown by α_1, α_2, α_3 and α_4 respectively. We have converted all the series into logarithms to linearize the form of the nonlinear Cobb–Douglas production. It should be noted that simple linear specification does not seem to provide consistent results. Therefore, to cover this problem, we use the log-linear specification to investigate the inter relationship between CO_2 emissions, energy consumption and economic growth in 14 MENA countries.

The three-way linkages between these variables are empirically examined by making use of the following three simultaneous equations:

$$\ln(GDP_{it}) = \alpha_0 + \alpha_{1i}\ln(ENC_{it}) + \alpha_{2i}\ln(CO_{2\,it}) + \alpha_{3i}\ln(K_{it}) + \alpha_{4i}\ln(L_{it}) + \pi_{it} \quad (3)$$

$$\ln(ENC_{it}) = \zeta_0 + \zeta_{1i}\ln(GDP_{it}) + \zeta_{2i}\ln(CO_{2\,it}) + \zeta_{3i}\ln(K_{it}) + \zeta_{4i}\ln(L_{it}) + \zeta_{5i}\ln(FD_{it}) + \zeta_{6i}\ln(POP_{it}) + \varepsilon_{it} \quad (4)$$

$$\ln(CO_{2\,it}) = \varphi_0 + \varphi_{1i}\ln(GDP_{it}) + \varphi_{2i}\ln(ENC_{it}) + \varphi_{3i}\ln(URB_{it}) + \varphi_{4i}\ln(TOP_{it}) + \lambda_{it} \quad (5)$$

Eq. (3) examines the impact of energy consumption, CO_2 emissions and other variables on economic growth. An increase in energy consumption leads to an increase in the GDP per capita, i.e. the level of energy consumption increases monotonically with GDP per capita (Sharma, 2010). Sharma suggests that energy is an input in the production process, as it is used in commercial (transport) and non-commercial (public sector) activities. This means that energy has a direct link to a country's GDP. The link could effectively be through consumption, investment or exports and imports, as energy production and consumption affects all these components of aggregate demand. Moreover, the level of CO_2 emissions can influence GDP per capita (Apergis and Payne, 2009 ; Saboori et al., 2012). This implies that degradation of the environment has a causal impact on economic growth, and a persistent decline in environmental quality may exert a negative externality to the economy. Domestic capital (K) and labor force (L) are also added as determinants of economic growth (De Mello, 1997). In the same order, we can also specify the determinants of the energy consumption (Eq. 4) and carbon dioxide emissions (Eq. 5).

Eq. (4) examines the determinants of energy consumption per capita (ENC). Economic growth, which is proxyed by GDP per capita, is likely to have a positive impact on energy consumption, i.e. an increase in the GDP per capita leads to an increase in energy consumption per capita (Lotfalipour et al., 2010; Belloumi, 2009 ; Halicioglu, 2009 ; Zhang and Cheng, 2009). Most of the literature on EKC shows that the level of CO_2 emissions usually increases with energy consumption (Apergis and Payne, 2009 ; Halicioglu, 2009 ; Soytas and Sari, 2009 ; Lean and Smyth, 2010). Then, capital and labor are added as the main determinant of energy consumption (Sari et al., 2008; Lorde et al., 2010). Financial development (FD), which is measured by total credit as a fraction of GDP, is likely to have a positive impact on energy consumption (Islam et al., 2013). POP indicates the total population. Islam et al. (2013) emphasized the importance of population in determining the level of CO_2 emissions.

Eq. (5) examines the determinants of CO_2 emissions per capita. Energy consumption, which is measured by kg of oil equivalent per capita, is likely to have an increase in CO_2 emissions (Menyah and Wolde-Rufael, 2010; Wang et al.,2011). Moreover, under the EKC hypothesis an increase in income is associated with an increase in CO_2 emissions. The URB indicates urbanization (% urban population of the total). Hossain (2011) has emphasized the importance of urbanization in determining the level of carbon dioxide emissions. TOP indicates trade openness (% of exports and imports of the GDP). On the other hand, Andersson et al. (2009) has insisted on the importance of foreign trade in determining the level of CO_2 emissions. In their analysis, they attempted to analyze the emission generated in the transport sector. They concentrated on China's export and found that trade plays an important role in generating emission in the transport sector and that greater emissions is attributable to exports rather than to imports.

