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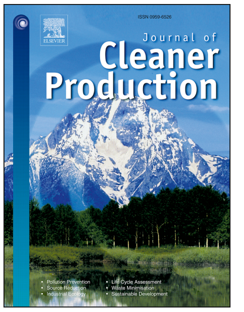

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All authors have equally shared the writing, revision and editing of the article.

Determinants of the Environmental Kuznets Curve considering economic activity sector diversification in the OPEC countries

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Abstract

Sectors contribute differently to the total level of CO_2 emissions per capita, since they are heterogeneous in terms of GDP structure. This work investigates the Environmental Kuznets Curve hypothesis considering a set of twelve of the fourteen OPEC countries. It contributes to previous literature exploring the Environmental Kuznets Curve relationship by analysing how economic activity sector diversification impacts the relationship between economic growth and carbon emissions, addressing an important identified gap. To address this gap, annual data from 1992-2015 is used. A panel cross-section analysis is provided between countries, and for the seven considered sectors, is estimated through panel corrected standard errors and convergence estimations are presented. Conclusions point to the relocation of pollution-intensive sectors to almost all of the OPEC countries. For all countries, a U-shaped relationship is evidenced, implying that economic growth in oil-producing and exporting countries increases environmental degradation. While energy consumption increases environmental damage, trade openness seems to have a significant and negative effect over emissions, leading to environmental improvements. This study points out that OPEC countries will have increased challenges facing them in terms of environmental degradation and only a few economic activity sectors can conduct environmental improvements through growth. The inclusion of oil prices increased coefficients magnitude. Probably these sectors are already allocating more labour and capital in projects and investments on renewable energy, energy efficiency and energy savings, substituting fossil fuels like oil.

Keywords: Organization of the Petroleum Exporting Countries (OPEC) countries; EKC hypothesis; Economic Activity Sectors; Panel Corrected Standard Errors (PCSE); Convergence

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Abstract

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Keywords: Organization of the Petroleum Exporting Countries (OPEC) countries; EKC hypothesis; Economic Activity Sectors; Panel Corrected Standard Errors (PCSE); Convergence

1. Introduction

This article tests the Environmental Kuznets Curve (EKC) hypothesis, considering 12 Organization of Petroleum Exporting Countries (OPEC) countries in a panel analysis and analysing this relationship also through economic activity sectors (7 have been considered), including energy consumption and trade openness as explanatory variables for this relationship when dealing with oil producers and exporters. In this way, it is possible to observe how sector diversification and growth (measured through gross value added (GVA) in oil-producing countries contribute or not to environmental improvements. Previous studies about the EKC hypothesis already exist, but no previous study, as far as we are aware, deals with several sectors diversification effects at the same time. Thus, the study intends to validate the Kuznets curve based on economic activity sector diversification and for that purpose, sector GDP is to be considered. Considering diversification allows OPEC countries betting over economic activity diversification to understand how emission control policies could be useful. As such, the empirical methodology employed allows the identification of critical sectors to support CO_2 emission mitigation policies.

The latest OPEC annual reports (2015, 2016) point out that member states hold approximately 80.8% of the world's oil reserves and currently account for about 36.19% of the world's oil supply. OPEC countries accounted for 44% of production and 57% of world crude oil exports in 2016 (OPEC, 2016), as well as having around 70% of proven and probable oil reserves. These facts about oil production and its reserve capacity are *per se* a problem in the mitigation of greenhouse gases, geo-economic and political dominance in some OPEC member countries, notably Saudi Arabia, Qatar, the United Arab Emirates, Iran, Iraq and Kuwait. Currently, the organisation has a total of 14 member countries. It seems consensual to state in any economic characterisation of OPEC countries that there are two main geopolitical and strategic pillars. On one side, there are proponents who see OPEC as a source of power in the oil market, so that all or some of its policies influence the energy market, creating behaviour asymmetries in the fulfilment of production quotas. On the other side are those who consider market conditions and competitive forces to act as driving forces and influencers in the energy market, and in particular in decisions about production quotas and the fixing of oil prices between OPEC members and OPEC non-member oil producers.

This work will analyse the evidence empirically to investigate whether environmental degradation is directly associated with certain sectors of economic activity that cause higher levels of carbon emissions, and, therefore, whether the EKC (Environmental Kuznets Curve) postulate should be interpreted more rigorously. It is emphasised that individualised economic growth by sector of activity does not directly influence the GDP of the economy as a whole, but will impact sector GDP, and particularly in these oil-producing and exporting economies, based on different geopolitical strategic decisions. In this context, we propose to study the following two hypotheses about the EKC hypothesis and relationship, which we intend to validate separately:

Hypothesis 1: CO_2 emissions in the OPEC economies have a statistically significant relationship with total GVA.

Hypothesis 2: CO_2 emissions in the OPEC economies have a statistically significant relationship with the GVA by economic activity sector.

Previous studies, such as that of Saboori et al. (2016), which tests the EKC hypothesis for 10 OPEC countries, that of Amri (2017) for Algeria, and Mrabet et al. (2017) in Qatar, test the EKC hypothesis for a group of OPEC countries or individual countries, while not studying the sector contributions for the relationship between environmental degradation and/or improvement and economic growth (measured through gross value added, considering these are economic activity sectors). Bringing in a sectoral study and the joining together of a larger number OPEC countries at once form a major contribution of the present study, reinforced by the study of the EKC hypothesis through panel corrected standard error (PCSE) model specifications by sector and including energy consumption and trade openness in the specification. PCSE techniques are used as they allow an analysis of deterministic and stochastic convergence, to identify the presence or absence of stochastic differences in the long term between driving forces related to CO_2 emissions and sector GDP growth by economic activity sector in OPEC countries. Hao et al. (2015) also study convergence, but for SO_2 in China.

Thus, these two hypotheses and their consequent proposed EKC relations will be tested between the variables considered in formulating the two theoretical proposals for the formulation of the EKC. EKC estimation was performed with panel data, among others, using the Panel Corrected Standard Errors (PCSEs) estimators, since these methods present better performance than the also used Ordinary Least Squares (OLS) estimator, by allowing correction of endogeneity, cross-dependence and sample correlation. An additional contribution of the present article relates to studies and tests performed with respect to stochastic and deterministic convergence, by country, by sector and for the overall set of OPEC countries in the sample, thus contributing to convergence studies of CO_2 emissions, GVA or growth, energy consumption and trade openness for oil-exporting countries. The PCSE model's advantage is in its consideration of the information available through the panel structure and the fact that all periods that make up the residue for each cross-section are considered to estimate the variance of the error term.

In accordance with the literature review performed, a majority of studies deal with the problem of the curvature of the EKC at the cross-country level, at the level of time series analysis or cross-sectional analysis or by the combination of both: that is, panel analysis. However, as far as can be determined, the empirical validity of the Kuznets curve according to the premise proposed in our second relationship (hypothesis 2) emerges as an important gap in the literature and justifies the contribution of this investigation. Another contribution to the existent literature is the fact that this study presents a new proposal for the EKC hypothesis which includes in this relationship economic activity sector, energy consumption and trade openness.

When considering sectors, the results suggest that energy consumption still increases environmental degradation, but that trade openness is only significant and positive under two different specifications of the PCSE model applied, revealing that trade policies should also be weighted by economic activity sector. Since the sectoral study is the focus here, this empirical work relates mainly to the extensive literature on the EKC hypothesis, and to the few studies on the sectoral EKC hypothesis, such as those by Moutinho et al. (2017) and Samargandi (2017). This paper contributes to existing studies in three ways. Firstly, it contributes to the sectoral EKC hypothesis. Our study is different from Samargandi's (2017) in its focus on a group of OPEC economies instead of a single country. Also, this study gives a comprehensive understanding of the EKC hypothesis in seven sectors, which is different from Samargandi's (2017) study, which focuses only on three sectors. Secondly, to the best of our knowledge, this empirical work is the first study that investigates the EKC at sector level for OPEC countries. Thirdly, this paper analyses deterministic and stochastic convergence, with the aim of identifying any stochastic differences in the long-term between driving forces related to CO_2 emissions and sector GDP growth by economic activity sector in OPEC countries.

The remainder of the article develops as follows. Section 2 presents a brief literature review regarding previous tests of the EKC hypothesis, while Section 3 describes the data and methodologies applied. Section 4 presents the results obtained, considering only the 12 OPEC countries and results respecting the different economic activity sectors considered (seven). Finally, Sections 5 and 6 present conclusions and describe policy implications, also pointing to limitations and future research directions which were possible to derive from our results.

2. Literature Review

Since the pioneering work by Grossman and Krueger (1991), the so-called Environmental Kuznets Curve phenomenon, describing the U-shaped relationship between environmental degradation and economic growth, has attracted considerable attention from environmentalists and economists. Grossman and Krueger (1991) argue that that environmental degradation increases up to a given point, which is the turning point, as income increases: yet, after the turning point, this degradation starts to decrease with an increase in the income level. The environment-growth relationship follows an inverted U-shape. Numerous studies empirically analyse the EKC. Tiba and Omri (2017), among others, offer a detailed review of the evidence and theories about the relationships between energy, environment and economic growth. This section focuses on some studies that provide observational evidence that establishes the sectoral EKC hypothesis considering oil price. Therefore, this empirical study reviews the literature that we believe is the closest to our paper's goal.

Majority of the early studies focused on the aggregate level of economic activities (total GDP or total GDP growth). The recently published studies, however, argue that different sectors could contribute differently to the total level of CO_2 emissions per capita (Al Mamun, 2014). This is because countries are heterogeneous in terms of GDP structure, and thus will sectors be in terms of GVA. Some economies rely mainly on the mining sector, like the OPEC region, while others are shifted towards the service sector, such as high-income economies. Thus, the literature suggests the need to investigate the sector-wise GDP and the quality of the environment (CO_2 emissions). These studies can be categorised based on the region, methodology and variables included in the model.

Among the pioneering studies was that of Al Mamun et al. (2014) who investigated the relationship between three key economic sectors (agriculture, industrial and service) for a panel of developed and developing countries during the period 1980- 2009. This study finds that moving to the service sector leads to more pollution in high-income countries compared to industrial and agriculture activities. However, the service sector promotes environmental quality for developing economies. The authors present two main reasons behind this path: advanced technologies; and transportation sector (logistics services). In developed economies, businesses (big and small) use more technologies, toxic products and pesticides in agricultural production, which increases the carbon dioxide emissions per unit of the agriculture output. However, developing countries rely severely on basic farming and logistics techniques that reduce carbon dioxide emissions (Al Mamun, 2014). Another mechanism that could explain this positive relationship is the high dependency of high-income countries on the transport sector, to meet the high demand for some products (Alcántara and Padilla, 2008), but also of individuals.

