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Working Paper No. 1260

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Abstract

A large number of studies on the validity of the environmental Kuznets curve for MENA countries, producing (as expected) a mixed bag of results. Several econometric issues are considered with reference to estimates of the EKC for Algeria, Egypt, Jordan and Tunisia. These issues include the order of the polynomial representing the EKC, the validity of the log-log specification, cointegration and spurious correlation, missing variables, and the sensitivity and fragility of the results. It is concluded that the most serious issue is the sensitivity of the results to model specification and other factors, which is not considered in the MENA studies of the EKC.

Keywords: Environmental Kuznets Curve Environmental Degradation, Log-Log Specification, Spurious Correlation

JEL Classifications: Q50, C10, C52

ملخص

يقدم عدد كبير من الدراسات حول مدى صحة منحنى كوزينتس البيئي لبلدان الشرق الأوسط وشمال أفريقيا ، مجموعة مختلطة من النتائج (كما هو متوقع). بأخذ في الاعتبار العديد من القضايا الاقتصادية في ضوء تقديرات ا لمنحنى البيئ فى الجزائر ومصر والأردن وتونس.، يتبين أنها تشمل ترتيب كثير الحدود يمثل منحنى كوزينتس البيئي ، ويظهرصحة مواصفات سجل مقابل سجل ، وكذلك التكامل المشترك والارتباط الهامشي ، والمتغيرات المفقودة ، وحساسية النتائج وهشاشتها. تخلص الدراسة إلى أن القضية الأكثر خطورة هي حساسية النتائج إلى المواصفات النموذجية والعوامل الأخرى ، والتي لا تؤخذ في الاعتبار في دراسات منطقة الشرق الأوسط وشمال أفريقيا.

1. Introduction

The environmental Kuznets curve (EKC) is a graphical representation of the relation between environmental degradation, typically represented by emissions of some sort, and income per capita. The underlying idea is that at low levels of income, growth causes environmental degradation (represented, for example, by increasing emissions per capita) but beyond a certain point, growth leads to environmental improvement (declining emissions per capita). The implication of this changing pattern is that the EKC takes the form of an inverted U-shaped curve. The inversion is explained in terms of the proposition that higher levels of income per capita are associated with a gradual shift towards information-intensive industries and services, a higher level of environmental awareness, enforcement of environmental regulation, better technology and a higher level of environmental expenditure.[2]

The notion of the environmental Kuznets curve is extrapolated from the original Kuznets curve, when Kuznets (1955) suggested that income inequality rose as the economy grew at low levels of income per capita, then declined beyond a certain point. Sometimes we come across the concept of the modified environmental Kuznets curve (MEKC), which represents a functional relation between environmental degradation and a wider concept of development than income per capita—in this case degradation is explained in terms of measures of economic development and well-being such as the United Nations' human development index (HDI). It is also possible to refer to the augmented environmental Kuznets curve, which represents the relation between environmental degradation and a range of factors in addition to income per capita.

The empirical evidence on the EKC is far from clear, as studies using various model specifications, samples, definitions and estimation methods have produced evidence supporting or rejecting the EKC. This is true for studies estimating the EKC for MENA countries, which have produced a mixed bag of results, showing support for an inverted U-shaped curve, a monotonic increasing function, an N-shaped curve, or simply no relation whatsoever.

Mandal and Chakravarty (2016) suggest that the literature on the EKC shows ambiguous results. They review 150 studies to find out whether the EKC is a universal phenomenon or that the findings of the studies depend on specific factors. These factors include the type of environmental indicators, measurement of environmental indicators, type of data set, the measure of income used, model specification, and the selected set of explanatory variables. Their review provides evidence for the fact that EKC is not a universal phenomenon but rather it is context-specific. By using a logit model, they found that studies using panel data, concentration per capita, multiple variable models, and unit root tests are more likely to support the EKC. On the other hand, studies using global data sets and studies adopting panel data along with unit root tests are less likely to show a significant EKC. Likewise, Youssef et

[2] Other theoretical explanations have been put forward for the inverted U-shaped curve. This paper is about the econometric estimation and testing of the EKC, in which case the theory of the EKC will not be dealt with in detail. For more on the theory of the EKC, see Moosa (2017c) and the references therein. See also Stern (2004) who describes the EKC as "an essentially empirical phenomenon" and presents a theoretical critique of the EKC.

al. (2016) examine 31 single and multi-country studies and suggest that the literature is divided on the validity of the EKC phenomenon, ranging from supportive to unsympathetic. Stern (2003) argues that the empirical work on the EKC is "econometrically weak". Specifically, he suggests that "little or no attention has been paid to the statistical properties of the data used such as serial dependence or stochastic trends". Perman and Stern (2003) contend that when these econometric considerations are taken care of, "we find that the EKC does not exist" and that "most indicators of environmental degradation are monotonically rising in income". This means that when econometric considerations are taken care of and "proper econometric methods" are used to conduct the analysis, the evidence for an inverted U-shaped curve will be weak. While this proposition may or may not be valid, an issue that must not be overlooked is the sensitivity of the results to model specification, estimation method, sample period, country-specific factors, and measures of income and environmental degradation. This is a more serious issue than considering or overlooking cointegration, particularly because it is a myth that cointegration can be used to detect spurious correlation (Moosa, 2017a, 2017b).

In this paper, five econometric issues arising from the literature on the EKC in MENA countries are considered to find out if "proper econometrics" produces reliable empirical evidence. These issue are (i) order of the polynomial representing the EKC, which depends on the presence (or otherwise) and the number of turning points; (ii) the validity of the log-log specification; (iii) cointegration issues; (iv) missing variables and the time trend, and (v) sensitivity and fragility of the results. It is demonstrated that the case for using cointegration is overstated. Alternative econometric methods are suggested, including the unobserved components model, which is used to account for missing variables and the possibility of time-varying parameters, and non-nested model selection and variable addition tests, which are used as tools for model selection. Following Auffhammer and Steinhauser (2012) and Yang et al. (2015), it is argued that irrespective of the kind of econometrics used, the sensitivity of the results means that reliable evidence on the EKC can only be derived from the distribution of the estimated coefficients rather than one or a small number of point estimates of the coefficients. The empirical work is conducted on time series data covering four MENA countries: Algeria, Egypt, Jordan and Tunisia. Nothing is special about the choice of these four countries, except for the availability of data over a long period of time. In any case, this is supposed to be an illustrative exercise, not an attempt to estimate the EKC for each and every MENA country.