2.2. *The Estimation method*

The Generalized Method of Moments is the estimation method most commonly used in models with panel data and in the multiple-way linkages between certain variables. This method uses a set of instrumental variables to solve the endogeneity problem.

It is well-known that the GMM method provides consistent and efficient estimates in the presence of arbitrary heteroskedasticity. Moreover, most of the diagnostic tests discussed in this study can be cast in a GMM framework. Hansen's test was used to test the overidentifying restrictions in order to provide some evidence of the instruments' validity. The instruments' validity is tested using Hansen test which cannot reject the null hypothesis of overidentifying restrictions. That is, the null hypothesis that the instruments are appropriate cannot be rejected. The Durbin-Wu-Hausman test was used to test the endogeneity. The null hypothesis was rejected, suggesting that the ordinary least squares estimates might be biased and inconsistent and hence the OLS was not an appropriate estimation technique.

In this context, we use the GMM technique to estimate the three-way linkages between carbon dioxide (CO_2) emissions, energy consumption, and economic growth by using an annual data from 14 MENA countries over the period 1990-2011. The GMM estimation with panel data proves advantageous to the OLS approach in a number of ways. First, the pooled cross-section and time series data allow us to estimate the environment-energy-growth relationship over a long period of time for several countries. Second, any country-specific effect can be controlled by using an appropriate GMM procedure. And finally, our panel estimation procedure can control for potential endogeneity that may emerge from explanatory variables.

2.3. Data and descriptive statistics

This paper uses annual time series data for the period 1990–2011 which include the real GDP per capita (constant 2000 US$), energy consumption (kg of oil equivalent per capita), carbon dioxide emissions (metric tons per capita), trade openness (% of exports and imports of GDP), financial development (total credit to private sector as a ratio of GDP), urbanization (% urban population of the total population), total population (in thousands), capital stock (constant 2000 US$), and total labour force (% of total population) for 14 MENA countries, namely Algeria, Bahrain, Egypt, Iran, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saoudi Arabia, Syria, Tunisia, and UAE which are considered for this panel analysis. The data are obtained from the World Bank's World Development Indicators. The selection of the starting period was constrained by the availability of data.

The descriptive statistics, the mean value, the standard deviation and the coefficient of variation of different variables for individuals and also for the panel are given below in Table 2. This table provides a statistical summary associated with the actual values of the used variables for each country. The highest means of per capita emissions (53.321), energy consumption (16859.35), and real GDP per capita (28382.74) are in Qatar. The lowest means of CO_2 emissions (1.281) and energy consumption (381.721) are in Morocco. Then, the lowest mean of GDP per capita (420.288) is in Syria. Additionally, Qatar is the highest volatility country (defined by the standard deviation) in per capita CO_2 emissions (10.528), energy consumption (2811.166) and GDP per capita (4416.412), while the least volatility countries in CO_2 emissions, energy consumption and GDP per capita are respectively Egypt (0.125), Morocco (73.347) and Syria (154.126).

Table 2

Summary statistics (before taking logarithm), 1990–2011.