Additionally, Ramos et al. (2018) tried to investigate the sectoral EKC hypothesis in more detail. This empirical work found that all 11 Portuguese economic activities contributed significantly to the CO_2 emissions, where the service sector was one of them. This result was consistent with that of Al Mamun et al. (2014). Also, Ramos et al. (2018) concluded that two different behaviours of the EKC were identified: the inverted U-shaped behaviour; and the N-shaped form. The conclusions of this work evidence that CO_2 emissions will not disappear automatically with economic growth. On the contrary, these emissions may become more serious after a certain level of growth.

In the case of comparison between two economies, Moutinho et al. (2017) test EKC under two quadratic and cubic specifications for 13 sectors of economic activity in Portugal and Spain in the period 1975-2012. The key results of this study are that in the Portuguese economy, trade, services, and non-metallic minerals activities, were associated with a high level of CO_2 emissions. This increase in emissions has been driven by growth in production as well as in energy consumption—the same pattern was found in Spain.

Nevertheless, there is some empirical evidence showing that the service sector reduces the pollution on the air while the industry/ manufacturing sector is the main driver of CO_2 emissions. Mazzanti et al. (2008) uses detailed data on both aggregate and disaggregate Italian GDP (29 sectors) during 1990-2001. To check the EKC hypothesis, Mazzanti et al. (2008) used several emissions for measuring pollution. They conclude for the existence of the EKC hypothesis at aggregated-level of GDP in Italy. After digging deep to identify the aggregate picture for EKC, it was found that industry activities were the main source. This is expected because Italy is a developed industrial economy. This result gives importance to test the sectoral EKC. Sohag et al. (2019) also confirmed the positive relationship between the manufacturing industry and pollution in the OPEC countries, but point that the agriculture sector reduces CO_2 emissions. Unlike the previous studies, Sohag et al. (2019) find that the service sector contributes differently to the CO_2 emissions. In the short run, more service GDP lowers CO_2 emissions in accordance with the authors' results, despite the fact that this sector deteriorates the environment in the long run.

It is worth mentioning that all the above studies tested the relationship between sector-level GDP (economic activities) and CO_2 emission simultaneously in the model for the developed countries. Another stream of papers focused on the effect of an individual sector on environmental quality, such as a study by De Vita et al. (2015), which concentrated only on the tourism sector. The core question now is whether the developing countries follow the same path or not. Therefore, this study narrows the review to focus on the studies related to the developing region: OPEC countries. In the remaining, we follow two key points: sectoral EKC hypothesis exploration in OPEC countries, and including studies that take oil prices into account while testing the EKC hypothesis.

To the best of our knowledge, Samargandi (2017) and Khathlan and Javid (2013) are among the few studies that analyse the impact of economic activity sectors on environmental quality for one of the OPEC economies, the Kingdom of Saudi Arabia (KSA), during different periods. In his study, Samargandi (2017) provides strong support for the service-led economy as a significant contribution to pollution, not only for the developed economies but for developing countries as well. However, the gross value added (GVA) of the agriculture sector was found to be negatively correlated with CO_2 emissions, under linear estimations during the period 1970-2014. This study nullifies the presence of the EKC thesis for Saudi Arabia. The reasons pointed to were that Saudi Arabia had recently transformed into the service sector, and in particular the transportation sector, accompanied by more oil extraction operations. Therefore, both the mining and service sector were found to degrade the quality of the environment in the KSA. This is indeed supported by Alkhathlan and Javid (2013). Alkhathlan and Javid (2013) find that oil and gas contribute significantly to the pollution in KSA as compared with electricity consumption. This study covers the annual time series data from 1980 to 2011.

Petroleum subsidies are common in oil-rich economies. The heaviest of fuel subsidisers are the OPEC-countries, mostly located in the Middle East and North Africa (MENA) region (Auneet al. 2017). Particularly, subsidies are concentrated on the transport industry. Based on the IMF (2014), subsidies of gasoline and diesel in the MENA region account for around 50% of all energy subsidies in the region. These supports make transport of people and goods cheaper but discourage fuel efficiency. This policy attracted researchers and environmentalists to investigate the EKC hypothesis in the transportation sector and has raised an issue about the role of oil prices on CO_2 emissions. Alshehry and Belloumi (2017) tested the relationship between transport, CO_2 emissions and economic growth in Saudi Arabia. They found that there was a significant correlation between total economic activities and pollution between 1971 and 2011. Their results indicate that CO_2 emissions in transportation are entwined with long-term economic growth in Saudi Arabia. It is difficult for Saudi Arabia to keep track of economic growth without continuing growth in carbon emissions. This means that measures to boost economic growth must be complemented by measures to reduce carbon dioxide emissions.

Considering the role of oil prices on CO_2 emissions, few empirical works included the oil prices as a variable in the EKC models. Richmond and Kufmann (2006) argued that the turning point in the EKC could vary as a result of the omission of energy prices. Rising energy prices in the late 1970s and early 1980s reduced energy use and carbon emissions. As such, this may have generated a spurious turning point in the association between economic growth, energy use and / or carbon emissions. After the oil price crash of 1986, lower energy prices may have allowed increased energy use and / or carbon emissions as income increased (Richmond and Kufmann, 2006; Heil, and Selden, 2001). To avoid this issue – endogeneity - some studies started including oil prices as a proxy of energy prices.

Crude oil price could be a poor measurement of energy prices, as because of international variation in energy taxes, there are significant differences between the price of crude oil and end-user prices (Richmond and Kufmann, 2006). Recent empirical studies have also used the price of oil in the EKC models testing. The pioneering effort to include the oil price variable under the EKC hypothesis was carried out by Agras and Chapman (1999). This leading paper found that energy price was the main determinant of pollution; the estimated model shows that an increase in oil price leads to low carbon emissions. In the same vein as this argument, Balaguer and Cantavella (2016) conclude that the EKC thesis is proven for the Spanish economy from 1874–2011, where an increase of 1% in real oil prices causes about a 0.4% drop in global CO_2 emissions.

For the OPEC region, Saboori et al. (2016) provide support for a negative relationship between oil prices and CO_2 emissions. Saboori et al. (2016) used the Autoregressive Distributed Lag (ARDL) during 1977-2008 to test the existence of the EKC hypothesis. The main findings are that the EKC phenomena are validated and oil price promotes environmental quality by reducing CO_2 emissions. The main reason behind this negative relationship is that the rise in oil prices leads to more foreign revenues in the OPEC countries and thus increases their income and economic development, which promotes people's awareness and appreciation. Hence, the environment will increase the demand for a better environment.

However, oil prices might influence the environment differently based on the structure of the economy. For example, in accordance with Boufateh (2019), the positive changes in oil prices harm the environmental quality in the Chinese economy. In other words, positive shocks in crude oil prices cause an increase in the use of polluting energy. In the long run, the Chinese production system relies on fossil fuel to achieve a high rate of economic growth regardless of environment conservation, in particular at the first stage of growth.

After this critical review on sectoral GDP-oil price-CO_2 emissions relationship, it is obvious that there is a shortage of studies that consider all these variables under the EKC hypothesis. In specific, for the OPEC region. This scarcity allows our study to contribute to the ongoing literature by using a detailed sector analysis (considering the GVA by economic activity sector) for OPEC countries.

3. Data and Methodology

3.1 Data and Variables selected

The data refers to the years 1992-2015 (a time series of 24 years: a total of 288 annual observations) and also included in the analysis were 12 OPEC countries (cross-section), namely Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.

As a dependent variable, we measured the environmental pollution indicator by carbon dioxide measured in million metric tons. The explanatory variables of the study include the value-added of seven sectors (as listed in Table 1), normalised (share) by GDP. This allows us to consider the relative impact of sector-wise decomposed GDP on CO_2 emissions, based on the belief that different sectors have different energy intensities and some sectors generate more emissions due to their production structure (Bowden and Payne, 2010; Congregado et al., 2016). Moreover, following the majority of previous studies, we consider energy use (EU, kg of oil equivalent per capita) and trade openness (TO, the total volume of trade normalised with GDP), as these are implicitly and explicitly linked with CO_2 emissions levels. Into the EKC relationship study we have also added into the analysis, provided the previous literature review performed and to control for omitted variable bias[1], data for spot crude oil prices ($/b - crude oil in dollars per barrel) from the data contained in the OPEC Annual Statistical Bulletin (the 'ASB')[2], is it historical and obtained directly from OPEC Member Countries and third parties listed in the publication. The period is limited to 1992-2015 because of the availability of data, provided we looked for a balanced dataset for all the variables. Unfortunately, this period is the only time span that has balanced data for all variables.

With respect to the selected variables and data collection sources for this investigation of EKC analysis in OPEC countries, carbon dioxide emissions are measured in tonnes per capita. Carbon dioxide emissions come from the burning of fossil fuels and from the manufacturing of cement, including carbon dioxide produced during the consumption of solid, liquid and gaseous fuels and gas burning, as extracted from WDI, World Bank data. The total GDP and GVA by sector represents the total added value in the economy, and also the value-added at the disaggregated level per group of 7 sectors, at constant prices for 2010, measured in dollars; was obtained using the Main Accounts Database of National Accounts.

Sectors were classified in accordance with the International Standard Industrial Classification of all Economic Activities (International Standard Industrial Classification of All Economic Activities –ISIC) (Table 1).

Table 1. Sector identification in accordance with the ISIC classification

Sector number	ISIC acronym	Comprises
1	A – B	Agriculture, Forestry and Fisheries industries
2	C – E	Extractive and manufacturing industries; Electricity, gas and water industries
3	D	All manufacturing industries
4	F	Construction sector

[1] We thank the reviewer for the suggestion of inclusion of oil prices into the analysis.

[2] https://www.opec.org/opec_web/flipbook/ASB2017/ASB2017/assets/common/downloads/ASB2017_13062017.pdf

5	G – H	Wholesale, Lodging, Restoration and similar activities
6	I	Transport activities, storage and communication
7	J – P	Remaining economic activities

We also include in the EKC analysis variable energy consumption (Saboori and Sulaiman, 2013a, 2013b), oil prices, and trade openness, which differs considering the economic activity sectors. The Trade Openness variable is measured as a percentage of GDP and represents the sum of exports and imports / GDP, for which the data source was the World Economic Indicators from the World Bank. Regarding energy consumption, this is measured in kg of per capita equivalent oil, which results in the use of primary energy before processing for other end-use fuels, and which is equivalent to domestic production plus imports and stock changes, fewer exports of fuels supplied to ships and aircraft involved in international transport. This data was obtained from the World Economic Indicators of the World Bank.