2. Econometric Issues in the MENA Studies

A large number of studies have been conducted to estimate the EKC for MENA countries using time series and panel data. The results are mixed and sensitive to a number of factors, as we can see in Table 1. As a measure of environmental degradation, most of the studies use CO_2 emissions but others use SO_2 (Fodha and Zaghdoud, 2010; Al-Rawashdeh, 2014; Akbostanci et al., 2009).

Various estimation and testing methods have been used in the MENA studies, including cointegration and causality (Al-Mulali, 2011; Arouri et al., 2012; Chebbi et al., 2011; Fodha and Zaghdoud, 2010), simultaneous equation models (Omari, 2013), fully modified OLS (Farhani et al., 2013), dynamic OLS (Farhani et al., 2013, 2014), bootstrap panel unit root tests (Arouri et al., 2012; M'henni et al., 2011), ARDL (Al-Khathlan and Javid, 2013), least square fixed effect (Sileem, 2015), and semi-parametric fixed effect estimation (Awad and Abugamos, 2017). The results are highly sensitive to the methodology used to conduct the empirical analysis.

Some of the MENA studies use panel data whereas others use time series data to estimate the EKC for individual countries. The former include Omari (2013), Sahli and Rejeb (2015), and Awad and Abugamos (2017). The latter include Arouri et al. (2012), M'henni et al. (2011), Al-Khathlan and Javid (2013), Al-Rawashdeh et al. (2014), Chebbi et al. (2009), and Akbostani et al, (2009). Actually, Akbostanci et al., (2009) estimated the EKC for Turkey as a country and for 58 provinces and found a monotonic and increasing relation at the national level and an N-shaped curve at the provincial level, implying the absence of evidence in support for the EKC.

The econometric issues to be discussed in this paper are apparent in the MENA studies of the EKC. The finding of an N-shaped relation by Akbostanci et al. (2009) implies the possibility of a higher order polynomial than the default case of a quadratic function. The problem here is that even when this issue is considered, it is not dealt with properly, as polynomials of higher orders may be estimated without saying which one is a better representation of the underlying relation.

The second and third econometric issues are also apparent in the MENA studies. The issue of log-log specification is not addressed properly, although this specification has been used in the majority of the MENA studies in an *ad hoc* manner. The issue is the appropriateness of cointegration and causality, and whether or not the case for cointegration is overstated, is not dealt with although most of the MENA studies employ cointegration, including the Johansen test which typically over-rejects the null of no cointegration.

The fourth issue is that of missing variables and the time trend. The majority of the MENA studies introduce other explanatory variables such as corruption (Sahli and Rejeb, 2015), energy consumption, trade openness, manufacturing value added, the role of law and the genuine saving index (Farhani et al., 2014), oil consumption (Al-Mulali, 2011) and urbanisation (Awad and Abugamos, 2017). In fact, Farhani et al. (2014) state explicitly that they use extra explanatory variables to avoid the problem of missing variables, but there is no guarantee that the variables they use constitute a comprehensive list of the variables that affect environmental degradation besides income. Only in one study (M'henni et al., 2011) a deterministic time trend is added to account for missing variables. This procedure, however, is inadequate. Last, but not least, there is the (major) issue of the sensitivity of the results to a wide range of factors, which is apparent in the MENA studies.

3. Preliminary Estimates of the EKC

Preliminary estimates of the EKC are based on annual time series data for four MENA countries: Algeria, Egypt, Jordan and Tunisia. The sample period is 1960-2014 for Algeria and 1965-2014 for other countries. Two variables are used for the estimation of the EKC: CO2 emissions per capita and GDP per capita. The emissions variable, which represents environmental degradation, is CO2 emissions in metric tons per capita, where CO2 emissions stem from the burning of fossil fuels and the manufacture of cement, including the CO2 produced during consumption of solid, liquid, and gas fuels and gas flaring. GDP per capita is measured in terms of current U.S. dollars as GDP divided by mid-year population. The data were obtained from the World Bank's database.

Figure 1 shows the ECK for the four countries. The shape of the EKC is a parabola with the equation

$$e = ay^2 + by + c \tag{1}$$

where e is CO2 emissions per capita and y is GDP per capita. The turning point can be determined by differentiating equation (1) with respect to y and equating the derivative to 0. Thus

$$\frac{de}{dy} = 2ay + b = 0 \tag{2}$$

which gives

$$y = -\frac{b}{2a} \tag{3}$$

By using equation (3), the value of y at the turning point can be calculated for the four countries—the results are displayed in Table 2. For some reason, Tunisia reached the turning point at a lower level of GDP per capita (642.9) than other countries, which was around 1974-75. Egypt, on the other hand, reached the turning point at 2666.6, which occurred around 2008-09.[3]

The estimated values of a, b and y at the turning point as reported in Table 2 are based on OLS, which may not be appropriate. A better estimation method is the Phillips-Hansen (1990) fully-modified ordinary least squares (FMOLS) because OLS does not produce valid t statistics, whereas FMOLS does. This is because with integrated variables, the OLS standard errors, and hence the t statistics, do not follow an asymptotic normal distribution, which means that the conventional critical values of the t distribution cannot be used to derive inference on the significance of the estimated coefficients. The EKC can be written in a stochastic form as

$$e_t = \beta_0 + \beta_1 y_t + \beta_2 y_t^2 + \varepsilon_t \tag{4}$$

For a valid EKC, the following coefficient restrictions must be valid: $\beta_1 > 0$ and $\beta_2 < 0$. The results are reported in Table 3 where it is shown that the coefficient on y_t (β_1) is significantly positive while the coefficient on y_t^2 (β_2) is significantly negative, which means that the coefficient restrictions required to obtain the inverted U-shaped curve are satisfied. The goodness of fit, as measured by the coefficient of determinations, seems to be quite high for all countries.