	Descriptives statistics	CO_2 (metric tons per capita)	ENC (kg of oil equivalent per capita)	GDP (constant 2000 USD)	K (constant 2000 USD)	L (in%)	FD (in%)	POP (in thousand)	URB (in%)	TOP (in%)
Algeria	Means	3.152	953.592	1908.692	2740.266	46.167	13.352	30776.530	61.943	57.016
	Std. dev.	0.241	122.749	212.142	313.657	1.202	12.943	3184.808	6.656	8 .387
	CV	7.645	12.872	11.114	11.446	2.604	96.937	10.348	10.745	14.709
Bahrain	Means	25.423	9122.009	12298.530	20369.260	68.095	52.266	730.585	88.402	160.306
	Std. dev.	2.951	787.855	1447.030	2932.932	3.068	15.040	251.811	0.129	17.870
	CV	11.607	8.636	11.756	14.398	4.531	28.776	34.467	0.145	11.147
Egypt	Means	2.017	707.562	1494.502	2575.714	45.741	40.358	68884.9	43.058	52.091
	Std. dev.	0.125	149.250	272.555	2207.125	2.071	11.666	7954.772	0.240	9.533
	CV	6.197	21.093	18.237	85.689	37.854	28.906	11.547	0.557	18.300
Iran	Means	6.009	2071.401	1727.876	3685.296	45.741	26.573	65294.13	63.821	46.860
	Std. dev.	1.763	548.424	369.371	819.271	1.959	7.977	6217.892	4.218	10.503
	CV	29.339	26.476	21.377	22.230	4.283	30.019	9.523	6.609	22.414
Jordan	Means	3.446	1085.146	1956.19	2944.683	43.169	72.695	4873.243	79.253	126.401
	Std. dev.	0.350	115.617	360.247	437.623	0.946	9.071	851.651	2.931	14.655
	CV	10.156	10.654	18.415	14.861	2.191	12.478	17.476	3.698	11.594
Kuwait	Means	29.118	9283.332	21691.77	28953.58	68.168	52.446	2105.789	98.116	92.874
	Std. dev.	2.765	2428.257	2292.088	6262.777	3.388	19.629	358.761	0.086	11.981
	CV	9.495	26.157	10.567	21.630	4.970	37.427	17.036	0.087	12.900
Lebanon	Means	4.142	1249.638	4962.087	6714.547	68.281	70.772	3733.474	85.68	69.398
	Std. dev.	0.619	251.357	880.789	3905.299	3.438	13.752	404.845	1.247	16.296
	CV	14.944	20.114	17.750	58.162	5.035	19.431	10.843	1.455	23.481
Morocco	Means	1.281	381.721	1413.937	1940.349	54.394	44.259	28787.87	53.283	64.412
	Std. dev.	0.216	73.347	248.795	1127.833	1.610	14.785	2278.95	2.507	10.081
	CV	16.861	19.215	17.595	58.125	2.960	33.406	7.916	4.705	15.650
Oman	Means	10.892	4064.466	8992.859	12184.79	58.569	33.706	2338.254	71.228	86.800
	Std. dev.	4.276	1575.096	1576.892	3365.855	2.251	8.608	254.024	1.863	6.777
	CV	39.258	38.753	17.535	27.623	3.843	25.538	10.864	2.616	7.808

Qatar	Means	53.321	16859.35	28382.74	42766.16	81.441	38.159	812.940	96.222	84.082
	Std. dev.	10.528	2811.166	4416.412	6833.614	3.660	9.103	448.36	1.789	9.820
	CV	19.745	16.674	15.560	15.979	4.494	23.855	55.153	1.859	11.679
Saoudi Arabia	Means	15.098	5258.383	9300.45	15226.85	52.446	29.326	21432.69	79.808	76.696
	Std. dev.	2.044	734.700	237.449	5147.935	2.021	10.150	3756.53	1.685	15.199
	CV	13.538	13.972	2.553	33.808	3.853	34.611	17.527	2.111	19.817
Syria	Means	3.486	1174.366	761.594	2292.02	42.502	27.282	24860.56	67.855	64.491
	Std. dev.	0.452	297.271	154.126	1860.457	0.789	20.318	4527.577	1.041	0.989
	CV	12.966	25.313	20.237	81.171	1.856	74.47	18.212	1.534	1.533
Tunisia	Means	2.091	764.809	2334.958	2885.232	50.573	61.996	5929.586	63.118	90.633
	Std. dev.	0.281	113.745	501.091	653.041	0.613	5.258	744.030	2.537	9.105
	CV	13.439	14.872	21.460	22.634	1.212	8.481	12.548	4.019	10.046
UAE	Means	27.262	10914.94	31663.3	40188.97	76.937	41.026	3743.463	80.804	100.614
	Std. dev.	5.117	1328.839	4710.084	7696.181	1.814	16.037	1879.105	2.035	29.360
	CV	18.768	12.174	14.876	19.150	2.358	39.090	50.197	2.518	29.181
Panel	Means	13.338	4563.622	9204.177	13247.69	57.605	43.161	19133.43	73.758	83.762
	Std. dev.	11.156	4041.955	8386.09	11483.79	12.558	20.909	18460.96	15.656	32.455
	CV	83.641	88.569	91.112	86.685	21.800	48.444	96.485	21.226	38.747

Notes : Std. Dev.: indicates standard deviation, CO_2: indicates per capita carbon dioxide emissions, ENC: indicates per capita energy consumption, GDP: indicates per capita real GDP, K indicates real capital per capita, L indicates labor force, FD indicates level of financial development , POP indicates total population, TOP: indicates trade openness, URB: indicates urbanization. UAE indicates United Arab Emirates.

