Panel analysis of CO2 emissions, GDP, energy consumption, trade openness and urbanization for MENA countries

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Abstract: This paper empirically parallels two approaches: The first one follows the studies of Halicioglu (2009), Jalil and Mahmud (2009), and Jayanthakumaran et al. (2012) which attempt to introduce energy consumption and trade into the environmental function (related carbon dioxide 'CO_2' emissions to Gross Domestic Product 'GDP'); whereas the second approach extends the single work of Hossain (2011) which attempts to introduce urbanization as a means to circumvent omitted variable bias. For 11 Middle East and North African (MENA) countries over the period 1980-2009, the empirical results appear to be relevant in light of the Environmental Kuznets Curve (EKC) literature based on the cointegrated and causal relationship. Policy implications indicate that: i) more energy use, higher GDP and greater trade openness tend to cause more CO_2 emissions; ii) the inclusion of urbanization in the environmental function improves the final results and positively affects the pollution level; and iii) MENA countries should search the best policy which can stabilize the rise of growth GDP and trade openness, and which can also control the continuous increase in the use of energy.

Keywords: Environmental Kuznets Curve (EKC) literature, Panel data analysis, Middle East and North African (MENA) countries

1. Introduction

Economic growth and energy consumption may generate considerable pressure on the environment as often mentioned in the environmental Kuznets curve (EKC) literature. These relationships between output and energy consumption, as well as output and environmental pollution, have been the subject of intense research over the past few decades. An assessment on the existing energy literature reveals that most studies focus on testing the nexus of either output-energy or output-pollution separately while only some investigations have so far been made to examine these two links under the same framework (Ang, 2007; Apergis and Payne, 2009, 2010; Lean and Smyth, 2010; Arouri et al. 2012). The main contribution of recent paper to examine the dynamic relationship between pollutant emissions, income, energy consumption, and trade openness under an integrated framework. Given that these four variables are strongly inter-related, the use of a naive bivariate or trivariate framework may be subject to the problems of omitted variables bias (Ang, 2009; Halicioglu, 2009; Jalil and Mahmud, 2009; Jayanthakumaran et al., 2012; Shahbaz et al. 2012, 2103). In this context, it is important to suggest that the potential gains from pollution mitigation may depend on the degree to which income, energy consumption, and trade openness act as complements. Recently, the inclusion of the urbanization in the environmental function examining the relationship between CO_2 emissions, GDP, energy consumption and trade openness is an important topic to study for several reasons. At the time of writing, the work by Hossain (2011) appears to be the only published paper specifically investigating this relationship. That is why the aim of this paper is two-fold: first, to identify the environmental function containing CO_2 emissions, GDP, energy consumption and trade openness as often mentioned in the EKC literature; and second, to identify the inclusion of urbanization in the same environmental function.

The remainder of this paper is organized as follow: Section 2 investigates the literature review; Section 3 highlights modeling, methodology and empirical results; and the last one concludes with a summary of the main findings and policy implications.

2. Literature review

As such, the statement of the EKC hypothesis makes no explicit reference to the possible relationship between level of environmental degradation and income distribution. In the discussion of income-environmental quality relationship, income distribution generally enters through either or both of three routes. First, the treatment of the environmental quality as a public good may argue that the observed level of the environmental quality is determined by the quantities of energy used for various interest groups of the society, where these quantities distribution may be closely related to income and other relevant socio-economic inequalities (Ang, 2007). Second, the demand for environmental damage may be regarded as a derived demand, being determined by the technology used to produce goods and services, the income level, the associated pattern of consumption of energy and the trade openness (Liu, 2005; Coondoo and Dinda, 2008). Finally, the inclusion of the urbanization may play a vital role in the relationship containing CO_2 emissions, GDP, energy consumption and trade (Hossain, 2011).

2.1. Emissions, GDP and Energy

Pollution is closely related to energy consumption since more energy consumption leads to higher economic development through the enhancement of productivity but it also leads to higher pollutant gases (see for example: Ang, 2007; Apergis and Payne, 2009, 2010; Lean and Smyth, 2010; Arouri et al., 2012). Ang (2007) examines the dynamic causal relationships between pollutant emissions, energy consumption, and output for France over the period 1960-2000. He argues that these variables are strongly inter-related and therefore their relationship must be examined using cointegration and vector error-correction (VEC) modeling techniques. The empirical results provide evidence for the existence of a fairly robust long-run relationship between these variables. The causality results support that GDP exerts a causal influence both on the energy use and the pollution in the long run. The results also point to a unidirectional causality running from energy use to GDP in the short run. The study of Apergis and Payne (2009, 2010) extend the work of Ang (2007) by examining the causal relationship between CO_2 emissions, energy consumption, and GDP within a panel VEC model for 6 Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) over the period 1971-2004; and for 11 countries of the Commonwealth of Independent States (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, and Uzbekistan) over the period 1992-2004, respectively. In long-run equilibrium, they argue that energy consumption has a positive and statistically significant impact on emissions while real GDP exhibits the inverted U-shape pattern associated with the EKC hypothesis. The short-run dynamics indicate unidirectional causality from energy consumption and real GDP to emissions, along with bidirectional causality between energy consumption and real GDP. In the long-run there appears the bidirectional causality between energy consumption and emissions. In other work, Lean and Smyth (2010) study the causal relationship between CO_2 emissions, electricity consumption and economic growth within a panel VEC model for 5 ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore and Thailand) over the period 1980-2006. The long-run estimates indicate that there are a statistically significant positive association between electricity consumption and emissions and a non-linear relationship between emissions and real GDP, consistent with the EKC. The long-run estimates, however, do not indicate the direction of causality between the variables. The results from the Granger causality tests suggest that in the long-run there is a unidirectional Granger causality running from electricity consumption and emissions to real GDP. The empirical results lead also to point unidirectional Granger causality running from emissions to electricity consumption in the short-run. Recently, Arouri et al. (2012) extend the recent findings of Liu (2005), Ang (2007), Apergis and Payne (2009) and Payne (2010) by implementing recent bootstrap panel unit root tests and cointegration techniques to investigate the relationship between CO_2 emissions, energy consumption, and real GDP for 12 MENA over the period 1981-2005. The finding results show that in the long-run energy consumption has a positive significant impact on CO_2 emissions while real GDP exhibits a quadratic relationship with CO_2 emissions for the region as a whole. However, although the estimated long-run coefficients of income and its square satisfy the EKC hypothesis in most studied countries, the turning points are very low in some cases and very high in other cases, hence providing poor evidence in support of the EKC hypothesis. The policy implications of this study prove that CO_2 emission reductions per capita have been achieved in the MENA region, even while the region exhibited economic growth and also prove that future reductions in CO_2 emissions per capita might be achieved at the same time as GDP per capita in the MENA region continues to grow.