4. Order of the Polynomial

Out of the MENA studies only one mentions an N-shaped curve, implying two turning points (Akbostanci et al., 2009) although others estimate explicitly a cubic function. Zhang (2012)

[3] Sometimes, a dynamic model of first differences is used to represent the EKC. For example, Stern (2004) suggests the use of a first difference model in the absence of cointegration. However, it seems that Stern overstates the importance of cointegration as we are going to see later. Furthermore, a dynamic model produces misleading random walk forecasts irrespective of the shape of the dynamics. On the hazard of generating forecasts from a dynamic model, see Moosa and Burns (2014).

argues that the inverted U-shaped curve may be "an artefact of restrictive functional forms in the sense that the 'true' relationship could be N-shaped or an even more flexible shape". However, Sileem (2015) states explicitly that only the quadratic form of the MEKC is estimated because many studies indicate that the cubic term turns out to be insignificant as suggested by Kallbekken (2000). This is rather strange, given that a large number of studies have shown that cubic and higher order polynomials are more valid than the quadratic function (for example, Canas et al., 2003; De Bruyn and Opschoor, 1997; Binder and Neumayer, 2005). Kilic and Balan (2016) examine the EKC for 151 countries and find support for a cubic function.

The order of the polynomial is an issue that has been largely overlooked in the MENA studies, although it has received considerable attention in the general literature on the EKC. Shafik and Bandyopadhyay (1992) estimated the relation between environmental degradation and income per capita by using three different functional forms: linear, quadratic and cubic. Van Alistine and Neumayer (2010) justify the use of a cubic function on the grounds that a second turning point may be observed. Canas et al. (2003) use both quadratic and cubic specifications, obtaining results of robust support for both of them. While they find evidence for an inverted U-shaped function (with the trend being mostly on the rising part of the curve), they suggest that the statistical support for the cubic specification means that their results need to be viewed with caution.

Consideration of higher order polynomials can be based on variable addition tests. For this purpose, a Lagrange multiplier test statistic (with a $\chi^2(1)$ distribution) can be calculated from the residual sum of squares of polynomials of orders m and m+1, which are written as follows:

$$e_t = \beta_0 + \sum_{j=1}^{m} \beta_j y_t^j + \varepsilon_t \tag{5}$$

$$e_t = \beta_0 + \sum_{j=1}^{m+1} \beta_j y_t^j + \varepsilon_t \tag{6}$$

The two equations are estimated for $m = 1,2,3,4$. The procedure starts by estimating a polynomial of order 1 (a linear function) and test for the significance of adding a quadratic term. The process is repeated by estimating a polynomial of order 2 (a quadratic function) and test for the significance of adding a cubic term, and so on. A significant test statistic means that the added term is important and must be included in the equation.

The results of variable addition tests are reported in Table 4 for polynomials of up to order 5. We can see that in the cases of Algeria and Tunisia, a polynomial of order 4 is more appropriate, whereas in the cases of Jordan and Egypt, the EKC (polynomial of order 2) is more valid. Figure 2 shows a comparison between polynomials of orders 2 and 4 for Algeria and Tunisia.

5. Model Specification: Logs or no Logs?

The majority of the MENA studies use log-log specification without theoretical or empirical justification, which is a common practice in the general literature on the EKC. Stern (2003) recommends the use of log-log specification on the grounds that the use of resources to fuel economic growth produces waste, which means regressions that allow levels of indicators to become zero or negative are inappropriate.[4] Schmalensee et al. (1998) advocate the use of the log-log specification with panel data on the grounds that multiplicative country and year fixed effects seem more plausible than additive effects, given the vast differences among countries in the panel.[5] On the other hand, Grossman and Krueger (1991) estimated EKCs for SO2, dark matter (fine smoke), and suspended particles (SPM) using a cubic function in levels (not logarithms) of PPP adjusted income per capita. Likewise, van Alstine and Neumayer (2010) specify the model in levels without logs. Holtz-Eakin and Selden (1995) examine both specifications and report very small differences. Yang et al. (2015) consider all possible combinations of logs or no logs (log emissions and log income, log emissions and the level of income, and so on). Like the case of the order of polynomial, they consider these possibilities to arrive at their universe of model specifications.

The choice between models with and without logs can produce different results, hence providing an opportunity to support pre-conceived beliefs, which is quite common in empirical work. Figure 3 shows the EKC specified in log-log form for the four countries. If anything, there is less evidence for a valid EKC when the log-log specification is used. The question here is whether we use the linear specification to find supportive evidence for the EKC or log-linear specification to discredit the EKC. One has to remember that the log-log specification is essentially a nonlinear power function. It may be odd, therefore, to have two different kinds of nonlinearity in the specification of the EKC: a quadratic form of a power function mixed together.

This problem can be solved empirically by testing the specification without logs against the specification with logs, which can be formulated as non-nested models with different dependent variables. In this case the model without logs is $e_t = \beta_0 + \beta_1 y_t + \beta_2 y_t^2 + \varepsilon_t$ (M1) while the model with logs is specified as $\log(e_t) = \beta_0 + \beta_1 \log(y_t) + \beta_2[\log(y_t)]^2 + \varepsilon_t$ (M2). This exercise is based on model selection tests and criteria using the double length regression test (*DL*) due to Davidson and MacKinnon (1984), as well as two criteria: *VLC* the Vuong's (1989) likelihood criterion (*VLC*) and Sargan's (1964) likelihood criterion (*SLC*). The *DL* statistic follows a t distribution, which means that a p-value greater than 0.05 implies that M1 is preferred to M2. Positive values of *VLC* and *SLC* imply that M1 is the preferred model. The results presented in Table 5 show clearly that M1 is preferred to M2, which means that the log-log specification is inappropriate.

6. Unit Root and Cointegration

A large number of the MENA studies use cointegration to test the EKC. Stern (2003) argues that studies of the EKC "do not report cointegration statistics that might tell us if omitted variables bias is likely to be a problem or not", concluding that "it is not really clear what we

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[4] It is not obvious why a log-log specification is needed to deal with the possibility of negative values for measures of degradation, since negative values will never appear in actual data for the very reason that production always produces waste. It could be that Stern (2003) is concerned about the possibility of negative forecast values, but again the log-log specification does nothing to change the situation. A forecast in log with a positive value may be translated into a negative value of the underlying measure of degradation.

