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Determinants of Carbon Dioxide Emissions: New Empirical Evidence from MENA Countries

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ABSTRACT

The paper emplyos the Pooled Mean Group (PMG) estimation to investigate empirically the relationship among carbon dioxide (CO_2) emissions and potential determinants for a panel of 18 MENA countries during the period 1980-2018. The good properties in terms of consistency and efficiency of the coefficient estimates make the PMG approach very useful for examining the determinants of pollution emissions in the framework of dynamic heterogeneous panel data models over both the long- and short-run. Unlike the extant literature on MENA economies, many determinants are included in the analysis to avoid the bias problem of omitted variables. Three energy sources and two classes of sub-panels according to regional proximities and oil wealth are considered in order to provide a sensitivity check on the findings and to make the analysis more homogeneous. The results reveal long-run relationships between pollution emissions and the selected variables. All determinants are found to be statistically significant for all panels and energy sources over the short-run. However, some variables are not significant determinants over the long-run. The Environment Kuznet's Curve (EKC) hypothesis is supported only for the panel of non-oil countries, which has meaningful implications and reveals the importance of splitting the global panel in order to appropriately examine the EKC hypothesis and conduct policy debates according to the findings of each panel. The obtained results provide important policy implications.

Keywords: CO_2 Emissions, Energy Sources, EKC Hypothesis, Dynamic Panel Data Model, MENA Region
JEL Classifications: C23, Q43, Q54

1. INTRODUCTION

The linkages between emissions of various pollutants and potential determinants become one of the most studied topics in the ecological economics literature during the past few decades with the improvement of econometric methods. This is mainly attributed to the high level of energy consumption in the world and its close relation with economic growth, which allows intensifying the emissions of pollution that cause global warming. Most of the conducted empirical works focus on testing the validity of the EKC hypothesis[1] at country and/or panel levels (see Dinda and Coondoo, 2002; 2006; Akbostancı et al., 2009; Lee and Lee, 2009; Fodha and Zaghdoud, 2010; Narayan and Narayan, 2010; Jaunky, 2011; Arouri et al., 2012; among others). Such hypothesis expresses the relationship between economic activity and pollution emissions (proxy of environmental quality according to Soytas et al. (2007)). Within this context, the theory stipulates that the environment deteriorates at the beginning of the economic development process. However, as the economy develops over time, there is improvement in the environmental quality.

The current study contributes to the literature on the linkages among CO_2 emissions and potential determinants for the MENA countries in four novel ways. First, as argued by Bimonte (2002), many variables and factors may influence the EKC hypothesis

1 It is found that the EKC hypothesis is theoretically explained based on the scale, structure and abatement effects (see Grossman and Krueger, 1991; and Islam et al., 1999).

through their impact on environmental performance of countries. For this purpose, we consider an extended-form model in which we include economic and demographic variables that may potentially influence the pollution level of a country such as the foreign direct investment, trade openness and urbanization. Second, most empirical works in the literature frequently employ one energy type proxy when investigating the relationship between pollution emissions and potential determinants in the MENA region, which may be insufficient to draw reliable and robust conclusions. From this perspective, we add something new to the literature and consider three energy type variables to provide a sensitivity check on the results. The selected proxies for energy consumption are expected to emit pollution in the MENA region.

Third, many empirical studies in the literature include a small number of MENA countries in the analysis and mainly consider the MENA region as a part of the whole panel of countries, which does not allow a good look on the relationship between pollution emissions and potential determinants for such a region. For this purpose, we extend the analysis by considering only the MENA region with the maximum possible number of countries in order to provide a good understanding of the linkages among CO_2 emissions and explanatory variables.

Fourth, different sub-panels are constructed according to regional proximities and oil wealth of economies to make the analysis more homogeneous. The selection of panels is motivated by the economic and institutional similarities that govern most countries of such panels, and by the fact that changes in terms of emissions regulation, economic and environmental policies, development and outward-oriented strategies, and boost of investment may significantly affect the whole sub-panel rather than the individual country.

The objectives of our current study are threefold. First, we examine how the CO_2 emissions are linked with the considered determinants in the long-run. Second, we investigate the short-run causal effects of the determinants on pollution emissions, and the dynamic adjustments of their short-run deviations from the long-run equilibrium level.[2] Third, we aim at identifying the differences in the environmental quality and EKC hypothesis across panels and energy type proxies,[3] with a view of contributing to previous studies and, in particular, of completing the MENA works that require further consideration. Testing the validity of the EKC hypothesis is crucial for policymakers in the sense that they can appropriately assess the environmental quality following the fluctuations of economic growth whose maximization is the main objective of any economy. As a result, policymakers can establish suitable policies in order to protect environment and combat global warming.

The remainder of the paper is structured as follows. Section 2 briefly reviews previous empirical works on the relationship between pollution emissions and potential determinants for MENA countries. Section 3 presents our extended-form panel model and data to establish the linkages between CO_2 emissions and related independent variables. Section 4 describes the econometric method to be used in our empirical issue. Section 5 discusses the obtained findings with a special focus on the EKC hypothesis. Section 6 provides concluding remarks and discusses the policy implications of the results.

2. LITERATURE REVIEW

The empirical study of the relationship between pollution emissions and related determinants for developing and developed economies receives growing attention in the ecological economics literature. A wide range of econometric procedures are employed to investigate empirically such a relationship. We review in this section the works that are connected to our investigation, namely those related to MENA countries. Within this context, M'henni (2005) opts for the Generalized Method of Moments (GMM) to investigate the EKC hypothesis in Tunisia during the period 1980-1997. The results do not support the EKC hypothesis for any of some considered pollutants. In a similar work, Chebbi et al. (2011) opt for Granger causality tests in the framework of a Vector Error-Correction Model (VECM) to assess the effect of economic growth and trade openness on CO_2 emissions for Tunisia over the period 1961-2004. The results show evidence of positive (negative) relationship between carbon dioxide emissions and trade (income) over the long-run. They also indicate that trade openness directly and positively affects pollution emissions in the long- and short-run, but it indirectly and negatively influences CO_2 emissions at least in the long-run. These insights support the environmental degradation caused by trade in Tunisia during the study period. Fodha and Zaghdoud (2010) employ cointegration techniques to investigate the EKC hypothesis for Tunisia from 1961 to 2004 through the study of the linkages between two pollutant emissions and income. The results show evidence of long-run relationships between the pollutant emissions and economic growth. Moreover, they reveal an inverted U relationship between sulphur dioxide emissions and income and a monotonically increasing relationship between carbon dioxide emissions and economic growth.

Akbostancı et al. (2009) opt first for time series cointegration procedures to examine the relationship between CO_2 emissions and income for Turkey over the period from 1968 to 2003. In a second stage, the linkages between sulphur dioxide and particulate matter emissions and income for 58 Turkish provinces are investigated based on panel data methods during the period 1992-2001. It is found that in the time series analysis, the carbon dioxide emissions monotonically increase with income over the long-run. In the panel data analysis, the results provide evidence of an N-shaped curve for sulphur dioxide and particulate matter emissions. Accordingly, the results do not support the EKC hypothesis at the nation and provinces level. Again for Turkey, Halicioglu (2009) investigates the relationship between carbon dioxide emissions, energy consumption, income and trade openness over the period 1960-2005 using a large battery of econometric procedures. The

2 It is important to stress that most empirical works on pollution emissions focus on long-run effects and neglect estimating the short-run coefficients.

