Energy Intensity and Environmental Governance: A MM-QR and BS-QR Analysis

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Abstract

This study examines the impact of environmental governance on energy intensity in OECD countries. Specifically, it investigates how governance mechanisms influence the efficiency of energy use and contribute to sustainable development outcomes. The analysis is based on panel data from OECD countries over an extended period. Method of Moments Quantile Regression and Bootstrap Quantile Regression are employed to capture heterogeneous effects across different quantiles. Energy intensity is the dependent variable, and environmental governance indicators and control variables are included in the model. The results reveal that stronger environmental governance significantly reduces energy intensity by indicating improved energy efficiency. The impact varies across quantiles, suggesting that countries with higher initial energy intensity benefit more from governance improvements. Environmental expenditures and policy interventions promote the adoption of energy-efficient technologies and cleaner energy sources, which lower energy consumption. The study provides important policy implications for OECD countries. Strengthening environmental governance through increased investment, effective regulation, and enforcement mechanisms can substantially enhance energy efficiency and reduce environmental degradation.

Keywords: Environmental Governance, Economic Growth, Energy Intensity, MM-QR

Introduction

Since the onset of the Industrial Revolution, human consumption of raw materials has steadily increased, leading to the unavoidable depletion of natural resources. In *Capital*, Karl Marx observed that the progress of civilisation and industrialisation has consistently caused significant destruction in forests, whereas the impact of agriculture and production on forests has been relatively minor in comparison. The ecological challenge stemming from this issue has intensified over time, ultimately leading to numerous cases of environmental problems. A well-known example is the Great Smog, a severe air pollution event that took place in London during the winter of 1952. During that time, large quantities of soot, dust, ash and exhaust filled the air, forming a thick, dark cloud over London (Qiu et al., 2024).

The concentration of harmful pollutants, including sulfur dioxide (SO2) and suspended particulate matter (SPMs), increased to three times their usual levels. This severe pollution caused around 12,000 deaths from respiratory illness. Environmental issues have clearly become a prominent and

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widespread challenge worldwide. Their growing negative impacts not only significantly impede global economic growth but also harm human health and disrupt ecosystems (Dogan et al., 2022). Another notable environmental event in OECD countries is the 2019 European heatwave, which severely affected several nations, including France, Germany, and the United Kingdom. Record-breaking temperatures were recorded, with Paris experiencing an all-time high of 42.6 °C. This extreme event caused significant public health challenges, leading to thousands of heat-related deaths, particularly among vulnerable populations. It also strained energy systems and the agricultural sector (Cao et al., 2020).

These environmental challenges, which affect not only global economic growth but also human health and biodiversity loss, underscore the urgent need for effective environmental governance and increased expenditures dedicated to protecting the environment. In response to the 2008-2009 economic crisis, government expenditures have increased significantly in many countries to mitigate their adverse effects. A substantial portion of GDP is allocated by the government, influencing various economic factors, including overall prosperity (Sackitey, 2023)

In recent years, the concept of green growth has gained prominence as nations seek to balance economic development with environmental sustainability. Green growth refers to fostering economic expansion while ensuring that natural resources are used efficiently and environmental degradation is minimised (OECD, 2011). This approach is crucial in the context of climate change, pollution, and resource depletion, which pose significant challenges to sustainable development. The OECD countries, being among the most industrialised nations, play a crucial role in setting global environmental standards and adopting policies that enhance environmental performance and governance (UNEP, 2002).

Environmental performance measures the effectiveness of policies and practices in meeting sustainability goals. It is a key indicator of a country's commitment to green growth. Several studies highlight the role of environmental governance in shaping this performance. Effective regulations, enforcement mechanisms, and institutional frameworks all contribute to meeting sustainability objectives (Dinda, 2004; Gunningham, 2019). Energy intensity, defined as the amount of energy consumed per unit of GDP, is a critical factor for environmental impact. High energy intensity shows energy use inefficiency, which increases carbon emissions and environmental degradation (Sackitey, 2023).e extensive research on green growth, environmental performance, and energy intensity, there remain gaps in understanding how environmental governance influences these factors, particularly within OECD countries. Many existing studies focus on individual aspects, such as the role of economic growth in environmental sustainability (Grossman and Krueger, 1995) or the relationship between energy intensity and carbon emissions (Hou, 2009). However, limited research has examined the interconnected dynamics among these variables within OECD nations, where environmental policies and governance structures differ significantly from those in developing economies. Addressing this gap is essential for devising comprehensive strategies that enhance environmental outcomes while sustaining economic growth.

