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Income-carbon Emissions Nexus for Middle East and North Africa Countries: A Semi-parametric Approach

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ABSTRACT

It is widely accepted that Middle East and North Africa (MENA) region is significantly impacted by climate change. Evidence suggests that the region is positioned at the second place after North America in carbon emission. This study attempts to further examine the impacts of income on carbon emissions in MENA region through investigation of the existence of an environmental Kuznets curve. Within the Stochastic Impacts by regression on population, affluence and technology framework, this is the first study in MENA region to explore the income-carbon emissions nexus; using panel data together with a semi-parametric panel fixed effects regression. Our data set is referred to a panel of 20 countries in MENA region spanning the period 1980-2014. With this information, we find evidence to support an inverted-U shaped relationship between income and CO_2 emissions in the region. These findings suggest that environmental degradation may be reversible and environmental quality may be recoverable alongside the economic growth process in the region.

Keywords: Per Capita Income, Carbon Emissions, Stochastic Impacts by Regression on Population, Affluence and Technology Environmental Kuznets Curve, MENA Region
JEL Classifications: Q01, Q28, Q52, Q51

1. INTRODUCTION

It is widely accepted that Middle East and North Africa (MENA) region is significantly impacted by climate change (Wodon et al., 2014; Al-Rawashdeh et al., 2014). According to the International Energy Agency (2014), the region is positioned at the second place after North America in carbon emission and documented by 9 metric tons of CO_2 per person; which is higher than the average value in Africa (1.1), Asia (3.7), Europe (7.1), and even higher than that worldwide (4.6). Empirical studies addressing this issue in the region agree that energy use and/or consumption and economic growth are the key sources of CO_2 emissions (Arouri et al., 2012; Al-Rawashdeh et al., 2014; Herrala and Goel, 2012; Méon and Sekkat, 2004). At one hand, the pattern of economic growth and structure change in the economy of the region may be responsible, at least partly, for the deterioration of the environmental quality. At the other hand, the extensive use of energy in the region which has been attributed to high subsidies on petroleum products may encourage an exaggerated and inefficient use of fossil energy. Studies show that eleven out of twenty countries in the world which subsidize gasoline consumption are from MENA region (Brown, 2011).

Recently, and for two reasons, environmental degradation and income nexus has received increased attention and emerged as one of the most attractive empirical topics of immense interest among economists and policy makers. First, due to the aggravation of pollution problems, policy makers in the region seek to identify the exact relationship between income and environmental quality in order to prepare the required appropriate policy. If the relationship between income and environmental degradation is found to be a monotonously (linear) positive relationship, then environmental quality will continue to deteriorate with income development. Only when income enters a stage of stagnation, the tendency towards environmental degradation would slow down. Therefore, policy makers should re-think about the pattern of economic growth to avoid environmental deterioration. However, if results show a monotonously negative relationship between income and environmental degradation, then environmental quality will continue to improve even with the continuation of the growth process. Hence, policy makers should continue promoting the process of development to maintain the quality of the environment. In contrast, if a non-monotonous (nonlinear) relationship is found between development and environmental quality, environmental degradation may be reversible and environmental quality may be recoverable. Theoretically, the existence of such a non-monotonous and nonlinear curve (analogous to an inverted U-shaped curve) may link income per capita to environmental quality indicators such as carbon dioxide and/or sulphur dioxide emissions as termed by the environmental Kuznets curve (EKC) hypothesis. The EKC hypothesis states that in the early stages of socioeconomic growth, environmental quality deteriorates with the increase of gas emissions. However, as the economy continues growing beyond a certain threshold (the turning point), emissions begin to decline and environmental quality starts to improve; forming an approximately inverted U-shaped curve. Validity of the EKC hypothesis indicates that income versus environmental protection dilemma can be resolved. In the context of developing countries, finding evidence in support of this hypothesis might have promising implications for sustainable development in the future (Wang et al., 2016).