3 Ansuategi (2003) and Maddison (2006) find that the quality of the environment of economies may be affected by their neighbouring economies. Stern and Common (2001) stress that examining the EKC hypothesis based on mixed data for OECD and non-OECD economies is unsuitable.

results reveal evidence of two cointegrating relationships where the pollution emissions and income are considered as dependent variables. Moreover, income is found to be the most significant determinant of CO_2 emissions compared to energy consumption and trade openness. Finally, the stability checks reveal stable pollution emissions function. Sari and Soytas (2009) employ the bounds testing approach to cointegration to examine the linkages among pollution emissions, energy consumption, income and total employment for five OPEC (Organization of the Petroleum Exporting Countries) economies (including Algeria and Saudi Arabia) from 1971 to 2002. The results show evidence of long-run relationship among the variables in consideration for Saudi Arabia only, and that all economies do not need to sacrifice economic growth to reduce the CO_2 emissions.

The above strand of literature focuses on individual economies using testing and estimation methods developed in the time series framework. Such methods may suffer from some shortcomings especially in small sample sizes as it is generally the case for the applications related to the determinants of CO_2 emissions. Furthermore, He (2007) offers a comparison between the existing empirical analysis of the EKC hypothesis and discuss the potential shortcomings of these. The study reveals high sensitivity of the EKC hypothesis to the time period, the sample size, the environmental measurements and the estimation techniques. For this purpose, another strand of literature has been developed where researchers make use of panel data procedures since the addition of the cross-section dimension improves the statistical properties of the considered methods. Within this context, Lee and Lee (2009) investigate the CO_2 emissions-income nexus for 109 economies (including 13 MENA countries) during the period 1971-2003 based on panel data testing and estimation approaches. The obtained results provide support for a positive response of carbon dioxide emissions to changes in income. Narayan and Narayan (2010) test for the EKC hypothesis for 43 developing countries (including 16 MENA countries) over the period 1980-2004 using panel data methods. The findings, based on the relationship between carbon dioxide emissions and income, support the EKC hypothesis for 15 individual economies (including 7 MENA economies) and for the panels of Middle Eastern and South Asian countries. Hooi and Smyth (2010) investigate the causal linkages between CO2 emissions, electricity consumption and real GDP for five ASEAN countries) Indonesia, Malaysia, Philippines, Singapore and Thailand (from 1980 to 2006 by using a panel vector error correction model. The results reveal positive and significant long-run connection between electricity consumption and CO2 emissions and significant non-linear relationship between CO2 emissions and economic growth. Morimoto and Hope (2004) use examine the impact of electricity supply on real GDP in Sri Lanka over the period 1960 -1998. The finding based on Granger-causality test indicate that there is a significant impact of electricity supply on economic growth.

Jaunky (2011) examines empirically the EKC hypothesis for 36 rich countries (including Bahrain, Oman and the UAE) from 1980 to 2005 based on panel data procedures through the study of the linkages among pollution emissions and income. It is found that income causes CO_2 emissions in both the short- and long-run. In addition, the EKC hypothesis is supported for Greece, Malta, Oman, Portugal and the UK. Sharma (2011) investigate the determinants of pollution emissions for 69 countries (including 8 MENA economies) from 1985 to 2005 in the framework of dynamic panel data models. The analysis is conducted for the whole panel and for sub-panels determined according to the countries income level. The findings indicate that income exerts a significant and positive influence on CO_2 emissions for the global, middle income and low income panels. The pollution emissions respond positively to the fluctuations of energy consumption for the high income panel. The urbanisation negatively affects emissions for the global panel. Arouri et al. (2012) examine the linkages among pollution emissions, energy consumption and real income in 12 MENA countries from 1981 to 2005 based on panel cointegration techniques. The empirical results indicate that the carbon dioxide emissions respond positively to the fluctuations of energy consumption, and that real income is linked to CO_2 emissions through a quadratic relationship for the whole region over the long-run. It is also found that future pollution emissions decreases may be attained at the same time as income continues to increase in the MENA region.

3. EMPIRICAL MODEL AND DATA

To conduct our investigation and establish the long-run relationship between CO_2 emissions and related determinants, we propose the following extended-form panel model:

$$CO_{2,it} = \alpha_0 + \alpha_1 E_{it} + \alpha_2 Y_{it} + \alpha_3 F_{it} + \alpha_4 T_{it} + \alpha_5 U_{it} + \varepsilon_{it} \quad (1)$$

Where i refers to the country, t refers to the time period for each country, $CO_{2,it}$ is the carbon dioxide emissions (measured in metric tons per capita), E_{it} represents the energy variable that is measured by three proxies, namely the energy use (EU, measured in kg of oil equivalent per capita), the road sector energy consumption (RSEC, measured in kt of oil equivalent per capita) and the electric power consumption (EPC, measured in kwh per capita), Y_{it} is the real GDP per capita (measured in 2005 US dollars), F_{it} is the foreign direct investment (net inflows) share in GDP, T_{it} is the trade openness measured as the ratio of exports plus imports to GDP, U_{it} is the urbanisation measured as the urban population as percentage of the total, and ε_{it} is the error term. The variables are converted into natural logarithms so that the coefficient estimates represent the elasticities of CO_2 emissions with respect to energy variable, real income, trade openness and urbanisation. The exception is the foreign direct investment that is introduced in the model without the log transformation because it contains negative values.

The data used in the empirical study are annual and span from 1980 to 2018 for 18 MENA countries, namely Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the UEA, and Yemen. The data on CO_2 emissions, energy type variables and urbanisation are gathered from the World Development Indicators (WDI) published by the World Bank, while data on real GDP per capita, foreign direct investment and trade openness are collected from the United Nations Conference on Trade and Development (UNCTAD).

4. ECONOMETRIC METHOD

Pesaran et al. (1999) formulate and estimate a dynamic heterogeneous panel model that accounts for short-run dynamics and long-run equilibrium state. It is expressed as follows:

$$\Delta CO_{2,it} = \mu_i e_{i,t-1} + \sum_{j=1}^{p} \beta'_{ij} \Delta CO_{2,i,t-j} + \sum_{j=0}^{q} \delta'_{ij} \Delta X_{i,t-j} + \gamma'_i X'_{it} + a_i + b_i t + v_{it} \quad (2)$$

where "Δ" stands for the first difference operator. $\Delta CO_{2,it}$ and ΔX_{it} are respectively the first differenced carbon dioxide emissions and the set of related determinants (energy type proxy, real income, foreign direct investment, trade openness and urbanization), $e_{i,t-1}$ is the one-period lagged error correction obtained from the estimation of the cointegrating relationship,[4] and v_{it} is the disturbance term with different variances across countries. The error correction term coefficient μ_i measures the adjustment speed of the short-run deviations of the carbon dioxide emissions towards the long-run equilibrium state, the set of coefficients β show the short-run past own impacts of CO_2 emissions, the vectors of coefficients δ and γ measure the short-run effects of the considered determinants on pollution emissions, and a_i and b_i are individual specific effects. The lag orders p and q are selected by the Schwarz Bayesian information criterion (SBC). The maximum likelihood technique and the Newton-Raphson's optimization algorithm are employed to estimate the above error correction model. The coefficient estimators are found to be consistent and normally distributed asymptotically (see Hsiao, 1986 and Pesaran et al., 1999).