Overall, for the MENA countries, Qatar has the greatest means and volatilities of per capita emissions, energy consumption and GDP, while Morocco has the lowest means and variances for per capita CO_2 emissions and energy consumption. Based on average trade, which is measured as a percentage of export and import values of total GDP, relatively low income countries are more open to trade compared to the high income countries. Based on urbanization, which is measured as the percentage of urban population to total population, relatively high income countries are more urbanized than low income countries.

3. Results and discussions

The above simultaneous equations are estimated by making use of two-stage least squares (2SLS), three stage least squares (3SLS) and the generalized method of moments (GMM). What follows, we only report the results of GMM estimation. While the parameter estimates remained similar in magnitude and sign, the GMM estimation results are generally found to be statistically more robust.

While estimating the three-way linkages between CO_2 emissions-energy consumption-economic growth, FD, POP, URB, TOP, K and L are used as instrumental variables. The Durbin-Wu-Hausman test was used to test for endogeneity. The null hypothesis of the DWH endogeneity test is that an ordinary least squares (OLS) estimator of the same equation would yield consistent estimates: that is, an endogeneity among the regressors would not have deleterious effects on OLS estimates. A rejection of the null indicates that endogenous regressors' effects on the estimates are meaningful, and instrumental variables techniques are required. In addition, the Pagan-Hall test was used to test for the presence of significant heteroskedasticity. The null hypothesis of homoscedasticity was rejected suggesting that the GMM technique is consistent and efficient. Then, the validity of the instruments is tested using Hansen test which cannot reject the null hypothesis of overidentifying restrictions. That is, the null hypothesis that the instruments are appropriate cannot be rejected. In the same order, we performed the augmented Dickey and Fuller (1979) and Philips and Perron (1988) unit-root tests on the used variables. We find that all the series are stationary in level.

Based on the diagnostic tests, the estimated coefficients of Eq. (3), (4) and (5) are given in Tables 3, 4 and 5.

The empirical results about Eq.(3) are presented in Table 3, which shows that energy consumption has a significant positive impact on GDP per capita for Algeria, Bahrain, Iran, Kuwait, Oman, Qatar, Saoudi Arabia, Tunisia and the United Arab Emirates, an insignificant positive impact for Jordan, Morocco and Syria, and a significant negative impact for Egypt and Lebanon. This suggests that an increase in energy consumption per capita tends to decrease economic growth in Egypt and Lebanon. From the elasticities, it can also be inferred that due to the increase in EC per capita, growth goes down more in Lebanon than in Egypt (0.414 > 0.179). The panel estimation has a significant positive impact on GDP per capita. The coefficient is 0.321, indicating that GDP per capita increases by 0.321% when there is a 1% increase in energy consumption. This indicates that an increase in energy consumption tends to promote economic growth (Shahbaz et al., 2012; Shahbaz et al., 2013; Wong et al., 2013). Since energy is an important ingredient for economic growth, strong energy policies are required to attain sustained economic growth. This result is consistent with the findings of Apergis and Payne (2010).

Regarding the pollutant variable, we find that CO_2 emissions have a significant negative impact on GDP per capita for all the countries, except Algeria, Jordan, Morocco and Syria. For these three countries it has an insignificant negative impact. For the panel estimation, CO_2 has a significant positive impact at 5% level. This indicates that 1% increase in pollutant emissions decrease economic growth by 0.304%. This result is consistent with the findings of Jayanthakumaran et al. (2012) for both China and India.

The coefficient of capital is positive and significant for 7 countries out of 14. Only for Algeria, Bahrain, Iran, Jordan, Morocco, Oman and Qatar, it positively affects GDP per capita, however for Syria it has a significant negative impact. For the remaining countries, no significant relationship is found. The sign of labor is negative for all the countries except for Egypt, Lebanon, Morocco and Tunisia. The panel results of the regression equation with GDP per capita as dependent variable show that the coefficient of K is positive and significant and the coefficient of L is negative and statistically significant. These results are consistent with the findings of Shahbaz et al. (2012). They suggest that a 1% increase in real capital per capita increase GDP per capita by 0.269%. Then, a 1% increase in labor force decrease GDP per capita by 0.410%. This implies that capital is an important determinant of economic growth.