The second reason, which is a main concern for economists and econometricians, is related to the appropriate theoretical model that can be used to describe income and environmental quality nexus as well as the relevant estimated method. With regard to the theoretical framework, previous studies frequently employ either ad hoc model or IPAT (i.e., population, affluence and technology) theoretical model as proposed by Ehrlich and Holdren (1971). However, the IPAT model is considered purely a simple function form; parsimoniously indicating that anthropogenic environmental impact is associated with multiple driving forces. Thus, it cannot -individually- determine the extent to which each factor affects the environment (Zhua et al., 2012; Liddle and Lung, 2010). Concerning the estimation method, most of the preceding studies employ a parametric panel fixed effects technique to estimate the impact of income on CO_2 emissions. However, using this technique usually yields biased estimators as a result of failure to consider relevant explanatory variables and therefore; leads to potential functional form misspecification (Wang et al., 2015).

The present study seeks to fill the gap in the literature concerning the income - CO_2 emissions nexus in MENA region in two principal fashions. First, and to avoid the limitations of IPAT mentioned previously, the present study employs the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model. According to York et al. (2010) the STIRPAT model could precisely specify the functional form of the relationship between anthropogenic gas emissions and economic growth. Second, and instead of using the parametric fixed panel; a method that is extensively used in the previous studies, we employ the semi-parametric regression developed by Baltagi and Li (2002). According to Wang et al. (2016) the semi-parametric regression is a consistent estimation method for a dynamic partially linear panel data model with fixed effects. In contrast to the parametric panel fixed effects regression, the semi-parametric panel fixed effects regression is more flexible; which enables addressing of the potential functional form misspecification (Desbordes and Verardi, 2012; Wang et al., 2015). Furthermore, it partially avoids dimensionality problems by combining features of parametric and non-parametric techniques. A further advantage of the semi-parametric panel fixed effects regression is the possible inclusion of a concise economic interpretation of the results. To the best of the authors' knowledge, this is the first empirical study in MENA region, to investigate the EKC hypothesis by employing the semi-parametric regression within the STIRPAT model.

The remaining of the paper is organized as follows. Section 2 briefly describes the empirical evidence from the literature. Sections 3 and 4 examine the models, estimation methods and data sources used to test the EKC hypothesis. Empirical results and related discussion are presented in Section 5. The final section; Section 6 contains concluding comments and policy implications.

2. LITERATURE REVIEW

According to Oscan (2013) there are three empirical research strands examining the above-mentioned topics in the environmental economics literature. The first strand focuses on the environmental pollutants and income nexus, and seeks to examine the validity of the EKC hypothesis. The first empirical study regarding the EKC is attributed to Grossman and Krueger (1991). Thereafter, numerous researchers have tested the EKC hypothesis and arriving to mixed findings (Agras and Chapman, 1999; Dinda and Coondoo, 2006; Fiedl and Getzner, 2003; Galeotti et al., 2009; Selden and Song, 1994; Saboori et al., 2012; Shahbaz et al., 2013; Holtz-Eakin and Selden, 1995; Stern, 2004; He and Richard, 2010; Al-Mulali et al., 2015; Ozturk and Al-Mulali, 2015; Al-Mulali et al., 2016). The second strand comprises studies exploring the growth -energy nexus. These studies date back to the seminal work of Kraft and Kraft (1978). Again, after that, numerous researchers have tested the growth - energy nexus and arriving to mixed findings (Belloumi, 2009; Akarca and Long, 1980; Bentzen and Engsted, 1993; Pao, 2009; Erol and Yu, 1987; Ghosh, 2010; Yu and Hwang, 1984). However, all the studies that tend to employ a bivariate model are criticized due to the omitted variables bias and also because they fail to get consensus results. Nevertheless, to avoid this problem, recent studies have started to examine the nexus of energy consumption and economic growth in a multivariate framework (Gurgul and Lach, 2011; 2012; Altinay and Karagol, 2004; Al-Iriani, 2006; Apergis and Payne, 2009; Narayan and Smith, 2008; Oh and Lee, 2004; Stern, 2000; Yang, 2000; Ozturk, 2010). However, analyzing the growth - environment nexus and growth - energy nexus in a bivariate framework suffers from omitted-variables bias as stated by Saboori and Soleyman (2011). The third stream of research has emerged as reflected by the fact that today numerous studies have gathered both nexuses in a single framework (Ang, 2007; Soytas et al., 2007; Hamit-Haggar, 2012; Ozturk and Acaravci, 2012; Esteve and Tamarit, 2012; Tiwari et al., 2013; Toda and Philips, 1995; Soytas et al., 2007; Akbostanci et al., 2009; Halicioglu, 2009; Jalil and Mahmud, 2009; Soytas and Sari, 2009; Tamazian and Rao, 2009; Zhang and Cheng, 2009; He and Richard, 2010; Lean and Smyth, 2010; Narayan and Narayan, 2010). Recently, the above mentioned multivariate framework has been extended further by including, for example, the impacts of foreign trade and urban population, and human development (HD) into the nexus, in order to avoid omitted variable bias in the econometric estimation (Halicioglu, 2009; and Zhang and Cheng, 2009).