3.2. Methodology: Econometric model and estimation proposal

The purpose of the study is to identify in the chosen OPEC countries if there is a significant relationship between CO_2 emissions and the related determinants. Equation (1) describes the econometric relationship estimated, which relates to environmental pollution or degradation and economic growth.

$$CO_2pc_{it} = \beta_0 + \beta_1 GVA_{it} + \beta_2 GVA_{it}^2 + \beta_3 CEner_{it} + \beta_4 TOp_{it} + \beta_5 OSP_{it} + \varepsilon_{it} \quad (1)$$

$CO2_{it}$ per capita is a measure of emissions/pollution (degradation measure) for the OPEC country i in moment t; GVA (which nationally is GDP) represents the income of OPEC country i at moment t; the variable $CEner_{it}$ corresponds to energy consumption in OPEC country i at moment t; TOp_{it} represents the variable trade openness of OPEC country i at moment t; OSP_{it} represents oil spot prices of country i in period t; ε_i is a non-observable random variable which follows the classic hypothesis for errors: independent, $E(\varepsilon_i) = 0$ and $var(\varepsilon_i) = \sigma^2$. In order to obtain an environmental Kuznets curve, the hypothesis described in Equation (1) must represent the following information with respect to the coefficients associated with variables GVA and GVA squared, or else, $H0$: $\beta_1 > 0$ and $\beta_2 < 0$ represent the EKC hypothesis under the inverted U shape versus $H1$: $\beta_1 < 0$ and $\beta_2 > 0$, representing the U-shaped curve.

In this research we propose a new relationship for the environmental Kuznets curve, expressed through Equation (2).

$$CO_2pc_{j,it} = \beta_0 + \beta_{1j}GVA_{j,it} + \beta_{2j}GVA^2_{j,it} + \beta_3 CEner_{j,it} + \beta_4 TOp_{j,it} + \beta_5 OSP_{j,it} + \varepsilon_{j,it} \quad (2)$$

with j= 1, 2, 3, 4, 5, 6 and 7 representing economic activity sectors in accordance with the ISIC classification, to test hypothesis 2. In order for the EKC hypothesis to be verified, the hypothesis described in Equation (2) should obey the following information with respect to the coefficients associated with variables GVA and GVA squared, given by, for country i sector j: $H0: \beta_{1j} > 0\ and\ \beta_{2j} < 0$ with j =1,2,3,4,5,6,7, representing the EKC hypothesis, or the inverted U-shaped relationship, versus $H1: \beta_{1j} < 0\ and\ \beta_{2j} > 0$ with j =1,2,3,4,5,6,7, representing the normal U-shaped relationship.

3.1. Panel Corrected Standard Errors (PCSE)

Conventional fixed and random effects models have, as a starting point, a one-way model or even models where the disturbance terms have two components: first, containing specific unobservable characteristics of individuals (that do not change over time); and second, identifying the disturbance. In the fixed-effects model, the constant term is not considered, allowing the disturbance error component to record the characteristics of each individual which is considered fixed. In the random-effects model, the constant is an average of all the cross-section observations, being added to disturbance terms as a fraction considering each characteristic. Considering these facts, a two-way error component model may be used, where disturbance terms will consider the three error components jointly. In doing this, we consider the specific unobserved individual characteristics of the individuals that do not change over time, a second component associated with the non-observed effects of time and a third error component considering the remaining of the error dispersion. For example, in the fixed effects model, the first two parameters are considered fixed.

The impact of the dependence between sectional units in estimation depends on different factors, such as the magnitude of the correlation between sections and the nature of that dependence. If we assume that sectional dependence is caused by common non-observed factors which are present, provided this component affects the error term but is uncorrelated with the other regressors, fixed and random effect estimators are consistent although not efficient, being estimated errors skewed. Besides, if the unobserved components that create sectional dependence are correlated with other regressors, this will cause bias and estimator inconsistency in either fixed or random effects. To solve this issue, Pesaran (2007) suggests the inclusion of instrumental variables in fixed and random effects, but it is hard to include those instrumental variables which are correlated with the remaining covariates but not with unobserved factors.

Previously, Beck and Katz (1995) suggested a solution which was able to correct the correlation problem between the standard error of cross-sections and between groups, heteroscedasticity, which consists of the use of Panel Corrected Standard Errors (PCSEs) and is a substitution for the traditional OLS method. However, Greene (2003) indicates that this type of analysis implies cross-sectional covariance (between observation units) and in the presence of non-spherical perturbation errors, the OLS method produced coefficients with inefficient estimates, turning the corresponding standard errors skewed. Another estimation method proposed by Parks (1967) is based on the generalised least squares (GLS) method to correct these standard errors, leading to asymptotically efficient coefficients and standard errors with no specific trend. To do this, the author assumes that the structure of the covariance error is specified in an appropriate way, where the elements of the error covariance matrix are known.

When the process of generating errors is not known, the problem is not solved, making it necessary to estimate the errors in the elements of the covariance matrix. A way to surpass this problem is through the PCSE method proposed by Beck and Katz (1995). In this method, we need to consider a square matrix where the non-diagonal elements are those of a square matrix NxN of the covariance of the errors of the cross-sections, being the diagonal elements represented by variances specific to each unit of the cross-section. Nonetheless, for each cross-section unit of the variance of the error term is estimated as the mean squared error of the estimation of the residual. The cross-sectional dependence on errors may be caused by common shocks, in particular those affecting the non-observable components, being part of the error term, which is known as a cross-section dependence.

The advantage of the PCSE model is in considering the information available through the panel structure and the fact that all periods that make up the residue for each cross-section are considered to estimate the variance of the error term. This method differs from White's procedure for heteroscedasticity correction (Beck, 2008), in that it deals with a one-term variance of observations, as there are T observations by estimation in each cross-section unit. Therefore, one increased time dimension by itself increases the performance of the PCSE estimate. PCSE estimates are considered robust to the correlation between cross-sections once they estimate the covariance between units, but the model is also restrictive. This happens if we assume the diagonal elements of each cross-section in the variance matrix are constant and the off-diagonal elements are all zero (Drukker et al., 2013a, 2013b, 2013c).

The existing discussion in the literature regarding PCSE estimate improvements from estimates obtained by feasible generalised least squares corroborates results from a comparison of the two methods, emphasizing the former. In related work, Hoechle (2007) developed the nonparametric estimator of the Driscoll and Kraay (1998) variance-covariance matrix, as a robust estimator when data reveals autocorrelation, heteroscedasticity and cross-section dependence. Not assuming a fixed number of panel units, the Driscoll and Kraay (1998) estimator does not impose a constraint in finite samples of N size. Thus, regardless of the sample size, the variance-covariance matrix is estimated in a consistent manner (which also goes for $N \to \infty$). Hoechle (2007) used Monte Carlos simulations to prove that for the estimator properties of Driscoll and Kraay (1998), infinite samples are better than those obtained by the PCSE and cluster estimators in the presence of contemporaneous correlation, including large panels and few observations in time. To choose between the fixed or random-effects model, the Hausman test is used.

3.2. Deterministic and Stochastic Convergence

Convergence means the tendency of series to converge among countries, regions or sectors, usually associated with GDP series. If per capita output disparities between converging economies follow a stationary process, we may conclude in favour of time series convergence. Therefore, stochastic or deterministic convergence is directly related to the unit root hypothesis of relative per capita output.

Strazicich and List's (2003) study was motivated by the inverted U-shaped relationship implied by the EKC (between income and environmental degradation) and is noted as the first to research convergence patterns of emissions in OECD countries. They claim to find the convergence of CO_2 emissions using conventional cross-sectional regressions of conditional stochastic convergence and the panel unit root test (Im et al., 2003). Li and Papell (1999) state that stochastic convergence implies that the log of relative emissions is trend stationary and for this, they propose a stronger convergence definition (deterministic convergence). In this case, the log of relative emissions would be mean stationary. In this case, both deterministic and stochastic trends are eliminated and emissions in one country move in parallel over the long run as compared to average emissions. Therefore, deterministic convergence implies stochastic convergence but not the other way around, and we investigate both convergence types. To test stochastic and deterministic convergence, we started with the EKC hypothesis variables analysis, ignoring oil price effects, and afterwards performed the same estimates including these. Since the results pointed in the same direction with or without oil prices, we have omitted a presentation of the latter estimates in order to save space. However, in all other tests performed, oil price inclusion has been compared to the results without considering these.

By taking a panel data approach, we are exploring both time series and cross-section dimensions of the data, allowing conditional convergence to be controlled for, including country-specific effects. These account for time-invariant compensating differentials. Hadri's (2000) panel stationarity test is employed, being the average univariate version of the Kwiatkowski et al. (1992) stationarity test (KPSS). The Hadri (2000) test allows for heterogeneity in the long-run variances across unit estimation, but homogeneity can be imposed as well.

4. Results

Some of the descriptive statistics are shown in Table 2 for the set of variables selected through which we study the EKC relationship in the panel sample with 12 OPEC member countries. Accordingly, average carbon emissions must be recorded, and in the period 1992 to 2015 they reached 4.433 tonnes per capita, where the maximum value was 6.486 tonnes per capita and the minimum value reached 1.358 tonnes per capita. All variables have been considered in natural logarithmic form.

Table 2. Descriptive Statistics

Panel OPEC	Obs.	Minimum	Maximum	Mean	Std. Dev.
Ln CO2	288	1.35840	6.48599	4.43267	0.99941
Ln GVA	288	23.7534	27.2438	25.6076	0.87382
Ln Energy Consumption	288	6.06339	9.96695	7.78538	1.13714
Ln Trade Openness	288	-3.86326	5.17472	4.2280	0.92639
Ln Oil Spot Prices	288	2.3890	4.7380	3.6251	0.73386
Ln GVA Sector 1	288	17.9695	25.1867	22.1398	1.80884
Ln GVA Sector 2	288	19.9196	25.1000	22.9472	1.16900
Ln GVA Sector 3	288	22.5844	26.6093	24.8401	0.928006
Ln GVA Sector 4	288	19.1836	24.386	22.5722	1.18915

Ln GVA Sector 5	288	20.5947	25.3122	23.1642	1.14588
Ln GVA Sector 6	288	19.1676	24.7600	22.5607	1.18644
Ln GVA Sector 7	288	22.0856	25.8531	24.1118	0.95337

Notes: Sector 1 comprising the Agriculture, Forestry and Fisheries industries; sector 2 corresponding to the sectors of the extractive and manufacturing industries and also includes the electricity, gas and water industries; sector 3 comprises all manufacturing industries; sector 4 includes the Construction sector; sector 5 encompassing the Wholesale, Lodging, Restoration and similar activities; sector 6 including transport activities, storage and communication; and sector 7 comprises the remaining economic activities. All values are in logs.