The negative impact of labor force on GDP per capita may be due to brain-drain, uneducated, unskilled and low productivity of labor force. Moreover, the results show that labor tends to decrease GDP per capita more than CO_2 emissions. This may be due to the fact that in developing countries, labor tends to be abundant and relatively cheaper.

The empirical results about Eq. (4) are presented in Table 4. It appears that GDP per capita has a significant positive impact on energy consumption per capita for Algeria, Bahrain, Iran, Jordan, Morocco, Oman, Saoudi Arabia, Tunisia and the United Arab Emirates. However, for Egypt, Lebanon and Syria, it has an insignificant positive impact, and it has a significant negative impact for Kuwait and Qatar. This indicates an increase in GDP per capita tends to decrease energy consumption per capita in Kuwait and Qatar. From these elasticities, it can also be inferred that due to increase in GDP per capita, energy consumption goes down more in Kuwait than in Qatar (0.601 > 0.349). For the panel estimation, it has a significant positive impact on GDP per capita. The coefficient is 0.392, indicating that energy consumption per capita will increase by 0.392% when there is a 1% increase in GDP per capita. This implies that an increase in economic growth tends to more energy consumption (Ang, 2008; Shahbaz et al., 2012; Islam et al., 2013; Stern and Enflo, 2013). The results are consistent with the findings of Oh and Lee (2004) for Korea; Altinay and Karagol (2004) for Turkey; Ang (2008) for Malaysia; Halicioglu (2009) for Turkey; Odhiambo (2009) for Tanzania; Belloumi (2009) for Tunisia.

Table 3
Results of Panel GMM estimation for Eq. (3).

	Dependent variable : Economic growth (GDP)				
	Intercept	ENC	CO_2	K	L
Algeria	-0.515***	0.412*	-0.036	1.135*	-0.067
Bahrain	-3.565*	0.831*	-0.078***	0.371*	-0.466*
Egypt	5.177*	-0.179***	-0.541*	0.092	0.117
Iran	-11.201*	0.441*	-0.199***	0.561*	-0.201***
Jordan	-4.697*	0.211	-0.356	0.357***	-0.257**
Kuwait	13.055*	0.305**	-0.780*	0.059	-0.119
Lebanon	5.383*	-0.414*	-0.288**	0.142	0.331*
Morocco	5.998*	0.167	- 0.089	0.291**	0.513***
Oman	7.667	0.380*	-0.279*	0.289***	-0.629*
Qatar	-3.811*	0.554*	-0.265*	0.411*	-0.348*
Saoudi Arabia	7.761*	0.341*	-0.220**	0.177	-0.102
Syria	2.633**	0.101	-0.245	-0.188***	-0.148
Tunisia	2.497*	0.199***	-0.188**	0.064	0.402*
United Arab Emirates	3.381*	0.724*	-222**	-0.063	-0.306**
Panel	4.217*	0.321**	- 0.304**	0.269***	-0.410*
Hansen test (p-value)			0.19		
Durbin-Wu-Hausman test (p-value)			0.04		
Pagan-Hall test (p-value)			0.01		

Notes: All variables in natural logs.
* Indicates significant at 1% level ,
** Indicates significant at 5% level ,
*** Indicates significant at 10% level.

Regarding the pollutant variable, we find that CO_2 emissions have a positive impact on energy consumption per capita for all the countries, except for Morocco and Tunisia. It has a positive significant impact for Egypt, Jordan, Kuwait, Lebanon, Qatar, Saoudi Arabia and the United Arab Emirates. The impact of CO_2 emissions on energy consumption is negative and statistically insignificant for Morocco and Tunisia. For the panel estimation, it has an insignificant positive impact of CO_2 emissions on energy consumption per capita. Our results are in line with the findings of Menyah and Wolde-Rufael (2010) for the United States and Wang et al. (2011) for china.

