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# Carbon dioxide emissions and economic growth: Panel data evidence from developing countries

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ABSTRACT

In this paper we test the Environment Kuznet's Curve (EKC) hypothesis for 43 developing countries. We suggest examining the EKC hypothesis based on the short- and long-run income elasticities; that is, if the long-run income elasticity is smaller than the short-run income elasticity then it is evident that a country has reduced carbon dioxide emissions as its income has increased. Our empirical analysis based on individual countries suggests that Jordan, Iraq, Kuwait, Yemen, Qatar, the UAE, Argentina, Mexico, Venezuela, Algeria, Kenya, Nigeria, Congo, Ghana, and South Africa—approximately 35 per cent of the sample—carbon dioxide emissions have fallen over the long run; that is, as these economies have grown emissions have fallen since the long-run income elasticity is smaller than the short-run elasticity. We also examine the EKC hypothesis for panels of countries constructed on the basis of regional location using the panel cointegration and the panel long-run estimation techniques. We find that only for the Middle Eastern and South Asian panels, the income elasticity in the long run is smaller than the short run, implying that carbon dioxide emission has fallen with a rise in income.



## 1. Introduction

The pollution–economic growth nexus is one of the most important empirical relationships tested in the ecological economics literature. This has been particularly so since the beginning of the 1990s, when concerns regarding climate change, in particular global warming, as a result of deteriorating environmental quality took centre stage. Substantial discharge of carbon dioxide is considered as the main cause of global warming. It is, thus, not surprising that a sizeable literature has been documented. The central focus of this literature is to examine the role of income in environmental quality. The theoretical proposition is that during the early stage of economic development pressure on the environment is high; thus the environment deteriorates. However, over time as the economy grows, the pressure on the environment eases and thus environmental quality improves. This relationship has been termed as the Environmental Kuznets Curve (EKC).

The main motivation for testing the relationship between environmental quality and economic growth is that it allows policy makers to judge the response of the environment to economic growth. The response of the environment to economic growth is crucial since the objective function of any economy is to maximise economic growth.

This literature follows two strands. The first strand (see, *inter alia*, Friedl and Getzner, 2003; Roca et al., 2001; De Bruyn et al., 1998; Roberts and Grimes, 1997) examines the pollution–economic growth nexus for individual countries. The second strand (see, *inter alia*, Canas et al., 2003; Stern, 2004; Perman and Stern, 2003; Huang and Lin, 2007) examines the pollution–economic growth nexus for a cross-section and/or panel of countries.

Our main contribution to this literature is in the interpretation, and draws motivation from the work of Stern (2004) and Perman and Stern (2003). Stern (2004) points out that most of the EKC literature is econometrically weak. We concur with this view. In addition, our work suggests that several of the studies (see, *inter alia*, Perman and Stern, 2003; Canas et al., 2003; Dinda et al., 2000; Galeotti et al., 2006) that model emissions as a function of income augmented by income-squared and income-cubed type variables suffer from an additional problem—that of collinearity or multicollinearity. We confirm this by undertaking a test for collinearity between income and income-squared and between income-squared and income-cubed for our panel dataset. For the correlation coefficient between income and income-squared we found it to be 0.9984 for the Middle Eastern panel, 0.9992 for the South Asian panel, 0.9998 for the Latin American panel, 0.9989 for the East Asian panel, and 0.9983 for the African panel. Meanwhile, the correlation coefficient between income-squared and income-cubed was 0.9985, 0.9992, 0.9998, 0.9990, and 0.9985 for the

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Middle Eastern, South Asian, Latin American, East Asian, and African panels, respectively.

An important exercise in testing the EKC hypothesis is estimating the turning point—a level of income at which income starts to exert a positive impact on the environment. It should be noted that the extant literature has found some unrealistic turning points—from as low as US$3137 (Panayotou, 1993) to US$101,166 (Stern and Common, 2001). Such disparity and extreme levels of per capita income for the turning point reflects some problems with the proposed model. Not surprisingly, Stern and Common (2001) claim that there is likely to be possible model misspecification. Given the extremely high correlation coefficients between income, income-squared, and income-cubed, this seems to be an obvious problem with the extant literature. We, thus, make an attempt to correct this.

