Available online at www.sciencedirect.com
ScienceDirect
Energy Reports 8 (2022) 23–28
www.elsevier.com/locate/egyr

The 8th International Conference on Energy and Environment Research ICEER 2021, 13–17 September

Does economic sectorial diversification affect the relationship between carbon emissions, economic growth, energy consumption, coal and gas consumption? Evidence from OPEC countries using panel cointegration analysis

Victor Moutinho[a,*], Mara Madaleno[b]

[a] *Nece and Management and Economics Department, University of Beira Interior, Portugal*
[b] *GOVCOPP—Research Unit in Governance, Competitiveness and Public Policy, Department of Economics, Management, Industrial Engineering and Tourism, University of Aveiro, 3810-193 Aveiro, Portugal*

Received 22 December 2021; accepted 8 January 2022
Available online xxxx

Abstract

This work aims to investigate a relationship between economic and environmental drivers under the economic diversification condition including seven economic activity sectors for a set of nine OPEC countries during 1974–2016. For validating the two Environmental Kuznets Curve – EKC – equations proposed, a panel data analysis was followed through the long and short-run estimations, including the Pooled Mean Group, Mean Group, and Dynamic Fixed Effect estimators. Results of the cointegration panel estimators show, for some sectors the validity of the EKC in the form of an inverted U shape, alternating with the U-shaped form. Namely, sector 2 of the extractive and manufacturing industries, including the electricity, gas, and water industries, and sector 5, including wholesale, lodging, restoration, and similar activities, validate the EKC hypothesis. However, the validity of the Kuznets curve with the panel data does not make it clear which OPEC countries are in the most favorable conditions to mitigate the polluting effects.

Peer-review under responsibility of the scientific committee of the The 8th International Conference on Energy and Environment Research, ICEER, 2021.

Keywords: Carbon emissions; Environmental Kuznets curve; OPEC countries; Sector diversification

1. Introduction

In the recent past, economic diversification has presented itself as a present and future challenge for some member states of the OPEC countries group. Despite different levels of diversification among this group of countries, these challenges impose strategic and effective policies, as well as concrete actions that will lead to the reduction of

* Corresponding author.
E-mail addresses: ferreira.moutinho@ubi.pt (V. Moutinho), maramadaleno@ua.pt (M. Madaleno).

https://doi.org/10.1016/j.egyr.2022.01.039

Peer-review under responsibility of the scientific committee of the The 8th International Conference on Energy and Environment Research, ICEER, 2021.

the collateral effects of oil production and other fuels by leveraging other sectors of the economic activity. Some countries such as United Arab Emirates, Bahrain, Kuwait, and Qatar are leveraging other sectors of the economy with petroleum revenues, to the point of creating a major socio-economic transformation. However, the projections from the OPEC World Energy Model (OWEM) indicate that, at least for the next two decades, fossil fuels will remain the world's dominant energy source meeting more than 90 percent of world energy requirements. Projections also show expected increases in renewable energy although with rates lower than those set out as goals of energy security. This means that member countries of OPEC might fail in stabilizing the oil market, guaranteeing secure demand and supply at reasonable prices. Under these differential objectives and challenges, it seems interesting to understand the efforts that the OPEC countries are implementing in the economic diversification and how these affect the mitigation of greenhouse gases at different levels — aggregate and sectorial. In the literature, some related studies can be found for a group of 10 OPEC countries, such as [1] or for individual ones such as [2] in Algeria and [3] in Qatar. Regarding the validation of the EKC curve in the OPEC countries at an individual level, we highlight the recent study of [4], which analyzes the EKC validation in the period 1970–2014 in Saudi Arabia through the application of the Autoregressive Distributed Lag (ARDL) model. The author has found significant evidence to postulate that economic growth promotes CO2 emissions under a linear specification. Some authors such [5,6], and [7], also evidenced that technological innovations must be highlighted as a statistically insignificant determinant to mitigate the CO2 discharge. Still, regarding Saudi Arabia, we evidence the paper of [8], which has studied the environmental Kuznets curve relationship for the period 1971–2011, by including in the analysis the variable Energy Consumption in the road transport sector. Regarding OPEC members, [9] with an ARDL approach investigate the EKC hypothesis in Algeria, showing no evidence of it. Even so, in India, the inverted U-shape curve premise was validated with the ARDL procedure for the periods of 1971–2014 and 1971–2015 [10,11], respectively. In another study, [12] investigate the EKC hypothesis for the OPEC countries group considering 10 members, for 1977–2008, using an ARDL approach. The results favored an inverted U-shape curve in Algeria, Iraq, Venezuela, Kuwait, Nigeria, and Qatar. In addition, oil consumption and income are the main sources of environmental degradation. Considering the literature reviewed, no studies were found relating the Gross Value-Added (GVA) of the economic activity sectors and environmental change through the application of the EKC in the OPEC countries group, except that of [13] but using panel corrected standard error models and with a shorter analysis period than the one to be presented here.

2. Methodology and data

We tested the EKC hypothesis, in a panel dataset of 9 OPEC countries which includes Algeria, Ecuador, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela. The other countries were excluded because they had inconsistent data for the entire period considered. The data used in this study refers to the period 1974–2016 (a time series of 43 years with a total of 387 annual observations). The selected variables include carbon dioxide emissions, the total GVA, and Energy Consumption. The carbon dioxide emissions are measured in tons per capita; the total GVA by sector represents the total Added Value in the economy and is measured in Dollars at constant prices of 2010; and, the variable energy consumption, following [14–16], is measured in kg of per capita equivalent oil. According to the ISIC classification (International Standard Industrial Classification of All Economic Activities), the Value-Added is disaggregated in a group of 7 sectors, following [13]. In the second step, the EKC specification besides including the disaggregation of the GDP by sector also considers the disaggregation of the variable Energy Consumption by type — electricity generation, oil, coal, and natural gas consumption. These variables are measured in million tons of oil equivalent. The data was retrieved from the WDI (World Bank Indicators) and Main Accounts Database of National Accounts. In terms of cointegration analysis, if the series is stationary and the variables are cointegrated, we can consider that deviations from the long-term balance influence the short-term [17]. The answer to these deviations can be represented by an Error Correlation Model (ECM).

$$\Delta y_{it} = \varnothing_i \left(y_{i,t-1} - \theta'_i X_{it} \right) + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta'^*_{ij} \Delta X_{i,t-j} + \mu_i + \in_{it} \tag{1}$$

in which $\varnothing_i = -(1 - \sum_{j=1}^{p} \lambda_{ij})$, $\theta_i = \sum_{j=0}^{p} \delta_{ij} / (1 - \sum_k \lambda_{ik})$, $\lambda^*_{ij} = -\sum_{m=j+1}^{q} \lambda_{im}$ with $j = 1, 2, \ldots, p-1$, e $\delta'^*_{ij} = \sum_{m=j+1}^{q} \delta_{im}$ com $j = 1, 2, \ldots, q-1$. The estimation can be done by a few techniques, in this paper, as said before, the Pooled Mean Group (PMG), the Mean Group (MG), and the Dynamic Fixed Effects (DFE) approaches were selected. The Mean Group (MG) developed by [17] allows all intercepts, coefficients, and error rates to vary between groups both in the short and long term. The PMG is an intermediate and alternative methodology, created by [18], working like the MG for the short-term, but for the long-term, the coefficient does not vary. In other words, it restricts the coefficients to be the same across the panel. This is a method of the maximum likelihood that makes consistent and asymptotically normal estimates of the coefficients, whether the integrated regressors can be of order I (1) or stationary I (0). The estimators are calculated according to Eq. (2).

$$\hat{\theta} = -\left\{\sum_{i=1}^{N} \frac{\hat{\varnothing}_i^2}{\hat{\sigma}_i^2} X'_I H_i X_i\right\}^{-1} \left\{\sum_{i=1}^{N} \frac{\hat{\varnothing}_i^2}{\hat{\sigma}_i^2} X'_I H_i \left(\Delta y_i - \hat{\varnothing}_i y_{i-1}\right)\right\} \tag{2}$$

Finally, the DFE estimation is similar to a PMG estimation in co-integration and estimator terms, but in the long run, it needs to be homogeneous across all panels. Different from the PMG, the DFE estimation also limits the speed of adjustment coefficient and the short-term coefficient to be homogeneous [19].

3. Empirical results

It is noted for the variables Gross Value-Added and Square Gross Value-Added variables, that we cannot reject the null hypothesis of the existence of unit roots according to the IPS, LLC, and Fisher estimators, which presupposes that the inclusion of these two variables in the EKC relationship may support problems of statistical significance for the sample used. In turn, for both models, there is statistical evidence at a 1% level of significance to reject the presence of a unit root in the variables CO2 emissions per capita, Energy consumption, Oil consumption, and Gas consumption. Additionally, at the same level of significance, we reject the presence of unit root in the Gross Value-Added and the Square Gross Value-Added series for sector 2 and sector 3 in model 2. Given these shreds of evidence, we will say that these series are stationary. However, the Hadri test results show that the null hypothesis is rejected for all the variables in both models considered, meaning that the series of these variables are non-stationary. Combining the results of the tests we conclude that the non-stationary variables are the GVA and the Square GVA series in model 1 (for the 9 countries panel – Table 1) and the GVA variables for sectors 1, 4, 5, 6, and 7 in model 2 (for the sectors – Table 2). Although the series is non-stationary, the combination of two or more non-stationary variables may be stationary. If there is a stationary linear combination between the variables, then the data series are cointegrated.

Table 1. Unit root tests — Model 1.

Variables	Model 1			
	IPS W-stat:t	LLC t*-stat	Fischer PPerron Z-stat	Hadri - Z-stat:
CO2	−4.257***	−4.088***	−4.538***	6.493***
GVA	−0.547	−1.468*	0.237	14.137***
GVA^2	−0.299	−1.301*	0.4827	14.252***
Energy consumption	−3.308***	−4.280***	−2.840***	9.201***
Oil consumption	−1.791**	−3.049***	−2071***	14.889***
Gas consumption	−2.974	−4.100***	−2.458***	8.291***

Notes:
*Statistically significance at 10%.
**Statistically significance at 5%.
***Statistically significance at 1%.

The stationary combination between the variables is called the cointegration equation and can be interpreted as a long-term equilibrium relationship between the variables. In Table 3 the Long-run elasticities estimation results are presented for the three models PMG, MG, and DFE. The Hausman test is performed to determine which method was more appropriate for the data sample, indicating that the PMG estimator is preferable to the MG estimator. Given that there are adjustment or convergence velocities for long-term equilibrium, contrary to what is assumed in the DFE estimation, we will interpret the results for the PMG estimator. This evidence implies in the period of analysis, that the adjustment to the equilibrium after a shock away from the stationary state is immediate.

In the long run (Table 3), the estimation results of model 2 do not confirm the existence of an EKC relationship (the coefficient associated with GVA is negative and the coefficient associated with square GVA is positive; a

Table 2. Unit root tests — Model 2.

Variables	Model 2			
	IPS W-stat:t	LLC t*-stat	Fischer PPerron Z-stat:	Hadri - Z-stat:
CO2	−4.257***	−4.088***	−4.538***	6.493***
Energy consumption	−3.308***	−4.280***	−2.840***	9.201***
Oil consumption	−1.791**	−3.049***	−2071***	14.889***
Gas consumption	−2.974	−4.100***	−2.458***	8.291***
GVA sector 1	0.3767	−0.487	0.49	11.539***
GVA sector 2	−3.533***	−3.105***	−2.212**	6.781***
GVA sector 3	−2.033***	−2.743***	−1.116	10.330***
GVA sector 4	1.726	1.601	1.808	15.754***
GVA sector 5	−1.420*	−0.283	−0.44	13.848***
GVA sector 6	0.809	0.105	1.04	14.939***
GVA sector 7	0.1452	0.923	−1.209	13.230***
GVA^2 sector 1	0.5451	−0.272	0.674	11.735***
GVA^2 sector 2	−1.943**	−2.685***	−1.034	10.365***
GVA^2 sector 3	−3.372***	−3.300***	−1.844**	6.563***
GVA^2 sector 4	1.9264	1.6797	2.077	16.012***
GVA^2 sector 5	−1.114	−0.118	−0.079	14.036***
GVA^2 sector 6	1.2106	0.209	1.61	15.138***
GVA^2 sector 7	1.2625	2.211	−0.829	13.461***

Notes:
*Statistically significance at 10%.
**Statistically significance at 5%.
***Statistically significance at 1%.

Table 3. Long-run elasticities using PMG, MG, and DFE estimators — Model 1 and Model 2.

Variables	Model 1			Variables	Model 2		
	PMG	MG	DFE		PMG	MG	DFE
GVA	−0.724	−5.703	−0.099	Energy consumption	0.625***	0.86	0.1128
GVA^2	0.022	0.109	0.0126	Oil consumption	0.111*	−0.077	0.158**
Energy consumption	0.475***	−0.162	−0.085	Gas consumption	−0.397***	1.818	0.0419
Oil consumption	0.391***	0.193	0.093	Coef. convergence	−0.425***	−1.046***	−0.363***
Gas consumption	−0.06	0.390***	0.319***	GVA sector 1	−0.224	−33.502	0.589
Coef. convergence	−0.288***	−0.599***	−0.280***	GVA sector 2	−4.027**	−200.42	−5.722***
				GVA sector 3	−8.850***	82.663	0.061
				GVA sector 4	−3.761*	47.96	−0.097
				GVA sector 5	9.147***	23.407	−2.571
				GVA sector 6	4.575**	−52.191	2.181**
				GVA sector 7	−4.225	135.192	3.519
				GVA^2 sector 1	0.011	0.7371	−0.012
				GVA^2 sector 2	0.181***	−1.654	0.0026
				GVA^2 sector 3	0.093**	4.435	0.1249***
				GVA^2 sector 4	0.0782*	−1.122	0.0024
				GVA^2 sector 5	−0.203***	−0.392	0.0574
				GVA^2 sector 6	−0.088*	1.125*	−0.0467*
				GVA^2 sector 7	0.077	−2.827	−0.701

Notes:
*Statistically significance at 10%.
**Statistically significance at 5%.
***Statistically significance at 1%.

U-shaped relationship) for sector 2, for sector 3 and sector 4 with a level of significance of 5%, 1%, and 10%, respectively

Table 4. Short run elasticities using PMG, MG, and DFE estimators — Model 1 and Model 2.

Variables	Model 1			Variables	Model 2		
	PMG	MG	DFE		PMG	MG	DFE
GVA	6.513	19.903	3.945*	Energy consumption	−0.392***	−0.111	−0.172***
GVA^2	−0.123	−0.39	−0.077*	Oil consumption	−0.135	0.0345	0.094
Energy consumption	−0.113	0.018	0.142**	Gas consumption	0.213	−0.219	0.105**
Oil consumption	−0.342**	−0.311*	−0.160**	Constant	41.446***	−400.86*	6.876
Gas consumption	0.078	−0.052	0.903**	GVA sector 1	22.396**	−7.649	1.628***
Constant	1.186***	35.041	−0.411	GVA sector 2	10.010**	50.255	1.929
				GVA sector 3	30.44***	−39.623	1.302
				GVA sector 4	6.105	−14.769	−0.5456
				GVA sector 5	−15.983**	−0.712	0.7824
				GVA sector 6	−14.143	11.162	0.1654
				GVA sector 7	5.607	−67.379*	0.409
				GVA^2 sector 1	−0.499**	0.149	−0.0378***
				GVA^2 sector 2	−0.621***	0.798	−0.0235
				GVA^2 sector 3	−0.304*	−1.102	−0.0441
				GVA^2 sector 4	−0.067	0.337	0.0116
				GVA^2 sector 5	0.350**	0.005	−0.0179
				GVA^2 sector 6	0.3183	−0.265	−0.0042
				GVA^2 sector 7	−0.107	1.383*	−0.0119