The coefficient of capital variable has a positive significant impact on energy consumption for Algeria, Bahrain, Egypt, Qatar and the United Arab Emirates. It has a significant negative impact only for Saoudi Arabia and Tunisia, while for the remaining countries, no significant relationship is found. This indicates an increase in real capital decrease energy consumption per capita in Saoudi Arabia and Tunisia. The labor force variable has a significant positive impact on energy consumption only in the case of Algeria and the United Arab Emirates. It has a significant negative impact only for Kuwait. For the panel estimation, it has a significant positive impact of real capital on the energy consumption per capita. The coefficient is 0.183, indicating that energy consumption per capita increases by 0.183% when there is a 1% increase in the real capital. This implies that capital plays an important role in energy consumption. Our result is consistent with what stated in literature that more capital accumulation is expected to raise energy consumption (see Lorde et al., 2010). The coefficient of labor force is statistically insignificant for the panel of countries. These results are in line with Sari et al. (2008) for the United States and Lorde et al. (2010) for the Barbados economy.

The variable of financial development has a positive impact on energy consumption per capita for all countries. It has a significant impact only for Iran, Jordan, Kuwait, Lebanon, Morocco and the United Arab Emirates. This implies that an increase in the domestic credit to the private sector increase the energy consumption per capita.

For the panel estimation, financial development has a significant positive impact on energy consumption per capita. The coefficient is 0.229, indicating that energy consumption per capita increases by 0.229% when there is a 1% increase in the domestic credit to the private sector. This implies that financial development promotes business activities and adds to demand for energy via cheaper credit. Easy credit facilitates the purchasing of cars, homes and appliances; and adds to the energy use. The findings are in line with those of Sadorsky (2010, 2011), Shahbaz and Lean (2012), Islam et al. (2013), Shahbaz et al.(2013), and Wong et al. (2013).

Table 4
Results of Panel GMM estimation for Eq. (4).

	Dependent variable : Energy consumption (ENC)						
	Intercept	GDP	CO_2	K	L	FD	POP
Algeria	-2.735**	0.256*	0.196	1.287*	0.508*	0.015	0.234***
Bahrain	3.527*	0.401*	0.054	0.297***	0.157	0.010	0.084
Egypt	-17.542*	0.214	0.299**	0.097***	0.387	0.155	2.895*
Iran	-10.733*	0.194***	0.105	0.201	-0.401	0.302***	0.092
Jordan	4.174*	0.625*	0.420*	-0.119	0.103	0.319*	-0.125
Kuwait	-11.470*	-0.601*	0.278***	0.058	-0.199***	0.349**	0.271**
Lebanon	-2.933**	0.492	0.543***	-0.031	0.102	0.197***	0.079
Morocco	6.979*	0.277***	-0.117	-0.026	-0.221	0.270*	0.129
Oman	-8.437*	0.403**	0.204	0.126	-0.056	0.185	0.118
Qatar	-14.189*	-0.349*	0.289**	0.179***	-0.127	0.177***	0.113
Saoudi Arabia	4.760*	0.511*	0.391**	-0.199***	-0.081	0.038	0.203***
Syria	5.294*	0.089	0.228	0.227***	-0.117	0.191	0.351**
Tunisia	-3.989*	0.201***	-0.092	-0.159**	-0.166	0.319	0.233***
United Arab Emirates	-7.045*	0.361*	0.749*	0.040	0.433***	0.409*	-0.111
Panel	5.217*	0.392*	0.153	0.183***	0.045	0.229**	0.029
Hansen test (p-value)				0.10			
Durbin-Wu-Hausman test (p-value)				0.02			
Pagan-Hall test (p-value)				0.01			

Notes: All variables in natural logs.
* Indicates significant at 1% level ,
** Indicates significant at 5% level ,
*** Indicates significant at 10% level.

The variable of population has a positive impact on energy consumption for all countries except for Jordan and the United Arab Emirates. It has a significant positive impact for Algeria, Egypt, Kuwait, Saoudi Arabia, Syria and Tunisia. This indicates that an increase in the population raises energy consumption. This is consistent with the findings of Batliwala and Reddy (1993) and Islam et al. (2013). For the panel estimation, it has an insignificant positive impact of population on energy consumption.

