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Empirical Analysis of an EKC for SO2 Emissions in Selected Middle East and North African Countries

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ABSTRACT

Studying the impact of economic growth on the environment in the context of developing countries has become of increasing economic importance in recent years. Alarming international reports showed that pollutants emissions are growing at their highest level ever, particularly in the South.
This study implements recent bootstrap panel unit root tests and cointegration techniques to investigate the relationship between Sulfur dioxide emissions and real GDP for 12 MENA countries over the period 1981–2005. Our investigations lead to the result that no evidence is found for the EKC for 10 country of the region. However EKC is valid for the case of Egypt and Tunisia which are the most industrialised and diversified economies in our sample. At the same time our finding showed that EKC is not valid for the region when token as a whole.

JEL Classification: C23, O11, Q25, Q28

Key words: Environmental Kuznets Curve, Sulfur Dioxide emissions, Economic Growth, panel data, MENA countries

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1. INTRODUCTION

Environmental Sustainability Index (ESI) report of 2005[2], shows that countries from the MENA region are characterized by low or moderate system, stresses, vulnerability and low capacity and stewardship. The same conclusion is found by the new version of the ESI called the Environmental Performance Index (EPI)[3] in 2010. This last index, divide the MENA region into two distinct groups. The first one is composed of Algeria, Morocco, Tunisia, Syria, Egypt, Lebanon, Iran and Jordan. Their main characteristics are that they perform well in terms of environmental burden of disease and indoor air pollution. They also have roughly average results on most other indicators, but poor air pollution performance. Their scores on urban particulates and industrial carbon dioxide performance scores fall far below other clusters.

The second group is composed of Bahrain, Kuwait, Libya, Oman, Qatar, Saudi Arabia, United Arab Emirates, Sudan and Yemen. This cluster is comprised of mainly fossil fuel producing and processing nations and too low-income countries. They perform well on the environmental burden of disease but poorly on outdoor air pollution. Their scores are among the lowest in some of the water indicators, but most notably, they have the worst greenhouse gas per capita performance of all the clusters.

The question of sustainability of growth in MENA Countries becomes central. From the one hand, environmental constraints may lead to lower the necessary growth for the region in a context of demographic boom associated with a high level rate of unemployment. From the other hand new opportunities and benefits from technological transfer may lead to better trend of growth and sustainability. One of the most important questions that arise in this context is: what is until now, the nature of the relation between economic growth and environmental quality in MENA countries? Do we have the same trends than elsewhere, or is there some specificity for the region?

According to the Environmental Kuznets Curve (EKC) hypothesis, as income increases, environmental degradation (emissions) increases as well until some threshold level of income is reached after which the environmental degradation (emissions) begin to decline.

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[2] Between 1999 and 2005 the Yale and Columbia team published four Environmental Sustainability Index reports (http://sedac.ciesin.columbia.edu/es/esi/) aimed at gauging countries' overall progress towards "environmental sustainability".

[3] The 2010 EPI ranks 163 countries on 25 performance indicators tracked across ten well-established policy categories covering both environmental public health and ecosystem vitality. These indicators provide a gauge at a national government scale of how close countries are to established environmental policy goals. A pilot exercise was conducted in 2006 and a complete report was published in 2008.

An extensive literature has shown that EKC was validated for different local pollutants in (Organisation for Economic Cooperation and Development) OECD countries. Most of OECD have shifted from the first branch of the curve, due to their income per capita level, to the second branch in pollutants especially for local pollutants like Sulphur' dioxide, PMP10, NOx and River pollutants. An extensive literature has discussed the theoretical foundation of such findings.

The picture seems quite different for developing countries, especially Middle East and North African (MENA) Countries. Most of recent works show that there is no evidence for supporting the U-shaped curve of EKC for the region and the theoretical values of the turning points are very high.

In a recent paper, Arouri et al, (2012) found an evidence of a U-shaped curve between economic growth and Carbon Dioxide for MENA countries at the regional level. At the main time they did not found any evidence at country level – except for Jordan. Our approach is to extend this work using the same econometric approach in order to examine whether or not the relationship still valid for a local pollutant like SO2.

Starting from these considerations, the aims of this work are threefold: First, to verify the existence of EKC in the 12 countries belonging to MENA Countries in matter of Sulfur' dioxide. Second, to characterize the theoretical values of the turning points until which the development improves the environmental quality, measured by Sulfur Dioxide in our case, in MENA Countries. Third, we want to understand the nature of the causality relationship between economic growth and emissions of SO_2. Our research relies on the empirical verification of EKC (Coondoo and Dinda, 2002 & 2006; Stern, 2004; Müller-Fürstenberger and Wagner, 2007; Ang, 2007; Caviglia-Harris et al. 2009; Lee and Lee, 2009) and especially those focusing on MENA Countries (Lise, 2006; Akbostanci et al. 2009, Fodha and Zaghdoudi, 2009, Arouri et al, 2012).

Three main arguments justify our choice of SO_2 emissions as the environmental quality proxy in order to test the existence of the Kuznets Curve.

First, emissions of Sulphur dioxide SO2 are among the most important forms of energy-related pollution. They originate primarily from stationary sources in the industrial and power-generating sector, and SO2 emissions are known for their adverse effects on human health and the natural environment (EPA 2007).