2.2. Emissions, GDP, Energy and Trade

While the importance of global warming issues is widely recognized among economists and policy makers, there has so far been little effort attempting to examine environmental performance with including the impact of trade openness (see for example: Ang, 2009;

Halicioglu, 2009; Jalil and Mahmud, 2009; Jayanthakumaran et al., 2012); Tiwari et al. 2013. For Ang (2009), the results of the pollution function are estimated using the variables per capita CO_2 emissions, per capita energy use, per capita real output and trade openness for the China case during the annual period 1953-2006. Adopting an analytical framework that combines the environmental literature with modern endogenous growth theories, the results indicate that CO_2 emissions are negatively related to research intensity, technology transfer and the absorptive capacity of the economy to assimilate foreign technology. The findings also indicate that more energy use, GDP and trade openness tend to cause more CO_2 emissions. In the same way, Halicioglu (2009) examines the dynamic causal relationships between CO_2 emissions, energy consumption, GDP, and foreign trade in Turkey over the annual period 1960-2005. This research tests the interrelationship between the variables using the bounds testing to cointegration procedure. The finding results indicate that there exist two forms of long-run relationships between the variables. In the first form, CO_2 emissions are determined by energy consumption, GDP and foreign trade. In the second form, GDP is determined by CO_2 emissions, energy consumption and foreign trade. The Granger causality results suggest that GDP is the most significant variable in explaining the CO_2 emissions and it is followed by energy consumption and foreign trade. Moreover, there exists a stable CO_2 emissions function. Jalil and Mahmud (2009) extend the same methodology of Halicioglu (2009) for the case of China over the period 1975-2005. This study aims at testing whether EKC relationship between CO_2 emissions and per capita real GDP holds in the long run or not using Auto regressive distributed lag (ARDL) methodology. A quadratic relationship between GDP and CO_2 emission has been found for the sample period supporting EKC relationship. The results of Granger causality tests indicate one way causality runs through GDP to CO_2 emissions. The empirical results also indicate that CO_2 emissions are mainly determined by GDP and energy consumption in the long run. Trade has a positive but statistically insignificant impact on CO_2 emissions. Recently, Jayanthakumaran et al. (2012) using the bounds testing approach to cointegration and the ARDL methodology to test the long and short-run relationships between growth, energy use, trade openness, and endogenously determined structural breaks for both China and India Using over the annual period 1971-2007. The finding results indicate that CO_2 emissions in China were influenced by per capita real GDP, energy consumption and structural changes. A similar causal connection cannot be established for India with regard to structural changes and CO_2 emissions, because India's informal economy is much larger than China's informal economy. Moreover, India possesses an extraordinarily large number of micro-enterprises that are low energy consumers and not competitive enough to reach international markets. Understanding these contrasting scenarios is prerequisite to reaching an international agreement on climate change affecting these two countries.

2.3. Emissions, GDP, Energy, Trade and Urbanization

From a broader perspective, there has been intense debate about the inclusion of urbanization in stimulating environmental and regional development. That is why there is only the work of Hossain (2011) that has documented the importance of the inclusion of urbanization in the relationship between CO_2 emissions, GDP (economic growth), energy consumption and trade. This paper empirically examines the dynamic causal relationships between these variables for the panel of newly industrialized countries (NIC: Brazil, China, India, Malaysia, Mexico, Philippines, South Africa, Thailand and Turkey) using time series data for the annual period 1971-2007. Panel unit root tests results indicate that all variables are integrated of order 1, I(1). Johansen Fisher panel cointegration test indicates that there is a cointegration vector among the variables. The Granger causality test results support that there is no evidence of long-run causal relationship, but there is unidirectional short-run causal relationship from GDP and trade openness to CO_2 emissions, from GDP to energy consumption, from trade openness to GDP, from urbanization to GDP, and from trade openness to urbanization. It is found that the long-run elasticity of CO_2 emissions with respect to energy consumption is higher than short run elasticity. This indicates that over time higher energy consumption in the NIC gives rise to more CO_2 emissions as a result our environment will be polluted more. But in respect of GDP, trade openness and urbanization the environmental quality is found to be stable in the long-run.

3. Modeling, methodology and empirical results

3.1. Models specification

The original form of environmental function is related to the statement of the EKC hypothesis which makes no explicit reference to the possible relationship between level of environmental degradation and income distribution. In the discussion of income-environmental quality relationship, Coondoo and Dinda (2008) suggest that income distribution generally enters through two routes: i) first route considers the environmental quality as a public good where the power distribution may be closely related to income and to other specific fields, ii) second route consists to accord the associated pattern of consumption of goods and services and the technology used to produce these goods and services where the demand for the environmental damage may be regarded as a derived demand being determined by the income level. From this point of view, the environmental damage-income relationship may be viewed as the Engel curve for environmental damage. In what follows, the Engel curve for environmental damage follows this form:

$$C = f(Y);\ Y \in [0,\infty[\qquad (1)$$

where C denotes the environmental damage, Y denotes the income, and $f'(Y)$ measures the marginal income response of environmental damage demanded. It is reasonable to expect $f'(Y)$ to be monotonically decreasing in income such that $f'(Y) < 0$ at income levels greater than a given threshold income level Y^* when environmental damage becomes an inferior good. This means that the environmental damage first increases with income, then stabilizes and eventually declines. Thus, the general function of Engel curve is specified as:

$$C = \alpha_0 + \alpha_1.Y + \alpha_2.Y^2 + ... \qquad (2)$$

In the last decade, the question of omitted variable bias in the relationship between income and emissions is also subject to the issue of the EKC hypothesis. For that, Ang (2007), Apergis and Payne (2009, 2010), Lean and Smyth (2010), and Arouri et al. (2012) introduced energy consumption into the relationship between income and emissions as a means to circumvent omitted variable bias. The inclusion of energy consumption appears to be relevant in light of the growing literature on the causal relationship between these variables.

In this approach, the long-run relationship between emissions, income and energy consumption is given by the following equation:

$$C = \alpha_0 + \alpha_1.Y + \alpha_2.Y^2 + \alpha_3.E \qquad (3)$$

Furthermore, Antweiler et al. (2001), Cole and Elliott (2003), and Ang (2009) have argued that it is possible to decompose the environmental impact of trade liberalization into three effects: scale (size of the economy), technique (production methods) and composition (specialization). Scale effect means that the increase in the size of the economy leads to increase pollution. Technique effect means that the use of technical production methods consists to improve the environmental conditions through more competition among the competing firms. Composition effect depends on the country's comparative advantage. Hence, the effect of trade on the environment depends on the relative empirical issue. With respect to this methodology, Halicioglu (2009), Jalil and Mahmud (2009), and Jayanthakumaran et al. (2012) include the impact of foreign trade into the nexus to reduce the problems of omitted variable bias in the econometric estimation, and the log quadratic EKC equation used to examine the relationship between emissions, income, energy consumption, and trade will be given by the following equation:

$$C = \alpha_0 + \alpha_1.Y + \alpha_2.Y^2 + \alpha_3.E + \alpha_4.T \tag{4}$$

The long-run relationship, in natural logs, will be given by the following equation:

Panel A. $$\ln C_{it} = \alpha_{0i} + \alpha_{1i}.\ln Y_{it} + \alpha_{2i}.\ln Y_{it}^2 + \alpha_{3i}.\ln E_{it} + \alpha_{4i}.\ln T_{it} + \mu_{it} \tag{5}$$

But still now only one has emphasized the importance of urbanization in determining the level of emissions. Suggested that the empirical work of environmental function should be determined by income, energy consumption, trade openness and urbanization, Hossain (2011) employs the following model:

$$C = A \;\; \mathrm{Y}^{\beta_1} \;\; \mathrm{E}^{\beta_2} \;\; \mathrm{T}^{\beta_3} \;\; \mathrm{URB}^{\beta_4} \tag{6}$$

Taking natural logarithms of Eq. (6), denoting lower case letters as the natural log of upper case letters and adding a random error term produces the following equation:

$$\ln C = \beta_0 + \beta_1.\ln Y + \beta_2.\ln E + \beta_3.\ln T + \beta_4.\ln URB \tag{7}$$

where $\beta_0 = \ln A$, and β_1, β_2, β_3, and β_4 are respectively the output elasticities of GDP, energy consumption, trade openness and urbanization.