Regarding the overall economic growth of the total panel, there is an average value in the period of 25.608, with the maximum and minimum values reaching 27.244 and 23.753, respectively. For the variable Trade Opening Indicator, variation is observed in the period of interest, with the minimum value shown to be negative in the weighted percentage regarding GDP, at -3.863, and the maximum value reaching 5.175. The average value for this economic variable is 4.723 (relative to GDP).

As regards the sectoral degradation of the GVA, it is noted that the highest average values, as well as the maximum values, occur in sector 3, sector 7 and sector 5 respectively, whereas the lowest minimum values occur in sector 1, sector 6 and sector 4 respectively.

Table 3. Stochastic and Deterministic Convergence analysis – KPSS tests: period 1992-2015 – specification 1 (by country)

	Stochastic Convergence - (Test KPSS trend)				**Deterministic Convergence - (Test KPSS Level)**			
Panel OPEC	**Ln CO2**	**Ln GVA**	**Ln Energy Consumpt**	**Ln Trade Openness**	**Ln CO2**	**Ln GVA**	**Ln Energy Consumpt°**	**Ln Trade Openness**
Algeria	0.179***	0.156***	0.169***	0.203***	0.791	0.89	0.838	0.544***
Angola	0.081***	0.165***	0.102***	0.161***	0.868	0.844	0.435***	0.190***
Equator	0.156***	0.198***	0.107***	0.154***	0.844	0.880	0.116***	0.399***
Iran	0.201***	0.124***	0.189***	0.115***	0.876	0.851	0.859	0.286***
Iraq	0.102***	0.120***	0.20***	0.145***	0.77	0.786	0.246***	0.437***
Kuwait	0,0988***	0,106***	0,196***	0,169***	0,198***	0,891	0,198***	0,350***
Libya	0,0629***	0,171***	0,163***	0,0914***	0,244***	0,247***	0,244***	0,726***
Nigeria	0.147***	0.152***	0.0992***	0.194***	0.570***	0.883	0.570***	0.543***
Qatar	0.196***	0.113***	0.0136***	0.0622***	0.153***	0.880	0.153***	0.475***
Saudi Arabia	0.127***	0.206***	0.156***	0.138***	0.864	0.858	0.864	0.418***
Arabian Emirates	0.0525***	0.096***	0.152***	0.195***	0.806	0.895	0.806	0.833
Venezuela	0.17***	0.143***	0.160***	0.061***	0.642***	0.759	0.642***	0.142***
Test Hadri	**Ln CO2**	**Ln GVA Total**	**Ln Cons-Energia**	**Ln Trade Openness**	**Ln CO2**	**Ln GVA Total**	**Ln Cons-Energia**	**Ln Trade Openness**
Group Total	4.7916***	7.4097***	9.8594***	6.5572***	15.371***	15.117***	7.4953***	6.7147***

Notes: Probability values are in subscript, ***, **, *, and refer to the rejection of the null hypothesis at the significance levels of 1%, 5% and 10%, respectively. All values are in logs. Sector 1 comprising the Agriculture, Forestry and Fisheries industries; sector 2 corresponding to the sectors of the extractive and manufacturing industries and also includes the electricity, gas and water industries; sector 3 comprises all manufacturing industries; sector 4 includes the Construction sector; sector 5 encompassing the Wholesale, Lodging, Restoration and similar activities; sector 6 including transport activities, storage and communication; and sector 7 comprises the remaining economic activities.

Before presenting the diagnostic tests, Tables 3 and 4 present the convergence test results. From the stochastic convergence results, considering the KPSS and Hadri univariate tests for each country individually and for the aggregated panel respectively, evidence for all OPEC economies shows the existence of stochastic convergence. The stationarity rate is rejected at a level of 1% for the dependent variable (CO_2) and independent variables (total GVA, energy consumption and indicator of trade openness) for the EKC relationship (specification 1 – Table 3).

Having established the existence of stochastic convergence in CO_2 emissions for the 12 OPEC economies, both individually and at the aggregate level, we analyse the deterministic convergence in CO_2 emissions and for the rest of the variables included in the EKC relationship. The notion of deterministic convergence supposes that the analysis of emitted emissions in a specific OPEC economy presents a tendency towards a parallel movement in the long run.

If there is divergence in CO_2 emissions intensity for all of the 12 associated countries, it is because the evidence has been supported. After rejecting the stationarity hypothesis of null tendency in the relative intensity of CO_2 emissions at the 1% level, this can be seen in the panel data test KPSS. This may be the result of the higher statistical power of the panel statistic, through an exploration of the data's transversal change.

In accordance with the deterministic convergence test results, for variables which integrate equation (1) of the EKC relationship, in the case of CO_2 emissions per capita, energy consumption and the indicator of trade openness, it is noted that Kuwait, Libya, Nigeria and Qatar present stationarity for these variables. However, only in Libya is there evidence which corroborates stationarity in all series of the selected variables in this first specification (Table 3). At the aggregate panel level, in accordance with the Hadri test result, there is deterministic convergence.

With respect to specification 2 (by sector and country – Table 4), in terms of stochastic convergence, we verify that there are series of sector GVA values by the country which present stochastic non-stationarity. This is the case for sector 1, 4 and 7 GVA for Algeria, sector 2 in Nigeria and the Unit Arab Emirates, sector 4 GVA for Angola and Qatar, sector 6 GVA for Angola, and sector 7 GVA for Saudi Arabia. In sum, only in sector 3, GVA is there evidence of stationarity for all economies in OPEC at the individual level (by country).

With respect to deterministic convergence of GVA by sector, in Libya only, there seems to exist stationarity for all sector GVA, meaning, in all the seven economic activity sectors considered, followed by Iraq with stationarity evidence of GVA in sectors 1, 2, 3, 6 and 7. In turn, Venezuela presents deterministic stationarity in GVA associated with economic activity sectors 2, 3, 4 and 5. These results explain that the added value generated in the economic activity sectors associated with OPEC countries in our sample which present structural differences will tend to rise in the direction of their pollution level. As such, convergence, in turn, is conditioned to OPEC country characteristics.

Table 4. Stochastic and Deterministic Convergence analysis – KPSS tests: period 1992-2015 – specification 2 (by economic activity sector)

	Stochastic Convergence - (Test KPSS trend)							Deterministic Convergence - (Test KPSS Level)						
Panel OPEC	**Ln GVA Sector 1**	**Ln GVA Sector2**	**Ln GVA Sector3**	**Ln GVA Sector4**	**Ln GVA Sector5**	**Ln GVA Sector6**	**Ln GVA Sector7**	**Ln GVA Sector 1**	**Ln GVA Sector2**	**Ln GVA Sector3**	**Ln GVA Sector4**	**Ln GVA Sector5**	**Ln GVA Sector6**	**Ln GVA Sector7**
Algeria	0.184***	0.200***	0.210***	0.208***	0.225	0.210***	0.224	0.887	0.783	0.549***	0.875	0.870	0.883	0.872
Angola	0.209***	0.208***	0.200***	0.218	0.141***	0.220	0.185***	0.835	0.832	0.863	0.848	0.295***	0.742	0.824
Equator	0.054***	0.124***	0.120***	0.141***	0.196***	0.213***	0.211***	0.900	0.888	0.878	0.853	0.819	0.884	0.870
Iran	0.063***	0.171***	0.128***	0.112***	0.154***	0.166***	0.139***	0.853	0.865	0.680***	0.757	0.830	0.888	0.878
Iraq	0.180***	0.085***	0.114***	0.100***	0.111***	0.137***	0.103***	0.488***	0.171***	0.688***	0.870	0.858	0.356***	0.864***
Kuwait	0,100***	0,062***	0,131***	0,086***	0,074***	0,101***	0,084***	0,732***	0,565***	0,863	0,803	0,791	0,851	0,872
Libya	0,182***	0,182***	0,182***	0,173***	0,160***	0,160***	0,143***	0,327***	0,379***	0,425***	0,174***	0,212***	0,386***	0,493***
Nigeria	0.110***	0.222	0.076***	0.226	0.180***	0.145***	0.186***	0.8075	0.809	0.856	0.865	0.849	0.870	0.896
Qatar	0.221	0.186***	0.053***	0.165	0.158***	0.127***	0.196***	0.475***	0.847	0.873	0.865	0.864	0.881	0.849
Saudi Arabia	0.193***	0.185***	0.140***	0.206***	0.185***	0.205***	0.225	0.856	0.894	0.820	0.878	0.868	0.800	0.881
Arabian Emirates	0.216***	0.217	0.052***	0.097***	0.177***	0.161***	0.111***	0.283***	0.826	0.882	0.852	0.861	0.891	0.895
Venezuela	0.147***	0.082***	0.074***	0.144***	0.134***	0.171***	0.188***	0.770	0.349***	0.438***	0.449***	0.623***	0.812	0.795
	Stochastic Convergence - (Test Hadri Trend)							**Deterministic Convergence - (Test Hadri Level)**						
Panel OPEC	**Ln GVA Sector 1**	**Ln GVA Sector2**	**Ln GVA Sector3**	**Ln GVA Sector4**	**Ln GVA Sector5**	**Ln GVA Sector6**	**Ln GVA Sector7**	**Ln GVA Sector 1**	**Ln GVA Sector2**	**Ln GVA Sector3**	**Ln GVA Sector4**	**Ln GVA Sector5**	**Ln GVA Sector6**	**Ln GVA Sector7**
Group Total	9.604***	8.554***	8.257***	8.123***	7.345***	8.542***	7.596***	12.68***	13.11***	13.73***	15.29***	14.99***	15.31***	16.05***

Notes: Probability values are in subscript, ***, **, *, and refer to the rejection of the null hypothesis at the significance levels of 1%, 5% and 10%, respectively. All values are in logs. Sector 1 comprises the Agriculture, Forestry and Fisheries industries; sector 2 corresponds to the sectors of the extractive and manufacturing industries and also includes the electricity, gas and water industries; sector 3 comprises all manufacturing industries; sector 4 includes the construction sector; sector 5 encompasses wholesale, lodging, restoration and similar activities; sector 6 includes transport activities, storage and communication; and sector 7 comprises the remaining economic activities.