Our second contribution to this literature, given the limitation of including different variants of the income variable, is that we suggest an alternative way of judging whether developing countries have reduced carbon dioxide emissions over time with growth in incomes. We argue that this can be achieved by comparing the short-run income elasticity with the long-run income elasticity. If the long-run income elasticity is smaller than the elasticity in the short run, then this implies that over time income leads to less carbon dioxide emissions.

Briefly foreshadowing the main results, based on individual countries, we find that for Iraq, Jordan, Kuwait, Yemen, Qatar, the UAE, Argentina, Mexico, Venezuela, Algeria, Kenya, Nigeria, Congo, Ghana, and South Africa—approximately 35 per cent of the sample—the long-run income elasticity is smaller than the short-run income elasticity. This implies that over time income contributes less to carbon dioxide emissions. We also examine the EKC hypothesis for panels of countries constructed on the basis of regional location using panel cointegration and panel long-run estimation techniques. We find that the income elasticity is smaller in the long run for the Middle Eastern and the South Asian panels.

We organise the balance of the paper as follows. In the next section, we provide an overview of the selected studies on the pollution–economic growth nexus related to our study. In Section 3, we discuss the econometric estimations techniques. In Section 4, we give an account of the data, and discuss the results. In Section 5, we discuss the policy implications. In the final section, we provide some concluding remarks.

## 2. An overview of existing panel/cross-sectional studies

As highlighted earlier, there is a large and growing literature that examines the EKC hypothesis. Thus, it is impossible to review all studies. It is not our objective to review all studies; rather, the goal is to review those studies that have some connection to our work. It follows that we only selected recent cross-sectional/panel data-based analysis of the EKC hypothesis. There are two features of this literature worth highlighting here. First, these studies are based on both parametric and non-parametric approaches. Second, they consider different samples, both in terms of countries and time periods, so in a strict sense the results cannot be compared. At best, some generalisations about the validity of the EKC hypothesis can be made.

Dinda et al. (2000) examined the relationship between suspended particulate matter (spm) and sulphur oxide emissions ($SO_2$) and per capita income over the period 1979–1990. They used income and income-squared as determinants of the environmental quality variables and did not find evidence of the EKC. In particular, for $SO_2$ they found an inverse relationship with per capita income, while for spm they found a U shape, implying that in the short run environmental quality improves as income grows, but it declines over the long run as income grows.

Galeotti et al. (2006) examined the relationship between per capita carbon dioxide emissions and per capita income, and per capita income squared and per capita income cubed for the OECD and non-OECD countries using two different datasets, namely the International Energy Agency database covering the period 1960–1998 and the Carbon Dioxide Information Analysis Centre database covering the period 1950–1997. They find evidence for the EKC only for the OECD countries.

Canas et al. (2003) examined the Environmental Kuznets Curve for a panel of 16 industrialised countries for the period 1960–1998. They measure environmental quality using direct material input per capita, which is regressed against per capita income, per capita income squared, and per capita income cubed. They found evidence for the inverted U-shaped EKC relationship.

Perman and Stern (2003) use a panel cointegration approach to examine the EKC hypothesis for a panel consisting of 74 countries. In this study, the authors consider per capita sulphur oxide emissions and regress it against per capita income and per capita income squared. They do not find evidence for the EKC hypothesis.

Finally, Azomahou et al. (2006) investigate the EKC hypothesis using a non-parametric approach. They use data for 100 countries over the period 1960–1996 and find some evidence of the EKC hypothesis. For other non-parametric-based analysis of the EKC, see Bertinelli and Strobl (2005) and Taskin and Zaim (2000), among others.