According to the knowledge of the author, still now only the work of Arouri et al. (2012) has examined the log quadratic EKC equation for MENA countries, but without including trade and urbanization. On this basis, the main purpose of the present paper has been made to combine the first approach of Halicioglu (2009), Jalil and Mahmud (2009), and Jayanthakumaran et al. (2012) with the second approach of Hossain (2011). This consists to examine the dynamic causal relationship between CO_2 emissions, GDP, energy consumption, trade openness and incorporating the variable urbanization for the panel of MENA region. The long-run relationship, in natural logs, will be given by the following equation:

Panel B. $$\ln C_{it} = \beta_{0i} + \beta_{1i}.\ln Y_{it} + \beta_{2i}.\ln Y_{it}^2 + \beta_{3i}.\ln E_{it} + \beta_{4i}.\ln T_{it} + \beta_{5i}.\ln URB_{it} + \varepsilon_{it} \tag{8}$$

where i, t, β_{0i} and ε denote the country, the time, the fixed country effect and the white noise stochastic disturbance term, respectively. The parameters $\beta_{1i}, \beta_{2i}, \beta_{3i}, \beta_{4i}$ and β_{5i} are the long-run elasticities of CO_2 emissions with respect to income, squared income, energy consumption, trade openness, and urbanization, respectively. As for the expected signs in Eq. (8), one would expect that the sign of β_{1i} expected to be positive whereas a negative sign is expected for β_{2i} for the EKC hypothesis to be true. The sign β_{3i} is expected to be positive because more energy consumption can increase the scale of an economy and stimulate CO_2 emissions. The expected sign of β_{4i} is mixed depending on the level of economic development stage of a country. For the case of developed countries, this sign is expected to be negative as they cease to produce certain pollution intensive goods and begin to import these from other countries with less restrictive environmental protection laws. But for the case of developing countries, this sign expectation is reversed as they tend to have dirty industries with heavy share of pollutants (Grossman and Krueger, 1995). It means also that an increase in trade openness will increase pollution due to a comparative advantage in dirty production under weaker environmental regulations (Jayanthakumaran et al. 2012). For the sign of urbanization, Hossain (2011) suggested that relatively high income countries are more urbanized than low and middle income countries. This means that the expected sign of β_{5i} is also mixed depending on the level of economic development stage of a country or a panel of countries.

3.2. Data

The data set is a balanced panel of 11 MENA countries over the annual period 1980-2009. It also contains 5 variables: CO_2 emissions (NC), Output (NY), Energy consumption (NE), Trade openness (NT), and Urbanization (NURB). Where CO_2 emissions is measured in metric tons per capita, output is measured using real GDP per capita in constant 2000 US$, energy consumption is measured using energy use in kg of oil equivalent per capita, trade openness is measured in % of exports and imports of GDP, and urbanization is measured using urban population in % of total. The dimensions of the panel data set are chosen to include as many countries as possible each with a reasonable time length of observations. The 11 MENA countries included in the sample are: Algeria (ALG), Bahrain (BHR), Egypt (EGY), Iran (IRN), Israel (ISR), Jordan (JOR), Morocco (MRC), Oman (OMN), Saudi Arabia (SAU), Syria (SYR), and Tunisia (TUN). These variables are obtained from World Bank Development Indicators (WDI). All variables are converted into natural logarithms to reduce the heterogeneity. The descriptive statistics of different variables for 11 MENA countries are given in Table-1.

Table-1
Descriptive statistics

	LNC	**LNY**	**LNE**	**LNT**	**LNURB**
Mean	1.4703	8.0480	7.2456	4.2974	4.1458
Median	1.2107	7.5591	6.9293	4.2748	4.1487
Maximum	3.4048	9.9961	9.2527	5.5260	4.5191
Minimum	-0.2365	6.7529	5.4880	2.6226	3.7186
Std. Dev.	0.9413	0.9900	0.9688	0.4488	0.2443
Skewness	0.3567	0.5513	0.4295	0.0285	-0.0054
Kurtosis	2.2147	1.6729	2.3021	3.5827	1.7373
Jarque-Bera	15.478	40.9354	16.8435	4.7140	21.923
Probability	0.0004	0.0000	0.0002	0.0947	0.0000
Observations	330	330	330	330	330
Cross section	11	11	11	11	11

3.3.Econometrical methodology and empirical results

The empirical study is organized to involve three objectives: the first is to examine the stationarity properties of individual series in panel datasets using a battery of panel unit root tests, the second is to examine the long-run relationship using appropriate long-run estimates [Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS)], and the third is to estimate a panel vector error correction model (VECM) in order to infer the Granger causal relationships.

3.3.1. Panel unit root tests analysis

We apply three types of panel unit root test to compute in order to assess the stationary of the variables: Breitung (2001), Levin, Lin and Chu (LLC, 2002), Im, Peasaran and Shin (IPS, 2003).

Breitung (2001) considered the following form:

$$W_{it} = \alpha_{it} + \sum_{j=1}^{k+1} \beta_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \tag{9}$$

In Eq. (9), the test statistic of Breitung (2001) assumes the following hypothesis: the null hypothesis is given by $H_0 : \sum_{j=1}^{k+1} \beta_{ij} - 1 = 0$, whereas the alternative hypothesis is given by $H_1 : \sum_{j=1}^{k+1} \beta_{ij} - 1 < 0$ and assumes that W_{it} is stationary. More precisely, Breitung (2001) uses the transformed vectors $w_i^* = AW_i = \left[W_{i1}^*, W_{i2}^*, ..., W_{iT}^*\right]'$ and $x_i^* = AX_i = \left[X_{i1}^*, X_{i2}^*, ..., X_{iT}^*\right]'$ in order to construct the following test statistic:

$$\lambda = \frac{\frac{1}{\sigma_i^2} \sum_{i=1}^{N} w_i^{*'} x_i^{*'}}{\sqrt{\frac{1}{\sigma_i^2} \sum_{i=1}^{N} x_i^{*'} A' A x_i^*}} \tag{10}$$

Levin, Lin and Chu (LLC, 2002) propose a panel based on the ADF test and they test the presence of the homogeneity in the dynamics of the autoregressive coefficients for all panel units with cross-sectional independence. They consider the following regression equation:

$$\Delta X_{it} = \alpha_i + \beta_i X_{i,t-1} + \delta_i t + \sum_{j=1}^{k} \gamma_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \tag{11}$$

where Δ is the first difference operator, X_{it} is the dependent variable, ε_{it} is a white-noise disturbance with a variance of σ_ε^2, i = 1, 2,..., N indexes country, and t = 1, 2,..., T indexes time. The LLC test involves: the null hypothesis $H_0 : \beta_i = 0$ for all "*i*" against the alternative $H_1 : \beta_i \prec 0$ for all "*i*".

