Environmental Kuznets Curve, a Mirage? A Non-parametric Analysis for MENA Countries

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ABSTRACT

We investigate the relationship between Carbon Dioxide emissions and Gross Domestic Product in the MENA region using World Bank data covering the period 1980-2010 on the eve of the Arab Spring. Unlike extant studies using parametric models, our results provide evidence against the postulated inverted-U shaped relationship between pollution and the level of economic development. Using instead a non-parametric model, we find new evidence against the existence of a carbon Environmental Kuznets Curve in contrast to previous studies on the region. The paper provides a cautionary note against the use of parametric models to draw policy implications about the trade-off (or lack of) between environmental quality and the level of economic development.

Keywords: carbon emissions; environmental Kuznets curve; non-parametric regression

JEL classification: C14; C23; Q54

Introduction

The relationship between pollution levels and economic development has been a contentious issue within the economics literature. The discussion is typically examined using the so-called Environmental Kuznets Curve (EKC) model, which postulates an inverted U-shaped relationship between income and pollution levels (e.g. Grossman and Krueger, 1991 and 1995; Shafik, 1994).

The EKC hypothesis first developed in the early 1990s is in fact based on the early work of Simon Kuznets (1955) stating the existence of an inverted U-shaped relationship between the level of economic development as measured by Gross Domestic Product (GDP) per capita and income inequality.[1] Specifically, the EKC hypothesis replaces measures of inequality with measures of environmental performance and postulates a trade-off between economic development and environmental quality in the initial stages of economic development. As the standard of living improves, society allocates more importance to the preservation of the environment, which defines the turning point of the curve. Additionally, society starts having the required means to adopt environmental regulations and energy efficiency measures. Such changes cause the previously mentioned trade-off to be broken. It is worth mentioning that the literature discusses two versions of the hypothesis. The strong (optimistic) view argues that the curve follows a strictly inverted U-shaped, while the weak (pessimistic) view asserts that, above a threshold of economic development, emission per capita reaches a plateau or keeps increasing (Dasgupta *et al.*, 2002).

Around this question, a large body of literature came to exist over the past two decades using mainly parametric empirical specifications of the EKC model (see Stern, 2004 and Pasten and Figuera, 2012 for a discussion on the links between the theory and its applications). The parametric approach to the EKC considers a polynomial functional form

[1] More recently, Ogundipe et al. (2014) use income inequality to explain the EKC relationship in Africa.

(second or third degree polynomial) that relates the level of pollutants with the level of income. The main pollutant under examination is typically Carbon Dioxide (CO_2) for the case of global pollutants. The extant literature considered both cross-sectional and time-series data sets, with the former strand being the most predominant (e.g. regional studies include, Coondoo and Dinda, 2002; Apergis and Payne, 2009; Pao and Tsai, 2010; and Arouri *et al.*, 2012). Overall, the findings of the parametric strand show that the most results are in line with the strong EKC hypothesis. However, given the potential model misspecification in parametric regressions, the reported evidence on the EKC has been highly mixed leading to contradictory policy recommendations (Kijima *et al.*, 2010; Wang, 2013).

A parallel strand of the literature uses non-parametric approaches that do not impose restrictions on the functional form of the emissions model. Compared to parametric models, the non-parametric methods consider that the distribution of the observations cannot be modelled using a finite set of regression parameters. Early evidence against the EKC curve was found for local and regional pollutants (e.g. Stern *et al.*, 1996 and Stern, 2004 for the case of Sulfur Dioxide (SO_2); Millimet *et al.*, 2003 for the case of Nitrogen Oxides (NO_X) and SO_2; and Roy and van Kooten, 2004 for the case of NO_X and Carbon Monoxide (CO)). More recently, non-parametric models were used to examine the carbon EKC for various countries (Bertinelli and Strobl, 2005; Azomahou *et al.*, 2006; Zanin and Marra, 2012; and Kim, 2013). The main findings of these papers go against the strong EKC hypothesis.

Our work contributes to the extant literature by being the first paper to examine the evidence from the Middle-East and North Africa (MENA) region using a non-parametric approach with panel data on CO_2 emissions and income. Specifically, we investigate the existence of a trade-off between emissions and income per capita, the turning point if any, and the general shape of the curve.

Analytical framework

Based on the EKC theory, emissions are seen as a by-product of economic activity. The traditional EKC framework postulates a quadratic relationship between real GDP per capita and emissions. However, since such a relationship is not known *a priori*, a more appropriate non-parametric representation can be specified as follows:

$$c_{it} = F(y_{it}) + \varepsilon_{it} \, , \tag{1}$$

where c_{it} is the logarithm of CO_2 emissions per capita of country $i = 1,...,N$ at time $t = 1,...,T$; y_{it} is the logarithm of real GDP per capita; $F(y_{it})$ is *a priori* unspecified functional form of y_{it}, ε_{it} is the stochastic error term with $\varepsilon_{it} = \mu_i + v_{it}$, where μ_i reflects country fixed effects and $E[v_{it} \mid y_{it}] = 0$.

In order to estimate the functional form of $F(y_{it})$ given in equation (1), we use the deviance difference test developed by Royston and Altman (1994) and Sauerbrei and Royston (1999). In general, the test postulates a flexible fractional polynomial of order *m* given by the following:

$$F(y_{it}) = \alpha_0 + \sum\nolimits_{k=1}^{m} \alpha_k h_k(y_{it}) \, , \tag{2}$$

where $h_k(y_{it})$ in equation (2) is given by

$$h_k(y_{it}) = \begin{cases} {y_{it}}^{p_k}, & p_k \neq p_{k-1} \\ h_{k-1}(y_{it}) \log y_{it}, & p_k = p_{k-1} \end{cases} , \tag{3}$$

Given that the EKC hypothesis postulates a single turning point, we consider, in the alternative hypothesis, the flexible fractional polynomial of order 2, i.e.

$$F(y_{it}) = \begin{cases} \alpha_0 + \alpha_1 y_{it}^{p_1} + \alpha_2 y_{it}^{p_2} & \mathit{if} \;\; p_1 \neq p_2 \\ \alpha_0 + \alpha_1 y_{it}^{p} + \alpha_2 y_{it}^{p} \log y_{it}^{p} & \mathit{if} \;\; p_1 = p_2 = p \end{cases} , \tag{4}$$

where p_1 and p_2 in equation (4) are chosen to take one of the following power values: $\{-2, -1, -0.5, 0, 0.5, 1, 2, 3\}$, such that the power zero represents the logarithmic transformation.

The deviance difference test selects the best fitting power value for the fractional polynomial against a set of null hypotheses. Three sequential nulls are considered for $F(y_{it})$. The first null hypothesis considers a model omitting y_{it}. If the first null is rejected, the test considers the second null, which is the linear model in y_{it}. If the second null is rejected, the test then considers the third null, which is the fractional polynomial of order 1, i.e.

$$F(y_{it}) = \alpha_0 + \alpha_1 y_{it}^{p}, \quad (5)$$

Finally, if the specification given by equation (5) is rejected, then the model specified by equation (2) is taken as the best fit.

Data and results

The data used in this paper are taken from the World Development Indicators (WDI, 2017) database of the World Bank spanning the period 1980-2010 for 10 MENA countries.[2] We retrieve two variables, which are CO_2 emissions per capita (in metric tons) and real GDP per capita (constant US$ 2005). The overall average of CO_2 emissions is around 9 tons per capita per year, while the average real GDP per capita is around US$ 9,700.

The best fitting model based on the results of the deviance difference test, reported in Table 1, is the fractional polynomial of order 2. The test rejects all three null hypotheses that consider the omission of y_{it} (I), the existence of linear relationship between y_{it} and c_{it} (II), and the fractional polynomial of order 1 (III) with *p*-value=0.000. The estimated fractional polynomial powers of equation (4) are $\hat{p}_1 = -0.5$ and $\hat{p}_2 = 0$.

Table 1: Deviance difference test

[2] It is worth mentioning that we restrict our data for the 1980-2010 period since it covers the most complete and balanced panel for the MENA countries. It also gains importance because the evidence draws from the period ending at the eve of Arab Spring.

Model		Deviance difference	Powers	*p*-value
(I)	H_0: Omitting y_{it}	626.895	.	0.000
	H_1: Fractional polynomial, order 2		(-0.5, 0)	
(II)	H_0: Linear relationship in y_{it}	219.154	1	0.000
	H_1: Fractional polynomial, order 2		(-0.5, 0)	
(III)	H_0: Fractional polynomial, order 1	46.502	0.5	0.000
	H_1: Fractional polynomial, order 2		(-0.5, 0)	

Sources: Authors' calculations based on data from World Development Indicators over the period 1980-2010 (WDI, 2017).

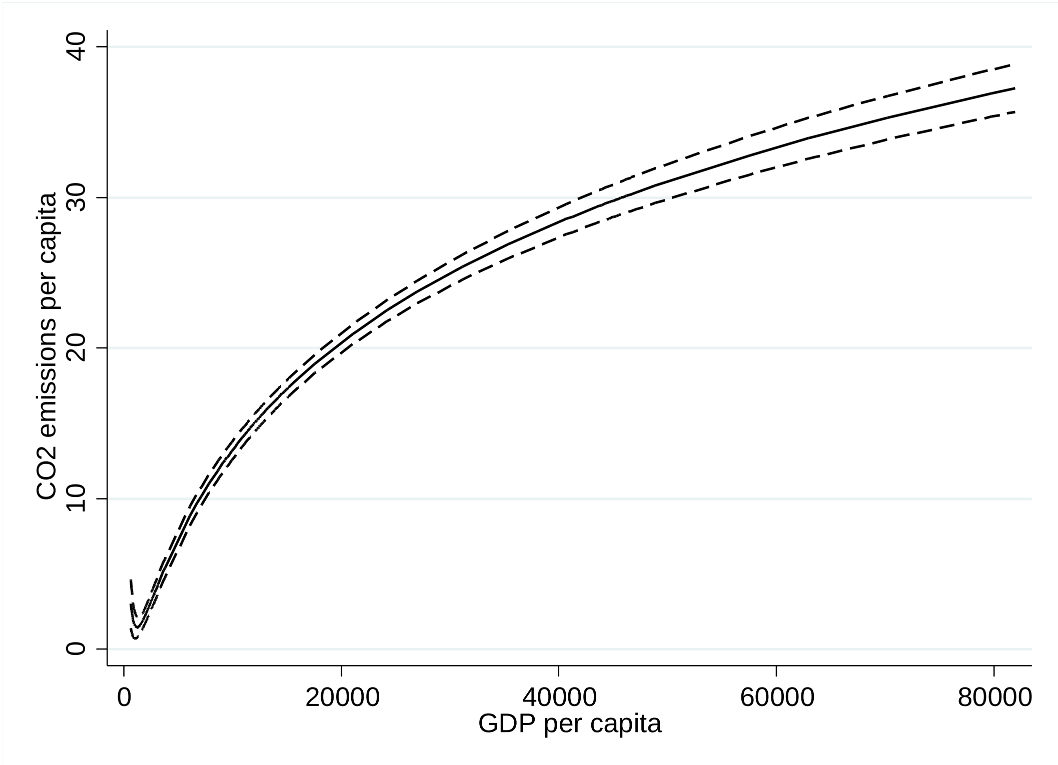
The non-parametric estimation of equation (1) is plotted in Figure 1. The estimated relationship is found to be acceptable as it lies within the 95% bootstrap confidence interval. Our results reveal a positive and concave relationship between CO_2 emissions and GDP. We find that emissions per capita are monotonically increasing in y_{it} except for low values of GDP per capita that our outside the sample range. Thus, in contrast with Arouri *et al.* (2012), our results strongly reject the strong EKC hypothesis for the MENA region. This divergence in the findings between the results reported by Arouri *et al.* (2012) and ours could be due to their use of parametric estimation model, while in our paper the approach is non-parametric. This confirms the importance of relaxing the restrictions imposed by the functional form on the data when it comes to the EKC applications.

Clearly, our results indicate that the trade-off is not broken yet. In fact, over the past decades, several economies in the MENA have witnessed a large increase in their use of energy derived from fossil fuel to propel economic growth. However, these countries have not yet developed clear policies to limit the negative local and global impacts of CO_2

emissions resulting from energy use, which explains the monotonic relationship between emissions and income.

For comparison purposes, we estimate equation (1) using, however, a fully parametric model. We consider the panel fixed effects to estimate three specifications, which are the linear, quadratic, and cubic polynomials, respectively. The results are reported in Table 2. The linear model indicates a positive relationship between GDP and emissions per capita, while both the quadratic and cubic models indicate the presence of a quadratic relationship lending support to the strong EKC hypothesis.

Figure 1: Non-parametric estimation; CO_2 emissions and GDP per capita.



Notes: The solid curve represents the estimated fit. The dashed curves correspond to the bootstrap 95% confidence intervals.
Sources: Authors' calculations based on data from World Development Indicators over the period 1980-2010 (WDI, 2017).

Table 2: Panel parametric estimation (Fixed effect)

Linear specification
$c_{it} = \underset{(0.314)^{***}}{6.302} + \underset{(0.000)^{***}}{0.000} y_{it}$
Quadratic specification
$c_{it} = \underset{(0.731)^{***}}{2.165} + \underset{(0.000)^{***}}{0.001} y_{it} - \underset{(0.000)^{***}}{0.000} y_{it}^2$
Cubic specification
$c_{it} = \underset{(0.951)}{1.417} + \underset{(0.000)^{***}}{0.001} y_{it} - \underset{(0.000)^{**}}{0.000} y_{it}^2 + \underset{(0.000)}{0.000} y_{it}^3$
N=310 observations

Notes: Standard errors are in parentheses. An *** indicates rejection at the 1% level, while ** indicates rejection at the 5% level, and * indicates rejection at the 10% level.
Sources: Authors' calculations based on data from World Development Indicators over the period 1980-2010 (WDI, 2017).

Conclusion

This paper sheds new light on the EKC hypothesis using a non-parametric approach on a panel of data from the MENA region. First, we use per capita measures instead of levels in order to capture the link between economic development and pollution intensity rather than the general link between growth and pollution. This is more in line with the traditional EKC theory. Second, unlike previous studies using parametric models, our results provide evidence against the postulated inverted-U shaped relationship between CO_2 emissions per capita and GDP per capita. Our results are thus in line with the pessimistic view on the EKC (Dasgupta *el al.,* 2002). The misspecification of the traditional parametric model is confirmed further when we use the same panel data to conduct parametric estimations, where the results are found to be in line with the strong EKC hypothesis. Taken together, our results provide a cautionary note against the use of parametric models (e.g. Al-Mulali *et al.*, 2015) to draw policy implications about the trade-off (or lack of) between environmental quality and the level of economic development. Finally, given the divergence between parametric and non-parametric models, future work might look into the work conducted on other countries and regions in order to provide more robust estimates.

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