## 3. Methodology

In this section, we explain our econometric approach. In panel cointegration, an essential first step is to examine whether the variables contain a panel unit root. While there are number of panel unit root tests, in this study we use the panel unit root test proposed by Breitung (2000) and Im et al. (2003). Our main motivation for using the Breitung (2000) panel unit root test is that using the Monte Carlo simulations Hlouskova and Wagner (2006) found that the Breitung (2000) panel unit root test generally had the highest power and smallest size distortions among a suite of panel unit root tests.

However, one of the drawbacks of the Breitung (2000) test is that the autoregressive coefficient is restricted to be identical across countries under both the null and alternative hypotheses. The test proposed by Im et al. (2003) has the advantage over the Breitung (2000) test that it does not assume that all countries converge towards the equilibrium value at the same speed under the alternative hypothesis and thus is less restrictive. These tests are widely used, hence we do not repeat the methodologies here, but refer interested readers to a recent paper by Narayan et al. (2008).

Following Pedroni (1999), to test for the cointegration relationship among variables for a panel of countries, we specify the following panel cointegration regression:

$$\ln CO_{2i,t} = \alpha_i + \beta_i \ln Y_{i,t} + \varepsilon_{i,t} \quad (6)$$

for $t=1,\ldots,T; I=1,\ldots,N$ where $T$ refers to the number of observations over time and $N$ refers to the number of individual members in the panel. ln$Y$ is the natural logarithm of real GDP and ln$CO_2$ is the natural logarithm of carbon dioxide emissions. The null hypothesis of no cointegration is examined based on seven different test statistics recommended by Pedroni. These test statistics are the panel $\nu$-statistic, the panel$\rho$-statistic, the panel $t$-statistic (non-parametric), the panel $t$-statistic (parametric), the group $\rho$-statistic, the group $t$-statistic (non-parametric), and the group $t$-statistic (parametric).

**Table 1**
Panel results.

| *Panel A: panel unit root test results* | | | | |
|---|---|---|---|---|
| Regional panel | IPS | | Breitung t-test | |
| | lnY | lnCA | lnY | lnCA |
| Middle Eastern | −1.3655 | −1.5756 | 1.1605 | 0.0344 |
| | (0.0860) | (0.0576) | (0.8771) | (0.5137) |
| South Asian | 4.5068 | 0.7997 | −1.5057 | 1.5229 |
| | (1.0000) | (0.7881) | (0.0661) | (0.9361) |
| Latin American | −0.0964 | −1.0347 | −1.0939 | −0.9028 |
| | (0.4616) | (0.1504) | (0.1370) | (0.1833) |
| East Asian | 2.8263 | 2.5959 | −0.7649 | 0.5099 |
| | (0.9976) | (0.9953) | (0.2222) | (0.6950) |
| African | 0.6085 | −0.8396 | 0.8551 | −0.5382 |
| | (0.7286) | (−0.2006) | (0.8037) | (0.2952) |

| *Panel B: Pedroni's panel cointegration test results* | | | | |
|---|---|---|---|---|
| Regional panel | Panel pp | Panel adf | Group pp | Group adf |
| Middle Eastern | −4.74*** | −4.26*** | −4.39*** | −4.38*** |
| | [0.0001] | [0.0001] | [0.0001] | [0.0001] |
| South Asian | −1.68* | −2.00** | −1.26 | −2.52** |
| | [0.0930] | [0.0455] | [0.2077] | [0.0117] |
| Latin American | −3.63*** | −3.02*** | −3.95*** | −3.43*** |
| | [0.0003] | [0.0025] | [0.0001] | [0.0006] |
| East Asian | −1.83* | −1.72* | −1.32 | −2.12** |
| | [0.0673] | [0.0854] | [0.1868] | [0.0340] |
| African | −3.47*** | −3.47*** | −2.91*** | −2.43** |
| | [0.0005] | [0.0005] | [0.0036] | [0.0151] |