Im, Peasaran and Shin (IPS, 2003) test is not as restrictive like the LLC test, since it allows for heterogeneous coefficients. The null hypothesis is that all individuals follow a unit root process, $H_0 : \beta_i = 0$ for all "i", whereas the alternative hypothesis is that some of the individuals allow to present unit root, then: $H_1 : \begin{cases} \beta_i < 0 \text{ for i=1,...,N}_1 \\ \beta_i = 0 \text{ for i=N}_1\text{+1,...,N} \end{cases}$.

This test is based on the averaging individual unit root test, denoted $\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{\beta_i}$.

The results of unit root tests reported in Table-2 indicate that each variable is integrated of order one, I(1).

Table- 2
Panel unit root tests results

		LNC	LNY	LNE	LNT	LNURB
Breitung	Level	-1.3315	2.5939	-1.7661	-0.6936	-0.4081
		(0.0915)	(0.9953)	(0.1387)	(0.2424)	(0.3416)
	Δ	-7.4891***	-5.3698***	-5.5466***	-2.7473***	-4.1356***
		(0.0000)	(0.0000)	(0.0000)	(0.0030)	(0.0000)
LLC	Level	-0.2185	-1.0035	-1.4158	1.0444	1.5949
		(0.4315)	(0.1578)	(0.0784)	(0.8519)	(0.9446)
	Δ	-18.8283***	-10.6419***	-14.2088***	-3.9508***	-3.6174***
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)
IPS	Level	-0.0805	-0.7294	0.1718	-1.9280	1.6584
		(0.4679)	(0.2329)	(0.5682)	(0.1269)	(0.9514)
	Δ	-18.7239***	-10.0086***	-15.4302***	-11.5816***	-10.6604***
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Decision		I(1)	I(1)	I(1)	I(1)	I(1)

Δ is the first difference operator.
The null hypothesis of Breitung, LLC and IPS tests examines non-stationary.
*** denotes statistical significance at the 1% level (Probabilities are presented in parentheses).
Lag selection (Automatic) based on Schwarz Information Criteria (SIC).

3.3.2. Panel cointegration tests analysis

Given that each of the variables contains a panel unit root, we proceed to examine whether there is a long-run relationship between the variables using Pedroni (1999, 2004) panel cointegration test.

Pedroni (1999, 2004) developed a number of statistics based on the residuals of the Engle and Granger (1987) cointegration regression. Assuming a panel of N countries, T observations and m regressors (X_m), Pedroni (1999, 2004) considered the following regression equation:

$$Y_{it} = \alpha_i + \lambda_i t + \sum_{j=1}^{m} \beta_{j,i} X_{j,it} + \varepsilon_{it} \qquad t = 1,\ldots,T \qquad i = 1,\ldots N \tag{12}$$

where $Y_{i,t}$ and $X_{j,i,t}$ are integrated of order one in levels, I(1).

Pedroni (1999, 2004) proposed two sets of panel cointegration tests. The first type, called panel cointegration tests, is based on the *within dimension* approach which includes four statistics: panel *v*- statistic (Z_v), panel *rho*-statistic (Z_ρ), panel *PP*-statistic (Z_{pp}), and panel *ADF*- statistic (Z_{ADF}). These statistics pool the autoregressive coefficients across different countries for the unit root tests on the estimated residuals taking into account common time factors and heterogeneity across countries. The second type, called group mean panel cointegration tests, is based on the *between dimension* approach which includes three statistics: group *rho*-statistic ($\tilde{Z}_\rho$), group *PP*-statistic ($\tilde{Z}_{pp}$), and group *ADF*-statistic ($\tilde{Z}_{ADF}$).

These statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each country (for more details see, Farhani and Ben Rejeb, 2012). Under null hypothesis, all seven tests indicate the absence of cointegration $H_0 : \rho_i = 0 \;\; ; \forall i$, whereas the alternative hypothesis is given by $H_1 : \rho_i = \rho \prec 1 \;\; ; \forall i$ where ρ_i is the autoregressive term of the estimated residuals under the alternative hypothesis and it is given by in the following equation:

$$\hat{\varepsilon}_{i,t} = \rho_i \hat{\varepsilon}_{i,t-1} + u_{i,t} \tag{13}$$

Pedroni (1999) privileges that all seven statistics have a standard asymptotic distribution which is based on the independent movements in Brownian motions when T and N $\rightarrow \infty$:

$$\frac{Z - \mu\sqrt{N}}{\sqrt{\nu}} \xrightarrow[N,T\rightarrow\infty]{} N(0,1) \tag{14}$$

where Z is one of the seven normalized statistics, and μ and ν are tabulated in Pedroni (1999, Table-2).

For both Panel A and Panel B, Pedroni's (1999, 2004) results for the within and between dimension panel cointegration test statistics Table-3 reports for each panel data set. For Panel A, all seven panel cointegration tests reject the null hypothesis of no cointegration at the 5% significance level except Panel v-statistic. For Panel B, all seven panel cointegration tests reject the null hypothesis of no cointegration at the 5% significance level except Panel rho-statistic and Group rho-statistic. In general, the results indicate that there is a long-run equilibrium relationship between all variables.

Table-3
Pedroni (1999, 2004)'s cointegration test [a]

	Panel A			**Panel B**	
	Test statistic	**Prob.**		**Test statistic**	**Prob.**
Within-dimension			**Within-dimension**		
Panel υ-stat	0.5936	(0.3345)	Panel υ-stat	-0.4587***	(0.0091)
Panel rho-stat	-2.8006***	(0.0079)	Panel rho-stat	-0.9505	(0.2539)
Panel PP-stat	-4.7192***	(0.0000)	Panel PP-stat	-3.6694***	(0.0005)
Panel ADF-stat	-4.5132***	(0.0000)	Panel ADF-stat	-3.7152***	(0.0004)
Between-dimension			**Between-dimension**		
Group rho-stat	-1.7774***	(0.0822)	Group rho-stat	0.3500	(0.3752)
Group PP-stat	-5.3799***	(0.0000)	Group PP-stat	-4.2857***	(0.0000)
Group ADF-stat	-5.2057***	(0.0000)	Group ADF-stat	-3.7177***	(0.0004)

Critical value at the 1% significance level denoted by "**".
The null hypothesis is that the variables are not cointegrated.
[a] Lag length selected based on SIC automatically with a max lag of 5.

3.3.3. Panel FMOLS and DOLS estimates

Although OLS estimators of the cointegrated vectors are super convergents, their distribution is asymptotically biased and depends on nuisance parameters associated with the presence of serial correlation in the data (See: Pedroni, 2001a, b and Kao and Chiang, 2001). Such problems, existing in the time series case, also arise for the panel data and tend to be more marked even in the presence of heterogeneity (see in particular Kao and Chiang, 2001).

To carry out tests on the cointegrated vectors, it is consequently necessary to use methods of effective estimation. Various techniques exist, such as Fully Modified Ordinary Least Squares (FMOLS) initially suggested by Philips and Hansen (1990) or the method of Dynamic Ordinary Least Squares (DOLS) of Saikkonen (1991) and Stock and Watson (1993). In case of panel data, Kao and Chiang (2001) showed that these two techniques led to normally distributed estimators, it means that both OLS and Fully Modified OLS (FMOLS) exhibit small sample bias and that DOLS estimator appears to outperform both estimators. Similar results are got by Phillips and Moon (1999) and Pedroni (2001b) for method FMOLS.

In the first way, The FMOLS is used by Pedroni (2001a, b) to solve the problem of the existence of endogeneity between regressors. He considered the following equation:

$$W_{i,t} = \alpha_i + \beta_i X_{i,t} + \varepsilon_{i,t} \quad \forall t = 1,\dots,T \ , \ i = 1,\dots N \tag{15}$$

and he proposes that W_{it} and $X_{i,t}$ are cointegrated with slopes β_i, which β_i may or may not be homogeneous across i. So we will obtain the following equation:

$$W_{i,t} = \alpha_i + \beta_i X_{i,t} + \sum_{k=-K_i}^{K_i} \gamma_{i,k} \Delta X_{i,t-k} + \varepsilon_{i,t} \quad \forall t = 1,\dots,T \ , \ i = 1,\dots N \tag{16}$$

We consider $\xi_{i,t} = (\hat{\varepsilon}_{i,t}, \Delta X_{i,t})$ and $\Omega_{i,t} = \lim_{T\to\infty} E\left[\frac{1}{T}\left(\sum_{t=1}^{T}\xi_{i,t}\right)\left(\sum_{t=1}^{T}\xi_{i,t}\right)'\right]$ is the long-run covariance for this vector process which can be decomposed into $\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i'$ where Ω_i^0 is the contemporaneous covariance and Γ_i is a weighted sum of autocovariance.

The panel FMOLS estimator is given as:

$$\hat{\beta}^*_{FMOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T}\left(X_{i,t} - \bar{X}_i\right)^2\right)^{-1}\left(\sum_{t=1}^{T}\left(X_{i,t} - \bar{X}_i\right)W^*_{i,t} - T\hat{\gamma}_i\right)\right] \tag{17}$$

where $W^*_{i,t} = W_{i,t} - \overline{W}_i - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}}\Delta X_{i,t}$ and $\hat{\gamma}_i = \hat{\Gamma}_{2,1,i} + \hat{\Omega}^0_{2,1,i} - \frac{\hat{\Omega}_{2,1,i}}{\hat{\Omega}_{2,2,i}}\left(\hat{\Gamma}_{2,2,i} + \hat{\Omega}^0_{2,2,i}\right)$.

In the second way, the DOLS was initially suggested by Saikkonen (1991) in the time series case, then adapted by Kao and Chiang (2001) and Mark and Sul (2003) to the case of panel data. This technique consists to include advanced and delayed values of $\Delta X_{i,T}$ (Eq. 16) in the cointegrated relationship, in order to eliminate the correlation between regressors and error terms. The panel DOLS estimator is defined as:

$$\hat{\beta}^*_{DOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T} Z_{i,t} Z_{i,t}'\right)^{-1}\left(\sum_{t=1}^{T} Z_{i,t}\tilde{W}_{i,t}\right)\right] \tag{18}$$

where $Z_{i,t} = \left[X_{i,t} - \bar{X}_i, \Delta X_{i,t-K_i}, \dots, \Delta X_{i,t+K_i}\right]$ is vector of regressors, and $\tilde{W}_{i,t} = W_{i,t} - \overline{W}_i$.

Table-4 and Table-5 provide the results of the country-by-country and panel FMOLS and DOLS tests, respectively. All variables are expressed in natural logarithms. The estimated coefficients from the long-run cointegration relationship can be interpreted as long-run elasticities. In all cases, the parameters are quite significant at the 10% level of significance. From the sign of the parameter, the results show that there are inverse U-shaped relationships between per capita pollution and per capita real GDP for all studied MENA countries, except Oman and Tunisia.

On a per country basis on Panel A (without urbanization factor), the Tunisian case presents special attention, since it is the only country where a positive monotonic relationship between CO_2 emissions and real GDP is found (the elasticities are 0.243+0.570.*LNY* and 25.587+3.213.*LNY* for FMOLS and DOLS, respectively). Oman presents an inverted curve as compared to what is predicted by the theory (the elasticities are -38.604+4.483.*LNY* and -41.574+4.823.*LNY* for FMOLS and DOLS, respectively). For panel FMOLS estimators, the coefficients are 0.118, -0.003, 0.915 and 0.041 for LNY, LNY², LNE and LNT, respectively. This means that the elasticity of CO_2 emissions with respect to the output in the long-run is 0.118–0.006.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.915%; and a 1% increase in trade openness increases CO_2 emissions by approximately 0.041%. However, panel DOLS estimators are 0.184, -0.007, 0.914 and 0.046 for LNY, LNY², LNE and LNT, respectively. This means that the elasticity of CO_2 emissions with respect to the output in the long-run is 0.184–0.014.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.914%; and a 1% increase in trade increases CO_2 emissions by approximately 0.046%.

On a per country basis on Panel B (with urbanization factor), the Tunisian case also is the only country where a positive monotonic relationship between CO_2 emissions and real GDP is found (the elasticities are 5.127+0.678.*LNY* and 16.647+2.030.*LNY* for FMOLS and DOLS, respectively). Oman presents an inverted curve as compared to what is predicted by the theory (the elasticities are -27.902+3.288.*LNY* and -25.873+3.109.*LNY* for FMOLS and DOLS, respectively). It is found that the long-run energy consumption has significant positive impact on CO_2 emissions for all selected MENA countries. For panel FMOLS estimators, the coefficients are 0.095, -0.001, 0.818, 0.025 and -0.068 for LNY, LNY², LNE, LNT and LNURB, respectively. This means that the elasticity of CO_2 emissions with respect to the output in the long-run is 0.095–0.002.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.818%; a 1% increase in trade openness increases CO_2 emissions by approximately 0.025%; and a 1% increase in urbanization decreases CO_2 emissions by approximately 0.068%. However, panel DOLS estimators are 0.188, -0.007, 0.818, 0.038 and -0.054 for LNY, LNY², LNE, LNT and LNURB, respectively.

Table-4
FMOLS results

Panel A.	LNY	LNY²	LNE	LNT	Constant
ALG	105.0499	-6.981549	0.320175	0.446736	395.8635
	(0.0564)*	(0.0562)*	(0.0958)*	(0.0007)**	(0.0573)*
BHR	35.71482	-1.930700	0.918130	-0.264366	-168.8843
	(0.0239)**	(0.0213)**	(0.0488)**	(0.0782)*	(0.0287)**
EGY	8.659942	-0.675470	0.198227	0.080587	26.90600
	(0.0179)**	(0.0084)**	(0.0900)*	(0.0496)**	(0.0386)**
IRN	0.037300	-0.009643	0.875535	0.008576	-5.686941
	(0.0936)*	(0.0758)*	(0.0000)**	(0.0535)*	(0.0430)**
ISR	27.72658	-1.387461	0.200561	-0.498148	-135.6932
	(0.0652)*	(0.0718)*	(0.0731)*	(0.0016)**	(0.0617)*
JOR	10.50374	-0.700953	1.116255	0.130219	-45.27002
	(0.0157)**	(0.0149)**	(0.0000)**	(0.0030)**	(0.0075)**
MRC	0.018381	-0.487680	0.960724	0.115646	-31.24809
	(0.0224)**	(0.0218)**	(0.0000)**	(0.0518)*	(0.0059)**
OMN	-38.60379	2.241654	0.120842	-0.290702	168.2514
	(0.0013)**	(0.0009)**	(0.0665)*	(0.0612)*	(0.0019)**
SAU	22.78738	-1.218168	0.149520	-0.454144	105.9540
	(0.0153)**	(0.0161)**	(0.0183)**	(0.0405)**	(0.0158)**