[5] The choice between multiplicative and additive fixed effects should be an empirical issue.

can infer from this body of work”. Stern (2014) refers to the problem of integrated variables and that of spurious regression. Perman and Stern (2003) test for unit root and cointegration and find that log sulphur emissions per capita, log GDP per capita and its square have unit roots (stochastic trends). However, their cointegration results are “less clear cut”. Even when cointegration is found, the form of the EKC varies considerably across countries. Van Alstine and Neumayer (2010) warn particularly of the possibility of spurious regression results. While estimating the model in first differences might work as a solution, they contend that cointegration is superior. Still, few studies have considered cointegration in the EKC (for example, Galeotti et al., 2006; Perman and Stern, 2003; Stern, 2000; Stern and Common, 2001). Galeotti et al. (2006) conclude that evidence for EKCs in CO2 emissions can be found by using fractional panel integration and cointegration. They contend that the existence of unit root in the log of per capita CO2 and GDP series, in addition to the absence of unit root in the linear combination among these variables, are pre-requisites in order for the notion of EKC to be statistically and economically meaningful.

The problem here is that the EKC equation is nonlinear, which means that conventional cointegration tests (such as the Engle-Granger residual-based test) are no longer valid because when the ADF test is applied to the residuals of a nonlinear function, the critical values of the test statistics cannot be used to derive inference. With respect to the EKC, Wagner (2008) notes that conventional panel cointegration tests are not intended for use with nonlinear functions. Hong and Wagner (2008) suggest that since income per capita is a unit root process, its square is a nonlinear transformation of an integrated process, which means that regressions involving such processes require a different asymptotic theory from the usual linear unit root and cointegration analysis. Medeiros et al. (2012) derive the asymptotic distribution of the ordinary least squares estimator in a regression with cointegrated variables when the regressors are nonlinear. This is not to mention that the ADF test is not reliable for at least two reasons: (i) it is based on a simple AR(1) process, which is likely to be misspecified; and (ii) conventional unit root tests cannot distinguish between unit root and near-unit root processes.

Let us for the sake of argument assume that cointegration is a necessary condition for the validity of the EKC. Another problem is that different cointegration tests produce different and inconsistent results, making it possible to find support for prior beliefs. The Granger representation theorem, that cointegration implies and is implied by the presence of a valid error correction model, to test for cointegration on the basis of the t statistic of the coefficient on the error correction term. The error correction model corresponding to the EKC represented by equation (4) is specified as follows:

$$\Delta e_t = a_0 + \sum_{j=1}^{p} b_j \Delta e_{t-j} + \sum_{j=0}^{q} c_j \Delta y_{t-j} + \sum_{j=0}^{s} d_j \Delta y_{t-j}^2 + \phi \varepsilon_{t-1} + \xi_t \qquad (7)$$

where ϕ is a measure of the speed of linear adjustment to a nonlinear attractor. Kremers et al. (1992) contend that a cointegration test involving the application of the DF unit root test (or similar tests) to the residuals of the cointegrating regression may not reject the null hypothesis of no cointegration when the coefficient on the error correction term in the corresponding dynamic model may be statistically significant. They suggest that this conflict arises because of the implied common factor restriction that is imposed when the DF statistic is used to test for cointegration. If this restriction is invalid the DF test remains consistent but loses power relative to cointegration tests that do not impose a common factor restriction, such as the test based on the coefficient of the EC term.

The error correction term can be extracted from the long-run static equation that can be derived from an autoregressive distributed lag equation relating e to y (Pesaran and Pesaran, 2009; Pesaran and Shin, 1995, 1996; Pesaran et al., 2001). In this case, the null of no cointegartion is rejected when ϕ is significantly negative. It is also possible to use the bounds test statistics F and W, where the null of no cointegration is rejected if the value of the test statistic is higher than the upper bound. The results presented in Table 6 are mixed. While the null of no cointegration is rejected by the t test, the F and W tests do not reveal cointegration, except in the case of Tunisia. This is the problem of inconsistency of the results obtained by using different tests. The Johansen test in particular is notorious for over-rejecting the null of no cointegation, thus it is a useful tool for those operating with confirmation bias. It is popular and used frequently because it gives the desired results in the presence of confirmation bias.

The importance of cointegration is often exaggerated. It is true that an OLS regression of integrated variables, such as emissions per capita and income per capita, is not suitable for deriving inference because the t statistics are not valid. As pointed out earlier, this problem can be solved by using the Phillips-Hansen (1990) FMOLS. The second problem is the possibility of spurious regression, which can produce misleading inference. However, it is a myth that cointegration can be used to distinguish between spurious and genuine relations. We can only tell whether a relation is spurious or otherwise if this relation is supported by economic theory or at least intuition (see, for example, Moosa, 2011, 2017a, 2017b).[6] We already have somewhat convincing arguments why growth is associated with environmental improvement beyond a certain level of per capita income. The absence of cointegration does not necessarily mean that the two variables are unrelated. After all, non-cointegration does not preclude the possibility of causality. Ignoring casual relations in the absence of cointegration does not seem to be the right thing to do.

7. Missing Variables and Time Trend

Stern (2003) suggests that a time trend is added to the EKC equation to account for time-varying omitted variables and stochastic shocks. Stern and Common (2001) contend that the EKC is an incomplete model that suffers from significant omitted variables bias. Stern (1998) argues that testing different variables individually is subject to the problem of potential omitted variables bias and that, given the poor statistical properties of most EKC models, it is hard to come to any conclusions about the roles of other additional variables such as trade. The problem is that the time trend used in the EKC regressions is deterministic, in which case it may not account properly for (time-varying) missing variables and certainly not for stochastic shocks.

[6] Moosa (2017a) warns of the hazard of using cointegration testing to detect spurious correlation, providing evidence indicating that this procedure may lead us to believe that NASA is responsible for suicide and that the consumption of margarine leads to divorce.

A large number of control variables have been suggested to be included in the EKC equation, but the list cannot be exhaustive. One way to account for missing variables (without identifying them explicitly) while introducing a stochastic time trend is to use an unobserved components model that is estimated in a time-varying parametric (TVP) framework. The model is specified as

$$e_t = \mu_t + \delta_{1t} y_t + \delta_{2t} y_t^2 + \varepsilon_t \quad (8)$$

where μ_t is a stochastic trend and ε_t is the random component. Equation (8) is estimated by using maximum likelihood and the Kalman filter to update the state vector (Harvey, 1989; Koopman et al., 2006).