These results show that the stationarity differentials found in the analysed series for each OPEC country and for the period 1992-2015 are important for the disaggregated information level, supporting the hypothesis that, in terms of economic growth, its changes or temporal variations are connected at different levels of sector productivity. Therefore, the disaggregation for the seven economic activity sectors, following the ISIC classification, seem to show the general tendency of economic growth rates for the general level of economic activity in each OPEC country, where convergence tends to be conditioned to the specific characteristics of each sector for some OPEC countries in the sample and to evidence unconditional or absolute convergence for others.

Regarding the diagnosis tests for econometric problems, heteroscedasticity and autocorrelation, whose regression included the oil spot prices, the results evidenced in Table 5 show that, through the Pesaran Test, it is possible to reject the null hypothesis of transverse independence for the random and fixed effects, as previously shown for the global sample. Frees' (1995) test also allows confirming the rejection of the null hypothesis. Therefore, the presence of contemporaneous correlation is not indicated.

For both specifications, without and with oil spot prices, the Wooldridge test for the presence of autocorrelation in a panel data sample indicates the rejection of the null hypothesis of the first-order autocorrelation, with a statistical significance of 1%. Additionally, the Wald modified statistic to test group heteroscedasticity indicates the rejection of the null hypothesis.

Table 5. Data Specification Tests without and with the Oil Spot Prices

Specification #1	**Pooled**	**Pooled**	**Random Effects**	**Random Effects**	**Fixed Effects**	**Fixed Effects**
Modified Wald Test (χ^2)					604.37***	138.93***
Pesaran's Test			0172	3.720***	0.425	4.881***
Frees' Test			0.946***	0.504***	0.916***	0.583***
Wooldridge Test F(1,11)	14.420***	14.000***				
Specification #2	**Pooled**	**Pooled**	**Random Effects**	**Random Effects**	**Fixed Effects**	**Fixed Effects**
Modified Wald Test (χ^2)					447.46***	447.46***
Pesaran's Test			0.010	0.010	0.205	3.696***
Frees' Test			0.712***	0.712***	0.206***	0.458***
Wooldridge Test F(1,11)	11.550***	11.550***				

Following the reasoning described in the EKC specifications 1 and 2, the simple random and fixed effects model (CSE), and the random and fixed effects model with the robust option to correct heteroscedasticity (RSE) were estimated, as well as the random and fixed effects model with AR1 disturbances (AR1). However, based on the results of the Hausman Test, the fixed effects specification should be used in both specifications, considering and not considering oil spot prices.

To check the robustness of the results, confirming a possible inefficiency in the estimation of coefficients and bias in the error estimation, the similarity should be compared with the estimators obtained through the panel with random effects and fixed effects. If the results are different from the PCSE estimators, the PCSE results are more robust (minimum variance). The results of the estimates for random effects and fixed effects lead to the erroneous rejection of the power to explain some explanatory variables in specification 1 and specification 2, respectively.

To deal with contemporaneous correlation, the PCSE model was estimated (CORR(IND)), as well as the PCSE estimator with the option for heteroscedasticity (HET). The PCSE estimator with the option for first-order serial correlation (AR1) was also performed to compare the PCSE estimator with options for both heteroscedasticity and first-order serial correlation (HET-AR1). Table 6 presents the results for panel corrected standard errors for model specification 1, including two versions of the estimates performed, without and including the oil spot prices in the analysis.

In accordance with the diagnostic test results performed, we will focus attention in the version including as explanatory variable the oil spot prices. We will privilege the results of this version for both equations (1) and (2) of the Kuznets curve specification proposed, although we will present in the remaining tables the results of the estimations for both versions, such that we will be able to access the importance of the inclusion of the variable oil spot prices in the econometric modelling.

Following the results attained for both versions of Panel Corrected Standard Errors, there is considerable consistency and stability between the estimators considered. For the income effect on carbon dioxide emissions, GVA and GVA quadratic variables are highly significant, evidencing these to be an economic driver to mitigate pollutant emissions. However, the statistical evidence, at a 1 percent level, for the coefficients associated with the two variables, does not validate the expected inverse U curve in order to confirm the existence of the general EKC hypothesis.

Table 6. Results of Panel Corrected Standard Errors for Specification 1 without and with Oil Spot Prices

Specification 1	CORR IND	CORR IND	HET	HET	psAR1	psAR1	HET - AR1	HET - AR1
Ln GVA	-5.5609*** (1.053)	-5.5352*** (1.090)	-5.5609*** (1.710)	-5.5352*** (1.090)	-10.4792*** (2.065)	-10.2649*** (2.070)	-11.2931*** (2.271)	-11.2186*** (2.268)
Ln GVA^2	. 12751*** (.0204)	. 12673*** (.0211)	. 12751*** (.0334)	. 12673*** (.03327)	. 2221*** (.0403)	. 21763*** (.0404)	. 237491*** (.0445)	. 236125*** (.0444)
Ln Cons. Energy	. 175040*** (. 0134)	. 17678*** (. 0135)	.175040*** (. 0233)	. 17678*** (. 0232)	.191086*** (. 0287)	.19971*** (. 0304)	.15876*** (. 0428)	.159298*** (. 0423)
Ln Tr. Openness	-. 13305*** (. 0386)	-. 14206*** (. 0395)	-. 13305*** (. 0363)	-. 14206*** (. 0368)	-.016999 (. 0280)	-.02013 (. 0284)	-.017492 (. 0258)	-.018550 (. 0260)
Ln Oil Prices		. 05485*** (. 0214)		. 05485 (. 0379)		.04801 (. 0313)		-.001283 (. 0389)
Constant	62.3074*** (13.50)	61.9866*** (13.95)	62.3074*** (21.89)	61.9866*** (13.95)	125.442*** (26.41)	122.397*** (26.45)	136.537*** (28.98	135.529*** (28.99)
Observations	288	288	288	288	288	288	288	288
R^2	0.8004	0.8018	0.8004	0.8018	0.9414	0.9477	0.7655	0.7675

Note: Values in parenthesis report to standard errors. *,**,*** represent significance at 10%, 5% and 1% respectively. Specification #1 does not include economic activity sectors. Contemporaneous correlation PCSE model (CORR (IND)); PCSE estimator with the option for heteroscedasticity (HET); PCSE estimator with the option for first-order serial correlation (psAR1); PCSE estimator with the options for both heteroscedasticity and first-order serial correlation (HET-AR1).

Moreover, the statistical significance associated with the variables of energy consumption and the indicator of trade openness in explaining the increase in carbon emissions should also be highlighted. In fact, increased energy consumption and trade openness stimulate economic activities and consequently, increase income. Considering, the version with oil spot prices the coefficients of the PCSE (HET-AR1): an increase of 1% in income (GVA), decreases CO_2 emissions by 11.21%; while an increase of 1% in energy consumption (Cons. Energy) increases CO_2 emissions by 15.92%. However, neither the trade openness indicator and oil spot price variables show statistical significance at the usual level.

In the PCSE, for EKC specification 2, considering economic activity sectors, according to the results shown in Table 7 for both versions, considering oil spot price effects or not, there is a good joint significance for the explanatory variable income by sector towards CO_2 emissions. Considering the PCSE model, this was estimated (CORR(IND)), and the PCSE estimator with the option for heteroscedasticity (HET) was applied. The results show important statistical evidence at the 1% level, such as an increase of 1% in income for sector 7 (GVA sector 7) decreases CO_2 emissions by 8.35%; an increase of 1% in income for sector 4 (GVA sector 4) decreases CO_2 emissions by 3.39%; an increase of 1% in income for sector 1 (GVA sector 1) decreases CO_2 emissions by 0.78%; while an increase of 1% in income quadratic for sector 7

(GVA^2 sector 7) increases CO_2 emissions by 0.185%; an increase of 1% in income quadratic for sector 4 (GVA^2 sector 4) increases CO_2 emissions by 0.083%; an increase of 1% in quadratic income for sector 1 (GVA^2 sector 1) increases CO_2 emissions by 0.20%.

Table 7. Results of Panel Corrected Standard Errors for Specification 2 without and with Oil Spot Prices