| *Panel C: panel long- and short-run elasticities* | | | |
|---|---|---|---|
| Regional panel | Long-run | Short-run | ECT |
| Middle Eastern | 0.45*** | 0.57*** | −0.29*** |
| | (9.29) | (7.59) | (−6.64) |
| South Asian | 0.78*** | 0.85** | −0.13** |
| | (6.77) | (2.20) | (−2.36) |
| Latin American | 1.73*** | 0.71*** | −0.12*** |
| | (36.23) | (8.66) | (−2.94) |
| East Asian | 1.17*** | 0.74*** | −0.03** |
| | (31.70) | (5.47) | (−2.21) |
| African | 0.48*** | 0.01 | −0.09*** |
| | (7.55) | (0.05) | (−3.89) |

*Notes*: In square brackets, for panel cointegration in Panel B, are the probability values while in parenthesis are the *t*-statistics. *, **, and *** denote statistical significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

## 4. Data and results

### 4.1. Data

Our dataset is for the period 1980–2004. Consistent data for all countries prior to 1980 are not available; hence, the sample period is dictated by data availability. The data on carbon dioxide emissions is obtained from the International Energy Agency 2004, while data on GDP is obtained from the Groningen Research Centre.

### 4.2. Unit root test results

A prerequisite for panel cointegration test is that all variables in the model need to be integrated of order one. We confirm this using univariate and panel unit root tests. We first estimate the ADF model and find that real GDP and carbon dioxide emissions are integrated of order one for all the 43 countries. We then attempt to confirm that the same integrational property exists for each of these two variables when considered in a panel form. We address the issue of panel stationarity by using two different panel unit root tests, namely the IPS test and the Breitung test. These tests differ in that the Breitung *t*-test statistic treats the null hypothesis as a unit root and assumes common unit root processes while the IPS test considers the null hypothesis of a unit root and assumes individual unit root processes. For the panel unit root test, we divide 43 countries into regional panels. We have: a panel of 12 Middle Eastern countries; a panel of four South Asian countries; a panel of nine Latin American countries; a panel of six East Asian countries; and a panel of 12 African countries. The results from the panel unit root tests are reported in panel A of Table 1 and are organised as follows. Column 2 consists of the IPS test while column 3 consists of the Breitung test; their associated *p*-values are reported beneath the test statistics in parenthesis. For all the five regional panels, we find that both test statistics reveal consistent results: that GDP and carbon dioxide emissions are panel non-stationary.

### 4.3. Panel cointegration test results

The panel cointegration test based on the Pedroni's suite of tests is reported in Panel B of Table 1 for all the five regional panels. For the Middle Eastern panel, all the four test statistics support a panel cointegration relationship between GDP and carbon dioxide emissions at 1 per cent level of significance. For the South Asian panel, three of the four test statistics reveal panel

