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Rule of law & property rights, FDI, and environmental quality nexus: a dynamic panel threshold analysis

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Abstract
The present study thoroughly examines the relationship between foreign direct investment (FDI), the rule of law, and environmental quality. This research uses a threshold method covering 123-panel countries from 2000 to 2019. The current study is distinctive given that it employs a new methodology and examines the nonlinear relationship between environmental quality and FDI inflows and the moderating factors that influence this relationship. An inverted U-shaped curve is identified, and the EKC hypothesis is verified through the conducted analysis. Current results imply that even though FDI accompanies higher levels of 2, its effect can become beneficial based on the institution's quality. The existing study contributes to previous research because it provides new insights into the ability of FDI to ensure environmental sustainability. Current findings indicate a need for strong legal institutions to make FDI environmentally friendly and facilitate global agendas to achieve carbon neutrality.

Keywords FDI, Environmental quality, Rule of law & property rights, Growth, Dynamic panel threshold

1 Introduction

FDI is a crucial financing method for economic development, encouraging a smoother flow of funds into developing countries. Such flows might be exploited to finance infrastructure, manufacturing installations, upgrade technology and enlargement-ease the size of industries [1, 2]. Moreover, the FDI-supported domestic industrial sector imports production techniques of the edge within a country, and R&D activities are performed in emerging economies. Both factors are essential for inducing economic growth and poverty reduction [3]. In addition, the role of export-oriented FDI should not be undermined in developing an economy. Export performance is effectively enhanced due to the increasing number of exports. In return, it pressures the regulatory authorities to facilitate foreign exchange earnings. As a result, traditional economic specialization is decreased, and thus, the balance of payments is enhanced [4, 5].

The above benefits suggest that any substantial decline in FDI inflows could have adverse implications for the growth trajectories of developing regions. Nevertheless, the global investment environment has encountered significant disturbances in the last few years, including the financial crisis of 2007 to 2008, the COVID-19 epidemic, and escalating political instability in specific areas of Asia. Due to these changes, real income and energy prices have decreased, increasing investor risk aversion and insecurity and pushing down global FDI (UNCTAD, 2022). Despite these challenges, fresh data show that global FDI inflows increased 64% in 2021 to $1580 billion, after stabilizing at a much lower base in 2020. UNCTAD (2022) records total FDI inflows of $837 billion for developing economies in 2021, a moderate growth. Unlike aid, which may come with strings attached or political motives, FDI has been proven to offer many benefits, such as technology transfer, economic growth, infrastructure development, employment opportunities, and skills development for the recipient countries [6].

FDI often causes environmental damage in the recipient nation through resource extraction and exploitation, which in turn causes deforestation, habitat loss, water pollution, and the exhaustion of non-renewable resources. Industries frequently associated with FDI, such as mining, logging, and oil drilling, can cause significant environmental damage because they prioritize profit maximization over sustainable practices [7, 8]. The United Nations' 2022 report indicates that the swift industrial recovery post-COVID-19 has resulted in heightened environmental awareness due to substantial CO2 emissions. The problem of air pollution dates to the mid-18th century, originating during the Industrial Revolution, and was exacerbated by the second wave of industrialization, marked by the widespread use of fossil fuel-powered machinery. This trend continued as MNEs expanded globally, fuelled by increased FDI [9]. The pressing issue of global warming has led many companies to take steps to transition toward a low-carbon economy [10]. Regarding global warming, a substantial body of research has produced unambiguous evidence that FDI inflows are associated with substantial increases in CO2 emissions [11].

FDI worsens the CO2 emissions of the host nation. Explaining this relationship, the pollution haven hypotheses confirm that the increased levels of FDI exacerbate their impact [12]. All at once, the assumptions of the given hypothesis might be loosely formulated about the overburdened, exhausting regulations and pollution of more economically developed countries. It is possible to suggest that less elaborative regulations in developing countries might allow them to compete more actively for the inflow of foreign investments, particularly if such investments involve the development of the most unwieldy, polluting industries [13]. Some authors perceived the related factor oppositely. FDI enables clean systems and norms of environmental management that are highly complicated. The pollution halo theory corroborates this perception [14]. The theoretical and empirical concerns raised by the contributed consequences of FDI on environmental preservation are still unresolved, and some are still controversial. This is because of the conflicting findings provided by these studies. For instance, some studies show that FDI can inhibit pollution by entering cleaner and more complicated technologies through MCNs [15, 16]. Contrarily, other reports confirm that FDI can augment emissions as it fuels economic activities. Also, the desire to generate sufficient revenues from short-term investments has prevented investors from adopting cleaner technologies or sustainable investments for centuries. Many moderating variables are causing the complexities of this relationship. Not much research has been done on this topic, so digging into these complications related to CO_2 emissions is essential. FDI, for instance, can significantly impact CO2 emissions, but this impact can vary considerably depending on the sector of activity and the motivation behind the investment. Since manufacturing industries tend to be more polluting than the service or technology sectors, the environment will have a greater negative impact [17, 18].

Many studies argue that strong institutional quality is necessary to ensure economic growth and protection of the environment, either directly or indirectly [19, 20]. Thus, the policy, which is determined by the quality of institutions, the government's ability to ensure macroeconomic development and environmental protection. Specifically, institutional quality is connected to the policy of government bodies, legislation, and legal culture, which defines social and economic activities. While the quality of its enforcement, in turn, is understood as political stability, ecological friendliness, public services, and adaptation to policy development and control [21]. The rule of law, one of the most commonly used categories of governance core concepts, is also one of the most important for environmental problems [22, 23]. In this sense, preserving property rights and the rule of law becomes ever more crucial for developing knowledge. As an amalgamated structure of laws and regulations, property rights preservation is indispensable to protecting intellectual property from its illegal use [24, 25]. For instance, poor RL&PR enforcement can easily result in air pollution and extensive environmental degradation [26]. The reason is that without enough neutral property rights provisions and laws, foreign companies will view the next innovative product as something that can be easily copied without the need for the appropriate, proper licenses to do so [27]. Conversely, strong rule of law laws should put foreign enterprises involved in innovation at ease far faster than they could extract their knowledge [28].

This study makes distinct contributions to existing literature by addressing critical theoretical gaps concerning the relationship between FDI, environmental quality, and institutional frameworks. First, it offers direct evidence to the ongoing pollution haven versus pollution halo debate, as it specifically investigates how institutional quality (i.e., Rule of Law and Property Rights (RL&PR)) has moderated the aforementioned relationship. Whereas previous studies often emphasize direct linear effects, this paper presents a dynamic threshold analysis to identify nonlinear responses. Second, this study validates a significant RL&PR tipping point with implications for FDI – it can switch from polluting to green, leading to concrete action lessons for policy advisors to unlock institutional potential. Thirdly, this study involves a fully large panel with 123 countries from different economic and institutional contexts (2000–2019), making the findings more robust, generalizable, and relevant. Finally, the holistic inclusion of seminal macroeconomic affairs—energy usage, GDP growth, trade openness, financial development, and population growth—intensifies the theoretical and empirical contribution, enabling a cleaner isolation of the unique relevance of institutional quality. Thus, these contributions collectively represent more than methodological advancements, providing substantial advancements in surplus understanding of sustainable FDI practices, institutional effectiveness, and environmental policy on a global level.

2 Theoretical and empirical review

A steadily increasing number of research studies investigate the link between FDI and CO2 emissions from various perspectives, including economic and political factors. This study aims to investigate the complex aspects of the relationship between FDI and CO2, an area that has been less emphasized in existing research focused on their direct correlation. An examination of the connection between economic growth, FDI, and environmental sustainability is a debated topic worldwide, largely because of inconsistent empirical evidence. Numerous theoretical studies have examined how FDI affects economic growth with foundational contributions from scholars such as Lucas Jr [29] and [30]. For example, Romer [30] suggested that FDI can help the recipient nation gain technological innovations and entrepreneurial expertise, resulting in significant positive impacts through spillovers. Conversely, in prevailing liberalization, deregulation, and privatization policies, some scholars, such as Boyd and Smith [31], predict that FDI may impede the allocation of resources, thereby reducing economic growth. Theoretical studies highlight the dual role of FDI, indicating that while some countries have leveraged FDI for economic development, this often occurs at the expense of environmental degradation. According to Grossman and Krueger [32], Environmental Kuznets Curve (EKC) hypothesis, environmental degradation generally increases with economic growth but declines after income levels reach a certain threshold. The findings indicate that the income level at which environmental degradation starts to decrease ranges from $4,000 to $8,000. Aghion Aghion and Howitt [33] utilized a panel data model to examine global environmental issues, specifically addressing the varied impacts of technological evolution on CO2. According to research, technological developments improve environmental sustainability and help to lower CO2 emissions.

A considerable frame of investigation has studied the association between CO2 emissions and FDI within the perspective of the Environmental Kuznets Curve (EKC) hypothesis. Stern [34] performed an empirical analysis of Environmental Kuznets Curve (EKC) literature, summarizing the results of many studies examining different pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO), and carbon dioxide (CO_2) in both developed and developing countries over the period spanning the 1960s through to the 1990s. The results indicated that pollution is frequently a lagging variable in economic growth, eventually decreasing once an average income threshold is passed.

The associations between FDI inflows and CO2 emissions are elucidated by two primary competing theories: the pollution halo hypothesis and the pollution haven hypothesis. The pollution haven hypothesis posits that developing countries frequently implement flexible policies that encourage environmentally hazardous industries to attract FDI, exacerbating pollution within these nations [35, 36]. For illustration, Solarin, Al-Mulali [37] in Ghana from 1980 to 2012 used ARDL, and Achuo and Ojong [38] applied quantile regression on the panel of 46 African countries to demonstrate that the pollution haven is supported in Africa, as they explained that the increase in CO2 emissions in conjunction with the increase in FDI, trade, and energy consumption. Chiriluș and Costea [39] provided empirical evidence supporting the pollution haven hypothesis in Romania, demonstrating that FDI is more likely directed toward regions with less stringent environmental regulations. Bulus and Koc [40] confirmed the pollution haven hypothesis in Korea, who conducted the ARDL bound test from 1970 to 2018 in Korea and discovered that increases in FDI, energy use, and GDP result in higher CO2 emissions. Singhania and Saini [41] conducted a study of 21 developing and developed countries from 190 to 2016, using the GMM technique, which confirmed the pollution refuge hypothesis in developing nations.

On the contrary, the pollution halo hypothesis argues that FDI can benefit host countries by transferring modern, environmentally friendly technologies. By allowing these technologies to effectively reduce CO2 emissions through environmental policies, we can make drastic cuts, especially in the developing world, where the pollution halo effect is strong. While FDI and emissions share a complex relationship in developed nations, Alshubiri and Elheddad [42] analysis brought new insights. Through fixed effects modeling and generalized method of moments for 32 OECD countries from 1990 to 2015, they found that FDI's impact on CO2 varies over time. Initially, incoming investment drove up pollution. Yet remarkably, once a certain level had accumulated, emissions pivoted and started to fall. Their findings suggest a nonlinear dynamic, with FDI benefiting the climate globally even as it burdens some locations temporarily. Policymakers thus gain perspective on addressing local air quality while the overall trend remains encouraging for future mitigation. Balsalobre-Lorente, Gokmenoglu [43] explored the pollution haven and halo hypotheses in MINT countries (Mexico, Indonesia, Nigeria, and Turkey) from 1990 to 2013. Employing FMOLS and DOLS methodologies, their findings revealed an inverted-U relationship between FDI and ecological footprint, suggesting that initial FDI inflows degrade the environment, but beyond a certain threshold, further inflows reduce environmental harm. In addition, Xie and Sun [44] investigated the relationship between FDI and CO_2 emissions in 11 emerging economies from 2005 to 2014, employing a Panel Smooth Transition Regression (PSTR) model. Their findings indicate a nonlinear relationship, revealing that initial FDI inflows exacerbate pollution, but after surpassing a specific threshold, increased FDI contributes to reduced CO_2 emissions, simultaneously supporting both the pollution haven and pollution halo hypotheses. Furthermore, Ayad, Shuaib [45] examined the relationship between FDI and environmental quality across 16 MENA countries from 1990 to 2018. Using various econometric models, they found an inverted U-shaped relationship between FDI and environmental quality, supporting both pollution haven and pollution halo hypotheses depending on the stage of economic development.

Improvements in institutional quality led to stronger positive relationships between FDI and a decline in carbon emissions, which is the study's central argument. To comprehend the ecological impact, one has to be familiar with the connection between institutions and CO2 emissions. Much empirical evidence shows a positive relationship between the quality of institutions and FDI [46–48]. In addition, it should be highlighted that many pieces of research stress the crucial role of good governance in CO2 emissions reduction. Along these lines, Wingqvist, Drakenberg [49] conducted data on G-20 countries from 1996 to 2010 and claimed that strong institutions are necessary for sustainable and effective regulation and implementation of policies designed to allow environmental resources to be used reasonably. Ozturk and Al-Mulali [50], in the case of Cambodia spanning 1996–2012, used Two-stage Least Square and GMM and stated that durable governmental systems are necessary to proceed with the implementation of the environmentally friendly policy, resulting in better environmental quality [51, 52]. Mansor Ibrahim and Law [53] used the S-GMM in 40 Sub-Saharan countries and argued that strong institutional quality is advantageous for the environment and that institutional reforms directly contribute to environmental enhancements.

The framework of institutions helps to maintain economic balance, and their working policies also influence the conditions of a country [54]. In this line of work, for instance, based on a view like that, Haldar and Sethi [55], in a strict sense, presented data revealing that the quality of the institution acted as a moderating factor between the lagged value of energy consumption and CO2 emissions in developing countries. With the help of GMM and quantile regression techniques and emphasis on the institution's quality, he found coping data to support the moderating effect of the institution's quality on energy consumption. It can indeed lead to a decline in CO2 emissions in developing countries. Similarly, Almeida and García-Sánchez [56] analyzed a panel of 152 countries and used GLS, also found that the quality of the environment was significantly improved as Democratic system regulations and policies became effective enough. In addition, a different study by Zheng, Umar [57] focused on the impact of education and institutional quality on CO2 emissions in E-7 economies. He used robust quantile regression spanning 1995–2020 and suggested that better quality education and institutions help E-7 economies achieve presiding circumstances to increase economic development and lower carbon emissions. On the same line of thought, Atta and Sharifi [21] used the PRISMA framework to explore the effect of the rule of law extended to CO2 emissions. They discovered that the addition of CO2 emissions would come to rest one sure way: the rule of law. They also estimated that quality institutions' core elements (the rule of law, political stability, and corruption control) are essential to decreasing CO2 emissions and improving environmental quality. Panayotou [58] also agreed that the negative relationship between either of these elements and the environment will call for reducing environmental quality.

3 Empirical data, model development, methodological approach

3.1 Data source and descriptive summary

Panel statistics from 123 countries from 2000 to 2019 are used in the study. The variable for environmental quality used in the study is carbon dioxide emissions. CO_2 is one of the greenhouse gas emissions contributing to climate change, which is duly acknowledged as a major factor in the phenomenon [59]. The IPCC 2019 report indicates that CO2 emissions present the most serious threats to health and quality of life, thus serving as the study's dependent variable.

The dataset is sourced from the World Development Indicators (WDI), with the primary independent variable represented by FDI. Furthermore, the RL&PR variable will serve as a moderating or threshold variable in this investigation. Energy consumption (EC), GDP growth, trade openness (TO), and financial development (FD) are some of the control variables taken from the WDIs. Per capita energy consumption is employed to assess energy usage following the technique established in previous research [59, 60]. Financial development is measured using domestic credit to the private sector, a widely accepted indicator in the literature [59]. Consistent with previous research, trade openness is defined as the proportion of GDP attributable to imports and exports [61]. All variables have been transformed into logarithmic forms to stabilize variance and improve normality.

Table 1 Descriptive summary

Variable		Mean	Std. dev.	Min	Max
CO_2	Carbon dioxide emission in metric tons per capita	4.6	5.261	0.022	31.274
FDI	Foreign direct investment, net inflows (% of GDP)	5.687	19.429	-57.532	449.081
ROL&PR	Rule of Law and Property Rights Index	5.405	1.494	1.78	8.55
EC	Energy use (kg of oil equivalent per capita)	2486.489	2760.145	63.057	18178.1
GDP	GDP growth (annual %)	3.767	3.953	-36.392	34.5
FD	Domestic credit to private sector (% of GDP)	54.65	55.321	0.002	525.643
TO	Trade (% of GDP)	82.701	51.737	11.855	437.327
POP	Population growth (annual %)	1.394	1.479	-3.848	18.128

123 global countries as listed in Appendix: T = 2000–2019

Table 2 Correlation

Variables	CO_2	FDI	RL&PR	EC	GDP Growth	FD	TRADE	POP
CO_2	1.000							
FDI	0.057	1.000						
RL&PR	0.502	0.113	1.000					
EC	0.804	0.030	0.560	1.000				
GDP Growth	-0.123	0.007	-0.185	-0.143	1.000			
FD	0.317	0.162	0.551	0.359	-0.239	1.000		
TO	0.296	0.306	0.279	0.272	0.045	0.208	1.000	
POP	0.114	-0.030	-0.351	0.080	0.137	-0.211	0.054	1.000

Table 3 Variance inflation factor

	VIF
FDI	1.03
RL&PR	1.60
EC	1.07
GDP Growth	1.09
FD	1.51
TO	1.24
POP	1.19
Mean VIF	1.24

Descriptive statistics for all the variables used in the analysis are shown in Table 1. Conversely, Table 2 displays the pairwise correlation matrix, providing preliminary insights into the relationships between the variables. The independent variables FDI, RL&PR, EC, FD, TO, and POP growth all exhibit positive correlations with CO_2 emissions, whereas GDP growth exhibits a negative correlation. In general, the independent variables exhibit weak correlation coefficients with one another, except EC. Multicollinearity is typically a concern only when the coefficient of correlation exceeds 0.8 Gujarati [62], which is not the case here.

Further, to check for possible multicollinearity among explanatory variables, a VIF test was conducted. As reported in Table 3, all variables exhibited VIF values below 2, with a mean VIF of 1.24, significantly lower than the common threshold of 10. These results confirm the absence of multicollinearity, validating the robustness and reliability of our empirical analysis. Thus, it can be concluded that multicollinearity does not pose a significant issue among the independent variables in this study.

4 Empirical model

STIRPAT illustrates Stochastic Impacts by Regression on Population, Affluence, and Technology. It is a model often used to look at the things that affect natural health and how they affect people. The STIRPAT model extends on the IPAT equation, positing that environmental impact is a linear function of three factors: population density (P), affluence or income (A), and innovations in technology (T).

Because of its essentially mathematical nature, the IPAT model is not suitable for hypothesis testing, which is a key disadvantage of the model. The reason for this is that the values of some variables are determined by the values of other variables that are known in advance [63].

$$I_{it} = aP_{it}^{b}\ A_{it}^{c}\ T_{it}^{d}\ Z_{it}^{e}\ \varepsilon_{it} \tag{1}$$

In this context, Z_{it} denotes additional variables that influence the environment, where e signifies the parameter corresponding to Z_{it}. All other variables in the model are held constant, and each variable is transformed into its natural logarithmic form before empirical analysis.

$$lnI_{it} = a + blnP_{it} + clnA_{it} + dlnT_{it} + elnZ_{it} \tag{2}$$

The particular model employed for the non-threshold analysis, based on adaptations and modifications from Li and Lin [63], Avom, Nkengfack [64], is formulated as follows:

$$CO_{2_{it}} = \beta_0 + \beta_1 FDI_{it} + \beta_2 RL\&PR_{it} + \gamma Z_{it} + \varepsilon_{it} \tag{3}$$

Where $CO_{2_{it}}$ represents environmental quality, measured by the quantity of $CO_{2_{it}}$ emissions in country "i" time "t"; FDI_{it} is the foreign direct investment, along with other macroeconomic factors, Z_{it} includes control variables. The constant term Equation is represented by $\beta_{\ 0}$, while the elasticities of CO_2 emissions concerning the independent variables are denoted by $\beta_{\ 1,2\ldots\ s}$. The stochastic error term has been denoted by $\epsilon_{\ it}$. The model includes energy consumption due to its contribution to increasing FDI inflows and its effect on environmental quality, as supported by prior research [50, 59]. Financial development is another crucial control variable, as it is believed to potentially reduce CO_2 emissions by providing adequate financing [65]. Furthermore, trade openness is factored in as a control variable, given its mixed effects on environmental quality, as suggested by earlier research [66].

4.1 Panel threshold estimation or regime switching

Specifically, this research uses Kremer, Bick [67] dynamic panel threshold model, which expands upon the work of Caner and Hansen [68] static threshold panel model. Hansen [69] originated the static threshold model, which introduced the estimation and inference methods in non-dynamic panel threshold regression models with exogenous covariates. After that, the research by Caner and Hansen [68] introduced the threshold for cross-sectional data with endogenous covariates of interest where the instrumental variables are the lags of the endogenous confounders. Besides, the research of Kremer, Bick [67] constituted a further expansion of this model, providing the threshold overlay for panel data considering that covariates such as Rule of Law and Property Rights (RL&PR) could affect the CO2 emissions above or below some unknown threshold. This research focuses on utilizing this approach to address the potential endogeneity issue because it could lead to bias in the results. In the current model, such dynamics characterize the RL&PR because it is possible to approach carbon emissions differently when the amount is above or below a certain level. This study estimates the threshold using Kremer, Bick [67] dynamic panel threshold analysis methodology. Thus, the primary objective of the current model is to evaluate the link between RL&PR and CO2 emissions and to consider the difference in this relationship if RL&PR is less or more than some threshold. The model specification is illustrated in Eq. (2) below:

$$\begin{aligned} CO_{2it} &= \mu_i + \beta_1 RL\&PR_{it} I\left(RL\&PR_{it} \leq \lambda\right) + \delta_1 I\left(RL\&PR_{it} \leq \lambda\right) \\ &\quad + \beta_2 RL\&PR_{it} I\left(RL\&PR_{it} > \lambda\right) + \alpha X_{it} + \theta_t + \varepsilon_{it} \end{aligned} \tag{2a}$$

Furthermore, the influence of RL&PR on the FDI- CO_2emissions relationship, considering levels both below and above a certain RL&PR threshold, is demonstrated in the following model:

$$\begin{aligned} CO_{2it} &= \mu_i + \beta_1 FDI_{it} I\left(RL\&PR_{it} \leq \lambda\right) + \delta_1 I\left(RL\&PR_{it} \leq \lambda\right) \\ &\quad + \beta_2 FDI_{it} I\left(RL\&PR_{it} > \lambda\right) + \alpha X_{it} + \theta_t + \varepsilon_{it} \end{aligned} \tag{2b}$$

In Eqs. 2a and 2b, CO_{2it} is the dependent variable in the "o" entry "i" during t"e" time "t"; FDI_{it} is explanatory Variable; the threshold value is denoted by λ, and the variable Rule of Law and Property Rights "RL&PR" will serve as the threshold. The RL&PR is selected as the threshold variable due to its crucial theoretical and empirical role in shaping the environmental impacts of FDI. Existing literature emphasizes that institutional quality significantly influences whether FDI leads to environmental harm or benefit. A strong RL&PR ensures effective enforcement of environmental regulations, encouraging firms to adopt cleaner technologies and sustainable practices. Conversely, weak institutional frameworks often enable foreign investors to exploit lax environmental regulations, resulting in greater pollution. Hence, analyzing RL&PR as a threshold clarifies under what institutional conditions FDI transitions from being environmentally detrimental to beneficial, providing policymakers with targeted insights for strengthening institutional frameworks to promote sustainable economic development.

Following the orthogonal forward transformation, the lags of the endogenous regressor CO_{2it-1} as instruments are used. X_{it} the vector contains the control variables, which consist of EC, FD, TO, and POP. u_i, which stands for the country-fixed effect, displays the variation across nations caused by various policies and their consequences, whereas θ_t denotes the time-based influence. The indicator function *I(.)* is used to define a threshold value λ, which separates the RL&PR variable into two regimes: one above the threshold and the other below it. The threshold value λ is associated with distinct regression slopes, denoted as β_1 and β_2. It is assumed that the error term ϵ_{it} follows an independent and identical distribution with $\epsilon_{it} \sim iid(0, \sigma_\epsilon^2)$.

The model specification is further enhanced by the inclusion of a regime-dependent intercept δ_1, under the assumption that the variation in regime intercepts is uniform across all cross-sections and does not differ by country [70]. The intercept δ_1 is instrumental in mitigating the prevalence of biased estimators that are associated with threshold impacts and their marginal effects. If the data-generating process includes *It*, including a regime intercept in the model estimation could result in a bias proportional to δ_1. This is because the regressor's orthogonality may no longer be maintained [71].

The dynamic panel threshold model was applied to determine the RL&PR threshold value (Gamma_Hat) for the RL&PR. The Gamma_Hat test specifically identifies the optimal threshold level at which the relationship between FDI and environmental quality (measured by CO_2 emissions) shifts significantly. Technically, the Gamma_Hat value is computed by minimizing the residual sum of squares (RSS) across different possible threshold values. This threshold estimate's validity and statistical significance are tested using the Likelihood Ratio [72] statistic, employing bootstrapping methods to obtain robust critical values. A threshold is deemed statistically significant if the LR statistic exceeds its critical value, confirming the existence of distinct regimes. By identifying Gamma_Hat, the analysis allows us to examine differences in the FDI-environmental quality relationship across regimes below and above this empirically estimated RL&PR threshold.

5 Empirical outcomes

In this section, the study presents the results gained from the empirical assessment with dynamic panel threshold estimations. The construction of the confidence interval for the RL&PR threshold model is illustrated in Fig. 1. The blue curve shown in the figure is called the likelihood ratio statistic, LR. The horizontal line indicates the alpha percentile of the asymptotic distribution of the likelihood ratio statistic. The confidence boundary is where these two curves correspond. The correct value of the threshold parameter, denoted by Gamma_Hat, is determined to be 5.2, identified as the point of intersection between the curve and the x-axis.

Table 4 shows the results from an analysis of the impact of RL& PR on environmental quality based on data from periods before and after a certain threshold level of RL&PR was reached. In this case, RL&PR acted as a regime-dependent variable and threshold variable. In contrast, Table 4 shows the empirical results related to FDI and environmental quality factors above and below the RL&PR thresholds. The top halves of Tables 4 and 5 show the estimated RL&PR threshold with the associated 95% confidence interval. The middle part consists of the regime-dependent RL&PR coefficients addressing environmental quality, CO2 emissions (Table 4), and the RL&PR coefficients regarding FDI and environmental quality (Table 5). In addition, the coefficients β_1 and β_2

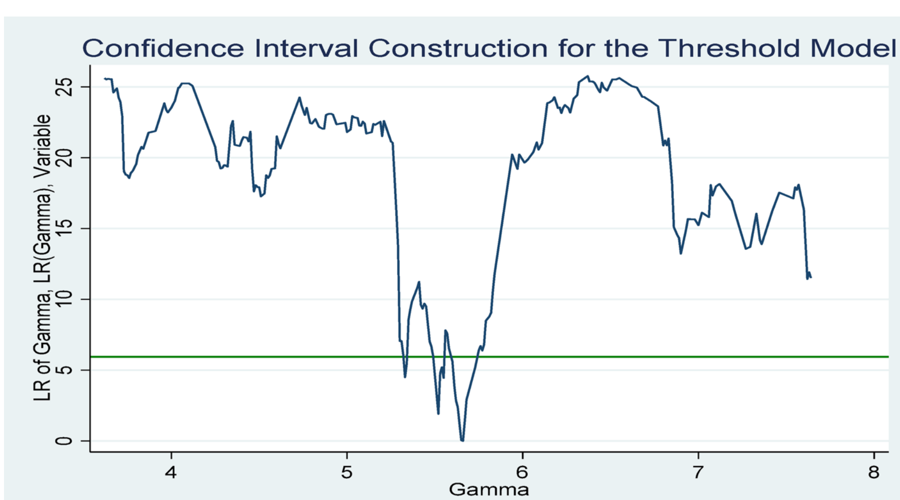

Fig. 1 Threshold estimation of RL&PR

Table 4 Dynamic panel threshold (RL&PR as a regime-dependent variable)

	Model 1(a)	**Model 1(b)**
Threshold estimates λ	5.2	5.2
95% confidence interval impact of RL&PR on CO_2	3.57 7.79	3.52 7.78
below_thres_string1 $\widehat{\beta}_1$	-0.0685*	-0.107*
	(0.0365)	(0.0600)
above_thres_string1 $\widehat{\beta}_2$	-0.0710**	-0.113**
	(0.0351)	(0.0548)
Impact of covariates *Ln* $CO_{2_{it-1}}$	0.507***	0.255**
	(0.0263)	(0.119)
ln FDI	0.0199***	0.0481***
	(0.00248)	(0.0163)
ln EC	0.00584***	0.00146
	(0.000552)	(0.00259)
ln GDP	0.00770***	0.0420***
	(0.000839)	(0.00675)
ln FD	0.0277***	-0.00223
	0.00701	(0.00193)
ln TO	0.0116	-0.0241
	(0.0146)	(0.0556)
ln POP		0.00186***
		(0.000537)
SupWstar	6.891***	5.286***
	(1.423)	(1.036)
Constant	-0.0915	-0.162
	(0.0673)	(0.253)
Observations	1,783	1,783
N	123	123

Significance levels *1, 5, and 10* are represented by ***, **, *. Parentheses indicate standard errors. DV is environmental quality, measured by CO_2 emissions, with RL&PR as the threshold variable

present the marginal effects of RL&PR on FDI and CO_2 emissions, in the low and high RL&PR regimes, respectively; that is, when RL&PR is less than (low regime) and greater than (high regime), the estimate threshold value. Results for Control variable coefficients (bottom of the tables) provide further insights into the relations across the different RL&PR regimes.

According to Model 1(a) in Table 4, the estimated RL&PR threshold is 5.25, with a 95% confidence interval that ranges from 3.56 to 7.79. In the model, the low RL&PR regime's coefficient (β_1 = -0.0685) shows statistical significance at the 10% level, while at high levels of RL&PR (β_2 = -0.0710), it achieves statistical significance down to just 5%. These results show that RL & PR is a significant positive factor for environmental quality, as measured by how much CO2 (in metric tons) the country emits during a given year. These results show in particular that both below as well as above the threshold point, RL&PR act in a positive and significant way to improve the quality of ecology (i.e., lower levels of emissions). As both β_1 and β_2 are negative, using RL&PR as the threshold variable may not result in a U-shaped curve.

Also, the EC, FD, GDP growth, and TO as control variables are included in model 1(a). The results indicate that EC, FD, and GDP growth are significant determinants of CO2 emissions with a positive impact and a significance level set to 1%. However, unlike the other variables, TO is singled out in this model as an insignificant determinant of CO2 emissions. In contrast, Model 1(b) examines the RL&PR threshold effect on environmental quality with Population growth included as an additional control variable to test

Table 5 Dynamic panel threshold (FDI as a regime-dependent variable)

	Model 2(A)	Model 2(b)
Threshold estimates λ	5.6	5.6
95% confidence interval impact of RL&PR on CO_2	5.33 7.67	5.3 7.67
below_thres_string1 $\widehat{\beta}_1$	0.0162**	0.0139*
	(0.00810)	(0.00827)
above_thres_string1 $\widehat{\beta}_2$	-0.0250**	-0.0220*
	(0.0121)	(0.0122)
Impact of covariates *Ln* $CO_{2_{it-1}}$	0.682***	0.702***
	(0.0368)	(0.0368)
ln GDP	0.0259***	0.0261***
	(0.00646)	(0.00633)
ln EC	0.00538*	0.00393
	(0.00324)	(0.00318)
ln FD	0.00204***	0.156***
	(0.000537)	(0.0537)
ln TO		-0.200**
		(0.0792)
SupWstar	4.131***	8.187***
	(1.536)	(1.478)
Constant	0.00965	0.432
	(0.0336)	(0.353)
Observations	1,699	1,699
N	123	123

Significance levels 1, 5, and 10 are represented by ***, **, *. Parentheses indicate standard errors. DV is environmental quality, measured by CO_2 emissions, with RL&PR as the threshold variable.

the validity of the threshold estimates. The results above showe that the threshold estimate does not change, and the 95% CI is (3.56, 7.79), similar to the model 1(a) range. The results from Model 1(b) are consistent with those from Model 1(a), indicating that the lower regime-dependent coefficient (β1 = -0.107, 10% level) and usage-and-production-dependent upper regime coefficient (β2= -0.113, 5% level) are both negative and significant, even with population growth in the control variables.

These findings reinforce the observation that a negative and significant threshold coefficient persists below and above the RL&PR threshold level. The findings show that when RL&PR surpasses the threshold value of 5.2, they have a negative impact on CO_2emissions across the countries in the sample. Model 1(a)'s results are consistent with those of Model 1(b), indicating that when RL&PR surpasses the threshold value, it strongly influences environmental quality. This emphasizes the significance of RL&PR as a major factor influencing environmental quality.

Model 1(b) shows that FD and TO are insignificant control variables. Conversely, EC, GDP growth, and POP have positive coefficients and are significant at the 1% level. In addition, also shown in Table 4, a bootstrap test is performed to verify whether there is a threshold value in the models. The SupW* statistic tests the belief in the null hypothesis that no threshold effect exists in the model against the alternate hypothesis that a threshold effect exists. The SupW* statistic for Model 1 and Model 1(b) shows that the p-values are significant at the 5% level; therefore, the null hypothesis may be rejected. Thus, it can be concluded that the threshold effects are validated in the previously mentioned models.

These results are consistent with previous literature as they show that a strong legal foundation concerning property rights leads to better environmental quality through reduced carbon dioxide emissions. It also agrees with the findings of [19, 22, 23]. Countries with strong legal systems with well-defined property rights adopt stronger environmental policies. Or, put another way, when countries can compel businesses to follow stringent regulations, the companies are more likely to transition to clean technologies and prevent any environmental harm and other negative impacts through the steps they take to adopt sustainable practices. But, the result is a significant reduction in CO2 emissions [73, 74].

Table 5 presents a detailed overview of the FDI-environment quality link concerning the threshold level. Table 5 is 5.6, with a 95% confidence interval between 5.3 and 7.67. This inflection value designates the shift from the below- to above-threshold PR&LS regime crucial for understanding the relation between FDI and CO2 emissions. In Model 2(a) of Table 5, the most remarkable regime-dependent coefficients include the following: β_1, which at 0.0162, is positive, and β_2 is -0.0250 negative, are crucially significant at the 5% level. In Model 2(a) of Table 4, additional control variables that could be listed are FD and EC, which significantly impact the changes in the environment at the 1% level. Therefore, these elements should be considered major factors affecting the relationship between FDI and its ecological outcomes.

Model 2(b) conducted an extensive analysis by introducing trade openness into its specification. This model's results aligned with Model 2(a), which examined the RL & PR threshold's effect on CO_2 emissions. The RL & PR threshold estimate remained at 5.6, with a 95% confidence interval between 5.3 and 7.62. This consistency highlights the robustness of the model's results. The positive and statistically significant coefficient β_1, observed at RL&PR levels below the threshold implies that an increase in FDI significantly raises CO_2 emissions. On the other hand, as soon as RL & PR is greater than the threshold, the coefficient β_2 turns negative and significant at the 10% level. The results indicate that FDI significantly reduces environmental quality, especially CO2 emissions, when RL&PR crosses the threshold, confirming the results of Model 2 A. In this context, controlling for additional factors, such as trade openness, further emphasizes the negative impact on CO2 emissions. Significantly, when RL&PR is at a high level, all the findings confirm that RL&PR is vital in adjusting the effect of FDI on CO2 emissions. These results support the pollution haven hypothesis's inverted U-shaped relationship of FDI with CO2 emissions worldwide.

The implementation of robust property rights has a beneficial effect on both environmental quality and FDI, indirectly contributing to a decrease in CO_2 emissions. These empirical findings show that property rights strongly influence FDI-environmental quality relationships.

Particularly when the usage of property rights surpasses the threshold level, strong property rights and a robust legal system are typically associated with a stable regulatory environment, attracting foreign investors by giving them the confidence that their investments will be protected. As a result, economies with effective property rights tend to attract more FDI [75]. The evident property rights and established legal frameworks provide less uncertainty for the reasons of making an investment that increases investor confidence about the stability of the rights and, therefore, a growth in FDI [76]. Another important notion is that strict legal systems with substantial property rights provide powers for countries to ensure stringent environmental policies. Under such conditions, businesses must utilize cleaner technologies and practices and pursue sustainable approaches to avoid the consequences of the law, which is supposed to decrease CO2 emissions [74].

6 Robustness checks

In Table 6, Model 2(c) included the total population as an additional control variable to ensure the threshold estimates' robustness. The inclusion of population growth (POP) in Model 1(b) was initially aimed at capturing demographic effects alongside other macroeconomic variables. However, to thoroughly verify the robustness of the identified RL&PR threshold effect, the robustness analysis in Table 5 explicitly isolates the influence of population growth as an additional robustness check. The model examines how the RL&PR threshold affects the FDI -environmental quality relationship. As identified in the STIRPAT model and extensively utilized in past research, population plays a vital role in influencing CO_2 emissions [59]. Numerous studies have demonstrated a strong correlation between population growth and environmental degradation [77, 78].

As can be seen from Table 6, the RL&PR threshold is still 5.6, similar to the results from models 2 (a) and (b). Model 2(c) has a significant positive β_1 at the 5% significance level. Collectively, these findings indicate that RL&PR is quite influential in determining the relationship between FDI and CO2 emissions. Moreover, the analysis shows that EC, GDP growth, and POP growth are all significantly impactful at the 1% level, emphasizing their importance as posters of environmental quality within the model. The similarity of outcomes among these models reinforces the conclusion that ROL&PR is a critical determinant of the FDI-CO2 relationship, and this effect is especially pronounced when population dynamics are controlled for.

Table 6 Dynamic panel threshold (Robustness check incorporating population growth as an additional Variable)

FDI regime-dependent variable	Model 2c
Threshold estimates λ	5.6
95% confidence interval impact of RL&PR on CO_2	5.33 5.73
below_thres_string1 $\widehat{\beta_1}$	0.0167**
	(0.00803)
above_thres_string1 $\widehat{\beta_2}$	-0.0207*
	(0.0121)
Impact of covariates *Ln* $CO_{2_{it-1}}$	0.644***
	(0.0388)
ln GDP	0.0218***
	(0.00656)
ln EC	0.00869**
	(0.00341)
ln FD	0.00240***
	(0.000547)
ln POP	0.0733***
	(0.0254)
SupWstar	
Constant	0.153**
	(0.0597)
Observations	1,699
N	123

Significance levels 1, 5, and 10 are represented by ***, **, *. Parentheses indicate standard errors. DV is environmental quality, measured by CO_2 emissions, with RL&PR as the threshold variable

Table 7 Dynamic panel threshold regression Estimation by seo, Kim [79]

Model 2		
Variables	**Lower regime**	**Upper regime**
Ln $CO_{2_{it-1}}$	-0.671***	1.698*
	(0.247)	(0.981)
Ln FDI	0.00559**	-0.0334***
	(0.00218)	(0.00426)
Ln EC	0.0315***	-0.0447**
	(0.00509)	(0.0177)
Ln TO	0.355***	-0.418
	(0.0760)	(0.256)
Ln FD	0.656***	-1.353***
	(0.121)	(0.305)
Ln GDP Growth	-0.00977	0.203**
	(0.0206)	1.698*
Constant	5.467***	
	(1.411)	
Threshold value (γ)	5.596***	
	[4.71 6.47]	
Bootstrap p-value for linearity test	(0.000)	
No. of moment conditions	391	
Observation	123	

The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors provided in parentheses. Following the method by Seo, Kim [79], the dynamic panel threshold estimation results are derived using the "xthenreg" command in Stata 17

For the Final robustness check, the alternative method, Seo, Kim [79], the dynamic panel threshold regression method, takes a novel approach compared to Kremer et al.'s ground-breaking 2013 threshold model. This study employs RL&PR as transition variables. The estimated threshold value of approximately 5.59 closely aligns with baseline models 2(a), 2(b), and 2(c), as shown in Table 6. These results validate the presence of threshold effects, passing the bootstrap linearity test at the 5% significance level. A substantially positive relationship between FDI and CO2 emissions exists in the lower RL&PR regime, evidenced by a coefficient of 0.0559. Consistently, Model 2 examined how RL&PR impacted the FDI-CO2 link. FDI and CO2 emissions positively correlate below the RL&PR threshold but negatively correlate above it, mirroring Model 2(b)'s findings assessing the RL&PR threshold's influence on the FDI-CO2 relationship. The dynamic panel threshold regression method offers a fresh lens on the enduring issue of international investment's environmental impacts.

Additionally, the control variables, EC, TO, and FD, also reveal a positive and significant impact on CO2 emissions in Model 2. An especially interesting relationship to highlight here is the similar threshold-dependent shape between FDI, EC, and FD in Table 6. Importantly, all areas are those parameters whose influence parameters show a gradual shift from positive to negative effects on CO_2 emissions when crossing the RL&PR threshold identified. This consistency indicates a potential systemic pattern such that strong institutional quality not only moderates the environmental effects of FDI but also plays a significant role in conditioning the influence of energy consumption and financial development on environmental performance. Particularly, institutions implement rigorous environmental regulations and an efficient financial policy promoting sustainable technology, resource-conserving production, energy efficiency use, and clean energy investments. Thus, the uniform regime shifts across these correlations highlights the vital role of institutional quality (RL&PR) in countering multiple causes of environmental degradation and calls for strengthening institutions as the holistic approach to accomplishing environmental sustainability standards.

Since the sign and significance levels were consistent across the different models, this reinforces the robustness of the findings. Moreover, these signs and significance levels will enrich RL&PR-related literature in terms of theory as they imply moderation of RL&PR in FDI and environment relationships.

7 Discussion

The empirical results depict a significantly nuanced interplay between FDI, institutional quality, as determined by the Rule of Law and Property Rights (RL&PR), and environmental quality (carbon dioxide emissions (CO_2)). The analysis identifies a clear level of RL&PR at 5.2, indicating a significant threshold effect, effectively demarcating two institutional regimes. At levels below this threshold, the positive and significant association between FDI and CO_2 emissions strongly substantiates the pollution haven hypothesis, indicating that foreign investors take advantage of weak environmental governance frameworks, which amplifies environmental degradation. On the other hand, when the institutional quality is better than the estimated threshold, the relationship between the two becomes significantly negative, with supporting pieces of evidence supporting the pollution halo hypothesis. This shows that strong institutional frameworks motivate foreign companies to engage in environmentally sustainable practices and technologies to a greater degree, significantly improving environmental outcomes.

Crucially, this institutional threshold also applies uniformly to other relevant variables, such as energy consumption and financial development. This shows that with high-growth economies, energy use and GDP increase, which causes CO_2 emissions. This is consistent with the rising limb of the EKC, which is representative of standard early-stage paths of economic development. In addition, the population growth robustness checks further support these conclusions, emphasizing demographic pressure as an extra key factor of environmental degradation.

Notably, the effects of trade openness were mixed across model specifications and did not achieve statistical significance. This inconsistency echoes prior research, suggesting that trade's environmental impacts can depend on the types and regulations of traded goods. As a result, economic openness must be balanced with the need for environmentally sound policy choices, so policymakers should take care when negotiating trade and opening up markets to ensure they do not bite off more than they can chew.

These empirical insights have considerable theoretical and policy consequences. Contextually, the RL&PR threshold can be characterized concerning the critical role of the quality of institution in establishing economic and environmental nexus. Developing economies, in particular, need to focus on developing their institutional capacity, particularly the rule of law, enforcement mechanisms, and protection of property rights. Some of these policy actions may include creating clear legal frameworks regarding environmental compliance, offering monetary or tax incentives for sustainable investments, or improving regulatory oversight capabilities.

Finally, where the focus is on attracting FDI without sacrificing environmental integrity, nations need targeted policies promoting increased FDI through value chains or technology. Well-structured legal and regulatory frameworks may thus ensure a "green"

FDI that promotes alignment between economic interests and global sustainability objectives. Overall, the study reveals that sustainable development relies on economic policies and effective institutions capable of governing economic spaces.

Furthermore, the study results are consistent with broad empirical evidence and theoretical references in ecological economics. For example, discovering a crucial RL&PR threshold corroborates previous assertions reported in the literature concerning the conditional effect institutional quality exerts on sustainable economic growth [50, 80]. Significantly, the current research adds to the literature by estimating an empirical threshold of institutions, which implies new and practical policy advice for policymakers. Moreover, the stable threshold-sensitive association for FDI, energy use, and financial development reflects that well-functioning institutions are imperative at different economic levels. Our analysis indicates a critical takeaway: International institutional reforms that target different sectors at once may enhance environmental and economic advantages more powerfully than singular policy actions."

In addition, while the analysis is rigorous and effectively identifies key institutional thresholds, the complex nature of actual economic exchanges opens the door for additional research. Sector-specific analyses shed light on the differential impacts of FDI across diverse industries, including the manufacturing, agriculture, technology, and energy sectors, which all have unique environmental footprints. Exploring such nuances would further bolster institutional moderation's theoretical and policy implications. Similarly, adding other indicators such as technological progress, innovation, governance efficiency, and political stability could mitigate potential omitted variable bias and provide a more comprehensive overview of sustainable economic development.

8 Conclusion

This study surveyed the impact of the RL&PR threshold value on environmental quality. It also focused on how RL&PR impacts the FDI of the environmental quality. The study embraced 123 countries for the period 2000–2019. Dynamic panel threshold regression facilitates evaluating the various threshold effects of RL&PR concerning the FDI of the environmental quality. Moreover, the approach provided a lower and higher regime effect of the RL&PR for the FDI of the environmental quality. The lower decree effect of the RL&PR value enabled understanding of the significant prevailing effect of the RL&PR whenever it is below or above the threshold. The study noted control variables like EC, GDP growth, FD, and TO and POP growth. Moreover, the other recommended variables for the study include the likes of lagged CO_2 emissions as well as FDI. From the empirical results, the RPP relative stringency variable and the RL&PR approach supported the reduction of the CO_2 emissions, as well as the FDI to the recipient countries. The results provided quite some empirical methodologies. The first empirical insight is that the RL&PR affects a country's environmental quality levels. Moreover, whenever their levels reach the threshold RL&PR, CO_2 emissions decrease in the recipient countries. This implies that alpha is vital in initiating the low level of CO_2 emissions upon adoption and application.

Governments need to act, though, as this study highlights that the benefits of well-targeted FDI can be far-reaching if strong RL&PR witnessing strict implementation are introduced, along with clear legislation protecting intellectual property and transparent enforcement mechanisms and reduced bureaucratic inefficiencies to enhance investor confidence. They are also advised to issue sector-wise environment certificates, promote investments in clean technology, and form compliance monitoring systems. Furthermore, enhancing international cooperation, capacity-building programs, and technology transfer agreements could further help countries translate institutional reforms into environmental sustainability emerging from the high-performance legal framework and the property right, they can help suppress dependence on dirty technologies enforced by the largest investors, meaning that reducing adverse impacts and climate change mitigation become easier. Targeted strategies of this kind guarantee that enhancements in RL&PR lead directly to quantifiable environmental and developmental results.

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Author contributions
M.A.I. (Muhammad Asim Imam) conceptualized the study, performed data collection and analysis, and drafted the manuscript.W.N.W.A.-S. (W.N.W. Azman-Saini), guided the research design, contributed to the methodology, and provided critical revisions to the manuscript.M.A.A. (Muhammad Adeel Abbas), as the corresponding author, assisted with the literature review, data interpretation, manuscript editing, and submission process.All authors reviewed and approved the final version of the manuscript.

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The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics, consent to participate, and consent to publish
Not applicable. This study did not involve human participants or animals, and no individual data were used that required consent to publish.

Competing interests
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