Specification 2	CORR IND	CORR IND	HET	HET	psAR1	psAR1	HET AR1	HET AR1
L Cons.Energy	.299719***	.28762***	.299719***	.28762***	.224679***	.23112***	.224031***	.224797***
	(.0567)	(.0567)	(.0499)	(.0496)	(.0563)	(.0573)	(.0562)	(.0558)
L Trade Open.	. 019025	0.26007	. 019025	0.26007	. 0119925	. 012779	. 0069946	.009018
	(.0240)	(.0241)	(.0245)	(.0244)	(.0230)	(.0231)	(.0221)	(.0222)
L Oil Prices.		. 053142*		. 053142*		-.009577		-.035179
		(.0298)		(.0323)		(.0310)		(.0346)
GVA sector 1	-.642011***	-.78130***	-.642011*	-.78130**	-.067332	.109890	-.067238	.010605
	(.0266)	(.0296)	(.3051)	(.0318)	(.4153)	(.4229)	(.4517)	(.446)
GVA sector 2	-4.53716**	-4.5120***	-4.5371***	-4.5120***	-3.9528***	-4.2889***	-3.7833***	-3.82959**
	(1.016)	(1.010)	(1.078)	(1.054)	(1.601)	(1.636)	(1.606)	(1.573)
GVA sector 3	5.41496***	5.1883***	5.41496***	5.1883***	2.51712	2.94113	3.93919*	4.01242*
	(1.505)	(1.526)	(1.610)	(1.612)	(2.091)	(2.072)	(2.257)	(2.212)
GVA sector 4	-3.46091***	-3.394***	-3.4609***	-3.394***	-.915154	-1.00138	-1.472665	-1.52982
	(. 7665)	(. 506)	(. 8196)	(.8219)	(.9068)	(.902)	(.9758)	(.9705)
GVA sector 5	-4.40562***	-3.8658***	-4.4056***	-3.8658***	-.20513	.172379	.366796	.288028
	(1.491)	(1.426)	(1.221)	(1.186)	(1.876)	(1.872)	(1.940)	(1.913)
GVA sector 6	1.88496***	1.2957	1.88496***	1.2957	1.94797	1.53704	1.915143	1.51251
	(.9774)	(.9524)	(.9487)	(.9247)	(1.212)	(1.226)	(1.134)	(1.126)
GVA sector 7	-8.8082***	-8.3593***	-8.8082***	-8.3593***	-6.7544***	-6.9867**	-7.4189***	-7.29330**
	(2.061)	(2.091)	(2.289)	(2.274)	(3.214)	(3.201)	(2.936)	(2.921)
GVA^2 sector 1	. 020272***	. 02308***	. 02027***	. 02308***	. 001909	.0010773	. 001942	.003206
	(.0059)	(.0060)	(.0070)	(.0073)	(.0097)	(.0099)	(.0106)	(.01049)
GVA^2 sector 2	-010500***	-0.10068***	-.10500***	-0.10068***	-.045637	-.054463	-.074158*	-.075846*
	(.0311)	(.0315)	(.0332)	(.0331)	(.0430)	(.0427)	(.0460)	(.0451)
GVA^2 sector 3	-0.97636***	. 09671***	-0.9763***	. 09671***	-0.85989**	.093369***	-0.81565**	.082401**
	(.0226)	(.0224)	(.02413)	(.0235)	(.0360)	(.0367)	(.0359)	(.0351)
GVA^2 sector 4	.084239***	.08329***	.084239***	.08329***	.0226443	.024856	.036144*	.037814*
	(.0175)	(. 0172)	(.01879)	(. 0188)	(.0208)	(.0207)	(.0224)	(.0222)
GVA^2 sector 5	-0. 1094***	-.09803***	-. 10948***	-.09803***	-. 0060776	-.014399	-. 0191765	-.017728
	(.0329)	(.0314)	(.02686)	(.0260)	(.0412)	(.0411)	(.0426)	(.0420)
GVA^2 sector 6	- .06060***	-.02447	- .06060***	-.02447	- .0301781	-.030004	- .0297575	-.02931
	(. 0222)	(.0217)	(. 02151)	(.0209)	(. 0274)	(.0277)	(. 0255)	(. 0254)
GVA^2 sector 7	.18584***	.18558***	.18584***	.18558***	.152572**	.157401**	.167431***	.164893***
	(. 0431)	(.0436)	(. 0478)	(.0474)	(. 0671)	(.0668)	(. 0609)	(. 0606)
Constant	60.8970***	67.993***	60.8970***	67.993***	82.7395***	80.424***	70.9363***	71.274***
	(18.88)	(18.895)	(19.09)	(19.287)	(25.41)	(25.308)	(27.50)	(27.22)
Observations	288	288	288	288	288	288	288	288
R^2	0.9329	0.9336	0.9329	0.9336	0.9580	0.9616	0.8675	0.8706

Note: Values in parenthesis report to standard errors. *,**,*** represent significance at 10%, 5% and 1% respectively. Specification #2 refers to estimations by economic activity sector. Sector 1 comprises the agriculture, forestry and fisheries industries; sector 2 corresponds to the sectors of the extractive and manufacturing industries and also includes the electricity, gas and water industries; sector 3 comprises all manufacturing industries; sector 4 includes the construction sector; sector 5 encompasses the wholesale, lodging, restoration and similar activities; sector 6 includes transport activities, storage and communication; and sector 7 comprises the remaining economic activities Contemporaneous correlation PCSE model (CORR

(IND)); PCSE estimator with the option for heteroscedasticity (HET); PCSE estimator with the option for first-order serial correlation (psAR1); PCSE estimator with the options for both heteroscedasticity and first-order serial correlation (HET-AR1).

All of this statistical evidence reveals a U-shaped EKC relationship between GVA in sector 7, GVA in sector 4, GVA in sector 1, and CO_2 emissions in OPEC countries. Moreover, for other sectors, an increase of 1% in income in sector 3 (GVA sector 3) increases CO_2 emissions by 5.18% and an increase of 1% in income in sector 6 (GVA sector 6) increases CO_2 emissions by 1.29%. However, while an increase of 1% in quadratic income in sector 3 (GVA^2 sector 3) decreases CO_2 emissions by 0.976%, while an increase of 1% in quadratic income in sector 6 (GVA^2 sector 6) decreases CO_2 emissions by 0.024%.

In this case, the results evidence an inverse U-shaped relationship between carbon emissions, GVA for sector 3 and sector 6. Other significant results show an increase of 1% in income in sector 2 (GVA sector 2) and an increase of 1% in income in sector 5 (GVA sector 5), which implies a decrease in CO_2 emissions of 4.51% and 3.86%; respectively.

Besides this, an increase of 1% in quadratic income in sector 2 (GVA^2 sector 2) and in sector 5 (GVA^2 sector 5), decreases CO_2 emissions by 0.100% and 0.098% respectively. However, these results do not corroborate any functional form for EKC specification 2, formulated in this study for OPEC countries during the 1992-2015 period analysed. In summary, our second hypothesis proposed in this study is only partially corroborated, suggesting a deeper discussion is needed of the mixed results evidenced by estimations.

It is challenging to compare these results with those of other authors, provided that no previous studies analyse individual economic activity sectors in OPEC countries. However, some interesting studies can be presented here which relate to the results. The EKC hypothesis has been investigated extensively in recent years. For instance, Shahbaz et al. (2018) found an inverse U shape between Indian economic growth and CO_2 emissions from 1971-2015 using an autoregressive distributed lag (ARDL) approach. For a developed economy, Shahbaz et al. (2018) provide a validation of the non-linear relationship between economic growth and environmental degradation in France, covering the period 1955-2016. Also, in this study, the authors found significant evidence for the pollution haven hypothesis; that FDI inflows contribute significantly to CO_2 emissions. Another example of the existence of the EKC is the study by Shahbaz et al. (2017) on the Chinese economy. These findings validate the EKC hypothesis in China from 1970-2012, applying Bayer and Hanck's combined cointegration test as well as the ARDL bounds testing approach to cointegration by accommodating structural breaks in the series. Sinha and Shahbaz (2018) attempted to estimate the EKC for CO_2 emission in India for the period 1971-2015 using unit root tests with multiple structural breaks and the ARDL approach to cointegration. The authors found evidence of an inverted U-shaped EKC for India, and conclude that renewable energy has a significant negative impact on CO_2 emissions and that trade is negatively linked with carbon emissions.

The results of the estimates for both FE and RE lead to the erroneous rejection of the power to explain certain explanatory variables. Additionally, a comparison of FE and RE is made regarding inefficiency in coefficient estimation using three options (see Tables A.1 and A.2 for specification 1, and A.3 and A.4 for specification 2 in the Appendix); Conventional Standard Errors (CSE), Robust Standard Errors (RSE) and First-order Autoregressive Errors (AR(1). In fact, these estimators are not well suited to dealing simultaneously with both serial and contemporaneous correlations, for which we found statistical evidence with the PCSE estimator. Therefore, with both results of FE and RE presented in tables A.1, A.2, A.3, and A.4 in the Appendix, the parameters reveal similar significances in both estimators, and the results of the Wald tests reveal statistical significance at a 1% level, rejecting the null hypothesis of non-significance as a whole for the parameters of the explanatory variables. On the other hand, the LM test statistically and strongly rejects the null hypothesis of the existence of specific effects. In fact, the results do not invalidate poor quality and inefficiency for both estimators FE and RE, while the PCSE estimator is highly efficient; in general, the variance of the PCSE estimators is smaller than FE or RE.

5. Discussion: Policy Implications

According to Dinda (2014, p.431), the EKC hypothesis "postulates an inverted-U-shaped relationship between different pollutants and per capita income, i.e., environmental pressure increases up to a certain level as income goes up; after that, it decreases". Results reveal that the EKC hypothesis is an inverted U shape for manufacturing industries and transport activities, storage and communication, but for others is not. Therefore, energy conservation policies in these two sectors should be addressed in the long run without caution to limit economic growth. In addition, from a sustainability perspective, continued economic growth is not possible in the remaining sectors without continuing increases in carbon emissions. A sizeable literature on EKC has grown up in the recent period, generally mentioning that environmental quality deteriorates in the early stages of economic development/growth and subsequently improves in the later stages (if only the quadratic form is assumed). According to our results, but not in all sectors, environmental pressure increases faster than income in the early stages of development and slows down relative to GDP growth at higher income levels, except for manufacturing and transport, storage and communication.

We hypothesise that the intrinsic vulnerabilities are directly associated with the historical fact that OPEC countries are overly dependent on income generated by the oil business, and therefore that these countries have some control and power to act to reduce the negative effects of these transmission mechanisms. This finding, reported by Hochman and Zilberman (2015), is corroborated by the description that Venezuela and Iran usually present their lowest production quotas within the OPEC organisation and consequently should contribute in a different way to the mitigation of carbon emissions. What paradoxically happens is that in these countries, the values of the subsidies to production are higher than in others.

Also, according to Hochman and Zilberman (2015), OPEC countries with governments/institutions that have experienced fragility and government crises are more likely to provide higher subsidies and avoid deviation to other sectors of activity. It is in this sense that, for environmental reasons, a strategic devaluation in the oil and hydrocarbon sector can be proposed in the medium or long term, with alternatives in the use of cleaner energy sources (alternative energy sources), while on the other hand, looking for diversions of concentrated production in the petroleum production sector, whose income from this sector can subsidise production in other sectors of economic activity. Stevens (2015) exemplifies the mechanism by suggesting that the crowding-out effect occurs when investment in oil, natural gas or minerals is so large relative to the rest of the economy that it attracts a large share of a country's scarce resources. As a result, OPEC economies that have the greatest difficulty in supplying other sectors with the necessary factors for development will hardly have implemented policies for the introduction, creation and/or reconversion of production plants to cleaner and less polluting sources. Thus, the validity of the Kuznets curve with the panel data does not make it perceptible in which countries that are in a more favourable condition to mitigate polluting effects in those economies.

According to Stevens (2015), this effect is especially relevant in smaller countries or in projects concentrated in a single region of the respective OPEC country. The environmental risks and damage of oil production in themselves demand a raising of awareness and responsibility of the OPEC organisations on the need to re-invest in other promising non-fossil energy sectors (biofuels, biomass, wind). In our study, this would be associated with economic growth generated in sector 2 (extractive industries, manufacturing industries and industries producing electricity, gas and water) and the capacity to contribute to the mitigation of emissions in the OPEC economies.

Unfortunately, not least is the fact that this reality may negatively affect the petro-states that have this sector as their main source of economic survival, as is the case for Angola, Nigeria, Venezuela and Equatorial Guinea in the current context. But we can also point out that our results show significant economic growth associated with sector 4 (construction) and associated with sector 5 (trade, housing, restoration and similar) linked to the behaviour of emissions in economies such as Qatar, the United Arab Emirates and Saudi Arabia, in which oil revenues have supported other sectors, such as through aid for the construction of buildings and infrastructure capable of responding to the present and future challenges of growing tourist demand.