It must be stated here that allowance is made for a stochastic trend to avoid imposing the restriction of a deterministic trend when this restriction is not valid. If the trend is deterministic, the results will show that. Furthermore, the model may be estimated with constant or time-varying coefficients on the explanatory variables, but the possibility of time-varying coefficients is considered to account for policy changes and shifts in private sector behaviour. Moreover, the use of TVP estimation is more appropriate for long data spans as changes in dynamic structures become more likely. This proposition is applicable to economic, financial and environmental time series.

The model estimation results are reported in Table 7, which displays the t statistics of the estimated components of the state vector as well as the coefficient of determination (R^2) and the diagnostics for serial correlation (*Q*) and heteroscedasticity (*H*). *Q* is the Ljung-Box statistic, which has a χ^2 distribution and *H* is a test statistic for heteroscedasticity with an *F* distribution. The results show that the model has a reasonable explanatory power and passes the diagnostics for serial correlation and heteroscedasticity. In all cases there is evidence for missing variables (that are accounted for) because μ_t is statistically significant. What is perhaps more important is that the conditions for an inverted U-shaped EKC ($\delta_{1t} > 0$ and $\delta_{2t} < 0$) are satisfied in all cases.

8. Specification Search, Data Mining and the Fragility of Results

Although the results presented so far provide evidence for the EKC, these results cannot be generalised to the extent of making the EKC a universal law. In fact the same data set used in this study may be used to produce overwhelming evidence against the EKC. One way or another, the results are fragile, which is a characteristic of the empirical literature on the EKC (and empirical work in economics at large).

With the exception of Auffhammer and Steinhauser (2012) and Yang et al. (2015), empirical studies of the EKC report one or a few estimated equations, showing that the EKC exists or that it does not exist and present the results as solid evidence for or against the EKC. This is the basis of the Leamer (1983) critique of econometrics, which revolves around the proposition that a regression model with a large number of potential explanatory variables (and other variations) can be used to prove almost anything and produce results (after extensive data mining) that support prior beliefs. Leamer diagnosed the empirical work of his contemporaries as suffering from a distressing lack of robustness to changes in key assumptions—assumptions he called “whimsical” because one seemed as good as another. As a result, he argued, “hardly anyone takes data analysis seriously”.

Brajer et al. (2011) conclude that the literature on the EKC is “quite varied” and “much like the blind men describing the elephant by touch”. Only two studies of the EKC consider the problem of specification search and the fragility of the results. Auffhammer and Steinhauser (2012) argue that “regardless of the adopted approach to model selection, the fact that one observes only a single realization of any time series means a danger that the observed predictive power of the chosen model may be due to chance rather than true forecasting ability of the model”. They identify the problem that most specification searches in practice are not systematic or comprehensive. They refer to this issue as “data snooping”, a situation in which data are used repeatedly for inference or model selection without accounting for the reuse of the data in inference tests. According to them, the oversight of this issue can be attributed to the lack of “an easily implementable and broadly applicable way of accounting for the impact of specification searches on inference tests”. As an alternative, they use a generally applicable method from the financial econometrics literature to test the null hypothesis that the best (EKC) model encountered during a specification search has no predictive superiority over a benchmark model (White, 2000; Hansen, 2005).

Likewise, Yang et al. (2015) relate regression estimate fragility to data snooping, which White (2000) describes by saying that “when a given set of data is used more than once for the purpose of model selection, it is possible that any satisfactory results obtained may simply be due to chance rather than any merit inherent in the model yielding the results”. Following Leamer (1983), they argue against the proposition that it is possible to identify a priori all explanatory variables in the model, the correct functional form and the distribution of errors, suggesting instead that in reality we confront a number of plausible explanatory variables, several functional forms and some guesses about the potential bias in the residual terms. They conclude that “data snooping through varying model assumptions may also be abused for mining any ‘wanted’ result”.

As an illustration, let us see what happens when the income per capita variable is changed while still measuring environmental degradation in terms of CO2 emissions per capita. In Figure 4 we can see how the results change in the case of Jordan by using four alternative measures of income per capita: GDP per capita in current local currency prices, GNI per capita in local currency prices, GDP per capita in constant local currency prices, and GDP per capita in constant U.S. dollar. When the first two measures are used, the EKC is quite evident, with a very close fit. When the third and fourth measures of income per capita are used, the relation turns out to be upward sloping. Other variations are likely to change the results, and not only for Jordan.

It follows that the major problem with the empirical studies of the EKC is not ignoring cointegration or using this and that method. Rather, the problem is that there are so many possibilities that any data set can be used to produce evidence for or against the EKC. The problem, therefore, is failure to use sensitivity analysis along the lines suggested by Auffhammer and Steinhauser (2012) and Yang et al. (2015).

9. Conclusion

One of the most frequently researched hypotheses in environmental economics, and economics at large, is the environmental Kuznets curve, which describes the relation between environmental degradation and some measure of economic growth or development. The EKC has been estimated and tested for MENA countries by a number of economists but the results have been inconclusive. The results are typically sensitive, *inter alia*, to a number of factors, including the type of environmental indicators, measurement of environmental indicator, type of data set, the measure of income used, model specification, and the set of explanatory variables.

In addition to the sensitivity and fragility of the results, four econometric issues are dealt with in this study with reference to the EKC for four MENA countries. These issues include the order of the polynomial representing the EKC, the validity of the log-log specification, cointegration, and missing variables. Several suggestions are made to deal with these issues. The order of the polynomial can be dealt with by using variable addition tests. The appropriateness (or otherwise) of the log-log specification can be determined by using non-nested model selection tests. The use of conventional cointegration testing is problematical because of the nonlinear specification of the EKC. However, it is argued that the case for cointegration is overstated because cointegration is not a test for spurious correlation as it is typically portrayed to be. The problem of missing variables can be circumvented by using the unobserved components model estimated in a TVP framework.

The major problem arising in empirical work on the EKC is the fragility of the results, in the sense they are not robust and sensitive to a number of factors. It is demonstrated that by changing the definition of income per capita, the evidence changes completely. There is no problem with changing results as a result of changing the measure of environmental degradation, because it is plausible to suggest that the EKC may be valid for some pollutants but not for others. However, it is a problem when the results are not robust with respect to measures of environmental degradation. One must be careful about deriving inference and policy recommendations from results based one or a small number of regression equations.