Second, although global sulphur emissions have increased over much of the last century, levels have begun to decline in recent decades. By 2000, global emission was approximately 25 percent lower than the peak level observed in the 1980s. Nevertheless, this decline was not homogenous across world regions. Whereas emissions are still rising in many developing countries, industrialized countries experienced an especially strong decline with emission reductions of more than 50 percent from 1970 to 2000. Obviously, it is important to understand if this decline is also observed in MENA Countries.

Third, Sulphur dioxide is produced by burning fossil fuels and is primarily emitted from stationary sources in the industrial generating sector (Olivier et al. 2005). Specifically, lignite and hard coal have high Sulphur contents so that their combustion is responsible for a large part of global Sulphur dioxide emissions. Yet, since the beginning of the 1970's, more end-of-pipe technologies, such as flue-gas desulfurization have been adopted to filter Sulphur dioxide. The existence of an EKC can reveals the extent to which MENA countries are adopting these new technologies.

The paper is structured like the followings: Section 2 surveys the theoretical foundation of the EKC, section 3 synthesis of the associated empirical studies and discusses their findings. Section 4 presents the data and the econometric models. Section 5 discusses the results. Section 6 recommends the appropriate policies and concludes.

2. LITTERATURE REVIEW

2.1. Theoretical explanations of the nature of the SO2-economic growth relationship

Generally the impacts of economic development on environment are disaggregated into three macro determinants: scale effect, technique effect, and composition effect (Grossman 1995; Copeland and Taylor 2004; Brock and Taylor 2006). The Scale Effect (SE) refers to the fact that increases in output require more inputs, and, as a by-product, imply more emissions. Economic growth therefore exhibits a scale effect that has a negative impact on the environment (Arrow, 1995). The Technique Effect (TE) refers to the invention of new technologies which are environmental friendly and to the application of these new technologies in production which in turn lead to the reduction of the pollution of the environment (Andreoni and Levinson, 2001). The impact of the technique effect is theoretically positive (de Bruyn 1997, Han and Chatterjie, 1997). The Composition Effect (CE) stems from changes in production of an economy caused by specialization (from agriculture or/and basic industries to high-tech services). All else equal, if the sectors with high emission intensities grow faster than sectors with low emission intensities, than composition changes will result in an upward pressure upon emission (Dasgupta, Mody, Roy, and Wheeler, 1995). The expected impact of the composition effect is positive deriving from the Rostow evolution postulate. Due to the different nature of these individual effects, the overall impact of growth on the environment is ambiguous (Grossman and Krueger (1991), Panayotou, (1997), and Cole (2004)).

Taking into account the nature of the Sulfur Dioxide as specific pollutant, several explanatory factors were proposed in order to explain the nature of the relationship between economic growth and SO2 Emissions: (i) the decomposition of the economy structure, (ii) adoption of new technologies and innovation, (iii) demographic factors like the structure of the population or the population density, (iv) environmental regulation, institutions and control system, and, (v) energy consumption structure.

According to De Bruyen (1997) change in industrial structure is the main factor affecting trends in SO2 emissions. Stern (2004 and 2005) asserts that changes in technology can lead with time to reductions in pollution-lowering of EKC- in both developing and developed countries. Case studies, particularly in China, show that pollution-reducing innovation and standards may be adopted with relatively short time lags in some developing countries. "Stern (2004b proposes that at middle-income levels, rapid growth can overwhelm these clean-up efforts, which have more effect in slower-growing higher income countries". Several articles show that population density is negatively correlated with sulfur dioxide emissions (Selden and Song, 1994, Cole and Neumayer, 2004 and Farzin and Bond, 2006). The main explanations are lower transportation requirements and higher environmental preferences in populated areas. Population compositional change has also considerable environmental policy implication. Recently, Menz and Kühling (2011) show that "Societies with a low population and young and high proportion of senior citizens emit more Sulfur Dioxide". They verified these facts for 25 EOCD Countries from 1970 to 2000. Panayotou (1997) demonstrated that improvement of environmental quality is dependent on environmental policy and environmental control system. For (Menz and Kühling, 2011), three proximate factors actually determine national Sulfur dioxide emissions: total national energy consumption, importance of fossil fuels with high Sulfur contents in the process of energy generation (energy mix), and usage of en-of-pipe technologies.

2.1. Empirical Validation of EKC for Sulfur Dioxyde

Sulfur emissions show the most typical environmental Kuznets curve among the air pollutants. A wide range of publications shows that SO2 EKC is empirically validated for most of EOCD countries. Since the findings of Selden and Song (1994) and Grossman and Krueger (1995) a plethoric literature has examined the EKC for Sulfur dioxide using several methodological and econometrical approaches. EKC was validated when we look at a regional level (sub set of countries) or at a single country level. Stern (1998) claims that the evidence for the inverted-U relationship applies only to a subset of environmental measures, e.g. air pollutants such Sulphur Dioxyde or suspended particulates in EOCD Countries. Cole and al. (1997), Selden and Song (1994), Stern and Common (2001) and Halkos (2003) supported the existence of U-shaped relationship between emissions and income for a sample dominated by, or solely of EOCD countries. Markandya et al. (2006) found a link between SO2 emissions and GDP per capita for 12 Western European Countries over a period of more than 150 years. They validate EKC either at the aggregate level and country level. Wang (2010) confirm the existence of Long-run Sulfur-income relationship and support the existence of EKC for 19 EOCD countries[4] during the period 1870-2001.