The results also seem to point to evidence of deterministic convergence at the aggregate panel level. However, at the country level, differences emerge, and only in Libya do the results seem to indicate convergence in CO_2 emissions, GVA, energy consumption and trade openness indicators. The manufacturing industry sector is the only sector revealing stationarity for all OPEC economies, and only Libya exhibits deterministic convergence for all sectors GVA. Therefore, the results seem to point to structural differences among OPEC countries which will tend to arise through their own pollution level, and convergence is conditioned to the OPEC country characteristics.

We were specifically interested in exploring whether the income-environment EKC dynamics of the more emission-intensive sectors (3- manufacturing and 6- transport) and those which are less emission-intensive (the service sector), differ, and the results lead to a favourable conclusion on this point. Therefore, this is a signal that policy action has already been taken into account in these two sectors, but pressure should be placed on the remaining ones. At least in the most emission-intensive sectors, policy actions in OPEC countries seem to have started to produce the desired effects.

The results seem to indicate that value-added growth generated in economic activity in the sectors of OPEC countries included in the sample present structural differences which will tend to grow in the direction of their own pollution level, while convergence becomes conditional on OPEC country characteristics. Empirical estimations performed indicate the validity of the

EKC hypothesis in only two economic activity sectors (manufacturing; transport, storage and communications) and show a U-shaped relationship for three sectors (agriculture, forestry and fisheries; construction; remaining activities), evidencing different degrees of environmental awareness regarding gross value added growth by economic activity sector. The results point to a U-shaped relationship when considering all 12 OPEC countries in all PCSE specifications, except in the random and fixed effects model with a robust option to correct for heteroscedasticity. Energy consumption has a positive and significant effect on carbon emissions: thus leading to environmental degradation, while trade openness has a negative and significant effect on emissions, leading us to conclude that trade openness in OPEC countries leads to environmental improvements.

Including oil prices in the analysis, and considering that we are analysing OPEC countries, these were introduced to avoid omitted variable biases, has reinforced some of the results attained previously. It has changed the confidence levels for the diagnostic tests, since with their introduction we have evidence in all for their significance, thus providing more robustness to the use of PCSE methods. For example, Pesaran's Test, which was not significant under the hypothesis of no oil prices in the analysis, became significant with oil price inclusion. Moreover, the introduction of oil price effects has changed the magnitude of the coefficients obtained through estimations, as well as the standard deviation in some of the model specifications. In the correlations, there are no significant changes, but in terms of magnitude, it was possible to verify that there are. As such, including oil spot prices in our analysis has rendered the results more robust.

Concerning sectors, we were only able to validate the EKC hypothesis, an inverted U-shaped relationship, for two economic activity sectors (manufacturing industries and transport activities, storage and communication). In other sectors, when both coefficients of GVA and GVA squared variables are significant, the results seem to point to a U-shaped relationship between carbon emissions and sector growth in only three sectors (agriculture, forestry and fisheries; construction; and remaining activities). However, we were unable to validate a significant relationship for the extractive and manufacturing industries, which also include the electricity, gas and water industries and wholesale, lodging, restoration and similar activities. Thus, policymakers should be aware of the significant differences among economic activity sectors and impose different restrictions once the results seem to indicate that sector diversification contributes to environmental awareness and impacts even in OPEC countries.

Given all the evidence found in this study, we believe that national policymakers should make serious commitments towards economic diversification as a solution to reduce the degree of the country's economic petro-dependence. This economic policy recommendation incorporates the challenges of diverting the wealth generated from the oil and hydrocarbons business to investments in origins/sources non-related to energy consumption. This is particularly seen in the economic activities of agriculture, manufacturing, commerce and services, as in industries and services in the waste treatment and disposal sector. In the latter cases, it is a matter of conceiving and disseminating technologies and methods of organisation of production processes which result in a decrease in carbon dioxide emissions.

6. Conclusions

The main focus of this research was to investigate the relationship between GVA and CO_2 emissions by adding energy consumption and the influence of the trade openness indicator on the relationship. Thus, this study empirically examined an EKC hypothesis applied to a panel of 12 OPEC economies for the period of analysis after the Gulf War, i.e. the period 1992-2015. Besides this, an attempt was made to test the existence of a new hypothesis related to the form of the EKC (second specification), in which the influence of economic growth generated in 7 sectors according to ISIC classification was analysed, including, as in the first specification, the impact of energy consumption and the impact of openness to trade recognised as a major cause of CO_2 emissions. Additionally, both deterministic and stochastic convergence was tested for all the relevant variables included in the analysis, by country and by economic activity sector.

The oil and hydrocarbon production industry in OPEC member countries is one of the sectors that contribute most to environmental pollution, through the release of carbon dioxide and oil spills that affect the ecosystem. Our results show a partial response given the objectives or hypotheses enumerated and the intended goals. If, on the one hand, it was intended to validate EKC for the panel of OPEC countries in quadratic form, and in the more conventional form, we conclude that, using the cointegration option, since the Kuznets curve is validated in the form of U and at a significance level of 1%, in the results of the Panel Corrected Standard Errors estimator, the results for the second proposal for the EKC shows for some sectors the validity of EKC in the form of an inverted U alternating with the U-shape. However, for sector 2 and sector 5 in the time period, the concave relationship between economic growth in these sectors and their contributions to the decrease in emissions is continuous. Given the non-convergence in the one-way results: i.e., the validity of Kuznets in the form of an inverted U, we believe that intrinsic and extrinsic vulnerabilities have different impacts between the countries that make up this OPEC sample.

It seems to be generally agreed, and our results constitute a permanent reflection that, in the long-term perspective, the economic and environmental reliability of the oil sector will have to be associated with the entry of other alternative energy sources into the OPEC economies.

Based on the results found, in the case of the quadratic specification of the EKC Kuznets relationship with the influence of global economic growth for the OPEC panel, we can infer that the Kuznets curve in the form of a U and at a level of significance of 1% is validated, based on the results of the Panel Corrected Standard Error estimator. Regarding the second specification of the EKC, with the inclusion of the relation of economic growth by sector of economic activity, the results of the Panel Corrected Standard Error estimation show that the EKC formats are presented in 2 forms: in the form of a U for the relationship between GVA and carbon emissions in sector 7, sector 4 and sector 1; and appearing as an inverted U in the relationship between GVA and carbon emissions in sector 3 and sector 6. Inclusion of oil prices in our analysis has increased the robustness of the results already attained, while also allowing us to provide full significance to all diagnostic tests presented, confirming the need to use PCSE methods for testing the EKC hypothesis.

So, given the non-convergence in the one-way results, i.e. as the validity of Kuznets in the form of an inverted U, it seems that intrinsic and extrinsic vulnerabilities have different impacts between the different countries that make up the OPEC sample. Therefore, one of the most important conclusions of this study is that actions against environmental problems in sectors of economic activity in OPEC member countries persist continuously in most sectors, even if Gross Value Added increases in these sectors. On the other hand, the results of the various estimators show that the variable energy consumption included in the two proposed EKC relationships presents statistical significance. In turn, the trade openness variable shows opposing statistical evidence, since in specification 1 it is shown to be statistically significant, while in the second specification, the results point to its non-significance.

This paper has some limitations that will form the basis for future research. Investigating the validity of the EKC hypothesis through the method used in the study, rather than modelling based on assumptions in quadratic or cubic form, is perhaps pioneering for future studies. However, our study has periodic, geographical data set and methodological limitations. First, since the technique used in the paper creates a trim in the sample, the model could be studied for a longer period in future studies. Second, a geographical limitation is found based on the fact that the appropriate sample period to use this methodology for indicators that represent sectoral emissions exists only for the OPEC economies. The development of data sets containing sectoral emission indicators for other countries or country groups will allow the study to be carried out from a wider perspective. Third, in terms of the methodology, it would be possible to apply different panel data techniques which control for endogeneity.

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To be included.

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Appendix

Table A.1. Comparison of Fixed effects (FE) estimation without and with oil prices - specification #1

Specification # 1	FGLS	FGLS	CSE Fixed Effect	CSE Fixed Effect	RSE Fixed Effect	RSE Fixed Effect	AR1 Fixed Effect	AR1 Fixed Effect
Ln GVA	-5.979*** (.4341)	-5.969*** (.4329)	-5.28003 (1.2516)	-1.02224 (1.320)	-5.28003 (4.445)	-1.02224 (4.126)	-7.446*** (2.533)	-6.0617** (2.429)
Ln GVA^2	.1356*** (..00848)	.1351*** (.00846)	. 1199*** (.02478)	.030133 (.0265)	.119945 (.08683)	.0301333 (.0816)	.1561*** (.0503)	.1286*** (.0484)
Ln Cons. Energy	.1706*** (.00592)	.1719*** (.00596)	.074490 (.06515)	.013910 (.0610)	.0744908 (.11011)	.0139102 (.1150)	.050867 (.0650)	.031191 (.0648)
Ln Tr. Open	-.1185*** (.01335)	-.1239*** (.0134)	-.013860 (.01678)	-.021933 (.0156)	-.0138607 (.03590)	-.0219339 (.0192)	.008711 (. 01824)	.007046 (.0181)
Ln Oil Prices		.0426*** (.0116)		.2002*** (.0296)		.2002*** (.0611)		.066171* (.0352)
Constant	67.6935*** (5.556)	67.58*** (5.539)	60.37*** (15.863)	10.0836 (16.477)	60.3737 (57.290)	10.083 (52.367)	92.24*** (7.985)	74.72*** (9.043)
Observations	288	288	288	288	288	288	288	288
Wald test / R^2	17247,2***	16618***	0.7824	0.7869	0.7824	0.7869	0.7735	0.7952

Note: Estimator FGLS for panel heteroskedastic with cross-sectional correlation; Hausman Test: Ho: difference in coefficients not systematic, the statistic chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 150.30, with Prob>chi2 =0.000, reject Ho.