This paper is about the econometrics of the EKC, but this does not mean that econometrics is the only problem with the literature on the EKC. An equally important issue is the assumption of automatic and optimal internalisation of pollution externalities as development unfolds, which underlies the static ECK modelling. A related issue is the lack of theory to guide the structural modelling of the EKC. Yet another issue pertains to the use of decomposition analysis whereby emissions are broken down into proximate sources of emissions changes, together with detailed sectoral information on fuel use, production, emissions, etc. Furthermore, empirical research on the EKC can be enhanced by the accumulation of detailed sectoral data, including improved social accounting matrices.

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Table 1: A Summary of the Results of EKC in MENA Countries

Study	Model/Variables	Methodology	Results
Akbostanci et al. (2009)	Cubic function in income and other variables such as population density. Both linear and log-linear models for PM10 and SO2	Johansen cointegration test	Evidence for a monotonic and increasing relation at the national level and an N-shaped curve at the provincial level
Halicioglu (2009)	Log-log quadratic function with trade openness	Bounds cointegration test and causality	Income is the most significant explanatory variable
Fodha and Zaghdoud (2010)	Cubic log-log model using CO2 and SO2	Johansen cointegration test and Granger causality test	Support for EKC with SO2, not CO2
Al-Mulali (2011)	GDP, oil consumption and CO2 emissions	Cointegration and causality	Evidence for a long-run relation among the three variables
M'henni et al. (2011)	CO2 emissions, energy consumption, and real GDP in a log-log form	Bootstrap panel unit root tests and cointegration	Real GDP exhibits a quadratic relationship with CO2 emissions for the region as a whole
Chebbi et al. (2011)	Log-log model for CO2, GDP and openness	Johansen cointegration, causality and impulse response functions	Positive linkage between income per capita and emissions and negative linkage between income per capita and emissions
Arouri et al. (2012)	Log-log specification involving economic growth, energy consumption and CO2 emissions	Bootstrap panel unit root and cointegration	Real GDP exhibits a quadratic relation with CO2 emissions. At the country-level, EKC is not verified
Al-Khathlan and Javid (2013)	Log-log (linear) model, including CO2 emissions, energy consumption and income per capita	Autoregressive distributed lag model	Monotonically increasing relation between CO2 emissions and per capita income
Omri (2013)	Log linear function with additional variables such as urbanisation, energy consumption and trade openness	Simultaneous-equations models with panel data	Bidirectional causal relation between economic growth and CO2 emissions for the region as a whole
Al-Rawashdeh et al. (2014)	Log-log model without additional variables for SO2	Johansen cointegration test	Limited evidence for the EKC for individual MENA

	and CO2 emissions		countries
Farhani et al. (2014)	CO2 emissions as a function of per capita GDP, energy consumption, trade openness, manufacturing value added, HDI and other variables.	Panel FMOLS and DOLS	Evidence for an inverted U-shaped relation between environmental degradation and income and between sustainability and HDI
Sileem (2015)	CO2 emissions per capita, human development index and corruption	Least square fixed effects regression and Granger causality test	Evidence for MEKC for the MENA region economies
Sahli and Rejeb (2015)	Log-log specification with additional explanatory variables such as corruption and trade	Dynamic panel	Positive direct impact of corruption on per capita emissions
Awad and Abugamos (2017)	Log-log function in levels and first differences relating CO2 emissions to GDP per capita, total population, energy intensity and urbanisation	Semi-parametric panel fixed effects regression	Evidence to support an inverted-U shaped relation between income and CO2 emissions

Table 2: The Value of GDP per capita at the Turning Points

Country	***a***	***b***	Turning Point
Algeria	-0.0000007	0.0016	1142.9
Jordan	-0.0000007	0.0024	1714.3
Egypt	-0.0000003	0.0016	2666.7
Tunisia	-0.0000007	0.0009	642.9

Table 3: Phillips-Hansen FMOLS Estimates of the EKC

Country	β_0	β_1	β_2	R^2
Algeria	0.427 (3.01)	0.002 (13.62)	-0.23×10^{-7} (-10.03)	0.74
Egypt	0.336 (15.49)	0.0017 (45.38)	-0.34×10^{-7} (-29.97)	0.95
Jordan	-0.014 (-010)	0.003 (16.82)	-0.47×10^{-7} (-13.66)	0.85
Tunisia	0.451 (17.04)	0.0099 (34.28)	-0.61×10^{-8} (-20.42)	0.96

t statistics are placed in parentheses.

Table 4: Variable Addition Tests

Country	y^2	y^3	y^4	y^5
Algeria	31.12	20.13	8.03	3.96
	[0.00]	[0.00]	[0.01]	[0.05]
Egypt	39.37	0.69	0.02	0.24
	[0.00]	[0.40]	[0.89]	[0.62]
Jordan	35.01	0.09	0.22	0.00
	[0.00]	[0.77]	[0.64]	[0.99]
Tunisia	34.49	8.81	15.47	2.63
	[0.00]	[0.003]	[0.00]	[0.10]

p-values are placed in square brackets. A p-value less than 0.05 implies that the missing term should appear in the regression.

Table 5: Model Selection Tests and Criteria (M1 vs M2)

	DL	***VLC***	***SLC***
Algeria	0.34 [0.73]	30.36	19.01
Egypt	1.86 [0.062]	13.95	7.41
Jordan	1.72 [0.09]	0.51	0.28
Tunisia	0.97 [0.33]	31.99	16.34

DL is the double length regression test statistic due to Davidson and MacKinnon (1984). *VLC* is the Vuong's (1989) likelihood criterion. *SLC* is Sargan's (964) likelihood criterion. For the *DL* test statistic, a p-value greater than 0.05 implies that M1 is preferred to M2. Positive values of *VLC* and *SLC* imply that M1 is the preferred model.

Table 6: Results of Cointegration Tests

Country	$t(\phi)$	***F***	***W***
Algeria	-3.14*	2.71	0.19
Egypt	-2.76*	4.05	4.53
Jordan	-4.09*	3.65	0.63
Tunisia	-3.42*	5.53*	40.81*

* Significant at the 5% level.