The empirical results pertaining to Eq. (6) are presented in Table 5. They show that GDP per capita has a significant positive impact on CO_2 emissions per capita for Bahrain, Egypt, Iran, Kuwait, Lebanon, Oman, Qatar, Saoudi Arabia, Syria and Tunisia. It has an insignificant positive impact for Jordan and Morocco, a significant negative impact for Algeria and the United Arab Emirates. This indicates that an increase in GDP per capita decrease the carbon emissions per capita in Algeria and the United Arab Emirates. For the panel estimation, the GDP per capita has a significant positive impact on CO_2 emissions per capita. The coefficient is 0.261, indicating that CO_2 emissions per capita increases by 0.261% when there is a 1% increase in GDP per capita. This implies that an increase in economic growth tends to increase the environment degradation. The results are consistent with the findings of Halicioglu (2009) for Turkey; Fodha and Zaghdoud (2010) for Tunisia; Wang et al. (2011) for China; Arouri et al. (2012) for 12 MENA countries; Jayanthakumaran et al. (2012) for both China and India; Saboori et al. (2012) for Malaysia; and Lee (2013) for G20 countries.

Table 5
Results of Panel GMM estimation for Eq. (5).

	Dependent variable : CO_2 emissions (CO_2)				
	Intercept	GDP	ENC	URB	TOP
Algeria	-12.619*	-0.167***	0.975*	0.042	-0.157
Bahrain	0.307**	0.498*	0.921**	0.201	-0.037
Egypt	8.961*	0.287**	0.452*	0.671*	-0.308
Iran	-9.211*	0.253***	0.198***	0.223**	0.209
Jordan	-3.100*	0.127	0.229	-0.217	-0.058
Kuwait	-6.194*	0.359*	0.178*	0.337**	-0.049
Lebanon	-5.284*	0.222***	0.424*	0.311	-0.124
Morocco	-9.725*	0.117	0.194***	0.399**	-0.211
Oman	-14.241	0.508*	0.092	0.376	-0.045
Qatar	-7.727*	0.871*	0.234	0.421	-0.367
Saoudi Arabia	15.446*	0.670*	0.219**	0.151*	-0.071
Syria	15.019*	0.219**	0.215**	0.188***	-0201
Tunisia	-4.291*	0.355**	0.461**	0.172	-0.101
United Arab Emirates	-1.141**	-0.223***	0.370	-0.299**	-0.058
Panel	-4.624*	0.261*	0.689*	0.221**	-0.062
Hansen test (p-value)			0.13		
Durbin-Wu-Hausman test (p-value)			0.00		
Pagan-Hall test (p-value)			0.02		

Note: All variables in natural logs.
* Indicates significant at 1% level ,
** Indicates significant at 5% level ,
*** Indicates significant at 10% level.

Regarding the energy variable, it is found that energy consumption per capita has a positive impact on CO_2 emissions per capita for all the countries. It has a significant impact for Algeria, Bahrain, Egypt, Iran, Kuwait, Lebanon, Morocco, Saoudi Arabia, Syria and Tunisia. This indicates that an increase in energy consumption increase the carbon emissions in these countries. For the panel estimation, energy consumption per capita has a significant positive impact on CO_2 emissions per capita. The coefficient is 0.689, indicating that CO_2 emissions per capita increases by 0.689% when there is a 1% increase in the energy consumption per capita. This implies that an increase in energy consumption increase the environment degradation. This finding is in line with Soytas et al. (2007) for United States; Halicioglu (2009) for Turkey; Zhang and Cheng (2009) for China and Arouri et al. (2012) for 12 MENA countries.

The urbanization variable has a positive significant impact on the CO_2 emissions for Egypt, Iran, Kuwait and Morocco. It has a negative significant impact only for the United Arab Emirates. However for the remaining countries, no significant relationship is found. This indicates that an increase in the urbanization tends to decrease the CO_2 emission per capita in the United Arab Emirates. For the panel estimation, it has a significant positive impact of urbanization on carbon emissions per capita. The coefficient is 0.221, indicating that CO_2 emissions per capita increases by 0.221% when there is a 1% increase in urbanization. This finding is consistent with Hossain (2011) for Newly Industrialized Countries.

The variable of trade openness has an insignificant negative impact on CO_2 emissions for all countries except Iran which has a significant positive impact. This indicates that trade openness has no impact on carbon dioxide emissions. The same result was concluded for the panel estimation. This result is in line with Hossain (2011) for Newly Industrialized Countries.

Therefore, according to the overall results, we can conclude that: (1) there is a bi-directional causal relationship between energy consumption and economic growth; (2) there is a unidirectional causal relationship from energy consumption to carbon dioxide emissions and (3) there is a bidirectional causal relationship between economic growth and pollutant emissions for the region as a whole. Fig. 1 summarizes the GMM panel data results of Tables 3, 4 and 5. These results corroborate the three-way linkages between environmental degradation, energy consumption and economic growth over the study period of 1990-2011.