Table A.2. Comparison of Random effects (RE) estimation without and with oil prices - specification #1

Specification # 1	CSE Random effect	CSE Random effect	RSE Random Effect	RSE Random Effect	AR1 Random effect	AR1 Random effect
Ln GVA	-5.35*** (1.243)	-1.960 (1.301)	-5.37 (4.489)	-1.960 (4.101)	-8.44*** (2.225)	-7.132*** (2.142)
Ln GVA^2	. 121*** (.0245)	.04989** (.0260)	. 12163 (.0874)	.049891 (.0808)	.1796*** (.0441)	.1533*** (.0426)
Ln Cons. Energy	.0991*** (. 0551)	.057961 (. 0541)	.099178 (. 0998)	.057961 (. 0917)	.11081** (. 0574)	.098467* (. 0569)
Ln Tr. Open	-.015609 (. 0166)	-.023020 (. 0157)	-.015609 (. 0355)	-.023020 (. 0214)	-.000838 (. 0189)	-.001966 (. 0188)
Ln Oil Prices		.1688*** (. 0284)		.1688*** (. 0566)		.059116* (. 0349)
Constant	61.09*** (15.75)	20.9047 (15.29)	61.096 (57.92)	20.9047 (52.49)	101.7*** (28.068)	85.45*** (26.95)
Observations	288	288	288	288	288	288
Wald test / R^2	0.7867	0.8097	0.7867	0.8097	0.7818	0.8076

Note: Estimator FGLS for panel heteroskedastic with cross-sectional correlation; Hausman Test: Ho: difference in coefficients not systematic, the statistic chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 150.30, with Prob>chi2 =0.000, reject Ho.

Table A.3. Comparison of Fixed effects (FE) estimation without and with oil prices – specification #2

Specification # 2	FGLS	FGLS	CSE Fixed effect	CSE Fixed effect	RSE Fixed effect	RSE Fixed effect	AR1 Fixed effect	AR1 Fixed effect
Ln Cons. Ener	.299719**	.28762***	.124425**	.090196	.124425**	.090196	.049123	. .0429701
	(.0465)	(.0468)	(.0575)	(.0573)	(.0898)	(.0966)	(.0614)	(.0617)
Ln Trade Open.	.019025	.0260784	. 052806***	.039686**	. 052806***	.039686	. 021940	.0214035
	(.0257)	(.0259)	(.0194)	(.0194)	(.0391)	(.0291)	(.0201)	(.0202)
Ln Oil Prices		-.053142*		.10848***		.10848**		.0250975
		(.0312)		(.0321)		(.0455)		(.0340)
GVA sector 1	-.642011	-.781310**	.876461*	.939167**	.876461*	.939167	.627184-	.6516447
	(.3330)	(.3413)	(. 5015)	(0.492)	(1.206)	(1.250)	(. 7297)	(.723)
GVA sector 2	-4.537***	-4.51205***	-3.27619***	-2.7734**	-3.27619***	-2.77345	-3.36594*	--3.23480*
	(1.142)	(1.137)	(1.215)	(1.201)	(2.096)	(1.976)	(1.897)	(1.867)
GVA sector 3	5.41496***	5.18839***	6.18366***	4.48946	6.18366***	4.48946	4.83517*	4.80428
	(1.744)	(1.740)	(2.184)	(2.200)	(5.541)	(4.848)	(3.101)	(3.064
GVA sector 4	-3.46091*	-3.39410***	.097040	.620790	.097040	.620790	-.034633	-.023923
	(.8028)	(.799)	(.9036)	(0.899)	(1.302)	(1.160)	(1.158)	(1.148)
GVA sector 5	4.40562*	3.86583***	-6.63931***	-6.43367	-6.63931***	-6.43367	-5.592***	-5.49654**
	(1.239)	(1.273)	(1.605)	(1.575)	(4.075)	(3.762)	(2.307)	(2.290)
GVA sector 6	1.08496	1.295724	2.60931***	2.36501	2.60931***	2.36501	2.54721*	2.42586
	(1.069)	(1.071)	(. 0340)	(1.017)	(1.806)	(1.765)	(1.564)	(1.557)
GVA sector 7	-8.3808***	-8.35937***	-7.27073	-.078032	-7.27073	-.078032	-.004182	.1520997
	(2.387)	(2.375)	(2.925)	(2.875)	(5.680)	(5.806)	(3.890)	(3.876)
GVA^2 sector 1	.020272***	.023083***	-. 018600	-.020484*	-. 018600	-.020484	-. 014581	-.0151406
	(.007)	(.0078)	(.0118)	(.0116)	(.0303)	(.0314)	(.0171)	(.0170)
GVA^2 sector 2	-.105003	-.10068***	-.12272***	-.08775**	-.12272***	-.087756	-.095927	-.0953685
	(.0360)	(.0359)	(.0448)	(.0452)	(.1132)	(.0995)	(.0633)	(.0626)
GVA^2 sector 3	.09763***	.096718***	-0.7172***	.061786**	-0.7172***	.061786	0.73728*	.070941*
	(.0256)	(.0255)	(.0264)	(.0261)	(.0466)	(.0444)	(.0421)	(.0414)
GVA^2 sector 4	.084239	.083290***	-.000539	-.012459	-.000539	-.012459	.0021335	.0018937
	(.0181)	(.0180)	(.0200)	(.0200)	(.0287)	(.0258)	(.0261)	(.0259)
GVA^2 sector 5	-.109485*	-.098038***	. 139327***	.13467***	. 139327***	.134679	. 11808**	.115948**
	(.0273)	(.0280)	(.0350)	(.0343)	(.0909)	(.0838)	(.0504)	(.0500)
GVA^2 sector 6	-.020609	-.0244728	- .0552***	-.0508**	- .0552***	-.050863	- .05321*	-.050716
	(.0240)	(.0240)	(. 0236)	(.0232)	(. 0415)	(.0409)	(. 0352)	(.0351)
GVA^2 sector 7	.185844***	.18558***	.024945	.009258	.024945	.009258*	.0082867	.0047612
	(.0496)	(.0494)	(. 0612)	(.060)	(. 1203)	(.123)	(. 0814)	(.0811)
Constant	60.9970*	67.993***	1.83917	4.2522	1.83917	4.25228*	5.472797	2.596115
	(21.97)	(22.24)	(31.48)	(30.88)	(74.13)	(73.68)	(15.24)	(15.80)
Observations	288	288	288	288	288	288	288	288
Wald Test / R^2	4006.77	4050.06	0.8594	0.8723	0.8594	0.8723	0.8398	0.8729

Note: Estimator FGLS for panel heteroskedastic with cross-sectional correlation; Hausman Test: Ho: difference in coefficients not systematic, the statistic chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 150.30, with Prob>chi2 =0.000, reject Ho.

Table A.4. Comparison of Random effects (RE) estimation without and with oil prices - specification #2

Specification # 2	CSE	CSE	RSE	RSE	AR1	AR1
Ln Cons. Ener	.124425** (.0575)	.28762*** (.0484)	.124425** (.0898)	.28762** (.1458)	.15776*** (.0530)	.160483*** (.0529)
Ln Trade Op	. 05280*** (.0194)	..0260784 (.0268)	. 05280*** (.0391)	..0260784 (.0234)	.0178956 (.02017)	.0186777 (.0203)
Ln Oil Prices		-.053142* (.0322)		-.0531427 (.0664)		-.004119 (.0332)
GVA sector 1	.876461* (. 5015)	-.78131** (.3525)	.876461* (1.206)	-.7813108 (.9124)	.346395 (.5182)	.3242329 (..5115)
GVA sector 2	-3.2761*** (1.215)	-4.512*** (1.174)	-3.2761*** (2.096)	-4.512*** (1.508)	-4.09978** (1.636)	-4.09035** (1.612)
GVA sector 3	6.18366*** (2.184)	5.1883*** (1.797)	6.18366*** (5.541)	5.188395 (4.194)	3.764853 (2.571	3.81005 (2.550)
GVA sector 4	.097040 (.9036)	-3.39410* (.826)	.097040 (1.302)	-3.39410* (2.008)	-.159594 (1.007)	-.210275 (.998)
GVA sector 5	-6.6393*** (1.605)	3.8658*** (1.315)	-6.6393*** (4.075)	3.86583* (2.255)	-2.553729 (1.972)	-2.51570 (1.965)
GVA sector 6	2.60931*** (. 0340)	1.295724 (1.106)	2.60931*** (1.806)	1.295724 (1.930)	1.9657*3 (1.128)	1.97071* (1.119)
GVA sector 7	-7.27073 (2.925)	-8.359*** (2.453)	-7.27073 (5.680)	-8.359379 (5.946)	-5.10025* (3.087)	-5.17173* (3.069)
GVA^2 sector 1	-. 018600 (.0118)	.02308*** (.0080)	-. 018600 (.0303)	.0230832 (.0199)	-.005626 (.0120)	-.005056 (.0119)
GVA^2 sector 2	-.12272*** (.0448)	-.1006*** (.0371)	-.12272*** (.1132)	-.100683 (.0868)	-.069908 (.0526)	-.0708262 (.0522)
GVA^2 sector 3	-0.7172*** (.0264)	.09671*** (.0263)	-0.7172*** (.0466)	.0967*** (.0337)	.088958** (.0365)	.088669** (.0360)
GVA^2 sector 4	-.000539 (.0200)	.08329*** (.0186)	-.000539 (.0287)	.083290* (.0476)	.0047559 (.0228)	.0059878 (.0226)
GVA^2 sector 5	. 13932*** (.0350)	-.0980*** (.0289)	. 13932*** (.0909)	-.098038* (.0518)	.0472616 (.0433)	.0463724 (.0431)
GVA^2 sector 6	- .05524*** (. 0236)	-.0244728 (.0248)	- .05524*** (. 0415)	-.0244728 (.0450)	-.0409067* (.0254)	-.041008* (.0252)
GVA^2 sector 7	.024945 (. 0612)	.18558*** (.0510)	.024945 (. 1203)	.1855831 (.1255)	.118797* (.0646)	.1203457* (.0642)
Constant	1.83917 (31.48)	67.993*** (22.974)	1.83917 (74.13)	67.9936* (35.478)	60.2622** (29.72)	60.7160** (29.475)
Observations	288	288	288	288	288	288
Wald Test / R^2	0.8594	0.9805	0.8594	0.9805	0.9083	0.9349

Note: Estimator FGLS for panel heteroskedastic with cross-sectional correlation; Hausman Test: Ho: difference in coefficients not systematic, the statistic chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)= 150.30, with Prob>chi2 =0.000, reject Ho.

Highlights:

- Economic activity sectors diversification influences EKC hypothesis?
- Different degrees of environmental awareness are evidenced by sector.
- Trade openness reveals to have a significant and negative effect over emissions.
- Deterministic and stochastic convergence differences in sectors and countries.
- Relocation of pollution-intensive sectors to almost all of the OPEC countries needed.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: