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How Institutional Quality Influences the Economic Development-Environmental Quality Relationship in Oil-Rich Countries: A Non-Linear Panel Threshold Regression Study

Reda Hamza BOUDJANA [1]

[1]*Centre de recherche en économie appliquée pour le développement (CREAD), (Algeria), r.boudjana@cread.dz.*

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ABSTRACT

This paper investigates how institutional quality moderates the relationship between economic growth and environmental quality in oil-dependent countries (some of the highest per capita CO_2 emitters in the world) using a Panel Threshold Regression (PTR) model from 20 oil-dependent economies during the period 1996–2023. The results reveal that economic development generally increases CO_2 emissions, but this negative effect is substantially reduced when institutional quality surpasses a certain level; in line with the non-linear relationship: countries with better institutions can soften the environmental costs of growth, whereas countries with weak governance structures suffer from a steeper trade-off between economic growth and environmental sustainability. The paper also demonstrates that human capital development, trade openness, and financial development help to lower emissions, while electricity consumption continues to be an important driver of environmental degradation. This study contributes to the Environmental Kuznets Curve debate by demonstrating how institutional quality mediates the relationship between economic development and environmental quality in oil-dependent economies using a synthesized governance index and considering threshold effects.

1. Introduction

Climate change represents one of the most significant challenges of our era (Derviş, 2008). Excessive CO2 emissions are widely blamed as the main cause of climate change(Garmann, 2014). The highest Co2 emissions per capita are in oil-rich countries, including Qatar, Bahrain and Kuwait(Budget, 2023). The vast availability of hydrocarbon resources, coupled with high domestic energy consumption due to the rapid population growth and substantial energy exports to meet rising global demand, has placed oil-rich nations such as Canada, Russia, Iran, Saudi Arabia, Mexico, Norway, and Indonesia among the top 20 highest CO2 emitters(Sadik-Zada & Gatto, 2021). According to the latest data and estimates from the International Energy Agency (IEA), oil and gas operations—including production, transportation, and refining—accounted for 5.1 billion tonnes of CO2 emissions in 2022, representing nearly 15% of total energy-related greenhouse gas emissions(International Energy Agency (IEA), 2023).Additionally, the economies of many oil-rich countries are substantially dependent on oil and gas revenues and are often marked by weak institutional frameworks (Antonakakis et al., 2017). These conditions significantly contribute to climate change, underscoring the importance of examining the particular context and primary determinants of CO2 emissions in these nations.Numerous scholarly investigations have delved into the intricate relationship between economic development and environmental quality. The pioneering work by (Grossman & Krueger, 1991)was seminal in identifying a nonlinear relationship characterized by an inverted U-shape between environmental degradation and economic development, now widely recognized as the Kuznets Curve (KC). Since this foundational study, a plethora of subsequent research has scrutinized this connection. Several studies have substantiated the initial findings, indicating a similar inverted U-shape relationship(Hanif et al., 2019; Muhammad et al., 2020; Shahbaz & Sinha, 2019). Conversely, other scholars have documented diverse relationship patterns, such as monotonically increasing relationships, U-shaped curves, or N-curves

* Corresponding Author : Reda Hamza BOUDJANA
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(Azlina et al., 2014; Boukhelkhal & Bengana, 2018; Koc & Bulus, 2020; Sugiawan & Managi, 2016; Zoundi, 2017) . Despite these efforts, a clear consensus on the nature of the connection remains elusive. The explanations for these findings are complex and multifaceted, encompassing a wide range of macroeconomic, social, and political factors beyond the commonly analyzed variables of economic development and energy consumption.

Recently, the growing acknowledgment of the importance of institutions has led to the inclusion of institutional quality indicators in studies on environmental sustainability. Within this framework, the present study aims to rethink this relationship between environmental quality and economic development, taking into account the dimension of institutional quality by considering the case of oil-rich countries.

We contend that improvements in environmental quality are not solely driven by higher levels of economic development but are significantly influenced by the institutional factors. Moreover, we posit that the relationships between economic development, environmental quality, and institutional quality are inherently non-linear.

The study makes the following contributions to the environmental economics literature: Although many variables have been used in the previous studies to determine the impact on carbon emissions, there has been no effort to assess the impact of the interaction between institutional quality and economic development in the case of oil-rich countries take countries into account.

To the best of our knowledge, this study is the first to utilize a synthesized index to comprehensively measure institutional quality by leveraging the governance pillars established by (Kaufmann et al., 1999)in the case of oil-rich countries. Another significant contribution of this research is its application of an econometric analysis that accounts for the threshold effect using a panel threshold regression (PTR) model. This approach allows us to assess whether the nonlinear impact of institutional quality on Co2 emissions exhibits a threshold effect that varies with the level of a country's development. Our analysis focuses on oil-rich countries over the period from 1996 to 2023, with this timeframe chosen due to data availability.

The remainder of this article is structured as follows: Section 2 provides a brief review of the relevant literature, while Section3 details the data and modeling methodology. Section 4 presents the interpretation and discussion of the results. Finally, Section 5 offers policy recommendations and conclusions.

2. literature revie*w*

A considerable body of academic research has investigated the impact of institutional arrangements on environmental quality, particularly in relation to carbon emissions, utilizing a range of research methodologies across diverse temporal and geographical contexts.

This section offers a concise overview of the pertinent empirical literature. Table .1 provides a summary of the authors, scope, variables used, and key findings. The table is divided into three sections: the first section reviews the empirical literature supporting positive effects of institutions on carbon emissions, the second section refers to empirical literature supporting negative effects of institutional quality, and the final section is devoted to literature that does not support any significant impact.

Table.1 Empirical literature on institutional and environmental quality.

1.Findings that support positive impact of institutional quality on CO2 emissions			
Author(s) & Year	Scope	Variables used and method	Findings
(Kerekes, 2011)	all countries for which the variables are available over the period(1982-2005)	-the average protection against risk of government expropriation -the Heritage Foundation’s Index of Private Property Cross sectional regression	Air pollution may actually increase as property rights become more secure .
(Halkos & Tzeremes, 2013)	the Group of twenty (G-20) countrie. (1996–2010)	using the six governance measures (World Governance Indicators—WGI) nonparametric techniques	Improving the quality of countries' various governance factors does not always lead to lower carbon emissions.

(Hassan et al., 2020)	Pakistani economy 1984 to 2016	International Country Risk Guide (ICRG) ARDL	institutional quality has a positive and significant impact on CO2 emissions.
(Bekun et al., 2021)	E7 economies 1995 to 2016	CPIA transparency, accountability, and corruption in the public sector rating second-generation panel econometrics strategies	The extent of institutional quality plays a central role in exacerbating carbon emissions in E7 economies
(Azam et al., 2021)	66 developing countries (1991 to 2017)	institutional quality index covering: political stability, administrative capacity, and democratic accountability. System GMM	Institutional quality increases energy consumption and environmental pollution
2.Findings that support negative impact of institutional quality on CO2 emissions			
(Abid, 2017)	58 MEA (Middle East & African) and 41 EU (European Union) countries) 1990 to 2011.	using the six governance measures (World Governance Indicators—WGI) GMM-system	In EU region: improving the quality of institutions leads to a reduction in CO2 emissions In Mena region: no effect
(Tang et al., 2021)	114 countries 1986 to 2015	Country Risk Guide (ICRG)	The interaction between institutional quality and human capital improves environmental quality
(Riti et al., 2021)	10 countries indexed as the most freedom of press countries (1993-2016)	freedom of press (Freedom House, 2017) pooled mean group (PMG)	Enhancing press freedom functions as a significant driver in reducing carbon emissions within countries that maintain strong press freedom.
(Muhammad & Long, 2021)	65 belt and road initiative countries (2000-2016)	political stability, control of corruption and rule of law (WGI) Panel GMM	Institutional factors, including political stability, anti-corruption measures, and adherence to the rule of law, play a crucial role in reducing carbon emissions and enhancing environmental quality.
Kamah et al. (2021)	Sub-Saharan countries 2001-2018	Regulatory quality and government effectiveness	Regulatory quality and government effectively contribute to reducing carbon emissions
(Hussain & Dogan, 2021)	BRICS economies 1992 to 2016	"international country risk guide (ICRG)" CS-ARDL	Institutional quality reduces enveiremental degradation
(Orach et al., 2024)	African countries 1996 to 2020	governance measures (World Governance Indicators—WGI)	the institutional quality reduces environmental pollution

		Panel data model	
3.Findings that demonstrates no significant impact of institutional quality on CO2 emissions			
(Abid, 2017)	58 MEA (Middle East & African) and 41 EU (European Union) countries) 1990 to 2011.	using the six governance measures (World Governance Indicators—WGI) GMM-system	In EU region: improving the quality of institutions leads to a reduction in CO2 emissions In Mena region: no effect

Source: Author compilation

3. Data and methodology

In order to test the relationship between economic development and environmental quality, several types of econometric specification and function forms have been used. Most studies have used polynomial specification in linear, semi-linear or log-linear form and modelling with ARDL.

We propose the use of an econometric approach within the regime change models, a panel threshold regression model (PTR) proposed by (Hansen, 1999a) and developed by (Q. Wang, 2015) for panel data. The dynamics of behavior are better reflected by the pan-el data approach, as well as a handling of the effects of heterogeneity between individu-als. These models capture the effect of non-linearity and data heterogeneity, they have the advantage of giving an economic explanation to non-linearity and allow an economic se-ries to have different dynamics depending on the regimes in which it evolves. They also make it possible to test combined effects.

We apply our model to a sample of 20 oil-rich countries (Algeria, Australia, Bahrain, Canada, Cameroon, Cote d'Ivoire, Colombia, Ecuador, Egypt, Gabon, Iran, Indonesia, Kuwait, Mexico, Nigeria, Norway, Oman, Qatar, Saudi Arabia, United Arab Emirates,) over a period from 1996 to 2023.

To select the countries, we adopted the IMF definition of resource-rich economies. These are defined as economies whose share of resource exports exceeds 25% of total goods exports (Lundgren et al., 2013). Our choice was also dictated by the availability of data for the period under consideration.

We used data from two databases, the World Development Indicators (WDI) database and the World Governance Indicators (WGI) database for the 20 countries in the sample The following table shows the variables introduced into the model:

Table 2: Definition of variables.

	Variable	Description	Source
dependent Variable	CO2 EMISSIONS	CO2 emissions in tones metric tones per capita	WDI
threshold dependent Variable	LGDPC	Log of per GDP per capita in Dollar constant 2015.	
Threshold variable	INST	The arithmetic mean of the World Governance Indicators (WGI) developed by the World Bank.Its value varies between -2.5 and 2.5.	WGI
Threshold independent variable	IDH	The Human Development Index (HDI)	UNDP
	CAPITAL	the acquisition of fixed assets produced	WDI
	TRADE	The opening rate	
	FDI	The sum of the net inflows of FDI as a percentage of GDP	
	OIL-RENT	Oil rents as a percentage of gdp	
	ELECTRIC _CONS	Electricity consumption in Khw per capita	
	RENEWABLE	The share of renewable energy consumption in total energy consumption final	

	ENERGY		
	FD	Financial development index	IMF

Source: Author's research

We write the threshold effect panel data regression model with two regimes as follows:

$$\begin{cases} Co_{2\,emissions_{it}} = \alpha_i + \beta_1 X_{it} + \beta_2 LGDPC_{it} + \varepsilon_{it} \quad 1(inst_{it} \leq c) \\ Co_{2\,emissions_{it}} = \alpha_i + \beta_1 X_{it} + \beta_3 LGDPC_{it} + \varepsilon_{it} \quad 1(inst_{it} > c) \end{cases}$$

$$i = \overline{1,,,20} \qquad t = \overline{1996 \ldots . 2023}$$

The matrix writing in (1) is given as follows:

$$Co_{2\,emissions} = \alpha + X\beta_1' + Lgdpc\beta'(c) + \varepsilon \ldots \ldots \ldots (2)$$

With

$$\beta = (\beta_2, \beta_3)$$

Where $\alpha_i$represents unobserved country-specific fixed effects that are time-invariant, $CO_2 emissions$ represents CO2 emissions in metric tons per capita, X_{it} the matrix of control variables,$inst_{it}$ the threshold variable and c the threshold value.

The threshold variable $inst_{it}$divides the sample into two regimes, the first regime represents a part of the sample, where the threshold variable takes values below the threshold value, and the second regime represents the remaining part of the sample where the threshold variable takes values above the threshold. The econometric relationship in each regime is of linear form and is characterized by different coefficients (β_2, β_3), these coefficients are estimated using the OLS method. To estimate the model as a whole, it is necessary to determine the value of the threshold $\hat{c}$.

the value of the threshold is determined according to the methodology presented by(Chan, 1993; Hansen, 1999), where it takes its value from the values of the threshold variable $inst_{it}$.

In order to obtain a sufficient number of observations in each regime to estimate the equations for each regime, the threshold value was determined by restricting the search and ensuring that a minimum of 10% (56 obs) of the observations are in one of the regimes.

(Hansen, 2000) recommended an estimation by minimizing the sum of squares of the residuals (Eq.3) to find the ideal threshold value.

Unlike traditional approaches that determine the existence of a threshold effect between variables in an exogenous way, the endogenous approach based on an empirical model will allow us to construct a confidence interval for the threshold value (Hansen, 2000).

$$\hat{c}=argminS(c) \ldots\ldots (3)$$

Where

$$S(c) = (CO_2 emissions - \hat{\alpha} + X\widehat{\beta_1}' + lgdpc\widehat{\beta'(c)})' * (CO_2 emissions - \hat{\alpha} + X\widehat{\beta_1}' + lgdpc\widehat{\beta'(c)})$$

It is essential to establish a confidence interval to test the statistical significance of the estimated threshold value, the null hypothesis of non-linearity versus the alternative hypothesis of the existence of a threshold are given as follows:

$$\begin{cases} H_0 : \beta_2 = \beta_3 \\ H_1 : \beta_2 \neq \beta_3 \end{cases}$$

(Hansen, 2000) proposed the application of the bootstrap method to determine the asymptotic distribution of the likelihood ratio test.

4. Results And Discussion

4.1. Descriptive statistics

Descriptive statistics indicate significant variability in CO2 emissions across the sampled countries, as evidenced by the large standard deviation. The lowest CO2 emissions were recorded in Cameroon, while Qatar exhibited the highest levels. A considerable disparity is also observed in GDP per capita, expressed logarithmically, with Cameroon having the lowest values and Norway the highest.

Regarding institutional quality, the average value is negative, suggesting that most oil-rich countries in the sample are characterized by poor institutional quality. However, there is considerable variation, ranging from low institutional quality in Cote d'Ivoire to high institutional quality in Canada.

This descriptive analysis underscores the substantial heterogeneity among the countries in the sample, a characteristic effectively addressed by the panel threshold model, which is adept at capturing individual heterogeneity.

Table 3. Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Co2	560	11,2803	17,8824	0.2030	66.81
lgdpc	560	9,179336	1,305084	6,894749	11,23353
inst	560	-0.085	0.887	-1.41	1.82
oil_rent	560	14.2546	13.59996	0.0345	58.36
idh	560	0,6700974	0,1479181	0,374	0,937
lcapital	560	24,23121	1,493518	21,22036	26,81364
fdi	560	2,337502	2,797671	-8,58943	33,566
renewable_enrgy	560	25,57103	31,26096	0	88,7493
electric_cons	560	6672,924	7559,231	74,49062	25590,69
trade	560	71,65302	30,13384	29,2282	191,878
FD	560	0.31	0.20	0.042	0.96

Source: constructed by the author.

4.2. Linearity test

Table.4 shows the results of the threshold value estimation and the number of thresholds test. The calculated test statistic (F-Stat) for a single threshold is higher than the critical values at different levels of significance (10%, 5%, 1%). It can therefore be seen that there is a single threshold in the estimation of the model; with an estimated value of 0.7854 at the 95% confidence level.

Table4. Linearity tests results

Threshold estimator (level=95)							
Model				Threshold			
Th-1				0.7854			
Threshold effect test (bootstrap=400)							
Threshold	RSS	MSE	F-stat	Prob	Crit10	Crit5	Crit1
Single	414.5129	1.1482	112.73	0.0000	33.8951	43.7468	65.7031

Source: constructed by the author from the results of the PTR model

As mentioned above, a restriction was made on the minimum number of observations that each scheme must contain (10% of observations). The results displayed in Table.5 show that the estimated threshold value divides the sample into two subgroups, whose number of observations allows to estimate an econometric model.

Table.5 Distribution of observations.

Number of observations	Percentage of observations 1st regime	Percentage of observations 2nd regime
560	76.78 (430 obs)	23.21%(130 obs)

Source: constructed by the author from the results of the PTR model

4.3. Regression Results and discussion

The linearity-test results show that the effect of economic development on environmental quality is non-linear. This result confers that the relationship is not monotonic (Acaravci & Ozturk, 2010; Apergis & Ozturk, 2015; Behera & Dash, 2017; Cho et al., 2014; Jebli et al., 2016; Panayotou, 1993; Saboori et al., 2012; Selden & Song, 1994; Shafik & Bandyopadhyay, 1992).

Also, the regression results displayed in Fig.1 demonstrate that in the lower regime, when the institutional quality level falls below the estimated threshold of 0.78, an increase in economic development produces a positive increase in per capita CO2 emissions with a magnitude of 3.06. At the upper regime, when institutional quality falls above the estimated threshold, economic development still has a positive effect on carbon emissions, but to a lesser extent. In other words. Improving institutional quality, especially governance, would significantly mitigate polluting emissions, and changes the relationship between development and CO2 emissions. This result is in line with the findings of studies putting forward the negative impact of institutional quality on Co2 emissions (Abid, 2017; Hussain & Dogan, 2021; Muhammad & Long, 2021; Orach et al., 2024; Riti et al., 2021; Tang et al., 2021).

The regression results displayed in Table.5 show that human capital has a negative but significant impact on CO2 emissions in the sample countries. An increase of 1% in the value of the human development index will lead to a reduction of more than 8 metric tons of CO2 per capita. This result is consistent with the results obtained by (Bano et al., 2018; Bayar et al., 2022; Khan et al., 2022; Wang & Xu, 2021).

For trade openness, the results presented in Table 6 show a negative and significant relationship between the openness rate and CO2 emissions per capita. In terms of elasticity, a 1% increase in openness will lead to a reduction of 0.016 metric tons of CO2 per capita. This result can be explained by the technology transfer effect, where the use of advanced technologies and production process of more efficient energy-saving and emission-reducing equipment will reduce energy intensity(Chen et al., 2021).

The results also revealed that financial development in the sample countries mitigates the carbon emissions. In terms of elasticity, an increase in FD by 1 point will lead to a reduction in CO2 emissions of 0.0106 metric tons per capita. This result is consistent with the results obtained by ((Abbasi & Riaz, 2016; Amin et al., 2022).

The results also showed that the electricity consumption will significantly increase the CO2 emissions. A 1% increase in electricity consumption per capita will lead to an increase of 0.00164 metric tons of CO2. This result is consistent with the results obtained by(Bouznit & Pablo-Romero, 2016).

The estimation results for the variables FDI inflow and electricity consumption reveal a relationship (negative, positive), without statistical significance.

The analysis of the marginal effects per country allows us to constitute three groups of countries:

Group 1: Includes countries with good institutional quality, namely Canada, Australia and Norway. These countries have lower marginal effects of economic development on CO2 emissions and can only be explained by the lower regime throughout the analysis period.

Group 2: includes the United Arab Emirates and Qatar, where there is an attenuation of the effect of economic development on CO2 emissions for the period analyzed in this study. Co2 emissions in these countries can be explained by both lower and upper regimes.

Group 3: includes the majority of the countries in our sample, which are countries with low institutional quality. At this level of institutional quality, an improvement in economic development does not lead to any change in Co2 emissions and the countries remain in the lower regime throughout the period analyzed in this study.

The analysis of marginal effects by country indicates that the mitigating effect differs across countries depending on their level of development and only emerges at a certain level of institutional quality, given that countries are at different stages of development. In our sample, only the United Arab Emirates and Qatar experienced a reduction in the impact of economic development on CO2 emissions during the period considered in our study. This finding supports the notion

that the relationship is not monotonic, and that beyond a certain level, which potentially depends on the quality of institutions, the positive effect diminishes and thus becomes mitigated.

Table.6 Regression results.

Panel Threshold Regression	
Dependent variable: CO2_emissions	
Threshold variable: government effectiveness	
Fdi	-0.00416
	(0.0240)
Idh	-8.599***
	(2.670)
electric_cons	0.00164***
	(8.81e-05)
FD	-0.0106*
	(0.00594)
Trade	-0.0162**
	(0.00642)
renewable_energy	0.00710
	(0.0240)
oil_expo	0.0125**
	(0.00527)
0b._cat#c.lgdpc (below the threshold)	3.065***
	(0.692)
1b._cat#c.lgdpc (above the threshold)	2.657***
	(0.701)
Constant	-21.47***
	(5.828)
Obs	560
Number of countries	20
R-squared	0.663

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: constructed by the author from the results of the PTR model



Figure.1. Marginal effect of GDP per capita on Co2 emissions

5. Conclusion

This work makes a contribution to the empirical literature devoted to explaining the relationship between environmental quality and economic development. Indeed, by using an econometric approach different from those used in previous empirical work. This work reveals the existence of an interaction effect between the level of development and the quality of institutions on the level of environmental quality.

Economic development has a positive effect on the level of CO2 emissions and therefore on the quality of the environment. However, the improvement of institutional quality mitigates this effect. This mitigation effect differs from one country to another according to the evolution of its level of development and only appears from a certain level of institutional quality. This result confirms that the relationship is not monotonic and that at a certain level, which potentially depends on the quality of the institutions, the positive effect diminishes.

From these results, some policy implications follow. Indeed, public authorities could envisage a system where judges would be dedicated exclusively to environmental issues, especially compliance with the rule of law and the right to the environment. Although this has been embodied in an environmental code in many countries, the courts on environmental issues are not yet specialized in many countries. On the other hand, there is a need to promote renewable energy and energy efficiency policies. Regulatory reforms are needed to facilitate the foreign investment needed to implement these environmental policies. Finally, there is a need for policies that encourage a growing environmental awareness among citizens, as improving the quality of institutions would encourage people to invest in the protection of natural resources and the environment as their development level increases.

The authors declare no conflict of interest.

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