What is MENA Region Initially Needed: Grow Output or Mitigate CO2 Emissions?

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4 August 2013

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Abstract: This paper examines the question: 'What is Middle East and North Africa (MENA) region initially needed: grow output or mitigate CO_2 emissions? This question is a focus on the issue of both production function and environmental function based on the environmental Kuznets curve (EKC) approach. Adopting a new analytical framework, the empirical study parallels two approaches: i) First one follows the studies of Lean and Smyth (2010a) and Sadorsky (2012) which examine the dynamic interaction of energy consumption and trade openness using production function; ii) Second one extends the recent works of Halicioglu (2009), and Jayanthakumaran et al. (2012) which attempt to introduce energy consumption and trade openness in the environmental function as a mean to circumvent omitted variable bias. For nine MENA countries over the period 1990-2011, the empirical results appear to be relevant in light of the growing literature on the cointegration and causal relationships. Policy implications for a better environment indicate that MENA countries should adopt policies to control the increase of pollution as well as to stabilize the productivity growth. One of these policies consists to facilitate the role of energy use by increasing the share of renewable energy relative to non-renewable energy sources.
Keywords: Growth, Energy, CO_2 Emissions, MENA

1. Introduction

The relationship between output growth and energy consumption is a well-studied topic in existing energy economics literature. Researchers used different methodologies and data sets to investigate this relationship in both developed and developing countries (e.g. Masih and Masih, 1996, 1998; Glasure and Lee, 1998; Asafu-Adjaye, 2000; Fatai et al. 2004; Wolde-Rufael, 2005; Soytas and Sari, 2003, 2006; Lee, 2005, 2006; Al-Iriani, 2006; Mahadevan and Asafu-Adjaye, 2007; Mehrara, 2007; Lee and Chang, 2007, 2008; Akinlo, 2008; Chontanawat et al. 2008; Huang et al. 2008; Lee et al. 2008; Narayan and Smyth, 2008; Apergis and Payne, 2009a; 2009b; Chiou-Wei et al. 2009; Lee and Lee, 2010; Ozturk et al. 2010; Payne, 2010; Belke et al. 2011; Lau et al. 2011; Dahmardeh et al. 2012; Farhani and Ben Rejeb, 2012), but in general the final results have failed to reach unanimous results (Shahbaz et al. 2011). One can observe that the concept of Granger causality has been widely used to describe the direction of causality. However, it is clear that there is no consensus on the results in the existing energy literature. A major reason for the absence of consensus is that Granger causality test in a bivariate framework is likely to be biased due to the omission of relevant variables affecting output growth and energy consumption nexus (Stern, 1993).

In econometrics, Lütkepohl (1982) noted that the exclusion of a relevant variable(s) makes the estimates biased and inconsistent. For this reason, some Granger causality-based studies examining the relationship between output growth and energy consumption had included other relevant variables such as capital and labor (e.g. Stern, 1993, 2000; Alam and Butt, 2002; Pokrovski, 2003;Ghali and El-Sakka, 2004; Beaudreau, 2005; Sari and Soytas, 2007; Lee and Chang, 2008; Narayan and Smyth, 2009; Apergis and Payne, 2009a, b, 2010a; Lean and Smyth, 2010a; Sadorsky, 2012; Stern and Kander, 2012; Shahbaz and Lean, 2012; Shahbaz et al. 2012a, 2013a). In this context, Wolde-Rufael (2009) suggested that the potential gains from economic growth may depend on the degree to which capital, labor and energy act as complements. Recently, the inclusion of trade in the production function examining the relationship between output, capital, labor, energy and trade is an important topic to study for several reasons. At the time of writing this work, papers by Narayan and Smyth (2009), Lean and Smyth (2010a) and Sadorsky (2012) appear to be the only published papers specifically investigating the relationship between output, capital, labor, energy and trade.

As often mentioned in the environmental Kuznets curve (EKC) literature, economic growth and energy consumption may generate considerable pressure on the environment (e.g. Ang, 2007; Halicioglu, 2009; Jalil and Mahmud, 2009; Jayanthakumaran et al. 2012; Apergis and Payne, 2009c, 2010b; Lean and Smyth, 2010b; Arouri et al. 2012; Shahbaz et al. 2012b, 2013b, c; Tiwari et al. 2013). 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 literature reveals that most studies focus on testing the nexus of either output-energy use or output-pollution separately. Few investigations have so far been made to examine these two links within the same framework (Ang, 2007; Apergis and Payne, 2009c, 2010b; Lean and Smyth, 2010b; Arouri et al. 2012). The main contribution of those research papers is to progress in examining the dynamic relationship between pollutant emissions, income, energy consumption, and trade 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 omitted variable bias (Ang, 2009; Halicioglu, 2009; Jalil and Mahmud, 2009; Jayanthakumaran et al. 2012).

To our knowledge, until today, no study has emphasized the importance of the level of output (production function) and pollution (environmental function) in one paper. This paper tries to fill the gap. Its aim is two-fold: first, to identify the production function containing income, capital, labor, energy and trade; and second, to identify the environmental function containing CO_2 emissions, income, energy and trade as often mentioned in the EKC literature.

The remainder of this paper is organized as follow: Section 2 and Section 3 investigate the literature review of production function and environmental function, respectively; Section 4 highlights modeling, methodology and empirical results; and the last one concludes and set up some policy implications.

2. Literature review: Production function

The relationship between economic output and energy consumption is one of the most widely studied topic in energy economics. While the relationship between economic output, energy consumption and trade is understudied area. The understanding of these relationships is very useful and even critical for two reasons. For instance, energy consumption plays a vital role in economic growth either directly or as a complement to other factors of production, especially when implementing energy conservation policies which reduce energy consumption (Apergis and Payne, 2009a, b, 2010a). Alternatively, if energy consumption is found to Granger cause trade, then any reductions in energy consumption, coming from say energy conservation polices designed to reduce greenhouse gas emissions, will reduce trade and lessen the benefits of trade (Sadorsky, 2012).

2.1. Output, Capital, Labor and Energy

Research exploring the relationship between output, capital, labor and energy emerged as an answer of the importance of energy in the production function (e.g. Stern, 1993, 2000; Alam and Butt, 2002; Pokrovski, 2003;Ghali and El-Sakka, 2004; Beaudreau, 2005; Sari and

Soytas, 2007; Lee and Chang, 2008; Apergis and Payne, 2009a, b, 2010a; Shahbaz et al. 2012a). In particular, Stern (1993) examined a multivariate adaptation of Vector Auto-Regressive (VAR) model including GDP, capital, labor and energy use in case of the USA. The findings proved that improving the measurement of factor input, is a contentious issue as assumptions must be invoked in aggregation and in the estimation of depreciation. Granger causality testis used to describe the direction of causality between the variables and it concluded that gross energy use Granger causes economic growth, but with specifying the measurement of factor input (a measure of final energy use adjusted for changing fuel composition). The results are likely to be improved for economic growth and the final output. In his second paper, Stern (2000) extended the analysis of the causal relationship between GDP, capital, labor and energy use in case of the USA. A majority of the relevant variables are integrated justifying a cointegration analysis. The results showed that cointegration does occur and that energy input cannot be excluded from the production function. The results are similar to Stern (1993). Both the single equation static cointegration analysis and the multivariate dynamic cointegration analysis exposed that energy is significant in explaining GDP. These results supported the conclusions of Stern (1993) regarding Granger causality between energy and GDP. In a different study, Alam and Butt (2002) investigated the causal relationship between energy consumption and economic growth in Pakistan. The study found that the relevant macroeconomic aggregates (energy consumption, economic growth, capital, and labor) are co-integrated by employing the Johansen and Juselius technique. They detected a two-way causality between energy consumption and economic growth in long run, whereas by employing error-correction modeling, one-way causality ran from energy consumption to economic growth in the short and long run. It also found that causality runs from capital to energy consumption, while energy consumption, labor and capital Granger cause economic growth. Pokrovski (2003) investigated the fundamental role of energy as a factor of US production. In his paper, capital, labor and productive energy were considered as important production's factors. However, in contrast to some theories, the author did not consider the variables such as capital, labor and energy to be independent. Energy and labor inputs act as substitutes for each other, while capital and labor-energy are complements. Pokrovski (2003) paid less attention to consider the capital as value of production equipment and as a substitute for labor, but used it like the means by which the labor resource is substituted by energy rather than a production factor. Empirical evidence from the US economy confirmed that the principle by which the evolution of the production system is followed is the principle of maximum power. It means that the production system is trying to devour all available resources. Energy can be considered a driving force of production; anyway, there is a strong correlation between output and energy.

In case of Canada, Ghaliand El-Sakka (2004) applied the Vector Error-Correction (VEC) model to test the direction of causality between real GDP, capital, labor and energy use. Using the Johansen cointegration technique, the empirical findings indicated that the long-run movements of output, labor, capital and energy in Canada are related by two cointegrating vectors. The causality analysis found that Granger causality is bidirectional between output growth and energy. This suggested that energy can be considered as a limiting factor to output growth in Canada. Beaudreau, (2005) examined the methodology of economic growth theory focusing specifically on the links between economics and engineering for three periods 1950-1984, 1950-1973 and 1974-1984, for USA, Germany and Japan, respectively. It is argued that including energy, the cornerstone of production processes as modeled in engineering, in simple growth accounting exercises, the Solow residual is nearly eliminated. The relevant energy elasticities for the USA, Germany and Japan were 0.54, 0.50 and 0.45, respectively. In all three cases, electric power consumption is, by far, the most important factor input, as evidenced by output elasticities for US manufacturing, German manufacturing and Japanese manufacturing were0.54, 0.75 and 0.61, respectively. Capital and labor output elasticities are lower than energy output elasticity. These estimates provide some support for the energy-organization view of production. Sari and Soytas, (2007) investigated the inter-temporal link between energy consumption and income in six developing countries (Indonesia, Iran, Malaysia, Pakistan, Singapore, and Tunisia) with diverse economic backgrounds and energy statistics, in a production function framework. They employed the generalized variance decompositions and generalized impulse response techniques to see if the growth of income and energy consumption contains considerable information to predict each other. In all countries, energy appears as an essential factor of production. The findings indicated that energy may be a relatively more important input than labor and/or capital in some countries. Lee and Chang, (2008) applied the most recently developed panel unit root, heterogeneous panel cointegration and panel-based error correction models to investigate co-movement and the causal relationship between real GDP, capital, labor and energy consumption for 16 Asian countries. The empirical results fully supported a positive long-run cointegrated relationship between real GDP and energy consumption when the heterogeneous country effect is taken into account. Granger test indicated that although economic growth and energy consumption lack short-run causality, and there is only long-run unidirectional causality running from energy consumption to economic growth. This means that reducing energy consumption does not adversely affect GDP in the short-run but would in the long-run; thus, these countries should adopt a more vigorous energy policy.

Furthermore, Lee and Chang (2008) broadened the investigation by dividing the sample countries into two cross-regional groups, namely Asia-Pacific Economic Cooperation (APEC: China, Hong Kong, India, Iran, Japan, Jordan, South Korea, Pakistan, Sri Lanka, the Syrian

Arab Republic, and Turkey) and Association of Southeast Asian Nations (ASEAN: Indonesia, Malaysia, the Philippines, Singapore, and Thailand). This provided even more important results and emerging implications. Recently, Apergis and Payne (2009a, b, 2010a) examined the relationship between real GDP, labor force, real gross fixed capital formation, and energy consumption for six Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) over the period 1980-2004; for eleven countries of the Commonwealth of Independent States (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, and Uzbekistan) over the period 1991-2005; and for nine South American countries (Argentina, Bolivia, Brazil, Chile, Ecuador, Paraguay, Peru, Uruguay, and Venezuela) respectively. Given the relatively short span of the time series data, a panel cointegration and error correction model was employed to infer the causal relationship. Based on the heterogeneous panel cointegration test by Pedroni, (1999, 2004), cointegration is present between all variables with the respective coefficients positive and statistically significant. The positive impact of energy consumption on economic growth suggests that energy consumption plays an important role in the growth process both directly and indirectly as a complement to labor and capital. The Granger causality results indicated the presence of both short-run and long-run causality from energy consumption to economic growth which supports the growth hypothesis.

Shahbaz et al. (2012a) investigated the relationship between energy consumption and economic growth using Cobb–Douglas production function in case of Pakistan over the period of 1972-2011. They have used the Auto regressive distributed lag (ARDL) bounds testing and Gregory and Hansen, (1996) structural break cointegration approaches for long run while stationarity properties of the variables have been tested applying Clemente el al. (1998) structural break unit root test. Their results confirmed the cointegration between renewable energy consumption, nonrenewable energy consumption, economic growth, capital and labor. The findings showed that both renewable and nonrenewable energy consumption add in economic growth. Capital and labor are also important determinants of economic growth. The VECM Granger causality analysis validates the existence of feedback hypotheses between renewable energy consumption and economic growth, nonrenewable energy consumption and economic growth, economic growth and capital.

2.2. Output, Capital, Labor, Energy and Trade

There is an extensive literature looking into the relationship between output growth, energy, and trade (e.g. Narayan and Smyth, 2009; Lean and Smyth, 2010a; Sadorsky, 2011, 2012; Shahbaz et al. 2013a). Narayan and Smyth, (2009) used the data of Middle Eastern countries (Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria) to explore the relationship between economic growth, energy (electricity) consumption. They applied panel cointegration and causality approached and found that exports and energy consumption contribute to economic growth. Their causality analysis exposed the neutral effect between exports and energy consumption. Lean and Smyth (2010a) examined the causal relationship between aggregate output, labor, capital, electricity consumption, and exports as a trade factor in a multivariate model for Malaysia. They found that there is bidirectional Granger causality between aggregate output and energy (electricity) consumption. Their empirical evidence suggested in adopting the dual strategy of increasing investment in electricity infrastructure and stepping up electricity conservation policies to reduce unnecessary wastage of electricity, in order to avoid the negative effect of reducing electricity consumption on aggregate output for Malaysia economy. They also found the support for export-led hypothesis which states Granger causality runs from exports to aggregate output. This result is consistent with Malaysia pursuing a successful export-orientated strategy.

Sadorsky, (2011) investigated how trade openness affect energy consumption in Middle East countries such as Bahrain, Iran, Jordan, Oman, Qatar, Saudi Arabia, Syria, and United Arab Emirates. The OLS, DOLS and FMOLS approached were applied and results indicated that energy consumption, exports and imports increase economic growth but oil price rise impedes it. The panel causality results showed that the feedback effect exists between exports and energy consumption and, same inference is drawn for imports and energy consumption. This implies that trade and energy consumption have complementary relationship. Sadorsky (2012) used panel cointegration regression techniques to examine the relationship between energy consumption, output and trade in a sample of 7 South American countries (Argentina, Brazil, Chile, Ecuador, Paraguay, Peru, and Uruguay) covering the period 1980-2007. Panel cointegration tests show two long-run relationships: 1) between output, capital, labor, energy, and exports; and 2) between output, capital, labor, energy, and imports. Short-run dynamics show the feedback relationship between energy consumption and exports, output and exports, and output and imports. There is evidence of a one way short-run relationship from energy consumption to imports. In long-run there is evidence of a causal relationship between trade (exports or imports) and energy consumption. These results have implications for energy policy and environmental policy. One important implication of these results is that environmental policies designed to reduce energy use will reduce trade. This puts environmental policy aimed at reducing energy consumption at odds with trade policy. Shahbaz et al. (2013a) applied Cobb-Douglas production function to investigate the relationship between exports and energy consumption by incorporating capital and labor. Their findings showed that energy consumption, exports, capital and labor add in economic growth and energy consumption is Granger cause of energy consumption.

3. Literature review: Environmental function

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 two routes. First, treating environmental quality as a public good, one may argue that the observed level of 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. Alternatively, 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 trade openness (Liu, 2005; Coondoo and Dinda, 2008).

3.1. Emissions, Income and Energy

Pollution is closely related to energy consumption since more energy consumption leads to higher economic development via productivity enhancement but it also leads to higher pollutant gases (e.g.Ang, 2007; Apergis and Payne, 2009c, 2010b; Lean and Smyth, 2010b; Arouri et al., 2012; Shahbaz et al. 2012b, 2013b, c; Tiwari et al. 2013). Ang (2007) examined the dynamic causal relationships between pollutant emissions, energy consumption, and output for France. Using cointegration and vector error-correction modeling techniques, he found that these variables are strongly inter-related and therefore their relationship must be examined using an integrated framework. The empirical results provided evidence for the existence of a robust long-run relationship between these variables. The causality results exposed that economic growth exerts a causal influence on growth of energy use and growth of pollution in long run. The results also pointed out the unidirectional causality running from energy consumption to output growth in short run. The study of Apergis and Payne (2009c, 2010b) extended the work of Ang (2007) by examining the causal relationship between CO_2 emissions, energy consumption, and output within a panel vector error correction model for six Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) and for eleven countries of the Commonwealth of Independent States (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, and Uzbekistan) respectively. In long-run equilibrium, energy consumption has a positive and statistically significant impact on CO_2emissions while real output exhibits an inverted U-shaped relationship with CO_2emissions i.e. EKC hypothesis is validated. The short-run dynamics indicated the unidirectional causality runs from energy consumption and real output to CO_2emissions along with bidirectional causality between energy consumption and real output. In long-run, there appears to be bidirectional causality between energy consumption and CO_2emissions.Lean and Smyth (2010b) studied the causal relationship between CO_2 emissions, electricity consumption and economic growth within a panel VEC model for five ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore and Thailand). The long-run estimates indicated that there is a statistically significant positive association between electricity consumption and CO_2emissions and a non-linear relationship between CO_2emissions and real output, consistent with the environmental Kuznets curve. The results from the Granger causality tests suggested that in long-run there is unidirectional Granger causality running from electricity consumption and CO_2emissions to economic growth. In short run, CO_2emissions Granger causes electricity consumption.

Arouri et al. (2012) extended the recent findings of Liu (2005), Ang (2007), Apergis and Payne (2009c) 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 twelve MENA. The finding results showed that in long-run energy consumption has a positive and 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 EKC hypothesis. CO_2 emission reductions per capita have been achieved in the MENA region, even while the region exhibited economic growth. Shahbaz et al. (2012b) applied CO_2emissions function to examine whether EKC hypothesis is valid in Pakistan or not. Their results indicated that relationship between economic growth and CO_2emissionsis inverted U-shaped. The causality results showed that CO_2emissions are Granger cause of economic growth in Pakistan. Shahbaz at al. (2013b) investigated the relationship between energy consumption, economic growth and CO_2emissions in case of Romania. They found that the relationship between economic growth and CO_2emissions is inverted U-shaped i.e. EKC while energy consumption adds in CO_2emissions but financial development declines it. In case of Indonesia, Shahbaz et al. (2013c) explored the relationship between energy consumption, economic growth and CO_2emissions. They noted the presence of EKC hypothesis and energy consumption contributes to CO_2emissions but financial development lowers it. In case of India, Tiwari et al. (2013) also reported the validation of environmental Kuznets' curve and coal consumption is a major contributor to CO_2emissions. Their causality results showed that the feedback effect is found between economic growth and CO_2emissions and same is true for energy consumption and economic growth.

3.2. Emissions, Income, Energy and Trade

While the importance of global warming issues is widely recognized among economists and policy makers, there was a few trials attempting to examine environmental performance with including the impact of trade openness (e.g. Halicioglu, 2009; Jalil and Mahmud, 2009; Jayanthakumaran et al. 2012; Shahbaz et al. 2012b, 2013c; Tiwari et al. 2013). Halicioglu (2009) examined the dynamic causal relationships between CO_2 emissions, energy consumption, income, and foreign trade in Turkey over the annual period 1960-2005. The author tested the interrelationship between the variables using the bounds testing to cointegration approach. The bounds test results indicated that there exist two forms of long-run relationships between the variables. In case of first form of long-run relationship, CO_2 emissions are determined by energy consumption, income and foreign trade. In case of second long-run relationship, income is determined by CO_2 emissions, energy consumption and foreign trade. Using an augmented form of Granger causality analysis, the empirical results suggest that income is the most significant variable in explaining the CO_2emissions which is followed by energy consumption and foreign trade. Moreover, there exists a stable CO_2 emissions function.

For case of China, Jalil and Mahmud (2009) extended the same methodology applied by Halicioglu (2009). Employing time series data of 1975-2005, the study aimed at testing whether EKC relationship between CO_2 emissions and per capita real GDP holds in the long run or not. The ARDL methodology is employed for empirical analysis. A quadratic relationship between income and CO_2 emission has been found for the sample period, supporting EKC relationship. The results of Granger causality test indicated one way causality runs from economicgrowthtoCO_2 emissions. The results also indicated that the CO_2 emissions are mainly determined by income and energy consumption in long-run. Trade has a positive but statistically insignificant impact on CO_2 emissions. Shahbaz et al. (2012b) investigated the relationship between energy consumption, economic growth, trade openness and CO_2 emissions in case Pakistan over the period of 1971-2009. They noted that EKC exists and trade openness decrease CO_2 emissions but impact is insignificant in short run. Using annual data over the period 1971-2007, Jayanthakumaran et al. (2012) compared China and India using the bounds testing approach to cointegration and the ARDL methodology to test the long and short-run relationships between growth, energy use, trade, and endogenously determined structural breaks. The CO_2 emissions in China were influenced by per capita income, structural changes and energy consumption. 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. 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. Shahbaz et al. (2013c) applied CO_2 emissions function to examine the impact of trade openness on CO_2 emissions. They exposed that trade openness improves environmental quality. Tiwari et al. (2013) examined the determinants of CO_2emissions in case of India. Their reported that trade openness adds in CO_2 emissions. They noted that causality is also running from trade openness to CO_2 emissions (in Granger sense).

4. Modeling, methodology and empirical results

4.1. Models specification

4.1.1. Production function

In economics, the production function relates the output of a firm or a country to the amount of inputs, typically technological progress, capital and labor.

$$Y = f(A, K, L)(1) \quad (1)$$

The Cobb-Douglas functional form of production function is widely used in economics to present the relationship between output and inputs. It was proposed by Cobb and Douglas (1928). The general form of production function is parameterized as follows:

$$Y = A \ K^{\alpha} \ L^{\beta} \quad (2)$$

where Y is the total production (output), A is the total factor productivity (technological progress), K is the capital input, L is the labor input. The α and β are the output elasticities of capital and labor, respectively. In the last two decades, energy-economist's theories took the view that energy plays a vital role in the production process, so in that case, it can be directly used as an input (Stern, 1993, 2000; Pokrovski, 2003; Shahbaz et al. 2012a). The results of Stern (1993, 2000) showed that energy input cannot be excluded from the output function. Moreover, Pokrovski (2003) and Shahbaz et al. (2012a) advocated that the production of output is determined by productive energy service, capital stock and labor. Beaudreau, (2005) confirmed this theory by suggesting that this would be reasonable especially when technical progress is included. The modified form of aggregate production function is as following:

$$Y = f(A, K, L, E) \ \Rightarrow \ Y = A \ K^{\alpha} \ L^{\beta} \ \mathrm{E}^{\delta} \quad (3)$$

where Y is total production (output), A is total factor productivity (technological progress), and α , β and δ are the output elasticities of capital, labor and energy, respectively. Recently, some studies examine the dynamic interaction of energy and trade in the production function and consider capital, labor, energy and trade as separate factors of production (Lean and

Smyth, 2010a; Sadorsky, 2012; Shahbaz et al. 2013a). Then extended version of Cobb–Douglas production function can be formulated as following:

$$Y = f\left(A, K, L, E, T\right) \Rightarrow Y = A \;\; K^{\alpha} L^{\beta} E^{\delta} T^{\theta} \tag{4}$$

where Y is total production (output), A is total factor productivity (technological progress), and α, β, δ and θ are the output elasticities of capital, labor, energy and trade, respectively. Adopting a new analytical framework, the first part of this study parallels the empirical works of Lean and Smyth (2010a) and Sadorsky (2012). For that, the long-run relationship is given by the following equation:

$$Y_{it} = A_i \;\; K_{it}^{\beta_{1i}} L_{it}^{\beta_{2i}} E_{it}^{\beta_{3i}} T_{it}^{\beta_{4i}} \tag{5}$$

wherei=1,…,N for each country in the panel and t= 1,…, T refers to the time period. Taking natural logarithms of Eq. (5), denoting lower case letters as the natural log of upper case letters and adding a random error term produces the following equation.

<u>Panel A.</u>

$$\ln Y_{it} = \beta_{0i} + \beta_{1i}.\ln K_{it} + \beta_{2i}.\ln L_{it} + \beta_{3i}.\ln E_{it} + \beta_{4i}.\ln T_{it} + \varepsilon_{it} \tag{6}$$

Where$i$, t, β_0 and μ denote the country, the time, the fixed country effect and the white noise stochastic disturbance term, respectively. $\beta_{0i} = \ln A_i$, and $\beta_{1i}, \beta_{2i}, \beta_{3i}$, and β_{4i} are the output elasticities of capital, labor, energy and trade, respectively (all variables are in natural logs, denoted ln).

4.1.2. Environmental function

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

$$C = f(Y); \ Y \in [0,\infty[\tag{7}$$

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 environmental damage first increases with income, then stabilizes and eventually declines. Thus, the general function of Engel curve is specified as:

$$C = \alpha_0 + \alpha_1.Y + \alpha_2.Y^2 + ... \tag{8}$$

In the last decade, the question of omitted variable bias in the relationship between income and emissions is also subject to the issue of EKC hypothesis. For that, Ang (2007), Apergis and Payne (2009c, 2010b), Lean and Smyth (2010b), 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 case, the long-run relationship between emissions, income and energy consumption will be given by the following equation:

$$C = \alpha_0 + \alpha_1.Y + \alpha_2.Y^2 + \alpha_3.E \tag{9}$$

Furthermore, Antweiler et al. (2001), Cole and Elliott (2003), and Ang (2009) 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) effects. 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 via 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), Jayanthakumaran et al. (2012), and Shahbaz et al. (2012b) included the foreign trade in order to reduce the problems of omitted variables' bias in the econometric estimation. Empirically, the log quadratic EKC equation used to examine the relationship between emissions, income, energy consumption, and trade will be given by the following equation:

$$C = \alpha_0 + \alpha_1.Y + \alpha_2.Y^2 + \alpha_3.E + \alpha_4.T \qquad (10)$$

According to our knowledge, until now, no one has used the log quadratic EKC equation to examine the relationship between emissions, income, energy consumption, and trade for the panel of MENA region. At this level, the second part purpose of this paper has been designed to follow the approach of Halicioglu (2009), Jalil and Mahmud (2009), Jayanthakumaran et al. (2012) and Shahbaz et al. (2012b). Taking the natural logarithms of Eq. (10), denoting lower case letters as the natural log of upper case letters and adding a random error term produces the following equation:

Panel B.

$$\ln C_{it} = \alpha_{0i} + \alpha_{1i}.\ln Y_{it} + \alpha_{2i}.\ln Y_{it}^2 + \alpha_{3i}.\ln E_{it} + \alpha_{4i}.\ln T_{it} + \mu_{it} \qquad (11)$$

Where i, t, α_0 and μ denote the country, the time, the fixed country effect and the white noise stochastic disturbance term, respectively. The parameters $\alpha_1, \alpha_2, \alpha_3$ and α_4 are the long-run elasticities of CO_2 emissions with respect to income, squared income, energy consumption, trade, respectively. As for the expected signs in Eq. (11), one would expect that the sign of α_1 expected to be positive whereas a negative sign is expected for α_2 for EKC hypothesis to be true (Kuznets, 1955).The sign α_3 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 α_4 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 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).

4.2. Data

The data set is a balanced panel of nine MENA countries over the period of 1990-2009. i) Panel A: Output (Y), Capital (K), Labor (L), Energy consumption (E), and Trade (T). Where Output is measured using real GDP per capita in constant2000 US$, Capitalis measured using gross fixed capital formation in constant 2000US$ per capita, Labor is measured labor per capita, Energy consumption is measured using energy use in kg of oil equivalent and Trade is exports plus imports (constant 2000US$) per capita. ii) Panel B: CO_2 emissions (C), Output (Y), Energy consumption (E), and Trade (T). Where CO_2 emissions is measured in metric tons per capita, Output is measured using real GDP per capita in constant2000 US$, Energy consumption is measured using energy use in kg of oil equivalent per capita, and Trade is exports plus imports (constant 2000US$) per capita.

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 nine MENA countries included in the sample are: Algeria (ALG), Egypt (EGY), Iran (IRN), Israel (ISR), Jordan (JOR), Morocco (MRC), Saudi Arabia (SAU), Syria (SYR), and Tunisia (TUN). These variables are obtained from the *World Bank Development Indicators* (CD-ROM, 2012). All of the data is converted into natural logarithms to reduce the heterogeneity. The descriptive statistics of different variables for nine MENA countries are given in Table-1.

Table-1: *Descriptive statistics*

Panel A.	LNY	LNK	LNL	LNE	LNT
Mean	7.8577	23.0839	15.5745	7.0806	16.4793
Median	7.4766	23.2013	15.5811	6.8939	16.4684
Maximum	9.9961	25.2272	17.0899	8.7608	18.0440
Minimum	6.8618	20.9266	13.3969	5.6351	15.3235
Std. Dev.	0.9114	0.95040	0.9145	0.7730	0.6061
Skewness	1.2640	-0.2290	-0.2520	0.4475	0.0070
Kurtosis	3.0633	2.2030	2.2178	2.4811	2.2687
Jarque-Bera	47.9625	6.3373	6.4931	8.0268	4.0124
Probability	0.0000	0.0420	0.0389	0.0180	0.1344
Panel B.	**LNC**	**LNY**	**LNY²**	**LNE**	**LNT**
Mean	1.29380	7.8577	15.7155	7.0806	16.4793
Median	1.1701	7.4766	14.9532	6.8939	16.4684
Maximum	2.8763	9.9961	19.9922	8.7608	18.0440
Minimum	-0.0512	6.8618	13.7237	5.6351	15.3235
Std. Dev.	0.7622	0.9114	1.8229	0.7730	0.6061
Skewness	0.4612	1.2640	1.2640	0.4475	0.0070
Kurtosis	2.3255	3.0633	3.0633	2.4811	2.2687
Jarque-Bera	9.7936	47.9625	4.96253	8.0268	4.0124
Probability	0.0074	0.0000	0.0000	0.0180	0.1344
Observations	180	180	180	180	180
Cross section	9	9	9	9	9

Std. Dev. indicates standard deviation.

4.3.Econometrical methodology and empirical results

The empirical study is organized to satisfy 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 estimators. The third is to estimate a panel VEC model in order to infer the Granger causal relationships.

4.3.1. Panel unit root analysis

To determine the order of integration, it is better to perform several unit root tests. In this paper, three panel unit root tests have been applied such as Breitung (2001), Levin et al. (LLC, 2002), Im et al. (IPS, 2003). Breitung (2001) considered the following regression equation:

$$W_{it} = \alpha_{it} + \sum_{j=1}^{k+1} \beta_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \tag{12}$$

In Eq. (12), 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:

$$\lambda = \frac{\frac{1}{\sigma_i^2} \sum_{i=1}^{N} w_i^{*'} x_i^{*'}}{\sqrt{\frac{1}{\sigma_i^2} \sum_{i=1}^{N} x_i^{*'} A' A x_i^*}} \tag{13}$$

Levin et al. (LLC, 2002) proposed a panel unit root test based on ADF test and assumed the homogeneity in the dynamics of the autoregressive coefficients for all panel units with cross-sectional independence. They considered the following regression equation:

$$\Delta X_{it} = \alpha_i + \beta_i X_{i,t-1} + \delta_i t + \sum_{j=1}^{k} \gamma_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \tag{14}$$

where Δ is the first difference operator, Y_{it} is the dependent variable, ε_{it} is a white-noise disturbance with a variance of σ^2, and t = 1, 2,..., T indexes time. $\begin{cases} H_0 : \beta_i = 0 \\ H_1 : \beta_i \prec 0 \end{cases}$; Which alternative hypothesis corresponds to Y_{it} being stationary.

The test is based on the test statistic $t_{\beta_i} = \hat{\beta}_i / \sigma(\hat{\beta}_i)$ (where $\hat{\beta}_i$ is the OLS estimate of β_i in Eq. (14) and $\sigma(\hat{\beta}_i)$ is its standard error). Levin et al. (LLC, 2002) found that the panel approach substantially increases power in finite samples when compared with the equation ADF test, proposed a panel-based version of Eq. (15) that restricts $\hat{\beta}_i$ by keeping it identical across cross-countries as follows:

$$\Delta X_{it} = \alpha_i + \beta X_{i,t-1} + \delta_i t + \sum_{j=1}^{k} \gamma_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \tag{15}$$

Where i =1, 2,…, N indexes across cross-countries. Levin et al. (LLC, 2002) tested:

$$\begin{cases} H_0 : \beta_1 = \beta_2 = ... = \beta = 0 \\ H_1 : \beta_1 = \beta_2 = ... = \beta < 0 \end{cases} ;$$

with the test based on the test statistic $t_{\beta} = \hat{\beta} / \sigma(\hat{\beta})$ (where $\hat{\beta}$ is the OLS estimate of β in Eq. (15) and $\sigma(\hat{\beta})$ is its standard error).

Im et al. (IPS, 2003) test is based on the mean group approach. They used the average of the t_{β_i} statistics from Eq. (14) to perform the following $\overline{Z}$ statistic:

$$\bar{Z} = \sqrt{N}[\bar{t} - E(\bar{t})] / \sqrt{V(\bar{t})} \tag{16}$$

where $\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{\beta_i}$, $E(\bar{t})$ and $V(\bar{t})$ are respectively the mean and variance of each t_{β_i} statistic, and they are generated by simulations. $\bar{Z}$ converges a standard normal distribution.

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 test results*

Panel A.	**Test**		**LNY**	**LNK**	**LNL**	**LNE**	**LNT**
	Breitung	Level	1.9644	2.8755	0.2665	0.8073	0.2110
			(0.9753)	(0.9980)	(0.5600)	(0.7903)	(0.5836)
		Δ	-6.7467**	-2.1584**	-4.1640**	-11.0678**	-8.2738**
			(0.0000)	(0.0154)	(0.0000)	(0.0000)	(0.0000)
	LLC	Level	4.0420	4.7712	-1.2874	3.0942	0.8754
			(1.0000)	(1.0000)	(0.0990)	(0.9990)	(0.8093)
		Δ	-7.4382**	-4.8334**	-3.52943**	-11.3267**	-5.1351**
			(0.0000)	(0.0000)	(0.0002)	(0.0000)	(0.0000)
	IPS	Level	0.0983	1.7915	1.7981	1.4116	0.4638
			(0.5392)	(0.9634)	(0.9639)	(0.9210)	(0.6786)
		Δ	-2.9813**	-2.6120**	-1.9974**	-3.6846**	-0.5234**
			(0.0014)	(0.0045)	(0.0229)	(0.0001)	(0.0000)
	Decision		I(1)	I(1)	I(1)	I(1)	I(1)
Panel B.	**Method**		**LNC**	**LNY**	**LNY²**	**LNE**	**LNT**
	Breitung	Level	-2.3986	0.0983	1.9892	1.4116	0.4638
			(0.0820)	(0.5392)	(0.9826)	(0.9210)	(0.6786)
		Δ	-6.8449**	-2.9816**	-9.0097**	-3.6846**	-4.1223**
			(0.0000)	(0.0014)	(0.0000)	(0.0001)	(0.0000)
	LLC	Level	-1.4095	1.9644	1.9892	0.8073	0.2110
			(0.0793)	(0.9753)	(0.9826)	(0.7903)	(0.5836)
		Δ	-17.2809**	-6.6555**	-9.0097**	-11.0678**	-7.2879**
			(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	IPS	Level	-0.1640	4.04201	0.2543	3.0942	0.8754
			(0.4348)	(1.0000)	(0.5988)	(0.9990)	(0.8093)
		Δ	-15.4067**	-7.4382**	-5.5507**	-11.3267**	-5.1351**
			(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 5% level (Probabilities are presented in parentheses).
Lag selection (Automatic) based on Schwarz Information Criteria (SIC).

4.3.2. Panel cointegration tests

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) and Kao (1999) panel cointegration tests. 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:

$$Y_{it} = \alpha_i + \lambda_i t + \sum_{j=1}^{m} \beta_{j,i} X_{j,it} + \varepsilon_{it} \quad t = 1,\ldots,T \quad i = 1,\ldots N \tag{17}$$

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:

$$\hat{\varepsilon}_{i,t} = \rho_i \hat{\varepsilon}_{i,t-1} + u_{i,t} \tag{18}$$

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 $\rightarrow \infty$:

$$\frac{Z - \mu\sqrt{N}}{\sqrt{\nu}} \xrightarrow[N,T\rightarrow\infty]{} N(0,1) \tag{19}$$

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

$$W_{i,t} = \alpha_i + \beta X_{i,t} + \varepsilon_{i,t} \tag{20}$$

where $W_{i,t} = \sum_{t=1}^{T} u_{i,t}$, $\mathrm{X}_{i,t} = \sum_{t=1}^{T} v_{i,t}$;$\forall t = 1,\ldots,T$, $i = 1,\ldots N$. The test of Kao (1999) is based on the residual and variants of Phillips and Perron, (1988) and Dickey and Fuller (1979). This test is given by:

$$\hat{\varepsilon}_{i,t} = \rho \hat{\varepsilon}_{i,t-1} + \sum_{j=1}^{p} \varphi_j \Delta \hat{\varepsilon}_{i,t-j} + u_{i,t,p} \tag{21}$$

where ρ is selected when $u_{i,t,p}$ are not correlated under the null hypothesis which indicated the absence of cointegration. Then the ADF statistic test will be given by:

$$ADF = \frac{t_{ADF} + \frac{\sqrt{6N}\hat{\sigma}_u}{2\hat{\sigma}_{0u}}}{\sqrt{\frac{\hat{\sigma}_{0u}^2}{2\hat{\sigma}_u^2} + \frac{3\hat{\sigma}_u^2}{10\hat{\sigma}_{0u}^2}}} \xrightarrow[under\ H_0]{} N(0,1) \tag{22}$$

where t_{ADF} is the t-staticitc of ρ in Eq. (21), and σ_{0u} comes from the covariance matrix $\Omega = \begin{bmatrix} \sigma_{0u}^2 & \sigma_{0uv} \\ \sigma_{0uv} & \sigma_{0v}^2 \end{bmatrix}$ of the bi-varied process $(u_{i,t}, v_{i,t})'$. As shown in Table-3 for both Panel A and Panel B, all seven panel unit root tests of Pedroni (1999, 2004) reject the null hypothesis of no cointegration at 5% significance level except Panel *v*-statistic and Group *rho*-statistic for Panel B. The second test of Kao (1999) reported in Table 3.B also rejects the null hypothesis of no cointegration at 5% significance level for both Panel A and Panel B. Thus, the results indicate that there is a long-run equilibrium relationship between all variables in Panel A and Panel B.

Table-3: *Cointegration tests results*

A.*Pedroni (1999, 2004)'s cointegration test* [a]

	Panel A			Panel B	
	Test statistic	**Prob.**		**Test statistic**	**Prob.**
Within-dimension			**Within-dimension**		
Panel υ-stat	2.5408**	(0.0158)	Panel υ-stat	-0.0359	(0.3987)
Panel r-stat	2.2230**	(0.0037)	Panel r-stat	0.4576**	(0.0393)
Panel PP-stat	-1.2087**	(0.0000)	Panel PP-stat	-1.7495**	(0.0163)
Panel ADF-stat	-0.9398**	(0.0265)	Panel ADF-stat	-1.6533**	(0.0017)
Between-dimension			**Between-dimension**		
Group r-stat	3.1878**	(0.0025)	Group r-stat	0.4636	(0.3583)
Group PP-stat	-1.5540**	(0.0193)	Group PP-stat	-5.3524**	(0.0000)
Group ADF-stat	-1.1797**	(0.0000)	Group ADF-stat	-2.9000**	(0.0060)

B. *Kao (1999)'s residual cointegration test* [b]

	Panel A			Panel B	
	Test statistic	**Prob.**		**Test statistic**	**Prob.**
ADF	2.1234**	(0.0000)	**ADF**	-1.7786**	(0.0376)

Critical value at the 5% 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 2.
[b] Lag selection: Automatic 2 lag by SIC with a max lag of 4.

4.3.3. Panel FMOLS and DOLS estimates

Although OLS estimators of the cointegrated vectors are super convergent, their distribution is asymptotically biased and depend 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 (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 the case of panel data, Kao and Chiang (2001) proved that these two techniques led to normally distributed estimators, it means that both OLS and 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 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:

$$W_{i,t} = \alpha_i + \beta_i X_{i,t} + \varepsilon_{i,t} \quad \forall t = 1,\ldots,T \ , \ i = 1,\ldots N \tag{23}$$

Where 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:

$$W_{i,t} = \alpha_i + \beta_i X_{i,t} + \sum_{k=-K_i}^{K_i} \gamma_{i,k} \Delta X_{i,t-k} + \varepsilon_{i,t} \qquad \forall t = 1,\ldots,T \ \ , \ \ i = 1,\ldots N \tag{24}$$

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:

$$\hat{\beta}^*_{FMOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T}\left(X_{i,t} - \bar{X}_i\right)^2\right)^{-1}\left(\sum_{t=1}^{T}\left(X_{i,t} - \bar{X}_i\right)W^*_{i,t} - T\hat{\gamma}_i\right)\right] \tag{25}$$

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) in case of panel data. This technique consists to include advanced and delayed values of $\Delta X_{i,T}$ (Eq. 24) in the cointegrated relationship, in order to eliminate the correlation between regressors and error terms. The panel DOLS estimator is defined as:

$$\hat{\beta}^*_{DOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T} Z_{i,t} Z_{i,t}^{'}\right)^{-1}\left(\sum_{t=1}^{T} Z_{i,t}\tilde{W}_{i,t}\right)\right] \tag{26}$$

where $Z_{i,t} = \left[X_{i,t} - \bar{X}_i, \Delta X_{i,t-K_i}, ..., \Delta X_{i,t+K_i} \right]$ is vector of regressors, and $\tilde{W}_{i,t} = W_{i,t} - \overline{W}_i$. Table-4 provides the results of the country-by-country, panel FMOLS and DOLS tests. The dependent variables are output and CO_2 emissions for Panel A and Panel B, respectively. All the variables are expressed in natural logarithms. The estimated coefficients from the long-run cointegration relationship can be interpreted as long-run elasticities.

On a per country basis for Panel A, all of the coefficients of LNK, LNL, LNE and LNT are statistically significant at the 5% and 10% level except LNK for SAU; LNL for MRC and SAU; LNE for ISR and SAU; and LNT for JOR. For panel FMOLS estimators, the coefficients are 1.179, 0.981, 0.004 and 0.234 for LNK, LNL, LNE and LNT, respectively. This means that a 1% increase in capital increases output by approximately 1.179%; a 1% increase in labor increases output by approximately 0.981%; a 1% increase in energy consumption increases output by approximately 0.004%; and a 1% increase in trade increases output by approximately 0.234%.However, the panel DOLS estimators for Panel A are 1.172, 0.975, 0.009 and 0.227 for LNK, LNL, LNE and LNT, respectively. This means that a 1% increase in capital increases output by approximately 1.172%; a 1% increase in labor increases output by approximately 0.975%; a 1% increase in energy consumption increases output by approximately 0.009%; and a 1% increase in trade increases output by approximately 0.227%.The signs of coefficients are similar to the findings of Lee and Chang (2008), Apergis and Payne (2009a, b, 2010a), Lean and Smyth (2010a) and Sadorsky (2012), whereas the models of Lee and Chang (2008) and Apergis and Payne (2009a, b, 2010a) only include capital, labor and energy consumption. To conclude, the country-by-country and panel cointegration tests results clearly indicate that there exists a cointegrated relationship between LNY, LNK, LNL, LNE and LNT in most of our sample of MENA economies.

Table-4: *FMOLS and DOLS estimates results*

Panel A.(LNY)	LNK		LNL		LNE		LNT	
Country	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
ALG	-0.1065 (0.0461)**	-0.4803 (0.0003)**	0.0012 (0.0048)**	-1.8908 (0.0039)**	0.6642 (0.0094)**	1.1431 (0.0316)**	0.5864 (0.0094)**	2.2309 (0.0818)*
EGY	0.1748 (0.0000)**	0.2040 (0.0000)**	0.8580 (0.0000)**	1.0604 (0.0125)**	-0.2093 (0.0290)**	-0.0281 (0.0367)**	-0.0012 (0.0634)*	-0.3133 (0.0088)**
IRN	0.1957 (0.0049)**	0.3520 (0.0001)**	-0.1036 (0.0479)**	0.6540 (0.0090)**	0.4837 (0.0000)**	-0.4875 (0.0000)**	0.1494 (0.0040)**	-0.1590 (0.0000)**
ISR	0.2624 (0.0000)**	0.1214 (0.0000)**	0.2521 (0.0014)**	0.0328 (0.0024)**	-0.0009 (0.9880)	1.2135 (0.9122)	0.1816 (0.0031)**	0.3010 (0.0159)**
JOR	0.0902 (0.0031)**	0.1498 (0.0020)**	0.3247 (0.0090)**	0.8553 (0.0000)**	0.8161 (0.0169)**	-0.2603 (0.0000)**	-0.1073 (0.6302)	0.3386 (0.9990)
MRC	0.3394 (0.0010)**	0.3123 (0.0004)**	0.0183 (0.9370)	-0.1983 (0.9977)	0.6011 (0.0181)**	1.4123 (0.0001)**	-0.3418 (0.0216)**	-0.3740 (0.0450)**
SAU	-0.0033 (0.8824)	0.3187 (0.9908)	-0.3044 (0.0884)*	-2.5222 (0.0967)*	0.1503 (0.2412)	0.9270 (0.1588)	0.1922 (0.0187)**	0.7651 (0.0088)**
SYR	0.3698 (0.0000)**	-0.1705 (0.0000)**	0.3723 (0.0154)**	-1.2002 (0.0000)**	0.6375 (0.0001)**	-0.5960 (0.0000)**	-0.3210 (0.0014)**	2.7860 (0.0000)**
TUN	0.3221 (0.0000)**	-0.2929 (0.0000)**	0.4545 (0.0478)**	0.9957 (0.0045)**	0.7490 (0.0018)**	1.2014 (0.0004)**	-0.6609 (0.0001)**	0.0848 (0.0000)**
Panel	1.1790 (0.0000)**	1.1721 (0.0000)**	0.9806 (0.0000)**	0.9753 (0.0000)**	0.0041 (0.0000)**	0.0094 (0.0000)**	0.2343 (0.0000)**	0.2269 (0.0000)**

Panel B.(LNC)	LNY		LNY^2		LNE		LNT	
Country	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
ALG	0.8623 (0.0080)**	2.2525 (0.0028)**	-0.5984 (0.0016)**	-0.6346 (0.0049)**	0.8982 (0.0029)**	1.4356 (0.0022)**	0.1264 (0.0172)**	0.9983 (0.0338)**
EGY	1.1448(0.0001)**	0.1341(0.0452)**	-0.9937 (0.0367)**	-0.0495 (0.0225)**	-0.3428(0.0908)*	-2.5770(0.0737)*	0.0630(0.4979)	1.0486(0.4304)
IRN	0.0384 (0.0033)**	6.4250 (0.0022)**	-1.6234 (0.9900)	-1.5752 (0.9990)	0.9639 (0.0016)**	5.1889 (0.0010)**	0.0034 (0.0099)**	1.3845 (0.0016)**
ISR	0.1428 (0.0005)**	0.1965 (0,0000)**	-0.0270 (0.0159)**	-0.0393 (0.0624)*	2.0966 (0.0000)**	2.1550 (0.0409)**	-0.1431 (0.5653)	-0.3373 (0.3624)
JOR	0.1870	0.0547	-0.4247	-0.2943	0.3438	0.0689	0.16295	0.1745

	(0.0781) *	(0.0263) **	(0.0040) **	(0.0001) **	(0.0459) **	(0.0113) **	(0.1032)	(0.2067)
MRC	-0.1144 (0.6141)	-0.3785 (0.5148)	1.5863 (0.0430) **	1.3032 (0.0040) **	0.6465 (0.0894) *	1.2662 (0.0594) *	0.18170 (0.0347) **	0.7718 (0.0775) *
SAU	0.8356 (0.0337) **	5.1554 (0.0298) **	-0.8004 (0.3588)	-0.7765 (0.3967)	0.2987 (0.0460) **	1.8362 (0.0041) **	-0.3273 (0.0648) *	-0.9544 (0.0010) **
SYR	0.2232 (0.4033)	0.5868 (0.2095)	-1.2995 (0.0401) **	-1.1828 (0.0045) **	0.7260 (0.0319) **	0.9948 (0.0335) **	0.5396 (0.0009) **	0.6006 (0.0271) **
TUN	0.4073 (0.0429) **	0.2866 (0.0133) **	0.1734 (0.1105)	0.0954 (0.4545)	0.2191 (0.0202) **	1.3965 (0.0855) *	-0.0798 (0.0769) *	-0.5072 (0.0837) *
Panel	0.0576 (0.0000) **	0.0574 (0.0000) **	-0.9806 (0.0000) **	-0.9858 (0.0000) **	0.9212 (0.0000) **	0.9191 (0.0000) **	0.0219 (0.0000) **	0.0274 (0.0000) **

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

On a per country basis for Panel B, all of the coefficients of LNY, LNY², LNE and LNT are statistically significant at the 5% and 10% level except LNY for MRC and SYR; LNY² for IRN, SAU and TUN; and LNT for EGY, ISR and JOR. The results also show that there are inverse U-shaped relationships between CO_2 emissions (LNC) and real GDP (LNY) for all studied MENA countries, expect Morocco and Tunisia. The Tunisian case presents special attention, since it is the only country where a positive monotonic relationship between income and CO_2emissions is found (the elasticities are 0.407+0.347.*LNY*and 0.287+0.191.*LNY* for FMOLS and DOLS, respectively). Morocco presents an inverted curve as compared to what is predicted by the theory (the elasticities are -0.114+3.173.*LNY*and -0.378+2.606.*LNY* for FMOLS and DOLS, respectively). These results confirm the findings of Arouri et al. (2012). For panel FMOLS estimators, the coefficients are 0.058, -0.981, 0.921 and 0.022 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 0.058–1.962.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.921%; and a 1% increase in trade increases CO_2 emissions by approximately 0.022%. However, the panel DOLS estimators for Panel B are 0.057, -0.986, 0.919 and 0.027 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 0.057–1.972.*LNY*; a 1% increase in energy consumption increases CO_2 emissions by approximately 0.919%; and a 1% increase in trade increases CO_2 emissions by approximately 0.027%. To conclude, 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).

4.3.4. Panel causality test

A panel VEC model is estimated to perform Granger causality test (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. (6) and Eq. (11) 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.

$$\begin{pmatrix} \Delta LNY_t \\ \Delta LNK_t \\ \Delta LNL_t \\ \Delta LNE_t \\ \Delta LNT_t \end{pmatrix} = \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \\ \omega_5 \end{pmatrix} + \sum_{k=1}^{m} \begin{pmatrix} \varpi_{1,1,k} & \varpi_{1,2,k} & \varpi_{1,3,k} & \varpi_{1,4,k} & \varpi_{1,5,k} \\ \varpi_{2,1,k} & \varpi_{2,2,k} & \varpi_{2,3,k} & \varpi_{2,4,k} & \varpi_{2,5,k} \\ \varpi_{3,1,k} & \varpi_{3,2,k} & \varpi_{3,3,k} & \varpi_{3,4,k} & \varpi_{3,5,k} \\ \varpi_{4,1,k} & \varpi_{4,2,k} & \varpi_{4,3,k} & \varpi_{4,4,k} & \varpi_{4,5,k} \\ \varpi_{5,1,k} & \varpi_{5,2,k} & \varpi_{5,3,k} & \varpi_{5,4,k} & \varpi_{5,5,k} \end{pmatrix} . \begin{pmatrix} \Delta LNY_{t-k} \\ \Delta LNK_{t-k} \\ \Delta LNL_{t-k} \\ \Delta LNE_{t-k} \\ \Delta LNT_{t-k} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \end{pmatrix} .ECT_{t-1} + \begin{pmatrix} \nu_{1,t} \\ \nu_{2,t} \\ \nu_{3,t} \\ \nu_{4,t} \\ \nu_{5,t} \end{pmatrix} \quad (27)$$

Panel B.

$$
\begin{pmatrix} \Delta LNC_t \\ \Delta LNY_t \\ \Delta LNY_t^2 \\ \Delta LNE_t \\ \Delta LNT_t \end{pmatrix} = \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \end{pmatrix} + \sum_{k=1}^{m} \begin{pmatrix} \theta_{1,1,k} & \theta_{1,2,k} & \theta_{1,3,k} & \theta_{1,4,k} & \theta_{1,5,k} \\ \theta_{2,1,k} & \theta_{2,2,k} & \theta_{2,3,k} & \theta_{2,4,k} & \theta_{2,5,k} \\ \theta_{3,1,k} & \theta_{3,2,k} & \theta_{3,3,k} & \theta_{3,4,k} & \theta_{3,5,k} \\ \theta_{4,1,k} & \theta_{4,2,k} & \theta_{4,3,k} & \theta_{4,4,k} & \theta_{4,5,k} \\ \theta_{5,1,k} & \theta_{5,2,k} & \theta_{5,3,k} & \theta_{5,4,k} & \theta_{5,5,k} \end{pmatrix} . \begin{pmatrix} \Delta LNC_{t-k} \\ \Delta LNY_{t-k} \\ \Delta LNY_{t-k}^2 \\ \Delta LNE_{t-k} \\ \Delta LNT_{t-k} \end{pmatrix} + \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{pmatrix} .ECT_{t-1} + \begin{pmatrix} \xi_{1,t} \\ \xi_{2,t} \\ \xi_{3,t} \\ \xi_{4,t} \\ \xi_{5,t} \end{pmatrix} \tag{28}
$$

where the term Δ denotes first differences; $\omega_{j,i,t}$ and $\phi_{j,i,t}$ (j=1,2,3,4,5) represent the fixed country effect; k (k=1,…,m) is the optimal lag length determined by the Schwarz Information Criterion, 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 $\lambda_{j,i}$ are the adjustment coefficient and $v_{j,i,t}$ and $\xi_{j,i,t}$ are the disturbance term assumed to be uncorrelated with zero means.

Table-5: *Panel causality test results*

Dependent Variable Panel A.	**Sources of causation (Independent variable)**					**Long run**
	Short run					
	ΔLNY	**ΔLNK**	**ΔLNL**	**ΔLNE**	**ΔLNT**	**ECT**
ΔLNY	#	0.0399** (0.0419)	0.1305** (0.0183)	0.0233* (0.0787)	0.0164* (0.0981)	-0.0208** [-2.2541]
ΔLNK	0.5259* (0.0693)	#	0.2710 (0.1500)	0.1004* (0.0916)	0.8915 (0.3463)	-0.1919 [-1.3257]
ΔLNL	2.7851 (0.3969)	0.6900 (0.1714)	#	2.5595 (0.1114)	2.6097 (0.1080)	-0.3577 [-0.4944]
ΔLNE	0.0212 (0.8842)	0.6533 (0.5274)	1.0688 (0.3026)	#	0.9496 (0.3311)	0.0101 [0.6181]
ΔLNT	1.6614 (0.1991)	1.7428 (0.1885)	3.6979 (0.1561)	2.5274 (0.1137)	#	0.0153 [0.4517]
Panel B.	**ΔLNC**	**ΔLNY(ΔLNY²)**		**ΔLNE**	**ΔLNT**	**ECT**
ΔLNC	#	0.6030** (0.0385)		3.0191** (0.0440)	0.0257* (0.0726)	-0.5553** [-1.9842]
ΔLNY(ΔLNY²)	0.0017 (0.9668)	#		0.0194 (0.8893)	0.0670 (0.7959)	-0.0238 [-0.1534]

ΔLNE	0.4136 (0.5210)	5.6E-05 (0.9940)	#	0.0001 (0.9890)	-0.2172 [-0.0798]
ΔLNT	0.0806 (0.7768)	0.1073 (0.7435)	0.0909 (0.7634)	#	-0.1733 [-0.3614]

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.
Statistics of ΔLNY^2 denote the same value listed for ΔLNY.

Table-5 reports the results of the short-run and long-run Granger causality tests for Panel A and Panel B. For Panel A, capital, labor, energy consumption and trade have a positive and statistically significant impact on the real GDP in short-run. Moreover, the error correction term is statistically significant at 5% level which suggests that the real GDP presents a relative slow speed of adjustment to long-run equilibrium. In terms of capital as a dependent variable, it appears that only real GDP and energy consumption have a positive and statistically significant impact at 10% level. However, the error correction term is statistically insignificant which suggests that the labor is not responsive to adjustments towards long-run equilibrium. These results imply that the capital plays a vital role in the relationship between real GDP, energy consumption and capital (Lee, 2005; Lee et al. 2008; Narayan and Smyth, 2008). For the rest, there is statistically insignificant impact both in short and long-run. For panel B, the result confirms the study of Ang (2007) and Apergis and Payne (2009c), which suggests that the degradation of CO_2 emissions does not have a causal impact on economic growth or energy consumption. This degradation does not also have a causal impact on trade. Instead, expansion of real GDP energy consumption and trade exert a causal significant effect on CO_2 emissions in short run. Moreover, the error correction term is statistically significant at 5% level which suggests that CO_2 emissions present a relative slow speed of adjustment to long-run equilibrium. However, the error correction term is statistically insignificant for other variables.

5. Conclusion and policy implications

There is an extensive literature looking at the production function (relationship between output, capital, labor, energy consumption and trade) and a separate even more extensive literature looking at the environmental function (relationship between CO_2 emissions, income, energy consumption and trade). There is, however, no published papers that bring these two separate streams of economic literature together to investigate the question: Grow output or mitigate CO_2 emissions? To attempt these linkages, the purpose of this paper is to parallel the two functions for a panel of nine MENA countries from 1990 to 2009.Short-run and long-run causality results have important implications for production level and environmental policy. For the production function, capital, labor, energy consumption and trade have a positive and statistically significant impact in short-run on real GDP. Moreover, the error correction term is statistically significant at the 5% level which suggests that the real GDP presents a relative slow speed of adjustment to long-run equilibrium. For FMOLS and DOLS estimates, the mean of the coefficients of capital, labor, energy consumption and trade are respectively 1.18, 0.98, 0.01 and 0.23. The signs of coefficients are similar to the findings of Lean and Smyth (2010a) and Sadorsky (2012).

For the environmental function, income, energy consumption and trade have a positive and statistically significant impact in the short-run on CO_2 emissions. Moreover, the error correction term is statistically significant at the 5% level which suggests that CO_2 emissions present a relative slow speed of adjustment to long-run equilibrium. For FMOLS and DOLS estimates, the mean of the coefficients of income, squared income, energy consumption and trade are respectively 0.06, -0.98, 0.92 and 0.03. 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 (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).

One general implication is that policies designed to increase energy and trade will also increase output and CO_2 emissions. This means that predictions of future energy consumption or trade openness that do not take into account the effect of production level or pollution level will likely under estimate the growth of economies and the pollution of environment. A better environmental approach that takes into account the production function is to facilitate a rise in energy consumption by increasing the share of renewable energy relative to non-renewable energy.

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