Understanding past emission patterns in EOCD countries has numerous insights for future emission projection especially in developing countries. One of the most important Case Studies is China. China has experienced rapid economic growth during last two decades and one can ask if this rapid growth has led to the validation of EKC for SO2. Recent works find that even in developing countries like China SO2 emissions and GDP per capita are following an EKC. Gao et al. (2011) found that EKC is valid for SO2 emissions in China during the last period for 29 Chinese provinces during the period between 2000 and 2008. Mou et al. (2011) find that the relationship between economic development and SO2 pollution during the period 2000-2008 in the biggest city in China (Chongqing) is following an EKC. They validate the findings of Gao et al. (2011) at smaller scale. Huang et al. (2009), state that however “in the case of China, air pollution control policies have been established. However, because of continuous increasing of GDP, emission reduction effect per capita has not been seen yet”.
Vincent (1997) shows that there is no confirmation of SO2 EKC for Malaysia.

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[4] These 19 EOCD countries are Australia, Austria, Belgium, Canada, Denmark, Finland, Germany, France, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

Few studies have challenged SO2 EKC for the MENA region. Chebbi and al. (2009) using the cointegration analysis reveals a positive linkage between trade openness and per capita emissions and a negative linkage between economic growth and per capita pollution emissions in the long-run. Fodha and Zaghdoudi (2010) provide support for a long-run N-shape relationship between the per capita emissions of SO2 and per capita GDP. They confirm the EKC hypothesis. Akbostanci and al. (2009) examined the relationship between SO_2 emissions, energy consumption and economic growth in Turkey at two levels. They have looked for the EKC at national level and also for the 58 provinces in Turkey. They found a monotonic and increasing relationship at the national level. However, they found an N shaped curve at provinces levels. Their findings do not support the EKC.

Regarding The turning point values, the results show a large dispersion across different studies. According to Lieb (2003) the reported turning points for Sulphur Dioxide range from USD 2900 to USD 908200 (in PPP USD 1985). The calculations are very sensitive to the estimation methods and the econometrics used. Recent studies show that turning point for most EOCD countries range from US$ 5000 to US$ 10000. Stern and Common (2001) show that the turning point in EOCD countries is US$ 9000. Markandya et al. (2006) found a turning point at US$ 11900 in 1990 PPP dollars. The turning points in non-EOCD countries are extremely high and show unilateral increase for most of them. The calculations of the turning point in non-EOCD countries are subject to a new empirical literature.

Our work extends the finding of this literature by examining the situation at two levels. The first level is for the whole region (12 MENA countries) and the second level is national level. Our findings support the sensitivity of the EKC to the level of observation. Stern (2004) asserts that a large portion of EKC literature is statistically weak and when these statistical problems are taken into account and appropriate techniques are used, EKC cannot exist". We challenge this view in our paper and we show that using recent and appropriate econometrics leads to the existence of EKC in MENA Countries[5].

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[5] Another concern is related to the environmental indicators' measurements. The "measures of the environmental degradation fall in two general categories: emission of the pollutants and environmental concentrations of pollutants" (Kaufman et al., 1998, p210). These two measurements illustrate different aspects of the environmental degradation situation and neither of them can offer a comprehensive description. "Emission directly measures the amount of pollutants generated by economic activities during a period without regarding to the size of the area into which the pollutants are emitted". It is actually a flow measurement for the polluting

3. METHODOLOGY AND EMPIRICAL RESULTS

3.1. Data

We investigate in this section the determinants of SO_2. In this optic, we investigate the relationship between SO_2 emissions, energy consumption and GDP in MENA region using recent panel econometric methods. As several MENA countries have signed Kyoto protocol, there are still concerns regarding the environmental problems. As discussed above, the relationship between SO_2 emissions, energy consumption and economic growth is a synthesis of the EKC and energy consumption growth literatures.

To conduct our empirical analysis, we need the following variables for all studied MENA countries:

- the SO_2 emissions (S);
- the per capita real GDP (Y).

We collect data form World Bank Development Indicators (WDI) and (Joint Research Center, JRC| Netherlands Environmental Assessment Agency, PBL: EDGAR[6]). Our data are annual and cover the period 1981-2005 for the following MENA countries: Algeria, Bahrain, Egypt, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Tunisia and UAE. The variables S, E, and Y are measured in metric tons per capita, kt of oil equivalent per capita, metric tons (divided by the land area populated at more than five persons per square kilometer) and constant 2005 international dollar, respectively.

At first, we empirically investigate the following model based on variables in natural logarithms:

$$S_{it} = a_i + b_i Y_{it} + c_i Y_{it}^2 + \varepsilon_{it} \quad (1)$$

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capacity of economic activities. “The concentration measures the quality of pollutants per unit area without regarding to the activity that emitted them”, it is more like a stock measurement describing the final result of the encounter between emission, abatement efforts and the self-purification capacities of nature. As concentration is a more direct environmental quality indicator and has more direct impact on productivity and public health, Selden and Song (1994) believe it should be easier to obtain an inverted-U curve for concentration than for emission indicators.

[6] Emissions (EM) for a country C are calculated for each compound x on an annual basis (y) and sector wise (for i sectors, multiplying on the one hand the country-specific activity data (AD), quantifying the human activity for each of the i sectors, with the mix of j technologies (TECH) for each sector i, and with their abatement percentage by one of the k end-of-pipe (EOP) measures for each technology j, and on the other hand the country-specific emission factor (EF) for each sector i and technology j with relative reduction (RED) of the uncontrolled emission by installed abatement measure k.