In the present study and to conserve space, we would only review some selected studies related to MENA region. However, to our knowledge, there are only few studies that analyze economic growth - CO_2 emissions nexus in MENA region. Most importantly, even among these few studies, no consensus exists in regards to the impact of income on carbon emission in the region. So, we classify these studies into country-based studies and panel or cross countries-based studies. Based on the country level analysis, Fodha and Zaghdoud (2010) investigate the validity of the EKC hypothesis for Tunisia using two indicators for pollutant emissions (SO_2 and CO_2), during the period 1961-2004. Employing the Johansen approach for cointegration, as well as Granger causality test, the study arrives to an evidence in support for EKC hypothesis when CO_2 has been used as a proxy for pollutant emissions. In contrast, a monotonically increasing relationship with gross domestic product (GDP) is found to be more appropriate for CO_2 emissions. The causality results support the argument that the relationship between income and pollution in the country is one of the unidirectional causality with income causing environmental changes and not vice versa; both in the short-run and long-run. Alkhathlan and Javid (2013) examine the relationship among economic growth, carbon emissions and energy consumption at the aggregate and disaggregate levels for Saudi Arabia during the period 1980-2011. For the aggregate energy consumption model, the authors use the total energy consumption per capita and CO_2 emissions per capita based on the total energy consumption. For the disaggregate analysis, they use oil, gas and electricity consumption models along with their respective CO_2 emissions. The results of the autoregressive distributed lag technique show that the estimated long-term income elasticities of carbon emissions is higher than the estimated short-term income elasticities of carbon emissions; which imply that over time, per capita carbon emissions increase with the rise in per capita incomes in Saudi Arabia. This result indicates that there is a monotonically increasing relationship between carbon emissions and per capita income in Saudi Arabia. Therefore, the EKC hypothesis does not hold for these three models. Likewise, Al-Rawashdeh et al. (2014) examine whether or not the EKC relationship exists between economic growth and two environmental pollution indicators (SO_2 and CO_2) based on a country level analysis using time series data for all of the 22 MENA countries in the region. Under a country level, the results suggest an evidence of SO_2 - EKC for Algeria, Tunisia, Yemen, Morocco, Turkey and Libya. Regarding CO_2, the findings also support an inverted U-shaped pattern associated with the EKC hypothesis for Tunisia, Morocco, Turkey and Jordan. In analyzing MENA region as a panel, the results show that there is no EKC evidence for SO_2 and CO_2 emissions, but there is only a monotonically increasing linear relationship between income and CO_2 emissions.

M'henni (2005) tests for the EKC hypothesis in Tunisia over the period from 1980 to 1997. The author employs the generalized method of moments and examines the following pollutants: CO_2 emissions, fertilizers' concentration and the number of cars in traffic which serve to calculate an index for environmental quality. The results show that there is no evidence to confirm the EKC for any of these pollutants. Based on the cointegration analysis, again, Chebbi et al. (2009) examine the same issue for Tunisia and arrive to different results. More specifically, they detect 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. Akbostanc et al. (2009) examine the relationship between CO_2, SO_2 and (particulate matter 10 micrometers or less in diameter) emissions. They examine the EKC in Turkey at both national level, as well as at provinces level (58 provinces). They find a monotonic and increasing relationship at the national level. However, at the level of provinces, they discover an N-shaped curve; implying the absence of evidence in support for the EKC.