**Table 2**
Long- and short-run income elasticities for individual countries.

| Country | Long-run | Short-run | |
|---|---|---|---|
| | Y | Change Y | ECM |
| *Panel A: Middle Eastern countries* | | | |
| Bahrain | 0.74***(3.61) | 0.26(0.48) | −0.59***(−3.32) |
| Iran | 1.22***(3.38) | 0.55(0.83) | −0.03(−0.50) |
| Iraq | −0.10***(−2.27) | 0.33***(3.82) | −0.45***(−2.71) |
| Israel | 1.20***(20.00) | 0.10(0.32) | −0.66***(−4.22) |
| Jordan | 0.34***(3.16) | 0.36**(1.81) | −0.74***(−4.98) |
| Kuwait | 1.13**(1.71) | 1.93***(4.66) | −0.57***(−3.40) |
| Oman | 1.88***(6.78) | 0.63(1.29) | −0.40**(−2.51) |
| Qatar | 0.15(1.07) | 0.35**(2.07) | −0.26**(−1.94) |
| Saudi Arabia | 0.40***(2.84) | 0.40***(2.61) | −0.30**(−1.95) |
| Syria | 0.71**(2.49) | −0.05(−0.22) | −0.19**(−1.85) |
| UAE | −0.04(−0.15) | 0.09(0.51) | −0.21**(−1.69) |
| Yemen | −2.20***(−10.43) | −2.46***(−3.14) | −0.67***(−2.87) |
| *Panel B: South Asian countries* | | | |
| Bangladesh | 1.84***(23.26) | 0.56(0.79) | −0.50***(−3.54) |
| India | 0.95***(11.44) | 0.11(0.30) | −0.18*(−1.55) |
| Pakistan | 1.04***(14.64) | 0.24(0.55) | −0.42**(−1.82) |
| Sri Lanka | 0.94***(4.86) | 0.11(1.18) | −0.25**(−1.88) |
| *Panel C: Latin American countries* | | | |
| Argentina | 0.44***(5.67) | 0.55***(4.31) | −0.73***(−3.43) |
| Brazil | 2.46***(6.30) | 1.21***(6.52) | −0.07(−0.88) |
| Chilli | 1.20***(16.98) | 0.85***(3.19) | −0.50***(−2.98) |
| Colombia | 0.01(0.05) | −0.12(−0.18) | −0.51***(−2.26) |
| Ecuador | 1.77***(6.11) | 1.11**(4.22) | −0.74***(−3.54) |
| Guatemala | 4.23***(5.98) | 0.25***(2.77) | −0.14(0.98) |
| Mexico | 0.43***(13.75) | 0.60***(6.26) | −1.15***(−5.48) |
| Peru | 1.08***(3.78) | 0.43***(2.64) | −0.19***(−2.50) |
| Venezuela | 0.29(1.57) | 0.25**(1.83) | −0.50***(−2.64) |
| *Panel D: East Asian countries* | | | |
| China | 0.50***(14.72) | 0.36*(1.61) | −0.32*(−1.70) |
| Indonesia | 1.22***(13.05) | 0.46***(4.03) | −0.19**(−1.93) |
| Malaysia | 1.12***(14.33) | 0.45(1.53) | −0.30**(−2.30) |
| Philippines | 1.73***(2.53) | 1.03***(3.70) | −0.04(−0.57) |
| Thailand | 1.52***(25.87) | 0.78***(4.27) | −0.53***(−4.58) |
| Vietnam | 0.94***(7.15) | 1.50(1.31) | −0.36**(−2.32) |
| *Panel E: African countries* | | | |
| Algeria | 0.38(0.91) | −0.59(−1.01) | −0.34**(−1.76) |
| Congo | −0.94***(−5.30) | −2.07**(−2.09) | −0.51***(−2.66) |
| Cote I voire | 0.78***(4.26) | 0.35(0.68) | −0.62***(−3.09) |
| Egypt | 1.02***(6.58) | 0.34(1.30) | −0.44***(−4.88) |
| Ethiopia | 0.64(0.79) | −0.85(−1.39) | −0.33***(−3.45) |
| Ghana | 1.21**(8.73) | 1.32**(2.52) | −0.73***(−3.45) |
| Kenya | −1.10(−1.38) | 0.06(0.08) | −0.48***(−3.54) |
| Morocco | 1.45***(4.94) | 0.37**(2.54) | −0.23**(−2.09) |
| Nigeria | −0.65(−0.79) | 0.34**(1.93) | −0.14(−1.12) |
| South Africa | 0.49***(2.75) | 0.75**(2.51) | −0.52***(−2.87) |
| Sudan | 1.41***(3.17) | 1.24***(3.07) | −0.26*(−1.72) |
| Tanzania | 1.03**(1.85) | −0.21(−0.31) | −0.40**(−2.29) |

*Note*: *, **, and *** denote statistical significance at the 10 per cent, 5 per cent, and 1 per cent levels, respectively.

cointegration at 10 per cent level or better: the panel pp test statistic is significant at 10 per cent level, while the panel adf and group adf tests are statistically significant at 5 per cent level. For the Latin American and the African panels, all the four test statistics are statistically significant at 1 per cent level, providing overwhelming support for panel cointegration.

### 4.4. Individual country results

The long- and short-run income elasticities together with the one-period lagged error correction term for each of the 43 countries are reported in Table 2. We group the countries by regions. Panel A consists of results for countries in the Middle Eastern region, panel B consists of countries in the South Asian region, panel C consists of countries in Latin America, panel D consists of countries in East Asia, and panel E consists of countries in the African region.

Beginning with the results for countries in the Middle Eastern region, we find that in the short-run income has a positive and statistically significant effect on carbon dioxide emissions in Iraq, Jordan, Kuwait, Qatar, and Saudi Arabia, and a statistically significant negative effect in Yemen: a 1 per cent increase in income reduces carbon dioxide emissions by around 2.5 per cent. The short-run income elasticity ranges from 0.33 in the case of Iraq to 0.40 in the case of Saudi Arabia. In Kuwait, the income elasticity is greater than one. In the long run, a 1 per cent increase in income reduces carbon dioxide emissions in Iraq by 0.1 per cent and in Yemen by 2.2 per cent. Because of the negative effect of income on emissions for Iraq and Yemen, this result is consistent with the EKC hypothesis. Another avenue for judging whether countries have reduced carbon dioxide emissions over time (as incomes have risen) is by comparing the long-run impact of income on emissions with the short run. As explained earlier, if the long-run income elasticity is smaller than the short run, then this implies that over time as income increases, carbon dioxide emissions have fallen. This turns out to be the case for Jordan, Kuwait, and Qatar. For the UAE, in both the short- and long-runs, income has a statistically insignificant effect on emissions. In terms of the error correction term, it is statistically significant at 5 per cent level or better for all countries except Iran. This suggests that a long-run relationship exists between income and carbon dioxide emissions.

The results for the South Asian countries reported in Panel B reveal that the error correction term is statistically significant at 10 per cent level or better for all the countries, implying that a long-run relationship exists between income and carbon dioxide emissions. The results suggest that in the short-run income has a statistically insignificant effect on emissions, while in the long run the impact is positive and statistically significant at 1 per cent level. The income elasticity ranges from 0.94 in the case of Sri Lanka to 1.84 in the case of Bangladesh. This finding is clearly inconsistent with the EKC hypothesis.

For the Latin American countries, the error correction term is statistically significant at 1 per cent level for all countries except for Brazil and Guatemala. For two countries, the income elasticity in the long run is lower than the short run. In Argentine, a 1 per cent increase in income increased carbon emissions by 0.55 per cent in the short run and by 0.44 per cent in the long run, while in Mexico the income elasticity was 0.60 in the short run and 0.43 in the long run. For Colombia, income elasticity is statistically insignificant in both the long-and short-runs, while in Venezuela, the income elasticity is insignificant in the long run. It follows that only four countries, namely, Argentina, Mexico, Colombia, and Venezuela, emissions have fallen over time.

The results for none of the countries in East Asia seem to be consistent with the EKC hypothesis. For all the six countries, the income elasticity is bigger in the long run than in the short run. Income elasticity in China increased from 0.36 in the short run to 0.50 in the long run, from 0.46 to 1.22 in Indonesia, from 0.45 to 1.12 in Malaysia, from 1.03 to 1.73 in Philippines, from 0.78 to 1.52 in Thailand, and from a statistically insignificant impact in the short run to a significant income elasticity of 0.94 in Vietnam. The error correction term is statistically significant at the 10 per cent level or better for all countries except Philippines.