The coefficients *b*, *c* and *d* represent the long-run elasticity estimates of SO_2 emissions with respect to real GDP and squared real GDP, respectively. According to the discussion above, we expect that an increase in energy consumption leads to an increase in SO_2 emissions ($b>0$). Moreover, under the EKC hypothesis an increase in income is associated with an increase in SO2 emissions($c>0$) and there is an inverted U-shape pattern at which point an increase in income leads to lower SO_2 emissions ($d<0$).

In what follows, we start by testing for unit roots in our variables. If these variables are non-stationary in our country panel, we investigate the existence of long run cointegration relationships and investigate their magnitude. Finally, we estimate panel error correction models (ECM) in order to examine the interactions between short and long run dynamics of our environmental variables.

4.2. Panel unit root testing

The body of literature on panel unit root and panel cointegration testing has grown considerably in recent years and now distinguishes between the first-generation tests [Maddala and Wu (1999), Levin *et al.* (2002) and Im *et al.* (2003)] developed on the assumption of the cross-sectional independence of panel units (except for common time effects), the second-generation tests [Bai and Ng (2004), Smith *et al.*(2004), Moon and Perron (2004), Choi (2006) and Pesaran (2007)] allowing for a variety of dependence across the different units, and also panel data unit root tests that make it possible to accommodate structural breaks [Im and Lee (2001)]. In addition, in recent years it has become more widely recognized that the advantages of panel data methods within the macro-panel setting include the use of data for which the spans of individual time series data are insufficient for the study of many hypotheses of interest. To test for the presence of such cross-sectional dependence in our data, we have implemented the simple test of Pesaran (2004) and have computed the CD statistic. This test is based on the average of pair-wise correlation coefficients of the OLS residuals obtained from standard augmented Dickey-Fuller regressions for each individual. Its null hypothesis is cross-sectional independence and is asymptotically distributed as a two-tailed standard normal distribution. Results available upon request indicate that the null hypothesis is always rejected regardless of the number of lags included in the augmented DF auxiliary regression (up to five lags) at the five percent level of significance. This confirms that the MENA countries are, as expected, cross-sectionally correlated, which can indeed reflect here the presence of similar regulations in various fields (such as environmental policy and regulation, economy, finance, trade, customs, tourism, legislation, and administration), high economic, fiscal and political corporation and increasing financial and economic integration.

To determine the degree of integration of our series of interest (S, E, Y, and Y^2) in our panel of 12 MENA countries, we employ the bootstrap tests of Smith *et al.* (2004), which use a sieve-sampling scheme to account for both the time series and cross-sectional dependencies of the data through bootstrap blocks. The specific tests that we consider are denoted $\bar{t}$, $\overline{LM}$, $\overline{\max}$, and $\overline{\min}$. $\bar{t}$ is the bootstrap version of the well known panel unit root test of Im et al. (2003), $\overline{LM} = N^{-1}\sum_{i=1}^{N} LM_i$ is a mean of the individual Lagrange Multiplier (LM_i) test statistics, originally introduced by Solo (1984), $\overline{\max}$ is the test of Leybourne (1995), and $\overline{\min} = N^{-1}\sum_{i=1}^{N} min_i$ is a (more powerful) variant of the individual Lagrange Multiplier (LM_i), with $\min_i = \min(LM_{fi}, LM_{ri})$, where LM_{fi} and LM_{ri} are based on forward and backward regressions (see Smith et al., 2004 for further details). We use bootstrap blocks of m=20.[7] All four tests are constructed with a unit root under the null hypothesis and heterogeneous autoregressive roots under the alternative, which indicates that a rejection should be taken as evidence in favour of stationarity for at least one country.

The results, shown in Table 1 suggest that for all the series (taken in logarithms) the unit root null cannot be rejected at the five percent level of significance in our country panel for the four tests.[8] We therefore conclude that the variables are non-stationary in our country panel. [9]

Table 1a – Panel unit root tests of Smith et al. (2004) for the carbon dioxide emissions and potential determinants (1981-2005)*

[7] The results are not very sensitive to the size of the bootstrap blocks.
[8] The order of the sieve is permitted to increase with the number of time series observations at the rate $T^{1/3}$ while the lag length of the individual unit root test regressions are determined using the Campbell and Perron (1991) procedure.
[9] The lag order in the individual ADF type regressions is selected for each series using the AIC model selection criterion. Another crucial issue is the selection of the order of the deterministic component. In particular, since the cross-sectional dimension is rather large here, it may seem restrictive not to allow at least some of the units to be trending, suggesting that the model should be fitted with both a constant and trend. However, since the trending turned out not to be very pronounced, we have considered that a constant is enough in our analysis. Actually, the results of the bootstrap tests of Smith et al. (2004) are not very sensitive to the inclusion of a trend in addition to a constant in the estimated equation (see Statistic b in Tables 1). We have of course also checked using the bootstrap tests of Smith *et al.* (2004) that the first difference of the series are stationary, hence confirming that the series expressed in level are integrated of order one.