Notes:
*Statistically significance at 10%.
**Statistically significance at 5%.
***Statistically significance at 1%.

However, in this same EKC relationship, it is found that the coefficients associated with the GVA of sector 5 and the GVA of sector 6 show the presence of an inverted U-shaped curve (the coefficient associated with GVA is positive and the coefficient associated with Square GVA is negative; validating the EKC only for these two sectors), with a significance level of 1% and 10%, respectively. In the environmental relationship assessment, the energy, oil, and gas consumption, are statistically significant at 1% and 10%, respectively. In terms of fuel type, the long-term elasticity of the CO2 emissions is positive and statistically significant for the energy consumption in aggregate terms, while the elasticity of the oil consumption is negative (as theoretically expected). In the short term, according to the PMG estimator results presented in Table 4, there is statistical evidence at the usual significance levels of 1%, 5, and 10% to validate the inverted U-form EKC curve for the relationship between CO2, the GVA, and the Square GVA in sector 1, sector 2 and sector 3.

In sector 5, the EKC relationship is presented as a U-shaped curve. It was largely the tendency of developments in productive activities in the OPEC countries over the long period of 1974–2016, the main explanatory factor for increases in sectoral emissions. Thus, the increases in sectorial emissions are largely explained by the growing trend of productive activities in the OPEC countries throughout the analysis period (1974–2016)

Moreover, our results point to the existence of non-convergence for the 9 countries that compose our sample, as well as the non-validation of the Kuznets curve in the short and long term when model 1 is considered, and a partial validation (some sectors) in model 2. This structural effect is of extreme importance since the economic growth verified in some sectors (which contributed to the structural effect) mitigates the effect of the global emissions in the OPEC panel. Thus, the validity of the Kuznets curve with the panel data does not make it clear which OPEC countries are in the most favorable conditions to mitigate the polluting effects, evidence in the line of the study developed by [13].

4. Conclusion

This paper contributes to the existing literature since it considers a new way of evaluating the sectorial economic growth in the EKC formulation, which permits the investigation of the contribution of each sector to the mitigation of the carbon emissions in a set of countries that have a high dependency on fossil fuels, and consequently, contribute intensively for the environmental degradation. In general conclusion, our results for the first EKC approach show a partial response regarding the validation of the EKC hypothesis. Results of the cointegration panel estimators show for some sectors the validity of the EKC in the form of inverted U shape, alternating with the U-shape. We also evidence for some sectors, such as sector 2 (extractive and manufacturing industries which includes the electricity, gas, and water industries) and sector 5 (Wholesale, Lodging, Restoration and similar activities), that their contributions to the decrease in emissions are continuous. Given that the results show a non-convergence separately, i.e., the validation of the Kuznets curve in the form of an inverted U-shape We believe that the intrinsic and extrinsic vulnerabilities have dispersed impacts between the different countries that compose the OPEC sample. According to our econometric results on the Kuznets environmental assessment, the expected signs of the sectoral GVA coefficients confirm the importance of the cause–effect relationship of economic growth and carbon emissions-

Declaration of competing interest

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.

Acknowledgments

This work was supported by NECE-UBI, Research Unit in Business Science and Economics, sponsored by the Portuguese Foundation for the Development of Science and Technology, Portugal, project UIDB/04630/2020, funded by national funds through FCT - Fundação para a Ciência e a Tecnologia, Portugal.

Funding

The NECE-UBI, Research Unit in Business Science and Economics, sponsored by the Portuguese Foundation for the Development of Science and Technology, project UIDB/04630/2020, financially supported this work.

References

[1] Saboori B, Al-mulali U, Bin Baba M, Mohammed AH. Oil-Induced environmental Kuznets curve in organization of petroleum exporting countries (OPEC). Int J Green Energy 2016;13(4):408–16.
[2] Amri F. Carbon dioxide emissions, output, and energy consumption categories in Algeria. Environ Sci Pollut Res 2017;24(17):14567–78.
[3] Mrabet Z, AlSamara M, Jarallah SH. The impact of economic development on environmental degradation in Qatar. Environ Ecol Stat 2017;24(1):7–38.
[4] Samargandi N. Sector value addition, technology and CO2 emissions in Saudi Arabia. Renew Sustain Energy Rev 2017;78:868–77.
[5] Esteve V, Tamarit C. Is there an environmental Kuznets curve for Spain? Fresh evidence from old data. Econ Mod 2012;29:2696–703.
[6] Álvarez-Herránz A, Balsalobre D, Cantos JM, Shahbaz M. Energy innovations-GHG emissions nexus: Fresh empirical evidence from OECD countries. Energy Policy 2017;101:90–100.
[7] Ramos AH, Madaleno M, Amorim Varum C. An analysis of the environmental Kuznets curve (EKC) hypothesis in Portugal: Sector data and innovation effects. In: 15th international conference on the european energy market (EEM), 2018. 2018, p. 1–6. http://dx.doi.org/10.1109/EEM.2018.8469919.
[8] Alshehry AS, Belloumi M. Study of the environmental Kuznets curve for transport carbon dioxide emissions in Saudi Arabia. Renew Sustain Energy Rev 2017;75:1339–47.
[9] Lacheheb M, Rahim ASA, Sirag A. Economic growth and carbon dioxide emissions: Investigating the environmental Kuznets curve hypothesis in Algeria. Int J Energy Econ Policy 2015;5(4):1125–32.
[10] Ahmad A, Zhao Y, Shahbaz M, Bano S, Zhang Z, Wang S, Liu Y. Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy. Energy Policy 2016;96:131–43.
[11] Sinha A, Shahbaz M. Estimation of environmental Kuznets curve for CO2 emission: Role of renewable energy generation in India. Renew Energy 2018;119:703–11.
[12] Saboori B, Al-Mulali U, Bin Baba M, Mohammed AH. Oil-Induced environmental Kuznets curve in organization of petroleum exporting countries (OPEC). Int J Green Energy 2016;13(4):408–16.
[13] Moutinho V, Madaleno M, Elheddad M. Determinants of the Environmental Kuznets Curve considering economic activity sector diversification in the OPEC countries. J Clean Prod 2020;271:122642.
[14] Saboori B, Sulaiman J. CO2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: a cointegration approach. Energy 2013a;55:813–22.
[15] Saboori B, Sulaiman J. Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia. Energy Policy 2013b;60:892–905.
[16] Kamoun M, Abdelkafi I, Ghorbel A. The impact of renewable energy on sustainable growth: Evidence from a panel of OECD countries. J Knowl Econ 2019;10:221–37.
[17] Pesaran MH, Smith R. Estimating long-run relationships from dynamic heterogeneous panels. J Econom 1995;68(1):621–34.
[18] Pesaran MH, Shin Y, Smith R. Pooled mean group estimation of dynamic heterogeneous panels. J Amer Statist Assoc 1999;94:621–34.
[19] Ahmed A, Uddin GS, Sohag K. Biomass energy, technological progress and the environmental Kuznets curve: Evidence from selected European countries. Biomass Bioenergy 2016;90(2016):202–8.