With regard to the panel or cross countries-based studies, Al-Mulali (2011) examines the impact of oil consumption on the economic growth of MENA countries during the period 1980-2009. The author regress gross domestic product on both oil consumption (in term of thousands of barrels per day) and total carbon dioxide emissions from the consumption of energy. After employing both Pedroni and Kao cointegration tests, the author employs Engle-Granger panel causality technique to examine the direction of the relationship. The results detect the existence of a long-run relationship between the variables. In addition, the causality test reveals the presence of a bi-directional relationship between the variables in both short and long run.

Likewise, Arouri et al. (2012) employ cointegration techniques on data related to economic growth, energy consumption and emissions of CO_2 for 12 countries in MENA region during the period 1981-2005. The main objective of these techniques is to, first, test for the EKC hypothesis in MENA region for CO_2. Second, to investigate the existence of EKC for each country. Finally, to explore the nature of the causality relationship between economic growth, energy consumption and emissions of CO_2. The results show that in the long-run, energy consumption has a positive significant impact on CO_2 emissions in MENA region. More interestingly, the results show that real GDP exhibits a quadratic relationship with CO_2 emissions. Taken together, the findings support an inverted U-shaped pattern associated with the EKC hypothesis for MENA region. In addition, CO_2 emissions increase with real GDP, stabilize, and then decrease. At the country-level, however, the results show that EKC is not verified for the studied countries; except for Jordan. Although the estimated long-run coefficients of income and its square satisfy the EKC hypothesis in most studied countries, the EKC turning points are very low in some cases and very high in other cases, hence providing rather poor evidence in support of the EKC hypothesis. For the causality relationship, the results show that in the short-run, the evidence suggests existence of positive causality from energy consumption to CO_2 emissions. However, in the long run, the evidence suggests existence of bidirectional relationship between the variables. Based on these findings, the authors suggest that future reductions in CO_2 emissions per capita might be achieved at the same time as GDP per capita continues to grow in MENA region.

Likewise, Omri (2013) examines the nexus between CO_2 emissions, energy consumption and economic growth using simultaneous-equations models with panel data of 14 MENA countries over the period 1990-2011. The study reveals existence of a bidirectional causal relationship between economic growth and CO_2 emissions for the region as a whole. The author suggests that degradation of the environment has a causal impact on economic growth, and that a persistent decline in environmental quality may exert a negative externality on the economy through affecting human health; and thereby may reduce productivity in the long-run. Meanwhile, Farhani et al. (2013) empirically parallels two panel. The first panel; denoted as panel A, pursues the studies of Halicioglu (2009), Jalil and Mahmud (2009), and Jayanthakumaran et al. (2012) which experiment the introduction of energy consumption and trade into the environmental function. The second panel; panel B, develops the work of Hossain (2011) which tries to propose urbanization as a mean to evade omitted variable bias. The study includes 11 MENA countries over the period 1980-2009. The authors employ panel fully modified ordinary least squares (FMOLS) and dynamic OLS (DOLS) as well as causality test. The empirical results show consistency in light of the EKC biography based on the cointegrated and causal relationships. The results imply that an increase in energy use, together with higher GDP and greater trade openness tend to reveal more CO_2 emissions. Furthermore, the addition of urbanization in the environmental function enhances the final results and positively affects the pollution level. Regarding the causality test, for Panel A, it is found that real GDP and energy consumption cause CO_2 emissions in the short-run panel causality. This implies that in the absence of energy conservation policies due to the economic development, these countries consume more energy; which may result in more pollution for the environment. In the log-run, there are two causal relationships among the variables running from all variables to CO_2 emissions and to energy consumption. For panel B, the results indicate that real GDP, energy consumption and urbanization exert a causal significant effect on CO_2 emissions, and trade openness exerts a causal significant effect on urbanization in the short-run.

Moreover, Farhani et al. (2014) examine the existence of long-run equilibrium relationships for two different EKC specifications for 10 MENA countries over the period 1990-2010. In the first one, CO_2 emissions variable has been regressed on per capita real GDP, energy consumption, trade openness, manufacture value added and modified HD index (HDI). In the second model, genuine saving index is regressed on HDI, energy consumption, trade openness, manufacture value added and the role of law. The two models have been estimated using two recent techniques; namely panel FMOLS and DOLS. The results of the first specification; namely EKC, show that there is an inverted U-shaped relationship between environmental degradation and income; while for the second specification; namely modified EKC, the findings show that there is an inverted U-shaped relationship between sustainability and HD. A study by Arouri et al. (2012) has implemented recent bootstrap panel unit root tests and cointegration techniques to investigate the relationship between carbon dioxide emissions, energy consumption, and real GDP for 12 MENA countries over the period 1981-2005. The results detect evidence in support of the EKC hypothesis in MENA region. More specifically, the results demonstrate that the level of CO_2 emissions first increases with income, then stabilizes, and then declines. In contrast, Ozcan (2013) tests the EKC hypothesis for 12 MENA countries during the period 1990-2008; by employing a cointegration approach. The results provide evidence contrary to the EKC hypothesis.

The review of the extant studies that examine MENA region demonstrates the absence of any consensus in regards to the nature of the relationships between income and carbon emission as described by the EKC hypothesis. The conflicting results of these studies may be attributed to country-specific policies, the use of different energy consumption and income measures, the econometric methodology, omitted variable bias, model specifications or the varying time spans of the studies. However, most importantly, all these studies, however, have weaknesses that this study aims to address. They mainly involve the use of *ad-hoc* model specifications which are not based upon solid theoretical models. As a result, the findings of the present study may prove beneficial and relevant value-added for policy-makers seeking to implement appropriate policies that can maintain environmental quality within the region.

3. THEORETICAL FRAMEWORK AND METHODOLOGY

To address the limitation of IPAT, we employ a stochastic version of IPAT designated STIRPAT; which provides a relative quantitative framework to explore the environmental impact of income progress (Dietz and Rosa, 1997). The model specification is

$$I_i = ap_i^b A_i^c T_i^d \varepsilon_i \tag{1}$$

In equation 1, I denotes environmental impact, P, A, and T stand for population, affluence, and technology factors respectively. Explanatory variable coefficients to be estimated are represented by a, b, c, and d; ε represents random error; and subscript i denotes the panel unit; which refers to 20 MENA countries in the present study. To test the existence of the EKC, York et al. (2010) incorporate a quadratic term of the per capita GDP factor into the STIRPAT model. Following previous studies, we derive extended versions of the STIRPAT model to test for the presence of an inverse U-shaped curve relationship between per capita GDP and carbon emission. In this model, all variables except urbanization are converted into natural logarithmic form for direct interpretation as elasticities. Accordingly, within the EKC hypothesis framework, the augmented model is estimated as

$$\ln CE_{ti} = \alpha_i + \beta_1 \ln P_{it} + \beta_2 \ln A_{it} + \beta_3 \ln EI_{it} + \beta_4 UR_{it} + \beta lA_{it}^2 + T_t + \varepsilon_{it} \tag{2}$$

Where countries are indexed by i and time periods by t; CE_{it} is the amount of CO_2 emissions of country i in year t; A is GDP per capita; P is the total population; EI is energy intensity; UR is the level of urbanization; α_i represents a country-specific effect that is constant with time, and a time specific effect T_t may be used to account for time-varying omitted variables and stochastic shocks that are common to all countries. Energy intensity may be interpreted as a proxy for technology level which may damage the environment (Zarzoso et al., 2007), whereas time-specific effect is sometimes interpreted as the effect of technical progress in carbon emission control overtime (Stern, 2002). Meanwhile, Anderson and Cavendish (2001) point out that prior studies paid little attention to the role of technical progress in air pollution abatement. Ignoring this determinant could drastically underestimate possibilities for countries to decrease pollution levels with economic growth.

With regard to urbanization, we follow Wang et al. (2016) and we add urbanization variable as an essential part in the investigation of income - carbon emission nexus. This is because; some possible effects of urbanization on the environmental quality are somewhat and independently debated in three relevant theories. The first is the ecological modernization theory; which claims that environmental problems may rise from low to intermediate stages of development. Nonetheless, extra modernization can reduce such inverse impacts; as societies start to recognize the significance of environmental sustainability. The second is the urban environmental transition theory; where an increase in affluence of cities often leads to an increase in manufacturing activities; leading to massive industrial pollution-related issues as air and water pollution. However, such inverse impacts decrease in affluent cities as a result of advanced environmental regulations, technological progress and structural improvement in the economy. The third is the compact city theory; where high urban density allows cities to accomplish economies of scale of urban public infrastructure, and decrease car usage, travel length, allocation losses of electricity supply, and minimize energy consumption and CO_2 emissions (Burton, 2000; Capello and Camagni, 2000; Burton et al., 2004; Newman and Kenworthy, 1989).