	Sulfur Dioxide Emissions (S)				Energy (E)			
Test	Statistic (a)	Bootstrap P-value*	Statistic (b)	Bootstrap P-value*	Statistic (a)	Bootstrap P-value*	Statistic (b)	Bootstrap P-value*
$\bar{t}$	-1.309	0.738	-2.021	0.685	-1.512	0.526	-2.026	0.385
$\overline{LM}$	3.197	0.287	4.456	0.617	5.505	0.229	6.645	0.198
$\overline{\max}$	-0.537	0.952	-1.610	0.750	-1.063	0.435	-1.855	0.404
$\overline{\min}$	1.650	0.518	3.264	0.670	2.513	0.112	4.221	0.255
	Per Capita Real GDP (Y)				Square of Per Capita Real GDP (Y^2)			
Test	Statistic (a)	Bootstrap P-value*	Statistic (b)	Bootstrap P-value*	Statistic (a)	Bootstrap P-value*	Statistic (b)	Bootstrap P-value*
$\bar{t}$	-1.521	0.492	-2.446 3	0.152	-2.393	0.187	-2.157	0.198
$\overline{LM}$	3.891	0.123	5.841	0.133	4.692	0.264	3.504	0.384
$\overline{\max}$	0.216	0.865	-0.685	0.974	0.327	0.846	-0.687	0.784
$\overline{\min}$	2.177	0.224	1.954	0.993	2.161	0.237	1.972	0.814

Notes: (a) Model includes a constant. (b) Model includes both a constant and a time trend.

* Test based on Smith et al. (2004). Rejection of the null hypothesis indicates stationarity at least in one country. All tests are based on 2,000 bootstrap replications to compute the p-values.

Null hypothesis: unit root (heterogeneous roots under the alternative).

4.3. Panel cointegration

Given that all the series under investigation are integrated of order one, we now proceed with the two following steps. First, we perform 2nd generation panel data cointegration tests (that allow for cross-sectional dependence among countries) to test for the existence of cointegration between S and its potential determinants E, Y, Y^2 contained in X. Second, if a cointegrating relationship exists for all countries, we estimate for each country the cross-section augmented cointegrating regression

$$S_{it} = \alpha_i + \gamma_i X_{it} + \mu_1 \bar{S}_t + \mu_2 \bar{X}_t + u_{it}, \quad i = 1,\dots,N; \quad t = 1,\dots,T \quad (2)$$

by the CCE estimation procedure proposed by Pesaran (2006) that allows for cross-section dependencies that potentially arise from multiple unobserved common factors. The cointegrating regression is augmented with the cross-section averages of the dependent variable and the observed regressors as proxies for the unobserved factors. Accordingly, $\bar{S}_t$ and $\bar{X}_t$ denote respectively the cross-section averages of S and X_i in year t. Note that the coefficients of the cross–sectional means (CSMs) do not need to have any economic meaning as their inclusion simply aims to improve the estimates of the coefficients of interest.

Therefore, this procedure enables us to estimate the individual coefficients γ_i in a panel framework.[10]

In addition, we also compute the CCE-MG estimators of Pesaran (2006). For instance, for the γ parameter and its standard error for N cross-sectional units, they are easily obtained as follows: $\hat{\gamma}_{CCE-MG} = \frac{\sum_{i=1}^{N} \hat{\gamma}_{i-CCE}}{N}$, and $SE(\hat{\gamma}_{CCE-MG}) = \frac{\sum_{i=1}^{N} \sigma(\hat{\gamma}_{i-CCE})}{\sqrt{N}}$, where $\hat{\gamma}_{i-CCE}$ and $\sigma(\hat{\gamma}_{i-CCE})$ denote respectively the estimated individual country time-series coefficients and their standard deviations.

We now use the bootstrap panel cointegration test proposed by Westerlund and Edgerton (2007). This test relies on the popular Lagrange multiplier test of McCoskey and Kao (1998), and makes it possible to accommodate correlation both within and between the individual cross-sectional units. In addition, this bootstrap test is based on the sieve-sampling scheme, and has the advantage of significantly reducing the distortions of the asymptotic test. Another appealing advantage is that the joint null hypothesis is that all countries in the panel are cointegrated. Therefore, in case of non-rejection of the null, we can assume that there is cointegration between S and its potential determinants contained in *X*.

The asymptotic test results (Table 2) indicate the absence of cointegration. However, this is computed on the assumption of cross-sectional independence, not the case in our panel. Consequently, we also used bootstrap critical values. In this case we conclude that there is a long-run relationship between sulfur dioxide emissions and potential determinants, implying that over the longer run they move together.

Table 2 – Panel cointegration between sulphur dioxide emissions and potential determinants (1981-2005)

	LM-stat	Asymptotic p-value	Bootstrap p-value #
Model with a constant term	11.272	0.000	0.859

Notes: bootstrap based on 2000 replications.

a - null hypothesis: cointegration of sulphur dioxide emissions and potential determinant series.

Test based on Westerlund and Edgerton (2007).

[10] Note that in order to estimate the long-run coefficients we have also implemented the Pooled Mean Group (PMG) estimators (see Pesaran and Smith (1995), Pesaran, Shin and Smith (1999)), which allowed us to identify significant differences in country behaviour. However, we only report the results of the Common Correlated Effects (CCE) estimators developed by Pesaran (2006), since they allow taking unobservable factors into account, which would not be the case of the PMG estimators.

4.4. The magnitudes of the cointegration relationship

Given the evidence of panel cointegration, the long-run pollution income relations can be further estimated by several methods for panel cointegration estimation. We estimate the above equation to assess the magnitude of the individual γ_i coefficient in the cointegrating relationship with the CCE estimation procedure developed by Pesaran (2006), which addresses cross-sectional dependency.

$$S_{it} = \alpha_i + \gamma_{1i} Y_{it} + \gamma_{2i} Y_{it}^2 + u_{it}, \qquad (3)$$

with $i = 1,\ldots, N$, $t = 1,\ldots,T$, and the respective estimation results are reported in Tables 3.

Table 3 – Individual country CCE estimates for 12 MENA countries for the sulfur dioxide emissions and potential determinants (1981-2005)

Country	Y		Y^2		Constant	
	γ_1	t-Stat	γ_2	t-Stat	α_i	t-Stat
Algeria	1.105	2.342	-0.020	-2.513	2.754	2.115
Egypt	2.066	2.949	-1.08	2.569	5.551	2.781
Jordan	1.833	2.679	-0.841	-3.689	4.849	2.898
Lebanon	4.513	4.073	-2.203	-4.253	-4.136	-2.417
Morroco	1.102	3.826	-0.343	-2.598	-0.205	-2.532
Tunisia	1.430	4.218	-0.435	-1.959	5.539	8.508
Bahrain	0.829	3.890	-0.203	-2.335	-3.672	-1.912
Kuwait	-5.165	-4.787	2.179	3.405	-14.200	-5.190
UAE	-2.310	-2.826	0.778	2.129	11.713	5.117
Oman	4.657	3.571	-1.490	-2.282	5.295	3.616
Qatar	-2.964	-2.715	1.813	2.772	-10.205	-5.818
Saudi	1.037	2.465	-0.352	-3.770	-4.734	-4.574

Note the coefficients of the variables $\overline{E}_t$ and $\overline{X}_{1t}$ of equation (2) have not been reported in the table.

The results show that there are an inverse U-shaped relationships between per capita pollution and per capita GDP for all studied MENA countries, expect Kuwait, UAE and Qatar. For instance, for Algeria the elasticity of SO2 emissions per capita with respect to real GDP per capita in the long-run is 1.105 -0.04Y with the threshold income of 27.625 (in logarithms) which is very high (when transformed in dollars) compared to its level of real GDP in that period. For another North African country, Tunisia, the elasticity is 1.430-0.870Y with the threshold income of 1.644 (in logarithms). EKC hypothesis seems to hold in this case. We reach the same conclusion in the case of Egypt.

For Saudi Arabia, the elasticity of SO2 emissions with respect to real GDP is 1.037-0.704Y, implying a threshold income of only 1.473 (in logarithms), which is very low compared to the Saudi real GDP.

We have to point out that for all countries where we found an EKC, we're confronted to the problem of the position of the threshold compared to the level of real GDP reached by each country during the period. Our calculations lead us to conclude that none of the studied cases verified this particular EKC hypothesis except Tunisia and Egypt.

Egypt noticed a remarkable improvement in sulfur dioxide concentrations during the first years of the 2000, whereas daily average concentrations were ranged between 20-40 µg/m3 which is lower than the limit stated in the Executive Regulation of Environment Law 4 /1994 (150 µg/m3). This improvement is due to the efficient use of fuel in power stations and industrial sector, reducing diesel fuel usage in these sectors and expands in natural gas usage.

The actions related to rationalisation of energy use in Tunisia were mainly focused on stepping up the actions of mandatory and periodic energy audits and signing performance contracts in the industry, transport and services sectors. Since the end of the nineties, pilot projects in the field of energy conservation were implemented in the housing and services sectors, and encouraging the use of energy saving equipments, appliances and materials. Besides, several programmes were pursued in relation to cogeneration in the industry sector, energy efficiency in street lighting networks, and rationalisation of energy use in the administration and public facilities. Also, as part of implementing the State policy in the field of energy substitution and directing consumption towards less costly energy, effort was invested in pursuing the programme of promoting the use of natural gas as a fuel in the transport sector and fostering the use of natural gas powered air conditioning in the services sector.

Finally, the results from the common correlated effects mean group (CCE-MG) method are reported in Table 4.

Table 4 – Results for common correlated effects mean group (CCE-MG) estimations, 12 MENA countries (1981-2005) for SO_2 emissions

	(1) X= (Y, Y^2)
Constant	-3.42
	(-2.76)
Y	0.250
	(5.28)
Y^2	-0.027
	(-4.37)

Note: t-statistics are in parentheses.

The last table shows that the elasticity of SO_2 emissions per capita with respect to real GDP per capita in the long-run is 0.250–0.054Y with the threshold income of 4.630 (in logarithms). This result is not supportive of the EKC hypothesis in the MENA region. This result was expected given the number of countries producing oil and gas in our sample[11].

4.5. Estimation of a panel ECM representation

In the previous sub-section we have estimated the long-run relationships between carbon dioxide emissions and potential determinants for our panel of 12 MENA countries, using the common correlated effects mean group (CCE-MG) estimates (see Tables 4). Having established the long-run structure of the underlying data and given that there exists a long-run relationship for all countries in our four panel sets, we turn to the estimation of the complete panel error-correction model (PECM) described by equations (5):

$$\Delta S_{it} = \sum_{j=1}^{p} \beta_j \, S_{it-j} + \sum_{j=0}^{p} \theta_j \, \Delta X_{it-j} + \lambda_i \left[S_{it-1} - \alpha - \gamma X_{it-1} \right] + \varepsilon_{it}, \qquad (5b)$$

We use the Pooled Mean Group (PMG) approach of Pesaran, Shin and Smith (1999), with long-run parameters obtained with CCE techniques, in order to obtain the estimates of the loading factors λ_i (weights or error correction parameters, or speed of adjustment to the equilibrium values), as well as of the short-run parameters β_j and θ_j for each country of our panel. Consequently, the loading factors and short-run coefficients are allowed to differ across countries.[12]

The lag length structure p is chosen using the Schwarz (SC) and Hannan-Quinn (HQ) selection criteria, and by carrying out a standard likelihood ratio testing-down type procedure to examine the lag significance from a long-lag structure (started with $p=4$) to a more parsimonious one. Afterwards, in order to improve the statistical specification of the model, we implemented systematically Wald tests of exclusion of lagged variables from the short-run dynamic (they are not reported here) to eliminate insignificant short-run estimates at the 5% level. We tested the residuals from each PECM model for the absence of heteroscedasticity, autocorrelation, ARCH effect, and we can report that they are not subject to misspecification. The results of the PECM estimations based on (5) are reported in Tables 5, only for significant short-run estimates at the 5% level.

[11] The burning of fossil fuels is the most significant source of air pollutants such as SO_2, CO, certain nitrous oxides such as NO and NO_2 (known collectively as NO_x), SPM, volatile organic compounds (VOCs) and some heavy metals. It is also the major anthropogenic source of carbon dioxide (CO_2), one of the important greenhouse gases.

[12] Note that before considering equation (3), we first used a Wald statistic to test for common parameters across countries (i.e $\lambda_i = \lambda$, and $\gamma_i=\gamma$, for i=1,...,N) with the CCE techniques of Pesaran, (2006), that allow common factors in the cross-equation covariances to be removed. We found that only the null hypothesis $\gamma_i=\gamma$, for i=1,…,N was not rejected by data, whereas the speeds of adjustment λ_i vary considerably across countries (results are available upon request).

Table 5 – Panel Error-Correction estimations for S_{it}, X= (Y, Y^2), (1981-2005)

	D S_{it-1}	DY_t	DY_{it-1}	D Y^2_{it}	D Y^2_{t-1}	Loading factor λ_i
Algeria	0.40 (2.08)	0.41 (3.14)	-	-0.015 (-2.76)	-0.10 (2.82)	-0.52 (-4.95)
Egypt	-	0.55 (2.23)	-	-0.21 (-4.48)	-0.04 (-2.72)	-0.86 (-3.22)
Jordan	-	0.57 (2.76)	-	-0.18 (-4.36)	-0.05 (-3.37)	-0.76 (-4.13)
Lebanon	-	0.58 (1.98)	-	-0.17 (-4.76)	-0.03 (-3.18)	-0.81 (-3.38)
Morroco	-	0.43 (2.21)	-	0.13 (3.77)	-0.09 (-2.85)	-0.78 (-5 .72)
Tunisia	-	0.15 (2.13)	-	-0.05 (-2.39)	-	-0.27 (-2.75)
Bahrain	0.28 (2.48)	0.10 (2.10)	0.07 (2.91)	-0.03 (-2.53)	-	-0.14 (-2.62)
Kuwait	-	0.05 (2.63)	-	-0.21 (-4.48)	-0.01 (-2.28)	-0.65 (-3.41)
UAE	-	0.31 (4.42)	-	-0.38 (-5.25)	-	-0.05 (-2.72)
Oman	-	0.21 (3.21)	-	-0.21 (-4.48)	-	-0.58 (-3.27)
Qatar	-	0.25 (2.74)	-	-0.22 (-3.79)	-0.07 (5.14)	-0.45 (-5.21)
Saudi	-	0.22 (2.16)	-	-0.08 (-2.82)	-0.07 (-2.94)	-0.40 (-3.52)
CCE-MG	intercept	*Y*	Y^2			
	-3.19 (-6.15)	0.37 (4.19)	-0.21 (-4.48)			

Notes: The estimations are obtained from the Pooled Mean Group approach with long-run parameters estimated with CCE techniques. The coefficients of the variables $\overline{E}_t$ *and* $\overline{X}_{1t}$ of equation (2b) have not been reported in the table. t-statistics are in brackets. S– Sulfur Dioxide Emissions; Y – Per Capita Real GDP; Y^2 – Square of Per Capita Real GDP.

Results from Table 5, allow checking for two sources of causation: (1) the lagged difference terms (short-run causality) and/or (2) the error correction terms (long- run causality). The causality from GDP to SO2 emissions depend on the level of economic growth. As for the long-run dynamics, the Loading factor, which measures the speed of adjustment back to the long-run equilibrium value, is significantly negative in all cases confirming that all the variables of our model move together over the long run. Thus, the long-run equilibrium deviation has a significant impact on the growth of SO2 emissions.

Table 6 - EKC for SO2 in the MENA region (1981-2005)

Country	Intercept	Inverted U shape curve	Turning point	Ymin	Ymax	EKC
Algeria	1.105 - 0.040 Y	Yes	Very high	5530	7176	No
Egypt	2.066 - 2.160 Y	Yes	2651	2460	4318	**Yes**

Jordan	1.833 - 1.682 Y	Yes	2971	3032	4360	No
Lebanon	4.513 - 4.406 Y	Yes	2784	6565	20368	No
Morocco	1.102 - 0.686 Y	Yes	4983	2254	3588	No
Tunisia	1.430 - 0.870 Y	Yes	5175	3602	6444	**Yes**
Bahrain	0.829 - 0.406 Y	Yes	7706	16648	28069	No
Kuwait	-5.165 + 4.358 Y	No	-	22873	44354	No
UAE	-2.310 + 1.556 Y	No	-	41862	90478	No
Oman	4.657 - 2.980 Y	Yes	4773	10269	19544	No
Qatar	-2.964 + 3.626 Y	No	-	43705	77232	No
Saudi	1.037 - 0.704 Y	Yes	4362	18243	34116	No
12 countries	0.250 - 0.054 Y	Yes	102514	2254	90478	No

5. CONCLUSION AND POLICY IMPLICATIONS

Our article had three aims. First, we investigate the existence of EKC in the MENA region (taken into account 12 Countries) in the matter of Sulfur dioxide. Second, we investigate the existence of EKC for each country. Finally, we explore the nature of the causality relationship between economic growth, energy consumption and emissions of SO_2. Our study extends the recent works of Liu (2005) and Ang (2007) and Apergis and Payne (2009) by implementing recent bootstrap unit root tests and panel cointegration techniques to investigate the relationship between carbon dioxide emissions, energy consumption, and real GDP for 12 MENA countries over the period 1981–2005.

Departing from the hypothesis that the 12 countries are homogenous and looking at the regional-level, our results show that in the long-run energy consumption has no significant impact on SO_2 emissions in MENA region. Our findings do not support an inverted U-shape pattern associated with the Environmental Kuznets Curve hypothesis for the MENA region. SO_2 Emissions seem to be increasing with real GDP for the moment. This result is contrary to the one founded by Arouri et al. (2012) in matter of CO_2 for the same sample of countries.

This result can be explained by at least three complementary arguments.

First, most of MENA countries have build recently a capacity to manage environmental problems and, especially, air pollution. Over the past two decades, most MENA countries have built specific environmental institutions in order to meet the challenges they face. Most MENA countries have dedicated Ministry for Environment and specific laws for different environmental areas especially in matter of Air pollution. In some countries specific agencies have been dedicated to these specific areas. The non-decline of SO2 emissions as GDP increases may be explained by corruption (Leitao, 2010). In his study, Leitao found an inverted U-shaped Curve between Sulfur dioxide and economic growth. However, he suggests that different income-pollution paths across countries are found due to corruption (Leitao, 2010). Most of the considered countries perform badly in matter of corruption. While laws in matter of Air pollution exists, the enforcement of laws and control are ineffective due to corruption.

Secondly, contrary to CO2 emissions that are more linked to consumer behaviour and are non-source pollution, SO2 emissions are more closed to producers' behaviour and are local pollutant. The non-decline of SO2 in MENA countries can be explained also by little or absence of change in matter of adoption of new technologies (end-of-pipe technologies). While, in EOCD there's a fall in SO2 emissions due to massive adoption of new technologies in matter of desulfurization, this is not the case in most of MENA countries. Changes in the technological behaviour may lead in the near future to a change in the relation between economic growth and SO2 emissions.

The rapid growth of energy demand and especially for electricity generation may explain poor performances in matter of SO2 reduction in MENA countries. It is well known that Electricity generation plants emit high levels of Sulfur dioxide. MENA countries are facing or will face shortage in this domain. As Krane (2010) states "for the six states of Golf Cooperation Council (GCC)…are unable to meet their own fast rising demand for domestic energy, mainly natural gas feedstock for electricity generation." They are going to face shortage in the near future due to their fast demand in matter of energy[13]. Energy conservation options are envisaged. Some GCC are investing in nuclear power to generate energy and other MENA countries are investing in renewable energy generation (Ghaddar, 2010).

Thirdly, most of the sample considered countries are based on primary sector (Rentier States[14]) and their move toward a service economy is low. They have not yet reached a positive regime where the effect of growth on SO2 emissions is environmental improving. The economic composition of these economies is changing slowly. Some non-oil countries like Tunisia, and Egypt are changing their structural economic composition and are performing better than the other countries in the sample.

At the country-level, our results show that EKC is not verified for the studied countries except for Tunisia and Egypt. Our result confirms the one found by Fodha and Zaghdoudi

[13] Qatar is an exception among these countries.

[14] The term Rentier States connotes a country that derives most of its national income from the external sale of natural resources.

(2010). They have found an evidence for Sulfur Dioxide EKC for Tunisia. Their main explanation relies on the enforcement of laws and the effectiveness of the control of plants, which are responsible of SO2 emissions. The Economic structure of Tunisia dominated by services may also explain this result. In the case of Egypt, the result is explained by technological change and adoption of new technologies. In fact, Egypt has shifted to cleaner technology in matter of electricity generation. Their generation plants are more using gas and less burning oil. This shift and more effective regulation lead to an improvement of the situation. Our results show that for these two countries the values of the turning points are very close to those found for EOCD countries.

In the case of Gulf Cooperation Council countries (GCC), the shift towards more energy efficiency could improve their performance (Doukas et al, 2006). These countries are exploring new policies, but this reorientation has not yet resulted in the development of consistent strategies and policies (Reiche, 2010). At the same time one must mention that several initiatives of renewable energy were taken in Algeria, the Kingdom of Saudi Arabia and other MENA countries like the pioneering project of Masdar Sustainable City[15]. These initiatives are expected to improve the situation in the next years. Actual efforts and policies changes are not captured by actual statistics and, the EKC is not verified at the country level. However all these initiatives are improving the situation.

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[15] MENA countries are estimated to have a potential to generate 630,000,000 megawatts of solar power and also 75000 megawatts of wind power potential (Ghaddar, 2009).

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