For countries in the African region, the income elasticity has fallen from 1.32 in the short run to 1.21 in the long run for Ghana, and from 0.75 in the short run to 0.49 in the long run for South Africa. For Algeria, Ethiopia, Kenya, and Nigeria, the income elasticity is statistically insignificant at least in the long run. For Congo, in both the short- and long-runs, the income elasticity is negative, implying that economic growth has reduced carbon dioxide emissions. It follows that Ghana, South Africa, Algeria, Ethiopia, Kenya, Nigeria, and Congo are the countries in the African region for which emissions have fallen with a rise in income.

We now turn to the panel long-run elasticities on the impact of income on environmental quality reported in Panel C of Table 1. For the Middle Eastern panel, we find that while in the short run a 1 per cent increase in income increases carbon dioxide emissions by 0.57 per cent, in the long run the impact is smaller—a 1 per cent increase in income increases carbon dioxide emissions by only 0.45 per cent. Both results are statistically significant at 1 per cent level. For the South Asian panel, the income elasticity falls from 0.85 in the short run to 0.78 in the long run; both results are statistically significant at 5 per cent level or better. However, for the Latin American and the East Asian panel, we notice that the income elasticity actually increases. For the Latin American panel, the income elasticity increases from 0.71 in the short run to 1.73 in the long run, while for the East Asian panel it increases from 0.74 in the short run to 1.17 in the long run. For the African panel, the income elasticity is statistically insignificant in the short run but has a positive and statistically significant impact in the long run. From these panel results, it is clear that only the Middle Eastern and South Asian panels have experienced a fall in emissions over time.

## 5. Policy implications

The increase in trend in carbon dioxide emissions has prompted a number of policy responses. Several studies have suggested ways of reducing carbon emissions. The objective of this paper is not to suggest new policies in this regard but rather to highlight the need for such policies in specific countries and regions. For existing work in this area, see Leach (1991) and Parag and Darvy (2009) for work on the UK; Dhakal (2009) and Ru et al. (2009) for work on China; Lee and Ryu (1991) for work on Korea; and for Davidson (1993) for work on Sub-Saharan Africa; among others.

The main implication of our findings is that even though for 35 per cent of the countries considered in this study (that is for 15 out of the 43 countries) reveal that in the long run income has contributed less to carbon dioxide emissions, the impact is still positive and only slightly lower than the short run.

Most significantly, only for six countries, namely Iraq, the UAE, Yemen, Congo, Kenya, and Nigeria, the income elasticity is negative. One feature of carbon emissions policy is carbon emissions tax. The literature on carbon emissions policies suggests a possible tax on polluters. A second feature of policy related to curbing carbon dioxide emissions is through a carbon emissions trading scheme. Whether a pollution tax or emissions trading scheme is more relevant is not an issue considered in this study. What is relevant here is that except for six countries, where in the long run income has reduced carbon dioxide emissions, for the remaining 37 countries some form of pollution control measures are imperative, whether this is implemented at the regional or individual country level is a matter for further considerations.

## 6. Concluding remarks

The relationship between economic growth and environmental quality, termed as the Environmental Kuznets Curve (EKC) hypothesis, has been a widely tested hypothesis in the energy policy literature. In this paper, we test the EKC hypothesis for 43 developing countries, using both time series and panel data estimation techniques. Our main contribution is that we avoid making the mistake of multicollinearity in the estimation, and suggest an alternative way of judging whether or not developing countries are somewhere along the EKC. We suggest making this judgement based on the short- and long-run income elasticities, in that if the long-run income elasticity is smaller than the short-run income elasticity then it is evident that a country has reduced its emissions with income growth. Our empirical analysis based on individual countries suggests that for Iraq, Jordan, Kuwait, Yemen, Qatar, the UAE, Argentina, Mexico, Venezuela, Algeria, Kenya, Nigeria, Congo, Ghana, and South Africa—approximately 35 per cent of the sample—carbon dioxide emissions have fallen over time. We take the analysis further and examine the EKC hypothesis for panels of countries, constructed on the basis of regional location. From these panel results, we find that only data for the Middle Eastern and South Asian panels suggest that emissions are lower in the long run compared to the short run.

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