4 The long-run coefficients are assumed to be identical across countries according to the PMG approach.

5. DISCUSSION OF THE RESULTS

We classify the considered countries into two classes of panels. The first class is constructed according to regional proximities, namely a panel of six GCC (Gulf Cooperation Council) countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the UAE), a panel of six North African countries (Algeria, Egypt, Libya, Morocco, Sudan and Tunisia), and a panel of six Middle Eastern economies (Iran, Iraq, Jordan, Lebanon, Syria and Yemen). The second class is constructed based on oil wealth and high financial surplus, namely a panel of ten oil-rich countries (Algeria, Bahrain, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Saudi Arabia and the UAE), and a panel of eight non oil-rich economies (Egypt, Jordan, Lebanon, Morocco, Sudan, Syria, Tunisia and Yemen).

5.1. Summary Statistics

Table 1 provides descriptive statistics for carbon dioxide emissions and the related determinants for the two classes of panels. For the first class of panels, the mean pollution emissions is recorded highest for GCC economies followed by Middle Eastern economies and North African economies at 3.026, 1.017 and 0.484, respectively. It is also found that North African countries are most volatile in emitting carbon dioxide, as indicated by the standard deviation (1.178), followed by Gulf countries (0.618) and Middle Eastern countries (0.594). For the second class of panels, the oil-rich countries record the highest levels in terms of mean CO_2 emissions and standard deviation compared with non-oil countries. These insights imply that the panels consisting of oil-based economies (GCC and oil-rich countries) pollute more than the other panels.

The mean energy consumption with respect to the three sources is the largest for Gulf countries followed by Middle Eastern countries and North African countries for the first class of panels. For the second

Table 1: Summary statistics of the variables

Panel		CO_2	EU	RSEC	EPC	Y	F	T	U
Whole panel	Mean	1.512	7.407	5.706	7.266	8.363	1.942	4.327	4.118
	Max	4.227	10.048	7.907	9.767	11.274	33.366	5.870	4.592
	Min	−2.273	5.027	3.098	3.494	6.132	−12.698	2.095	2.805
	Std. Dev.	1.384	1.259	1.108	1.484	1.364	3.661	0.529	0.389
GCC	Mean	3.036	8.893	6.863	8.850	10.027	1.932	4.610	4.420
	Max	4.227	10.048	7.907	9.767	11.274	33.366	5.457	4.592
	Min	1.492	6.688	5.246	6.436	8.806	−12.698	4.099	3.862
	Std. Dev.	0.618	0.688	0.572	0.671	0.588	4.088	0.292	0.147
North Africa	Mean	0.484	6.569	4.766	6.232	7.572	1.762	3.967	3.915
	Max	2.429	8.182	7.104	8.457	9.484	9.623	4.841	4.351
	Min	−2.273	5.479	3.098	3.494	6.178	−2.853	2.095	2.994
	Std. Dev.	1.178	0.722	0.927	1.171	0.826	2.083	0.496	0.319
Middle East	Mean	1.017	6.760	5.487	6.717	7.491	2.132	4.404	4.019
	Max	2.061	7.973	6.274	8.154	8.840	23.537	5.870	4.467
	Min	−0.868	5.027	4.359	4.153	6.132	−3.673	3.107	2.805
	Std. Dev.	0.594	0.655	0.480	0.953	0.629	4.387	0.542	0.434
Oil-rich	Mean	2.422	8.241	6.417	8.121	9.188	1.372	4.432	4.319
	Max	4.227	10.048	7.907	9.767	11.274	33.366	5.870	4.592
	Min	0.637	6.355	4.626	5.787	6.132	−12.698	3.107	3.774
	Std. Dev.	0.943	1.015	0.791	1.097	1.212	3.332	0.488	0.192
Non oil-rich	Mean	0.375	6.365	4.817	6.197	7.332	2.655	4.196	3.867
	Max	1.660	7.445	6.197	8.154	8.840	23.537	5.163	4.467
	Min	−2.273	5.027	3.098	3.494	6.178	−3.673	2.095	2.805
	Std. Dev.	0.932	0.567	0.748	1.181	0.660	3.928	0.549	0.425

class of panels, the mean energy consumption is higher for the oil countries than the non-rich countries for both energy type variables.

For the first class of panels, the highest mean real income is recorded for Gulf countries followed by North African countries and Middle Eastern countries. However, the greatest volatility is recorded for North African economies followed by Middle Eastern economies and GCC economies. For the second class of panels, the highest mean and volatility are recorded for the panel of oil-rich countries compared with the panel of non-oil countries. The results indicate that the panels of oil-based economies are considered as high-income panels compared with the other panels.

A similar pattern reveals for trade openness and urbanization where the average values of the two determinants are recorded highest for Gulf countries followed by Middle Eastern countries and North African countries for the first class of panels, and for oil-rich economies followed by non oil-rich economies for the second class of panels. In terms of volatility, the panels of GCC and rich countries record the lowest levels for the two determinants. The findings indicate that the panels of oil-based countries are more open to trade and more urbanized compared with the other panels of countries.

A reverse trend is observed for the foreign direct investment where the oil-based economies are not ranked first since the highest average is recorded for Middle Eastern countries followed by Gulf countries and North African countries for the first class of panels, and for non-oil countries followed by oil countries for the second class of panels. As for average value, a similar pattern exists for volatility.

To sum up, the preliminary analysis provides support to the classification of economies into sub-panels according to regional proximities and oil wealth that is important in matter of homogenization of countries by similar features since the descriptive statistics of all variables reveal practically a clear distinction between the considered sub-panels of each class.

Table 2 presents the empirical correlations between carbon dioxide emissions and the considered determinants for all panels. The CO_2 emissions are positively and highly correlated to all energy sources, real income and urbanization. For the foreign direct investment and trade openness, the correlations are positive and relatively moderate, except of that of foreign direct investment for the panel of North African countries and that of trade openness for the panel of Middle Eastern economies. The empirical correlations among the three energy sources for all panels provided in Table 3 are high and positive. The correlation coefficients give preliminary insights on the relationship between carbon dioxide emissions and the related determinants, and do not support the potential effects of such determinants on pollution emissions. A thorough analysis based on powerful econometric tools is then needed to complete this study.

5.2. Integration Properties of the Variables

The study of non-stationary data has become essential in econometric analysis as time series underwent stationarity analysis before driving a depth empirical issue. The analysis of non-stationary panel data has extensively developed since the pioneering work of Levin and Lin (1992) especially with the increasing use of macroeconomic data having sufficient time dimension. In this context, sevral panel unit roor tests are developed under the assumption of no cross-section dependence, which may be inconvenient in many applications given that the countries in consideration may share common economic and institutional features. These insights prompt researchers to develop another generation of tests taking into account eventual dependence between countries that may be due to unobservable common factors. Within this context, Strauss and Yigit (2003) point out the importance of contemporary dependence in panel unit root tests and suggest that ignoring cross-dependence leads to false inference. This generation of tests includes Bai and Ng (2004), Choi (2006), Moon and Perron (2004), Pesaran (2007), among others.

Prior to the panel cointegration analysis, we determine the integration order of the variables by performing unit root and stationarity tests for all panels. Since no panel test developed in the related literature is perfect in terms of statistical properties (including size and power), a wide range of tests (Maddala and Wu 1999; Levin et al., 2002; Im et al., 2003; Hadri, 2000; and Carrion-i-Silvestre et al., 2005)[5] are conducted to avoid misleading inferences and, so, to infer overwhelming evidence on the integration order of the variables. The tests of Levin et al. (2002), Im et al. (2003) and Hadri (2000) are performed using two specifications. The first specification includes an intercept only, while the second specification includes an intercept and a deterministic time trend as macroeconomic variables are expected to exhibit a time trend in their structure. For the test of Carrion-i-Silvestre et al. (2005), we consider two regressions in which we allow for structural change in constant in the first one, and structural change in constant and trend in the second regression to account for potential breaks due to domestic and international events. The results of the tests for all panels and specifications[6]

5 The tests of Maddala and Wu 1999, Levin et al. (2002) and Im et al. (2003) test for unit root under the null hypothesis, while the tests of Hadri (2000) and Carrion-i-Silvestre et al. (2005) are constructed with stationarity under the null hypothesis.

6 Given the multiplicity of the variables and panels, the results of the tests are not reported to conserve space, but are available upon request from the authors.

Table 2: Empirical correlations between CO_2 emissions and all determinants

Panel	EU	RSEC	EPC	Y	F	T	U
Whole panel	0.941	0.953	0.958	0.919	0.019	0.518	0.836
GCC	0.931	0.792	0.829	0.843	0.071	0.128	0.727
North Africa	0.822	0.922	0.935	0.898	−0.125	0.650	0.903
Middle East	0.969	0.915	0.922	0.649	0.134	−0.010	0.876
Oil-rich	0.976	0.900	0.934	0.934	0.208	0.366	0.837
Non oil-rich	0.733	0.902	0.936	0.744	0.237	0.729	0.778

are consistent and support that all variables are integrated of order one, *I*(1).

5.3. Panel Cointegration Analysis

Having ascertained that the variables are integrated of order one, we now proceed with the application of panel cointegration tests to explore the long-run relationships between CO_2 emissions and the determinants in consideration for all panels and energy sources. As unit root tests, the panel cointegration tests experienced increasing development since the pioneering work of Levin and Lin (1992) and can be classified into two classes. The first class embodies tests in which the long-run relationship among variables is known a priori (see Banerjee, 1999; Pedroni, 1999; 2004; Kao, 1999; Bai and Ng, 2004; and Westerlund, 2005; and Westerlund and Edgerton, 2007), while the second class is devoted to tests developed for the case where the cointegrating relationships are unknown a priori (see Larsson et al., 2001; Groen and Kleibergen, 2003; and Breitung, 2005).

The panel cointegration tests of Pedroni (1999) and Westerlund (2005) are conducted to provide robust evidence about cointegrating relationships among the variables.[7] As recommended by Pedroni (1999), we employ the group-ADF test since it performs well in small samples in terms of power and, therefore, leads to more reliable conclusions. The cross-section independence assumption is not credible and can be violated in practice in macroeconomic applications given the links that can characterize the countries of the panel. To handle dependence between countries, we complement the analysis by performing the bootstrapped version of the Lagrange multiplier statistic of Westerlund (2005) by extending the bootstrap test of Westerlund and Edgerton (2007).[8]

Each panel embodies three different models where we use in each one an energy type variable, but the other determinants of carbon

7 The test of Pedroni (1999) tests for no cointegration under the null hypothesis, while the test of Westerlund (2005) is constructed with cointegration under the null hypothesis.

8 The bootstrap version of the test has the advantage to strongly reduce the distortions of its asymptotic counterpart.

Table 3: Empirical correlations among energy type variables

Panel		EU	RSEC	EPC
Whole panel	EU	1.000	0.926	0.921
	RSEC		1.000	0.920
	EPC			1.000
GCC	EU	1.000	0.790	0.872
	RSEC		1.000	0.770
	EPC			1.000
North Africa	EU	1.000	0.951	0.712
	RSEC		1.000	0.849
	EPC			1.000
Middle East	EU	1.000	0.892	0.932
	RSEC		1.000	0.870
	EPC			1.000
Oil-rich	EU	1.000	0.906	0.951
	RSEC		1.000	0.910
	EPC			1.000
Non oil-rich	EU	1.000	0.778	0.810
	RSEC		1.000	0.801
	EPC			1.000

Table 4: Results of the panel cointegration tests for EU

Panel	LM test		Group-ADF test	
	Intercept	Trend	Intercept	Trend
Whole panel	1.295	1.358	−4.947***	−7.421***
	(0.999)	(0.999)	(0.000)	(0.000)
GCC	1.441	1.831	−1.304*	−4.591***
	(0.969)	(0.929)	(0.096)	(0.000)
North Africa	0.088	0.511	−1.905**	−2.749***
	(0.999)	(0.987)	(0.028)	(0.003)
Middle East	0.714	0.010	−5.362***	−5.513***
	(0.993)	(0.992)	(0.000)	(0.000)
Oil-rich	1.658	1.012	−3.248***	−5.448***
	(0.999)	(0.996)	(0.001)	(0.000)
Non oil-rich	0.088	0.905	−3.791***	−5.040***
	(0.999)	(0.966)	(0.000)	(0.000)

For all panels, CO_2 emissions is the dependent variable and the vector of independentvariables consist of energy use, real income, foreign direct investment, trade openness and urbanization. LM test is the test of Westerlund (2005) that is constructed with cointegration under the null hypothesis; and Group-ADF test is the test of Pedroni (1999) that is constructed with no cointegration under the null hypothesis. The values in parentheses refer to the P values. ***, ** and * denote cointegration at 1%, 5% and 10% levels, respectively.

Table 5: Results of the panel cointegration tests for RSEC

Panel	LM test		Group-ADF test	
	Intercept	Trend	Intercept	Trend
Whole panel	1.077	0.607	−7.632***	−8.068***
	(0.999)	(0.999)	(0.000)	(0.000)
GCC	1.249	0.678	−2.764***	−5.203***
	(0.948)	(0.954)	(0.003)	(0.000)
North Africa	0.893	0.880	−3.767***	−3.168***
	(0.998)	(0.987)	(0.000)	(0.001)
Middle East	−0.276	−0.506	−6.687***	−5.604***
	(0.999)	(0.999)	(0.000)	(0.000)
Oil-rich	1.294	0.117	−4.566***	−5.990***
	(0.999)	(0.999)	(0.000)	(0.000)
Non oil-rich	0.169	0.780	−6.343***	−5.405***
	(0.999)	(0.999)	(0.000)	(0.000)

For all panels, CO_2 emissions is the dependent variable and the vector of independent variables consists of energy use, real income, foreign direct investment, trade openness and urbanization. LM test is the test of Westerlund (2005) that is constructed with cointegration under the null hypothesis; and Group-ADF test is the test of Pedroni (1999) that is constructed with no cointegration under the null hypothesis. The values in parentheses refer to the P values. *** denotes cointegration at 1% level

Table 6: Results of the panel cointegration tests for EPC

Panel	LM test		Group-ADF test	
	Intercept	Trend	Intercept	Trend
Whole panel	0.427	−0.010	−7.671***	−7.123***
	(0.999)	(0.999)	(0.000)	(0.000)
GCC	0.433	−0.083	−4.491***	−4.530***
	(0.995)	(0.999)	(0.000)	(0.000)
North Africa	0.041	0.026	−−4.557***	−3.380***
	(0.999)	(0.998)	(0.000)	(0.000)
Middle East	0.266	0.039	−4.239***	−4.428***
	(0.999)	(0.999)	(0.000)	(0.000)
Oil-rich	0.971	0.029	−6.261***	−5.968***
	(0.999)	(0.999)	(0.000)	(0.000)
Non oil-rich	−0.444	−0.048	−4.506***	−4.012***
	(0.999)	(0.999)	(0.000)	(0.000)

For all panels, CO_2 emissions is the dependent variable and the vector of independent variables consists of energy use, real income, foreign direct investment, trade openness and urbanization. LM test is the test of Westerlund (2005) that is constructed with cointegration under the null hypothesis; and Group-ADF test is the test of Pedroni (1999) that is constructed with no cointegration under the null hypothesis. The values in parentheses refer to the P values. *** denotes cointegration at 1% level.

dioxide emissions are considered in all models. Indeed, in model 1, we consider the energy use per capita; in model 2, we consider the road sector energy consumption per capita; and in model 3, we use the electric power consumption per capita as proxies for energy. The results of the panel cointegration tests are provided in Tables 4-6 for the three models where each Table reports the results of all panels. A visual inspection of the results supports the evidence of long-run relationships between the CO_2 emissions and the selected determinants for all panels and models since all tests reject the no cointegration hypothesis regardless of whether or not deterministic time trend is included in the specification.[9]

9 The fact that the considered variables are cointegrated allows obtaining meaningful findings.

5.4. Long-run Estimates

The homogeneity of the long-run coefficients across countries for each panel and model is checked by the Hausman type test (see, Pesaran et al., 1996). The results (not presented) support the evidence of identical coefficients across economies over the long-run for all panels and models. The PMG long-run estimate results for all models and panels are displayed in Tables 7-9. Table 7 consists of results for all panels when using the energy use per capita in the model; Table 8 reports the results of all panels when measuring the energy variable by the road sector energy consumption per capita; and Table 9 presents the results of all panels when considering the electric power consumption per capita as energy type proxy.

Table 7: PMG long-run estimates for EU

		Dependent variable: CO_2					
		Whole panel	GCC	North Africa	Middle East	Oil-rich	Non oil-rich
Explanatory variables	EU	0.636***	0.160***	0.298***	0.578***	0.229***	0.539***
		(0.058)	(0.062)	(0.110)	(0.113)	(0.063)	(0.095)
	Y	0.239***	0.374***	0.354***	0.152*	0.437***	−0.180**
		(0.057)	(0.099)	(0.095)	(0.082)	(0.067)	(0.104)
	F	0.003	0.004	0.005	0.001	0.001	0.003
		(0.003)	(0.005)	(0.004)	(0.003)	(0.005)	(0.003)
	T	−0.008	−0.669***	−0.033	−0.025	−0.071**	−0.034
		(0.026)	(0.090)	(0.033)	(0.042)	(0.028)	(0.039)
	U	0.173	−2.344***	0.191	1.206**	−1.443***	−0.436
		(0.272)	(0.343)	(0.328)	(0.521)	(0.368)	(0.345)

The values in parentheses are the standard errors. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively

Table 8: PMG long-run estimates for RSEC

		Dependent variable: CO_2					
		Whole panel	GCC	North Africa	Middle East	Oil-rich	Non oil-rich
Explanatory variables	RSEC	0.229***	0.108	0.208***	0.399***	0.139**	0.263***
		(0.047)	(0.105)	(0.069)	(0.061)	(0.070)	(0.054)
	Y	0.186***	0.407***	0.255***	0.063	0.337***	−0.075
		(0.056)	(0.126)	(0.096)	(0.070)	(0.069)	(0.106)
	F	0.001	0.001	0.006	0.001	0.002	0.002
		(0.003)	(0.005)	(0.004)	(0.003)	(0.004)	(0.003)
	T	−0.014	−0.696***	−0.026	−0.080**	−0.067**	−0.033
		(0.024)	(0.094)	(0.032)	(0.036)	(0.029)	(0.047)
	U	−0.314	−2.341***	−0.176	1.168**	−1.037***	−0.301
		(0.272)	(0.290)	(0.343)	(0.486)	(0.346)	(0.430)

The values in parentheses are the standard errors. *** and ** denote statistical significance at 1% and 5% levels, respectively

Table 9: PMG long-run estimates for EPC

		Dependent variable: CO_2					
		Whole panel	GCC	North Africa	Middle East	Oil-rich	Non oil-rich
Explanatory variables	EPC	0.522***	1.032***	0.198*	0.565***	0.625***	0.611***
		(0.073)	(0.162)	(0.104)	(0.101)	(0.114)	(0.089)
	Y	0.231***	0.355***	0.208*	0.229**	0.356***	0.147
		(0.065)	(0.116)	(0.115)	(0.095)	(0.081)	(0.124)
	F	0.002	−0.004**	0.011***	0.002	−0.002	0.002
		(0.002)	(0.002)	(0.004)	(0.003)	(0.004)	(0.002)
	T	−0.093***	−0.241**	−0.063	−0.074*	−0.206***	−0.001
		(0.028)	(0.117)	(0.040)	(0.041)	(0.042)	(0.042)
	U	0.532	3.071***	−0.262	0.661	1.537	0.095
		(0.339)	(0.994)	(0.390)	(0.540)	(1.003)	(0.438)

The values in parentheses are the standard errors. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively

The findings of the global panel reveal that the three energy type variables have a statistically significant positive effect on the carbon dioxide emissions, with a noticeable feature that the energy use and electric power consumption have similar influence in terms of magnitude. It is also found that the CO_2 emissions respond positively to the movements of real GDP since a 1% increase in real income leads to an increase by 0.239%, 0.186% and 0.231% in CO_2 emissions for the three energy sources, respectively. Moreover, the trade openness exerts a significant negative effect on the CO_2 emissions only for the third model. However, the foreign direct investment and urbanisation do not have the power to significantly influence the CO_2 emissions for all models.

We now turn out to the results of the first class of panels (GCC, North Africa and Middle East). The results of the panel of Gulf countries indicate that only the energy use and electric power consumption significantly and positively affect the carbon dioxide emissions, with a greater impact for the latter energy proxy for which the long-run elasticity is larger than one. It is also seen that for all models, the real GDP and trade openness exert statistically significant positive and negative impacts on the CO_2 emissions, respectively. The foreign direct investment negatively influences the pollution emissions only for the third model. The urbanisation has a predictability power on the CO_2 emissions since it exerts a significant negative effect for the first two energy measures[10] and a positive impact when including the electric power consumption in the model. The estimates of the urbanisation coefficients are more important in absolute magnitudes than the coefficient estimates of the remaining determinants for all models. A striking evidence is that for the GCC region, all determinants influence the CO_2 emissions when using the electric power consumption as energy variable.

The estimate results of the panel of North African economies reveal that all energy variables are found to be significant determinants of the CO_2 emissions since they exert positive influence. They also show evidence of significant and positive effect of real GDP on pollution emissions for all energy proxies. In addition, the CO_2 emissions respond positively to the fluctuations of foreign direct investment when measuring the energy variable by the electric power consumption. However, the trade openness and urbanisation do not exert any impact on the carbon dioxide emissions whatever the energy proxy used in the model.

The coefficient estimates of the panel of Middle Eastern countries indicate that the three energy type variables are strongly significant and have the power to positively affect the pollution emissions. It is also observed that the impact of the energy use and electric power consumption on CO_2 emissions is very similar. The real GDP is significantly positive when using the energy use and electric power consumption as energy type variables. It is also noted that foreign direct investment does not significantly influence carbon dioxide emissions for any model, while urbanisation has a significant positive impact on CO_2 emissions only for the first two models. Trade openness is found to have a significant negative influence on pollution emissions for the road sector energy consumption and electric power consumption.

10 The influence of the urbanisation on CO_2 emissions is almost the same for the two energy variables.

We now discuss the results of the second class of panels (oil-rich and non oil-rich countries). The results of the panel of oil countries indicate that the three energy type variables are relevant determinants since they exert a significantly positive impact on pollution emissions. The real income elasticity of CO_2 emissions is statistically significant and positive for all models. The foreign direct investment does not have the power to predict the fluctuations of the carbon dioxide emissions whatever the used energy proxy. Trade openness negatively influences CO_2 emissions for all energy type variables. The pollution emissions respond negatively to the movements of urbanisation only for the first two models.

For the panel of non-oil economies, the results show evidence of statistically significant and positive association between the energy sources and CO_2 emissions. Unlike the results of all other panels, the real GDP has the power to significantly and negatively impact the carbon dioxide emissions only when including the energy use in the model. The foreign direct investment, trade openness and urbanisation have an insignificant effect on pollution emissions for all models.

From the above estimate results, we can draw interesting insights. First, the energy elasticity of CO_2 emissions is statistically significant and positive for all panels, except for the panel of GCC countries when measuring the energy variable by the road sector energy consumption. The significantly positive influence of energy type variables on carbon dioxide emissions may confirm somehow the strong correlation between the three measures for all panels, as mentioned in Table 3. A feature of substantial importance is that all energy elasticities are <1, except for the panel of Gulf economies for the third energy proxy where the elasticity is >1. This implies that the pollution emissions increase by a more important percentage that the electric power consumption does. For the first class of panels, the long-run energy elasticity ranges from 0.108 for the GCC countries in model 2 to 1.032 for the GCC countries in model 3. For the second class, it varies from 0.139 for the oil-rich economies in model 2 to 0.625 for the oil-rich economies in model 3. It is clear that the extreme values are observed for the same subset of countries and models in both classes of panels.

Second, the real income is found to be a relevant driver of the carbon dioxide emissions since it exerts a positive impact for most panels.[11] It is found that for these cases, the elasticity is <1, implying that higher real income gives rise to a less than proportionate boost in carbon dioxide emissions.[12] The exception is for the panel of Middle Eastern countries in model 2 and the

11 It is important to notice that by making comparison between the panels, we find that for the panels of GCC and oil-rich countries, the real income affects pollution emissions more importantly than the others do, suggesting that high-income economies of each class of panels pollute more environment. Overall, the long-run income elasticity is not high, explaining thus the moderate levels of carbon dioxide emissions that may be due to the fact that MENA countries slightly rely on local production and consumption.

12 Within this context, Jaunky (2011) outlines that people are concerned about protecting environment.

panel of non oil-rich countries in models 2 and 3 where the income elasticity is not statistically significant. In addition, the real GDP elasticity is significantly negative for the panel of non-rich economies in model 1. The high positive empirical correlations between carbon dioxide emissions, and energy type variables and real income (Table 2) may partly explain the obtained findings. It is also equally important to stress that the positive linkages between the energy type proxies and pollution emissions on the one hand and between the real income and CO_2 emissions on the other hand for almost all panels are unsurprising and consistent with empirical and theoretical studies revealing that an increase in energy consumption, a prerequisite for high GDP, generates a rise in pollution emissions. The long-run income elasticity ranges from 0.063 for the panel of Middle Eastern countries to 0.407 for the panel of GCC countries in model 2 for the first class of panels. It is between −0.180 for the panel of non oil-rich countries and 0.437 for the panel of oil-rich countries in model 1 for the second class of panels. It follows that the extremes values are observed in the same model for each class of panels.

Third, the foreign direct investment is significant and has marginal effect on carbon dioxide emissions for the panels of GCC and North African countries when using the electric power consumption as energy source. For the other cases, it does not have the power to influence pollution emissions. These insights may be due to the fact that foreign direct investment is conducted in less pollutant sectors.

Fourth, trade openness exerts significant negative impact on pollution emissions for the panels of GCC and oil-rich countries in all models, for the panel of Middle Eastern countries in models 2 and 3, and for the global panel in model 3. However, for the other cases, trade openness is statistically insignificant and negative.[13] In the same context, Hossain (2011) finds evidence of significant negative long-run effect of trade openness on carbon dioxide emissions for a panel of nine newly industrialized countries from 1971 to 2007. Jayanthakumaran et al. (2012) stipulate that the negative effect of trade on pollution emissions should be interpreted with caution since such effect may rely on the relative strength of many opposing factors. Stern (2004) indicates that the effect of trade on pollution emissions in the EKC literature in unclear.

Fifth, there is a significant positive linkage between urbanisation and pollution emissions for the panel of Middle Eastern economies when using the energy use and road sector energy consumption as energy type variables and for the panel of Gulf countries in model 3. This finding supports the view that more urbanized population leads to more pollution emissions through the pressures on urban resources given the high demand for goods and services that results from increasing migration of rural population to cities in search of jobs and better services. Moreover, urbanisation has the power to negatively influence CO_2 emissions for the panels of GCC and oil-rich countries in models 1 and 2. The urbanisation elasticity exceeds one in absolute value for all cases where there is statistical significance, showing thus evidence of high responsiveness of pollution emissions to changes in urbanisation. In fact, a 1% variation in the urbanisation gives rise to a variation by more than 1% in carbon dioxide emissions. There is also evidence of mixed insignificant coefficients for the urbanisation variable in some cases. Within the same context, Hossain (2011) shows that urbanization negatively affects pollution emissions in the long-run for a panel of nine newly industrialized economies. In addition, Duh et al. (2008), Kahn and Schwartz (2008), and Li and Yao (2009) outline that sterner environmental policies and regulations may be required for increasing urbanisation and population.

13 The results do not comply with the Heckscher-Ohlin trade theory stipulating that trade openness positively influences pollution emissions through the production process of goods and services that requires more consumption and processing of goods.

5.5. Short-run Estimates and Error Correction Mechanism

Having estimated the long-run relationship between pollution emissions and the related determinants for all panels and specifications, we now turn out to the study of the short-run interactions among variables and the adjustment speed towards the long-run equilibrium state using the PMG approach[14]. The estimate results are summarized in Tables 10-12. All variables are found to be relevant drivers of the carbon dioxide emissions for all panels and whatever the considered energy type variable since they are statistically significant at 1% level.

With regard to the coefficient sign, the estimates have the same sign as those obtained over the long-run for all panels and models. In terms of absolute magnitude, the energy, income and urbanisation short-run elasticities of CO2 emissions are smaller than those found over the long-run for all panels and energy sources. The short-run estimates of trade openness are smaller than the long-run estimates, except for the panel of non oil-rich countries when considering the electric power consumption as determinant of pollution emissions. For the foreign direct investment, the results are mixed for all energy type variables. For the first differenced variables, the results show evidence of statistically significant coefficients for some panels and models.

The one-period lagged error correction term coefficients are statistically significant and negative (correctly signed) for all panels and energy type variables, implying a return to the long-term equilibrium level in the case of disequilibrium.[15] Moreover, this finding suggests that the growth of carbon dioxide emissions is significantly influenced by the long-run equilibrium deviation. For the global panel, we need 1.66 years for model 1, 1.59 years for model 2 and 1.78 years for model 3 to reach the long-run equilibrium.

14 The heterogeneity of the short-run coefficients allows the dynamic specification of the model to be different across countries, and may be attributed to some specific features that characterize each country in terms of pollution and economic regulations.

15 The significant negativity of the error correction terms provides extra support for the stable long-run relationships between pollution emissions and the considered determinants for all panels and specifications. Moreover, the estimate values of the error correction terms tell us about the strong predictability of the linkages between pollution emissions and the related determinants. In addition, there is evidence of mean-reversion of the spread movement.

Table 10: PMG short-run estimates for EU

		Dependent variable: D (CO_2)					
		Whole panel	GCC	North Africa	Middle East	Oil-rich	Non oil-rich
Explanatory variables	EU	0.218***	0.106***	0.208***	0.375***	0.151***	0.333***
		(0.026)	(0.032)	(0.050)	(0.044)	(0.022)	(0.060)
	Y	0.143***	0.250***	0.247***	0.098***	0.289***	−0.112***
		(0.017)	(0.075)	(0.059)	(0.012)	(0.042)	(0.020)
	F	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	T	−0.005***	−0.446***	−0.023***	−0.016***	−0.047***	−0.021***
		(0.001)	(0.135)	(0.006)	(0.002)	(0.007)	(0.004)
	U	0.104***	−1.564***	0.134***	0.782***	−0.953***	−0.270***
		(0.012)	(0.471)	(0.032)	(0.092)	(0.138)	(0.048)
	D (EU)	0.244	0.311***	0.305	0.108	0.139	0.382
		(0.157)	(0.091)	(0.469)	(0.131)	(0.150)	(0.308)
	D (Y)	0.221	0.043	0.479	0.091	0.192	0.235
		(0.135)	(0.273)	(0.336)	(0.074)	(0.218)	(0.191)
	D (F)	−0.002	−0.011	−0.002	−0.001	−0.001	−0.006
		(0.007)	(0.015)	(0.009)	(0.004)	(0.011)	(0.005)
	D (T)	−0.198**	−0.155	−0.054	−0.056**	−0.233	−0.026*
		(0.094)	(0.239)	(0.059)	(0.026)	(0.149)	(0.015)
	D (U)	−9.237*	−18.388	−2.736	−4.961	−18.083**	−1.247
		(5.008)	(15.717)	(9.123)	(6.631)	(7.601)	(4.726)
	Adj. speed	−0.601***	−0.667***	−0.698***	−0.649***	−0.660***	−0.619***
		(0.071)	(0.201)	(0.168)	(0.077)	(0.096)	(0.110)
	Trend	0.002	0.020*	0.001	−0.006	0.010**	0.006***
		(0.002)	(0.012)	(0.002)	(0.004)	(0.005)	(0.002)
	Intercept	−2.268***	7.087***	−3.019***	−5.508***	1.866***	0.136
		(0.286)	(2.066)	(0.751)	(0.612)	(0.277)	(0.140)

'D' stands for the first difference operator. The values in parentheses are the standard errors. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively

Table 11: PMG short-run estimates for RSEC

		Dependent variable: D (CO_2)					
		Whole panel	GCC	North Africa	Middle East	Oil-rich	Non oil-rich
Explanatory variables	RSEC	0.144***	0.070***	0.150***	0.295***	0.093***	0.162***
		(0.014)	(0.021)	(0.027)	(0.021)	(0.012)	(0.025)
	Y	0.117***	0.264***	0.184***	0.046***	0.226***	−0.046***
		(0.012)	(0.079)	(0.034)	(0.003)	(0.030)	(0.007)
	F	0.003***	0.003***	0.005***	0.004***	0.003***	0.003***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	T	−0.009***	−0.452***	−0.019***	−0.059***	−0.045***	−0.020***
		(0.001)	(0.134)	(0.003)	(0.004)	(0.006)	(0.003)
	U	−0.197***	−1.521***	−0.128***	0.865***	−0.695***	−0.186***
		(0.020)	(0.452)	(0.023)	(0.063)	(0.091)	(0.029)
	D (RSEC)	0.088	0.049	0.103	−0.073	0.064	0.112
		(0.075)	(0.081)	(0.123)	(0.122)	(0.115)	(0.104)
	D (Y)	0.285**	0.024	0.393	0.257***	0.344*	0.168**
		(0.114)	(0.024)	(0.278)	(0.090)	(0.197)	(0.068)
	D (F)	0.002	0.001	0.005	−0.002	0.003	−0.002
		(0.006)	(0.001)	(0.011)	(0.003)	(0.010)	(0.004)
	D (T)	−0.183	0.001	−0.046	0.001	−0.255	0.005
		(0.115)	(0.001)	(0.047)	(0.010)	(0.190)	(0.011)
	D (U)	−11.658**	−8.315	−4.463	−7.139**	−19.885**	−1.378**
		(5.695)	(15.294)	(10.169)	(3.427)	(8.317)	(4.520)
	Adj. speed	−0.627***	−0.650***	−0.723***	−0.741***	−0.670***	−0.617***
		(0.062)	(0.193)	(0.132)	(0.054)	(0.088)	(0.097)
	Trend	0.006**	0.022**	0.003	−0.002	0.009	0.009***
		(0.003)	(0.011)	(0.003)	(0.002)	(0.006)	(0.001)
	Intercept	−0.035	7.184***	−0.923***	−4.343***	2.017***	0.575**
		(0.148)	(2.100)	(0.290)	(0.312)	(0.247)	(0.225)

'D' stands for the first difference operator. The values in parentheses are the standard errors. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively

Table 12: PMG short-run estimates for EPC

		Dependent variable: D (CO_2)					
		Whole panel	GCC	North Africa	Middle East	Oil-rich	Non oil-rich
Explanatory variables	EPC	0.294***	0.738***	0.143***	0.341***	0.367***	0.353***
		(0.035)	(0.186)	(0.019)	(0.074)	(0.068)	(0.058)
	Y	0.130***	0.254***	0.150***	0.138***	0.209***	0.085***
		(0.015)	(0.064)	(0.020)	(0.030)	(0.039)	(0.014)
	F	0.004***	−0.003***	0.008***	0.004***	−0.005***	0.006***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	T	−0.052***	−0.173***	−0.045***	−0.044***	−0.121***	−0.006***
		(0.006)	(0.044)	(0.006)	(0.010)	(0.023)	(0.001)
	U	0.300***	2.195***	−0.189***	0.398***	0.903***	0.055***
		(0.035)	(0.554)	(0.025)	(0.087)	(0.168)	(0.009)
	D (EPC)	−0.155*	−0.072	0.017	−0.140	−0.298***	−0.043
		(0.090)	(0.167)	(0.137)	(0.152)	(0.113)	(0.127)
	D (Y)	0.402***	−0.211	0.597*	0.210**	0.485*	0.270
		(0.155)	(0.148)	(0.326)	(0.090)	(0.261)	(0.188)
	D (F)	0.001	0.002	−0.001	−0.002	0.004	−0.003
		(0.005)	(0.002)	(0.008)	(0.005)	(0.007)	(0.004)
	D (T)	−0.204*	0.003	−0.016	−0.019	−0.337*	−0.011
		(0.120)	(0.003)	(0.056)	(0.029)	(0.197)	(0.026)
	D (U)	−7.990	−8.300	−5.197	−4.552	−13.975	−1.674
		(5.161)	(16.292)	(9.120)	(3.320)	(9.915)	(3.170)
	Adj. speed	−0.563***	−0.715***	−0.722***	−0.603***	−0.588***	−0.577***
		(0.066)	(0.180)	(0.095)	(0.131)	(0.109)	(0.096)
	Trend	−0.006***	−0.010**	0.003	−0.010**	−0.006	−0.009***
		(0.002)	(0.005)	(0.003)	(0.005)	(0.004)	(0.002)
	Intercept	−3.200***	−15.734***	−0.550*	−3.843***	−6.692***	−2.599***
		(0.386)	(3.992)	(0.313)	(0.839)	(1.340)	(0.432)

'D' stands for the first difference operator. The values in parentheses are the standard errors. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively

For the first class of panels, the estimate values slightly differ across panels and energy type variables since they range from −0.741 for the panel of Middle Eastern countries in model 2 to −0.603 for the panel of Middle Eastern countries in model 3, indicating that the extreme values are observed for the same panel in two different models. Accordingly, the deflections from the long-run in the current year will be redressed by 60.3% to 74.1% in the next year, implying that the error correction mechanism of the short-run deviations of the carbon dioxide emissions following a shock takes 1.35-1.66 years to reach the long-term state according to the panel and model. For the second class of panels, the error correction term ranges from −0.670 for the panel of oil-rich economies in model 2 to −0.577 for the panel of non oil-rich countries in model 3. This indicates that we need 1.49-1.73 years to restore the long-run equilibrium state according to the panel and model. Overall, the adjustment speed is quick for all panels and models since the convergence process to the equilibrium following a shock of the carbon dioxide emissions takes <2 years, supporting the little control over pollution emissions growth.

5.6. The EKC Hypothesis

Various ways adopted in the literature consist in testing for a cointegrating relationship between carbon dioxide emissions and selected independent variables and using the long- and short-run income elasticities to test the validity of the EKC hypothesis. Within this context, the EKC hypothesis is supported when a rise in income increases carbon dioxide emissions in the long-run and that there is evidence of inverted U-shape pattern at which point emissions reduce following an increase in income. Narayan and Narayan (2010) argue that the turning points are unrealistic in the extant literature, reflecting thus problems with the considered model specification. To correct this and given the collinearity between income and its different variants, the authors propose another way to judge the validity of the EKC hypothesis based on both the long- and short-run income elasticities. Indeed, the EKC hypothesis holds if the long-run income elasticity is lower than the short-run income elasticity, implying that the CO_2 emissions fall following an increase in income.

The results reveal that the elasticity of carbon dioxide emissions with respect to real income is significantly negative for the panel of non oil-rich countries when including the energy use as energy type proxy in the model.[16] In addition, it passes from −0.112 in the short-run to −0.180 in the long-run, which is consistent with the EKC hypothesis according to Narayan and Narayan (2010) since higher income leads to less pollution emissions. One possible explanation is that the economies of interest are not oil-based economies and do not embrace energy-intensive industries, leading thus to reduce carbon dioxide emissions.

For the other panels, the long- and short-run income elasticities of pollution emissions are positive. Moreover, it is clear that the long-run income elasticity is greater than the short-run income elasticity, implying that following the conjecture of Narayan and Narayan (2010), the EKC hypothesis is not supported. This suggests that CO2 emissions increase more following a rise in real GDP over time, suggesting thus a monotonically increasing relationship between pollution emissions

16 Jaunky (2011) indicates that in this case, there is evidence of massive use of green technology in the production process, and that individuals are concerned about degrading the environment.

and income. This may be explained by the fact that most countries of all panels are oil-based countries that encompass energy-intensive sectors, contributing thus to increase their level of pollution.

Within the same context, Narayan and Narayan (2010) opt for panel cointegration and estimation procedures, and find that for one third of the sample composed of 43 developing economies, the EKC hypothesis is supported. Moreover, they examine the EKC hypothesis for regional panels, and reveal evidence of fall in carbon dioxide emissions following a rise in income for only the Middle Eastern and South Asian panels. Jaunky (2011) finds that the EKC hypothesis is supported for 5 out of 36 high-income economies as there is evidence of long-run linkages between emissions and income, and significant negative long-run elasticity of pollution emissions with respect to income. Moreover, following the conjecture of Narayan and Narayan (2010), the EKC hypothesis holds for the whole panel and two other individual countries. Ang (2007), Apergis and Payne (2009), Halicioglu (2009), and Arouri et al. (2012) find similar conclusions based on different econometric approaches. In fact, their results support the EKC hypothesis in the sense that the relationship between pollution emissions and real income appears to be inverted U-shaped as the emissions initially rise with income, stabilize and then decrease.

6. CONCLUSION AND POLICY IMPLICATIONS

The current paper aims at examining empirically the determinants of carbon dioxide emissions for 18 MENA countries during the period from 1980 to 2018 in the framework of dynamic heterogeneous panel models. In addition to energy consumption and income, the study includes other variables such as foreign direct investment, trade openness and urbanization to avoid the bias problem of omitted variables.

The results provide evidence of long-run relationships between CO_2 emissions and the considered determinants for all panels and energy sources. Also, energy consumption, real GDP, foreign direct investment, trade openness and urbanisation are found to be relevant determinants of carbon dioxide emissions for all panels and energy type variables over the short-run. However, there is evidence of mixed results over the long-run since some determinants are not statistically significant for some cases.

The main policy implications emanating from our results are summarized as follows. First, the long-run energy elasticity is greater than the short-run energy elasticity, suggesting that stronger energy consumption leads to more carbon dioxide emissions over time. As a result, the environmental quality is poor since the environment is becoming increasingly polluted. The implication is that strict environmental regulations and energy conservation strategies should be established to curb pollution emissions without impeding the level of economic activity given the close relation between energy consumption and economic activity.

Second, the increase in income leads to less pollution emissions over time in the panel of non-oil countries since the income elasticity of emissions is significantly negative and smaller in the long-run compared to the short-run when using the energy use in the specification, which supports the EKC hypothesis. This finding implies that the non-oil economies are fully aware of the dangers of environmental pollution, which pushes them to strictly control their pollution level. Moreover, the low process of industrialization of these economies may help to reduce the carbon dioxide emissions.

Third, for the other panels of countries, the elasticity of carbon dioxide emissions with respect to income is significantly positive and larger in the long-run compared to the short-run, leading thus to more pollution emissions over time when income rises. This provides evidence of a monotonically increasing relationship between pollution emissions and income, and does not support the EKC hypothesis for the panels and models of interest. This finding implies that the economies are not aware of the dangers of environmental pollution and, therefore, they have not opted for strict environmental policies to fight against pollution. These policies should not be performed at the expense of economic activity in the considered countries to reach a sustainable scale of economic activity in a clean environment.

Other policies such as tax system on CO_2 emissions, investment in clean energy, and use of solar and wind energy[17] may be undertaken to control the pollution emissions for all panels and, therefore, to avoid the effects of calamities and disasters that may lead to affect human health, reduce productivity, etc. All these policies should be implemented without affecting the economic activity for all panels. Within the same context, Doukas et al. (2006) argue that more energy efficiency in the Gulf countries could perform well in reducing pollution emissions. Moreover, Reiche (2010) indicate that new policies are explored in these countries, but there are no tangible and consistent results in this context.

In the related literature, empirical evidence on the EKC hypothesis is mixed and conflicting. For instance, Narayan and Narayan (2010), and Arouri et al. (2012) find no evidence of the EKC hypothesis for Oman, which conflicts with the result of Jaunky (2011) who provides evidence of the EKC hypothesis for such a country. Arouri et al. (2012) find that the EKC hypothesis holds for a panel of 12 MENA countries as a whole over the period 1981-2005, which does not comply with our findings for the global panel consisting of 18 countries from 1980 to 2018. Within the same context, Lee et al. (2010) find that the EKC hypothesis is verified for the global panel and not for the four subsets they consider. Bernard et al. (2015) show evidence of the EKC hypothesis for the whole panel and only for the panel of OECD countries as a sub-panel. The mixed and conflicting findings on the EKC hypothesis may then be due to some reasons such as the way to define the variables, the time frame, the panel of countries and the econometric techniques. As a result, the findings of the EKC hypothesis cannot be compared in a strict sense.

17 A project of Masdar Sustainable City was taken in some MENA countries to generate solar and wind power, with a view of improving the situation in matter of control of pollution emissions.

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