Within the aforementioned framework, we first examine the existence of income and carbon emission EKC; using parametric panel fixed effects regression. A more flexible method is used to explore this topic is the semi-parametric panel fixed effects model of Baltagi and Li (2002); which does not place an ex-ante restriction on the shape of the relationship curve between income and carbon emission and can therefore address potential functional form misspecification (Wang et al., 2015). In the present study, the semi-parametric model for testing the relationship between income and carbon emission may be described as

$$\ln CE_{ti} = \alpha_i + \beta_1 \ln P_{it} + \beta_2 \ln El_{it} + \beta_3 u_{it} + f(lA_{it}) + T_t + \varepsilon_{it} \quad (3)$$

Where the functional form f (.) in the model is unspecified because the income variable is a non-linear input to the model. Unobserved heterogeneous effects can be removed at the first difference:

$$\ln CE_{it-1} - \ln CE_{it-1} = \beta_1(\ln P_{it} - \ln P_{it-1}) + \beta_2(\ln El_{it} - \ln El_{it-1}) + \beta_3(U_{it} - U_{it-1}) + [f(lA_{it}) - f(lA_{it-1})] + T_t - T_{t-1} + \varepsilon_{it} - \varepsilon_{it-1} \quad (4)$$

To consistently estimate the first difference model, the following series of differences are derived to respectively estimate $[f(UR_{it})$-f $(URi_{t-1})]$ in line with Baltagi and Li (2002).

$$p^k(lA_{it}, lA_{it-1}) = [p^k(lA_{it}) - p^k(lA_{it-1})] \quad (5)$$

Where, p^k (UR) and p^k (ln A) are the first k terms of a sequence of function (p1 (UR), p2 (UR),…) and (p^1 (ln A), p^2 (ln A),…), respectively. In practice, a typical example of p^k series could be a spline; corresponding to piecewise polynomials with pieces depicted by a sequence of smooth knots. Once β coefficients are estimated, the values of unit-specific intercepts α_i can be calculated. Thus, equation 5 can be reduced to

$$\hat{u}_{it} = \ln CE_{it} - \hat{\beta}_1 \ln P_{it} - \hat{\beta}_2 \ln EL_{it} - \hat{\beta}_3 U_{it} - \hat{\alpha}_i = f(lA_{it}) + \varepsilon_{it} \quad (6)$$

The curve f (.) can be easily estimated by performing spline regression u_{it} on the UR_{it} variable in equation 6. We execute a B-spline regression model of order k=4.

4. DATA AND VARIABLES

We investigate whether there is an evidence of a non-monotonic relationship between income and carbon emission; as postulated by the EKC hypothesis, for a balanced panel of 20 MENA countries and data spanning 1980-2014. All data for the analysis was collected from the World Bank Development indicators. For this dataset, we apply, and for the first time, parametric and semi-parametric panel fixed effects models. All underlying variables with their descriptive statistics are listed in Table 1. It should be noted that all variables except urbanization are converted into natural logarithmic form.

5. RESULTS AND DISCUSSION

Empirical results for per capita GDP - CO_2 emissions nexus are given in Table 2. Column 1 of the table presents results of the parametric fixed effects regression estimator within the per capita GDP - CO_2 emissions EKC hypothesis framework. The findings reveal that the elasticity of CO_2 emission with respect to energy use is highly significant at the 1% level, and its sign is positive. A 1% increase in energy use leads to 0.6% increase in carbon emission. The estimated coefficients for both; urbanization and population variables are not significant and have unexpected signs. The affluence variable and its quadratic term are both highly significant and they have the expected signs. Findings from the parametric fixed effects model confirm the presence of the income - CO_2 emissions EKC hypothesis. Column 2 presents estimates of control variables in the semi-parametric panel fixed effects model. Unlike the parametric fixed, the semi-parametric results detect insignificant impact for the energy use variable. In contrast to the parametric fixed effects model, the population variable is positive and highly significant at the 1% level. The results of the semi-parametric panel data model suggest that only population variable is the main source for carbon emission in MENA region.

The partial fit for the per capita GDP and CO_2 emissions nexus in the semi-parametric panel fixed effects model is represented in Figure 1. The plot seems to confirm the existence of an EKC between income and CO_2 emissions in the region. The relationship appears more obviously inversely U-shaped; CO_2 emissions increase with real GDP, stabilize, and then start to decrease. The

Table 1: Descriptive statistics of variables

Variables	Definition	Mean	Minimum	Maximum
Ln CE	Carbon dioxide emissions, metric tons per capita	1.55	−2.38	4.22
Ln A	GDP per capita (constant 2005 US$)	8.36	6.08	11.05
Ln El	Energy use (kg of oil equivalent) per $1,000 GDP (constant 2011 PPP)	4.75	3.71	5.70
Ln P	Population, total	15.98	13.07	18.31
UR	Urban population (% of total)	69.58	20.93	99.16

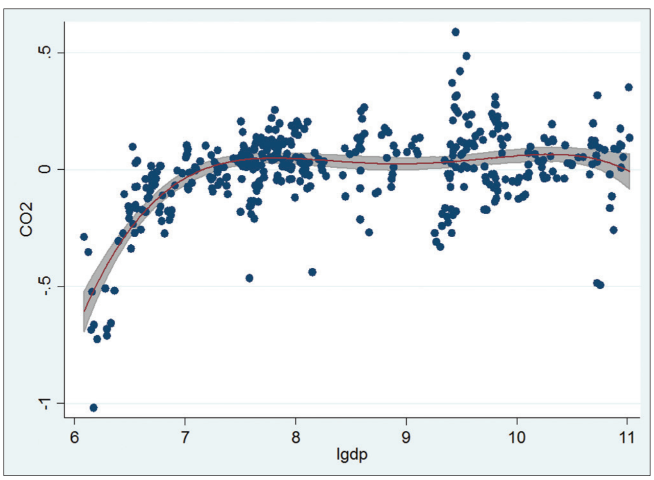
GDP: Gross domestic product

Table 2: Estimates for income-CO_2 emissions models

Variables	Parametric model	Semi-parametric model
Constant	−14.84* (1.19)	
Ln A	2.55* (0.27)	
Ln EL	0.60* (0.05)	0.09 (0.20)
Ln P	−0.03 (0.03)	0.61* (0.13)
UR	−0.002 (0.003)	−0.01 (0.013)
Ln A^2	−0.09* (0.02)	
Country dummies	Yes	Yes
Year dummies	Yes	Yes
Adjusted R^2	0.76	0.66
Observed	415	401

Cluster-robust standard errors in parentheses. Superscripts *denote statistical significance at 1% levels

Figure 1: Partial fit of per capita gross domestic product and CO_2 emissions nexus



Points on graph are estimated partial residuals for carbon emission. Maroon curve represents fitted values for adjusted effects of other explanatory variables in the model, and 95% confidence bands are indicated by shading areas

curve develops gradually to be largely flat; suggesting that it is approaching the turning point. Once income reaches the turning point, carbon emission begins to fall. Thus, from the results of the two panel regression methods, we confirm the presence of the income - CO_2 emissions EKC hypothesis, and it is more pronounced in the semi-parametric fixed effects model.

6. CONCLUSION AND POLICY IMPLICATION

The present study seeks to examine the impacts of income on carbon emission in MENA region through investigation of the existence of an EKC. Within the STIRPAT framework, this is the first study in MENA region to explore the income and carbon emission nexus; using panel data together with semi-parametric panel fixed effects regression. Our data set is referred to a panel of 20 countries in MENA region spanning the period 1980-2014. With this information, we find evidence to support an inverted U-shaped relationship between income and CO_2 emissions in the region. One possible justification for our findings is related to the fact that in the region, there are several initiatives of renewable energy which are taken in consideration in Algeria, the Kingdom of Saudi Arabia and other MENA countries like the pioneering project of Masdar Sustainable City. These initiatives are expected to improve the situation in the next years. Overall, our results suggest that environmental degradation may be reversible and environmental quality may be recoverable alongside the development process in the region.

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