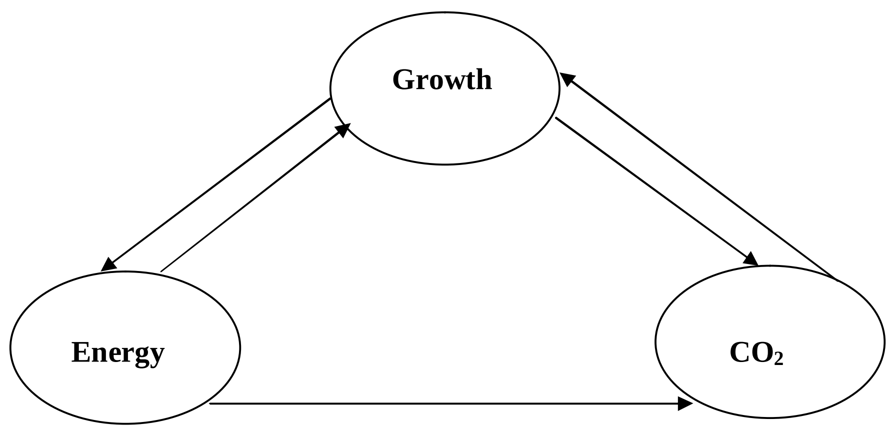

Fig. 1 Interaction between CO_2, Energy and GDP for MENA countries.

4. Conclusion and policy implications

The present study investigates the three-way linkages between CO_2 emissions, energy consumption and economic growth using the Cobb–Douglas production function. While the literature on the causality links between emissions-energy-growth has increased over the last few years, there is no study that examines this interrelationship via the simultaneous-equations models. The objective of the present study is to fill this research gap by examining the above interaction for 14 MENA countries over the period 1990-2011.

Our results suggest that energy consumption enhances economic growth. We found a bidirectional causal relationship between the two series. Our results significantly reject the neo-classical assumption that energy is neutral for growth. This pattern is similar to the findings of Oh and Lee (2004), Mahadevan and Asafu-Adjaye (2007), Ang (2008), and Apergis and Payne (2009). Thus, we conclude that energy is a determinant factor of the GDP growth in these countries, and, therefore, a high-level of economic growth leads to a high level of energy demand and vice versa. As such, it is important to take into account their possible negative effects on economic growth in establishing energy conservation policies.

Our empirical results also show that there is a unidirectional causal relationship from energy consumption to carbon dioxide emissions without feedback. This implies that due to the expansion of production, the countries are consuming more energy, which puts pressure on the environment leading to more emissions. Hence, it is very essential to apply some sorts of pollution control actions to the whole panel regarding energy consumption. It is found that bidirectional causality between economic growth and CO_2 emissions implies that degradation of the environment has a causal impact on economic growth, and a persistent decline in environmental quality may exert a negative externality to the economy through affecting human health, and thereby it may reduce productivity in the long run.

The main policy implications emerging from our study is as follows. First, these countries need to embrace more energy conservation policies to reduce CO_2 emissions and consider strict environmental and energy policies. The research and investment in clean energy should be an integral part of the process of controlling the carbon dioxide emissions and find sources of energy to oil alternative. These countries can use solar energy as the substitute of oil. Thus, implementing the environmental and energy policies and also reconsidering the strict energy policies can control carbon dioxide emissions. As a result, our environment will be free from pollution and millions of peoples can protect them-selves from the effects of natural disasters.

Second, high economic growth gives rise to environmental degrading but the reduction in economic growth will increase unemployment. The policies with which to tackle environmental pollutants require the identification of some priorities to reduce the initial costs and efficiency of investments. Reducing energy demand, increasing both energy supply investment and energy efficiency can be initiated with no damaging impact on the MENA's economic growth and therefore reduce emissions. At the same time, efforts must be made to encourage industries to adopt new technologies to minimize pollution. Finally, given the generous subsidies for energy in the exporting countries, there is a relatively more scope for more drastic energy conservation measures without severe impacts on economic growth in these countries. Indeed, it is unlikely that the elimination of energy price distortions restrain economic growth in the oil exporting countries. However, subsidy reform should be embedded in a reform program that engenders broad support and yield widespread benefits.

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