Table 7: Estimated Unobserved Components Models

Country	t Statistics			Goodness of Fit and Diagnostics		
	μ_t	δ_{1t}	δ_{2t}	R^2	Q	H
Algeria	2.87	3.62	-3.03	0.41	10.05	0.08
Egypt	3.76	3.38	-2.93	0.47	4.40	1.05
Jordan	2.45	4.68	-3.57	0.52	9.23	0.004
Tunisia	4.81	3.83	-2.07	0.46	9.19	0.15

Q is distributed as $\chi^2(5)$ for Algeria and $\chi^2(4)$ for the others (the critical values are 11.07 for Algeria and 9.48 for the others). H is F(54,54) for Algeria and F(49,49) for the others (the critical values are 1.57 for Algeria and 1.61 for the others).

Figure 1: Environmental Kuznets Curve

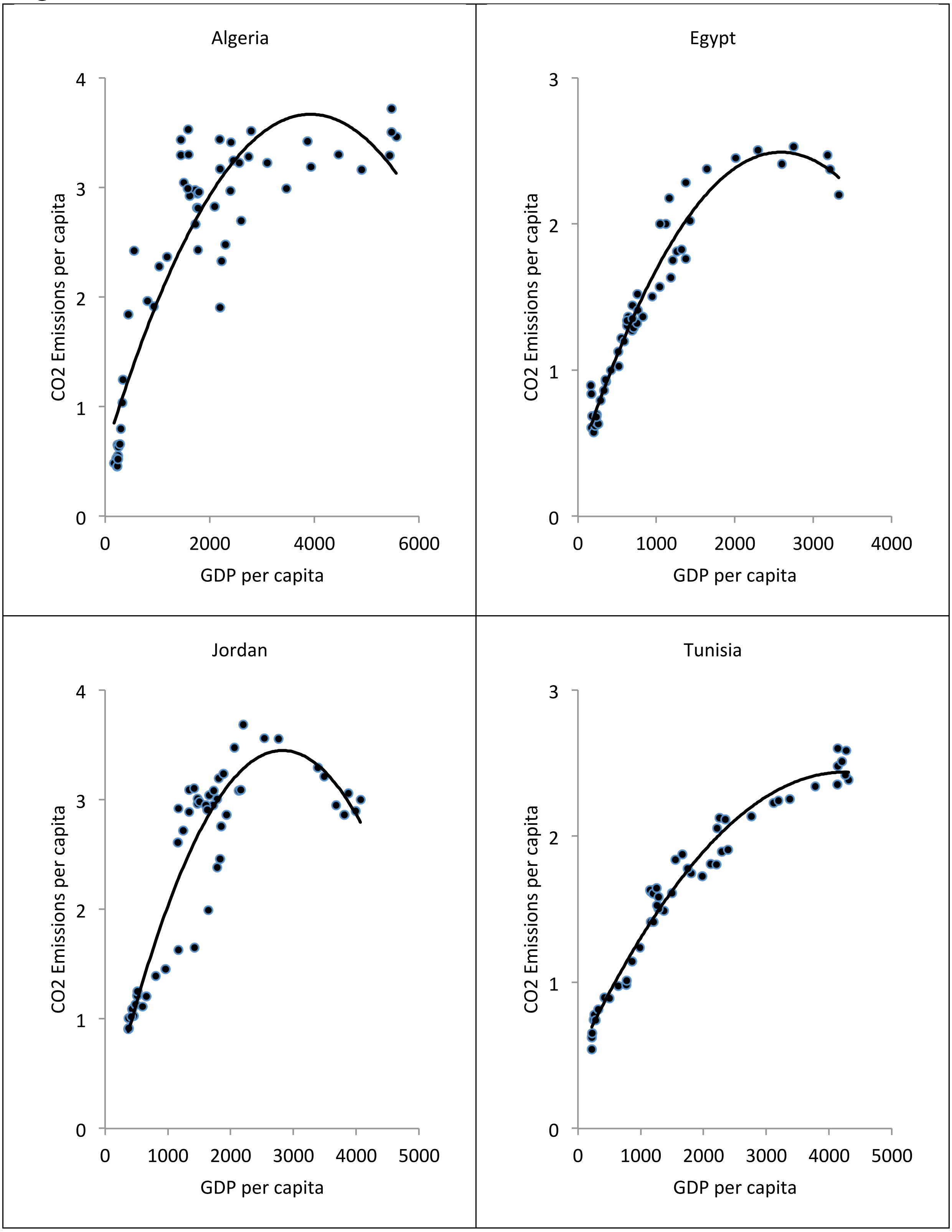

Figure 2: Polynomials of Orders 2 and 4

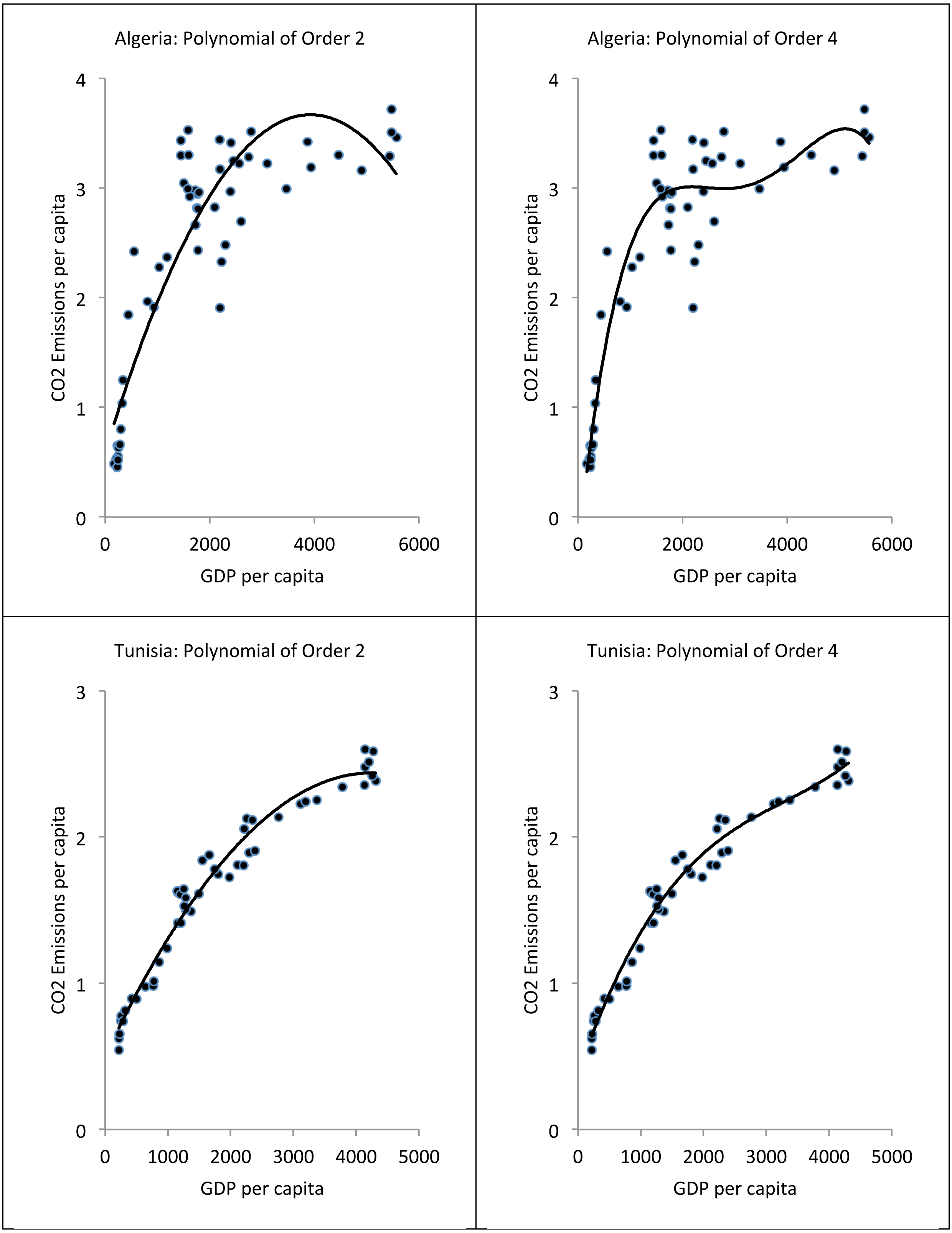

Figure 3: EKC with log-log Specification

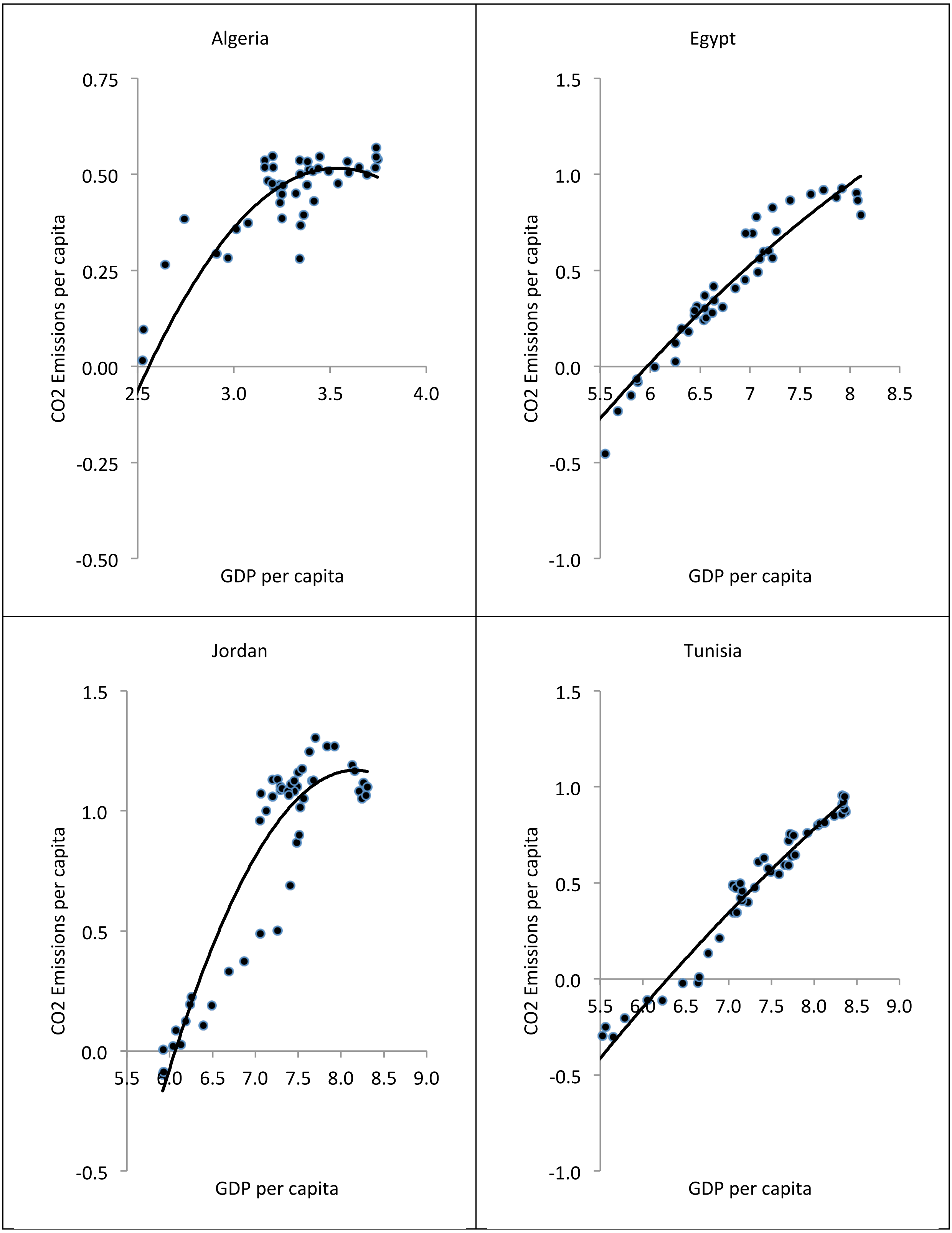

Figure 4: EKC for Different Measures of Income per capita (Jordan)