SYR	3.868339	-0.244495	0.152742	0.079620	14.87221
	(0.0174)**	(0.0373)**	(0.0847)*	(0.0385)**	(0.0027)**
TUN	0.243455	0.028514	0.571566	0.035523	-3.048271
	(0.0499)**	(0.0063)**	(0.0477)**	(0.0173)**	(0.0288)**
Panel	0.117916	-0.003079	0.915251	0.041162	-5.732542
	(0.0172)**	(0.0184)**	(0.0000)**	(0.0662)*	(0.0049)**

Panel B.	**LNY**	**LNY^2**	**LNE**	**LNT**	**LNURB**	**Constant**
ALG	98.45570	-6.573064	0.600008	0.678779	0.838675	373.1388
	(0.0203)**	(0.0197)**	(0.0691)*	(0.0000)**	(0.0033)**	(0.0201)**
BHR	35.74207	-1.933783	0.937229	-0.212242	-1.404953	-175.6006
	(0.0362)**	(0.0332)**	(0.0603)*	(0.0850)*	(0.0924)*	(0.0373)**
EGY	12.05287	-0.894332	0.380182	0.106104	-1.865630	45.93418
	(0.0465)**	(0.0296)**	(0.0598)*	(0.0721)*	(0.0161)**	(0.0147)**
IRN	4.394745	-0.327014	0.245270	0.041585	1.662984	7.407643
	(0.0490)**	(0.0086)**	(0.0286)**	(0.0712)*	(0.0005)**	(0.0921)*
ISR	59.74302	-2.989147	0.100115	-0.406388	-12.85379	-237.2243
	(0.0029)**	(0.0032)**	(0.0451)**	(0.0015)**	(0.0251)**	(0.0054)**
JOR	11.40071	-0.758136	1.084696	0.122240	0.047188	-48.80913
	(0.0115)**	(0.0111)**	(0.0000)**	(0.0073)**	(0.0257)**	(0.0055)**
MRC	7.939244	-0.550991	1.011051	0.104664	0.121904	-34.28338
	(0.0475)**	(0.0477)**	(0.0000)**	(0.0004)**	(0.0441)**	(0.0765)*
OMN	-27.90247	1.644209	0.312287	-0.500872	-1.052992	124.2122
	(0.0246)**	(0.0180)**	(0.0446)**	(0.0195)**	(0.0193)**	(0.0243)**
SAU	20.62643	-1.102830	0.107101	-0.459064	-0.136076	95.58267
	(0.0763)*	(0.0762)*	(0.0077)**	(0.0470)**	(0.0408)**	(0.0815)*
SYR	20.71437	-1.475053	0.538069	0.190676	3.128434	81.64933
	(0.0486)**	(0.0500)*	(0.0326)**	(0.0744)*	(0.0045)**	(0.0202)**
TUN	5.126526	0.339221	0.550690	0.000529	0.485498	14.40861
	(0.0354)**	(0.0126)**	(0.0573)*	(0.0946)*	(0.0675)*	(0.0514)*
Panel	0.095224	-0.001224	0.817728	0.025162	-0.067729	-5.478216
	(0.0520)*	(0.0675)*	(0.0000)**	(0.0101)**	(0.0328)**	(0.0077)**

Probability values are reported in parentheses.
*and ** indicate the significance at the 10% and 5% level, respectively.

Table-5
DOLS results

Panel A.	**LNY**	**LNY^2**	**LNE**	**LNT**	**Constant**
ALG	24.03214	-1.620991	0.579341	0.195691	87.07240
	(0.0204)**	(0.0162)**	(0.0192)**	(0.0287)**	(0.0319)**
BHR	35.70035	-1.930532	0.542458	-0.862624	-152.3599
	(0.0040)**	(0.0366)**	(0.0339)**	(0.0038)**	(0.0973)*
EGY	19.08632	-1.416756	0.385303	0.117586	67.39674
	(0.0475)**	(0.0392)**	(0.0403)**	(0.0994)*	(0.0580)*
IRN	6.007193	-0.349463	0.770617	0.040908	-29.19344
	(0.0451)**	(0.0188)**	(0.0000)**	(0.0236)**	(0.0150)**
ISR	50.81968	-2.533540	1.046958	-1.064180	-239.5971
	(0.0001)**	(0.0835)*	(0.0283)**	(0.0001)**	(0.0860)*
JOR	11.05275	-0.728476	1.055444	0.118056	-47.47452
	(0.0535)*	(0.0542)*	(0.0063)**	(0.0679)*	(0.0167)**
MRC	16.06605	-1.181862	1.072361	0.231672	-61.58360
	(0.0404)**	(0.0351)**	(0.0000)**	(0.0930)*	(0.0289)**
OMN	-41.57405	2.411463	0.269311	-0.220083	179.7814
	(0.0000)**	(0.0000)**	(0.0022)**	(0.0338)**	(0.0000)**
SAU	776.9846	-42.66042	0.095180	-0.850918	-3537.984
	(0.0204)**	(0.0211)**	(0.0913)*	(0.0435)**	(0.0198)**
SYR	7.615943	-0.615496	0.752064	1.053598	-21.16605
	(0.0934)*	(0.0807)*	(0.0393)**	(0.0942)**	(0.0159)**
TUN	25.58697	1.606352	2.514132	0.181917	85.08697
	(0.0055)**	(0.0043)**	(0.0132)**	(0.0250)**	(0.0072)**

Panel	0.183579	-0.006829	0.914336	0.045549	-5.989062	
	(0.0457)**	(0.0380)**	(0.0000)**	(0.0612)*	(0.0080)**	

Panel B.	**LNY**	**LNY²**	**LNE**	**LNT**	**LNURB**	**Constant**
ALG	57.56112	-3.750922	0.380948	0.257528	0.267391	-218.4510
	(0.0607)*	(0.0656)*	(0.0706)*	(0.0627)*	(0.0861)*	(0.0554)*
BHR	11.07537	-0.614872	1.474097	-2.101088	-26.30525	194.9808
	(0.0955)*	(0.0845)*	(0.0746)*	(0.0459)**	(0.0021)**	(0.0373)**
EGY	5.867424	-0.459959	0.033264	0.013621	-0.748667	22.03217
	(0.0607)*	(0.0401)**	(0.0842)*	(0.0459)**	(0.0516)*	(0.0927)*
IRN	53.92416	-3.810675	0.283836	0.164226	3.471702	178.9660
	(0.0930)*	(0.0845)*	(0.0491)**	(0.0681)*	(0.0024)**	(0.0170)**
ISR	77.75770	-3.882003	0.186284	-0.616322	-16.95840	-306.3877
	(0.0115)**	(0.0121)**	(0.0323)**	(0.0005)**	(0.0077)**	(0.0178)**
JOR	52.56265	-3.431875	0.679270	0.028205	1.833065	-212.6146
	(0.0221)**	(0.0225)**	(0.0195)**	(0.0320)**	(0.0141)**	(0.0193)**
MRC	9.093222	-0.690452	1.302636	0.079184	0.095592	-37.35961
	(0.0106)**	(0.0745)*	(0.0222)**	(0.0657)*	(0.0162)**	(0.0446)**
OMN	-25.87308	1.554333	0.226307	-0.563433	-0.376345	103.1215
	(0.0027)**	(0.0037)**	(0.0572)*	(0.0960)*	(0.0838)*	(0.0088)**
SAU	1261.283	-69.21078	0.530243	-0.821503	-7.247972	-5774.493
	(0.0136)**	(0.0144)**	(0.0209)**	(0.0604)*	(0.0191)**	(0.0088)**
SYR	49.75485	-3.701783	0.542545	0.600422	8.475750	195.2773
	(0.0495)**	(0.0446)**	(0.0480)**	(0.0515)*	(0.0004)**	(0.0380)**
TUN	16.64713	1.015076	2.791806	0.097445	0.070670	49.31451
	(0.0420)**	(0.0462)	(0.0056)**	(0.0122)**	(0.0714)*	(0.0112)**
Panel	0.187792	-0.006745	0.818356	0.037532	-0.053581	-5.869887
	(0.0418)**	(0.0411)**	(0.0000)**	(0.0061)**	(0.0301)**	(0.0108)**

Probability values are reported in parentheses.
*and ** indicate the significance at the 10% and 5% level, respectively.

This means that the elasticity of CO_2 emissions with respect to the output in the long-run is 0.188–0.014.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.818%; a 1% increase in trade openness increases CO_2 emissions by approximately 0.038%; and a 1% increase in urbanization decreases CO_2 emissions by approximately 0.054%.

In general, it is found that the long-run energy consumption has significant positive impact on CO_2 emissions for all selected MENA countries because more energy consumption can increase the scale of an economy and stimulate CO_2 emissions. The variable trade openness has long-run insignificant positive impact on CO_2 emissions for all the countries except Bahrain, Israel, Oman and Saudi Arabia because these countries present a high income in the classification of the World Bank. The variable urbanization has long-run significant negative impact for Bahrain, Egypt, Israel, Oman and Saudi Arabia.

To conclude, the EKC hypothesis is verified for all studied MENA countries, and the expected sign of trade coefficient is positive for MENA countries as developing countries. This means that these countries have dirty industries with heavy share of pollutants (Grossman and Krueger, 1995). It also means that an increase in trade openness will increase pollution due to a comparative advantage in dirty production under weaker environmental regulations (Jayanthakumaran et al. 2012). Based on urbanization sign, Hossain (2011) suggested that relatively high income countries are more urbanized than low and middle income countries. This means that the expected sign of urbanization coefficient is also mixed depending on the level of economic development stage of a country or a panel of countries.

For the environmental quality, the inclusion of urbanization is found to be good in respect of energy consumption because the panel long-run elasticity of CO_2 emissions with respect to energy consumption (0.818) is lower than the elasticity of 0.915. This means that over time

1% increases in energy consumption in the panel of MENA countries gives rise to 0.915% of CO_2 emissions in model without urbanization, while it gives rise only to 0.818% with model included urbanization.

3.3.4. Panel causality test

A panel Vector Error Correction Model (VECM) is estimated to perform Granger-causality tests (Pesaran et al. 1999). This panel followed by the two steps of Engle and Granger (1987) is employed to investigate the long-run and short-run dynamic relationships. The first step estimates the long-run parameters in Eq. (5) and Eq. (8) in order to obtain the residuals corresponding to the deviation from equilibrium. The second step estimates the parameters related to the short-run adjustment. The resulting equations are used in conjunction with panel Granger causality testing:

Panel A.

$$\begin{pmatrix} \Delta LNC_t \\ \Delta LNY_t \\ \Delta LNY_t^2 \\ \Delta LNE_t \\ \Delta LNT_t \end{pmatrix} = \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \\ \omega_5 \end{pmatrix} + \sum_{k=1}^{m} \begin{pmatrix} \varpi_{1,1,k} & \varpi_{1,2,k} & \varpi_{1,3,k} & \varpi_{1,4,k} & \varpi_{1,5,k} \\ \varpi_{2,1,k} & \varpi_{2,2,k} & \varpi_{2,3,k} & \varpi_{2,4,k} & \varpi_{2,5,k} \\ \varpi_{3,1,k} & \varpi_{3,2,k} & \varpi_{3,3,k} & \varpi_{3,4,k} & \varpi_{3,5,k} \\ \varpi_{4,1,k} & \varpi_{4,2,k} & \varpi_{4,3,k} & \varpi_{4,4,k} & \varpi_{4,5,k} \\ \varpi_{5,1,k} & \varpi_{5,2,k} & \varpi_{5,3,k} & \varpi_{5,4,k} & \varpi_{5,5,k} \end{pmatrix} . \begin{pmatrix} \Delta LNC_{t-k} \\ \Delta LNY_{t-k} \\ \Delta LNY_{t-k}^2 \\ \Delta LNE_{t-k} \\ \Delta LNT_{t-k} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \end{pmatrix} .ECT_{t-1} + \begin{pmatrix} \nu_{1,t} \\ \nu_{2,t} \\ \nu_{3,t} \\ \nu_{4,t} \\ \nu_{5,t} \end{pmatrix} \quad (19)$$

Panel B.

$$\begin{pmatrix} \Delta LNC_t \\ \Delta LNY_t \\ \Delta LNY_t^2 \\ \Delta LNE_t \\ \Delta LNT_t \\ \Delta LNURB_t \end{pmatrix} = \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \\ \phi_5 \end{pmatrix} + \sum_{k=1}^{m} \begin{pmatrix} \theta_{1,1,k} & \theta_{1,2,k} & \theta_{1,3,k} & \theta_{1,4,k} & \theta_{1,5,k} \\ \theta_{2,1,k} & \theta_{2,2,k} & \theta_{2,3,k} & \theta_{2,4,k} & \theta_{2,5,k} \\ \theta_{3,1,k} & \theta_{3,2,k} & \theta_{3,3,k} & \theta_{3,4,k} & \theta_{3,5,k} \\ \theta_{4,1,k} & \theta_{4,2,k} & \theta_{4,3,k} & \theta_{4,4,k} & \theta_{4,5,k} \\ \theta_{5,1,k} & \theta_{5,2,k} & \theta_{5,3,k} & \theta_{5,4,k} & \theta_{5,5,k} \\ \theta_{6,1,k} & \theta_{6,2,k} & \theta_{6,3,k} & \theta_{6,4,k} & \theta_{6,5,k} \end{pmatrix} . \begin{pmatrix} \Delta LNC_{t-k} \\ \Delta LNY_{t-k} \\ \Delta LNY_{t-k}^2 \\ \Delta LNE_{t-k} \\ \Delta LNT_{t-k} \\ \Delta LNURB_{t-k} \end{pmatrix} + \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \end{pmatrix} .ECT_{t-1} + \begin{pmatrix} \xi_{1,t} \\ \xi_{2,t} \\ \xi_{3,t} \\ \xi_{4,t} \\ \xi_{5,t} \\ \xi_{6,t} \end{pmatrix} \quad (20)$$

where the term Δ denotes first differences; $\omega_{j,i,t}$ and $\phi_{k,i,t}$ (j=1,2,3,4,5 and k=1,2,3,4,5,6) present the fixed country effect; l (l=1,…,m) is the optimal lag length determined by the Schwarz Information Criterion (SIC), and $ECT_{i,t-1}$ is the estimated lagged error correction term derived from the long-run cointegrating relationship. The terms $\gamma_{j,i}$ and $\lambda_{k,i}$ are the adjustment coefficient and $\nu_{j,i,t}$ and $\xi_{k,i,t}$ are the disturbance term assumed to be uncorrelated with zero means.

We definite the lagged residuals estimated in Eq. (19) and Eq. (20) as the Error Correction Term (ECT) then estimates the parameters related to the two short-run models:

Panel A. $$ECT_{i,t} = LNC_{i,t} - \hat{\alpha}_{1,i} LNY_{i,t} - \hat{\alpha}_{2,i} LNY_{i,t}^2 - \hat{\alpha}_{3,i} LNE_{i,t} - \hat{\alpha}_{4,i} LNT_{i,t} \quad (21)$$

Panel B. $$ECT_{i,t} = LNC_{i,t} - \hat{\beta}_{1,i} LNY_{i,t} - \hat{\beta}_{2,i} LNY_{i,t}^2 - \hat{\beta}_{3,i} LNE_{i,t} - \hat{\beta}_{4,i} LNT_{i,t} - \hat{\beta}_{5,i} LNURB_{i,t} \quad (22)$$

The panel short-run and long-run Granger causality results are reported in Table-6. For Panel A, the finding results indicate that there is short-run panel causality running from real GDP and energy consumption to CO_2 emissions. In log-run, there are two causal relationships among the variables running from all variables to CO_2 emissions and to energy consumption. For panel B, The results indicate that the expansion of real GDP, energy consumption and urbanization exert a causal significant effect on CO_2 emissions, and the expansion of trade openness exert a causal significant effect on urbanization in short run. Moreover, the error correction term is statistically significant at the 5% level which suggests that CO_2 emissions, energy consumption and urbanization present a relative slow speed of adjustment to long-run equilibrium. However, the error correction term is statistically insignificant for other variables.

Table-6

Panel causality test results

Dependent Variable	Sources of causation (Independent variable) Short run					Long run
Panel A.	**ΔLNC**	**ΔLNY—ΔLNY²**	**ΔLNE**	**ΔLNT**		**ECT**
ΔLNC	#	6.2498**	5.5566**	0.7089		-0.0522**
		(0.0090)	(0.0124)	(0.4929)		[-2.4905]
ΔLNY—ΔLNY²	0.0162	#	0.0132	0.6545		-0.0018
	(0.9839)		(0.9868)	(0.5204)		[-0.4480]
ΔLNE	0.0903	0.0790	#	1.0504		-0.2105**
	(0.9136)	(0.9240)		(0.3510)		[-1.9759]
ΔLNT	0.9653	1.0330	1.6609	#		-0.0007
	(0.3819)	(0.3571)	(0.1916)			[-0.2262]
Panel B.	**ΔLNC**	**ΔLNY—ΔLNY²**	**ΔLNE**	**ΔLNT**	**ΔLNURB**	**ECT**
ΔLNC	#	9.0014**	3.1358*	1.2549	3.0012*	-0.0475**
		(0.0052)	(0.0773)	(0.2634)	(0.0824)	[-2.46647]
ΔLNY—ΔLNY²	0.0239	#	0.0300	1.3168	0.1276	-0.0002
	(0.8771)		(0.8626)	(0.2520)	(0.7211)	[-0.3053]
ΔLNE	3.5E-06	0.1454	#	2.0039	0.0068	-0.1954*
	(0.9985)	(0.7032)		(0.1579)	(0.9340)	[-1.9320]
ΔLNT	0.1441	0.5520	0.6340	#	1.5100	-0.0060
	(0.7044)	(0.4580)	(0.4265)		(0.2200)	[-0.9311]
ΔLNURB	0.1858	0.0171	0.2780	4.3448**	#	-0.0119*
	(0.6667)	(0.8958)	(0.5984)	(0.0379)		[-1.7675]

Short-run causality is determined by the statistical significance of the partial F-statistics associated with the right hand side variables. Long-run causality is revealed by the statistical significance of the respective error correction terms using a t-test.
P-values are listed in parentheses and t-statistics are presented in brackets.
* and ** indicate statistical significance at the 5% and 10% level, respectively.

4. Conclusion and policy implications

There is an extensive literature looking at the environmental function (relationship between CO_2 emissions, income, energy consumption, trade openness and urbanization). There is, however, only one published paper that brings this stream of the inclusion of urbanization in the EKC approach to investigate the question of "What is the role of urbanization in environmental function?" To attempt this linkage, the purpose of this paper consists to parallel two functions (Panel A does not include urbanization, while Panel B includes urbanization) for a panel of 11 MENA countries from 1980 to 2009.

Three different panel unit root tests, Breitung (2001), Levin et al. (LLC, 2002) and Im et al. (IPS, 2003) tests are applied. These tests results support that all the panel variables are integrated of order one. The Pedroni (1999, 2004) panel cointegration test results support that all the panel variables are cointegrated.

For Panel A (without urbanization factor), the mean of FMOLS and DOLS coefficients are 0.151, -0.005, 0.915 and 0.043 for income, squared income, energy consumption and trade openness, respectively. This means that the elasticity of CO_2 emissions with respect to the output in the long-run is 0.151–0.010.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.915%; and a 1% increase in trade openness increases CO_2 emissions by approximately 0.043%.

For Panel B (with urbanization factor), the mean of FMOLS and DOLS coefficients are 0.142, -0.004, 0.818, 0.032 and -0.061 for income, squared income, energy consumption, trade openness and urbanization, respectively. This means that the elasticity of CO_2 emissions with respect to the output in long-run is 0.142–0.008.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.818%; a 1% increase in trade openness increases CO_2 emissions by approximately 0.032%; and a 1% increase in urbanization decreases CO_2 emissions by approximately 0.061%.

For two cases, the EKC hypothesis is verified, while the positive sign of trade coefficient indicate that these countries have dirty industries with heavy share of pollutants. It means also that an increase in trade openness will increase pollution due to a comparative advantage in dirty production under weaker environmental regulations. Based on urbanization sign, the relatively high income countries are more urbanized than low and middle income countries. This means that the expected sign of urbanization coefficient is also mixed depending on the level of economic development stage of a country or a panel of countries.

Short-run and long-run causality results have important implications for environmental policy. For Panel A, it is found that real GDP and energy consumption cause CO_2 emissions in short-run panel causality. This implies that in the absence of energy conservation policies due to the economic development these countries consume more energy as a result the environment will be more polluted (Hossain, 2011). In log-run, there are two causal relationships among the variables running from all variables to CO_2 emissions and to energy consumption. For panel B, The results indicate that real GDP, energy consumption and urbanization exert a causal significant effect on CO_2 emissions, and trade openness exerts a causal significant effect on urbanization in short run. Moreover, the error correction term is statistically significant at the 5% level which suggests that CO_2 emissions, energy consumption and urbanization present a relative slow speed of adjustment to long-run equilibrium. However, the error correction term is statistically insignificant for other variables.

For the environmental quality, the inclusion of urbanization is found to be good in respect of energy consumption because the panel long-run elasticity of CO_2 emissions with respect to energy consumption (0.818) is lower than the elasticity of 0.915. This means that over time 1% increases in energy consumption in the panel of MENA countries gives rise to 0.915% of CO_2 emissions in model without urbanization, while it gives rise only to 0.818% with model included urbanization. These effects have particularly important consequences for the understanding the implications of the difference between urban and rural energy use, including the outlook for environmental effects and energy consumption, would be facilitated by disaggregating our finding results over urban and rural energy use types, a direction of research we leave for future work.

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