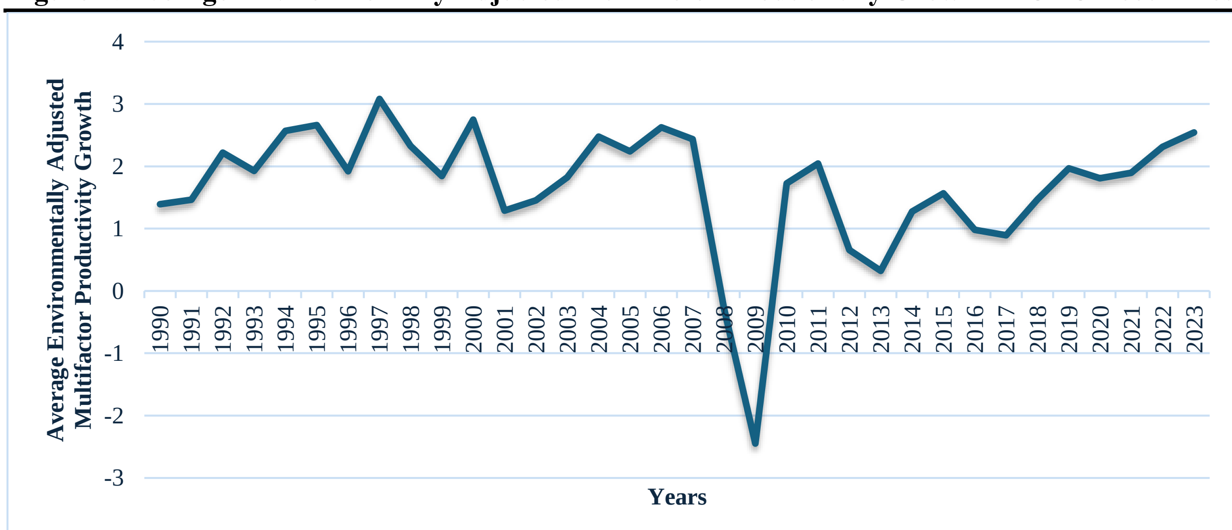
OECD countries have made considerable progress in improving environmental performance through policy innovations and technological advancements. However, challenges remain, as some nations still rely on energy-intensive industries, resulting in high carbon emissions (IEA, 2022). Additionally, discrepancies in environmental governance frameworks across these countries create variations in policy effectiveness. According to the Environmental Performance Index (EPI), OECD countries exhibit differing levels of environmental success, indicating that governance structures and regulatory frameworks play a critical role in shaping outcomes (Wendling et al., 2020). Understanding these variations is essential for identifying best practices that can be implemented across different policy environments.

This study seeks to contribute to the existing literature by examining the relationships among green growth, environmental performance, environmental governance, and energy intensity in OECD countries. By examining how environmental governance influences both environmental performance and energy intensity, this research aims to provide insights to inform policy decisions. The findings will have implications for governments, policymakers, and international organisations striving to enhance sustainability while maintaining economic competitiveness.

The growing concerns over climate change, environmental performance and unstable energy consumption have placed significant pressure on nations to adopt green growth strategies. Among OECD nations that are at the forefront of economic and technological advancement, the challenge lies in balancing economic growth with environmental sustainability. Expenditures on environmental protection as a percentage of GDP are one proxy for measuring environmental governance.

Environmentally Adjusted Multifactor Productivity Growth (EAMFP), serving as a proxy for measuring green growth, reflects the efficient use of natural resources while minimising environmental degradation. However, the observed fluctuations in EAMFP growth, as shown in Figure 1, suggest an inconsistency in achieving sustainable development. Despite global efforts, many countries struggle to sustain steady progress in green growth, raising concerns about the role of environmental governance.

Figure 1: Average Environmentally Adjusted Multifactor Productivity Growth in OECD countries

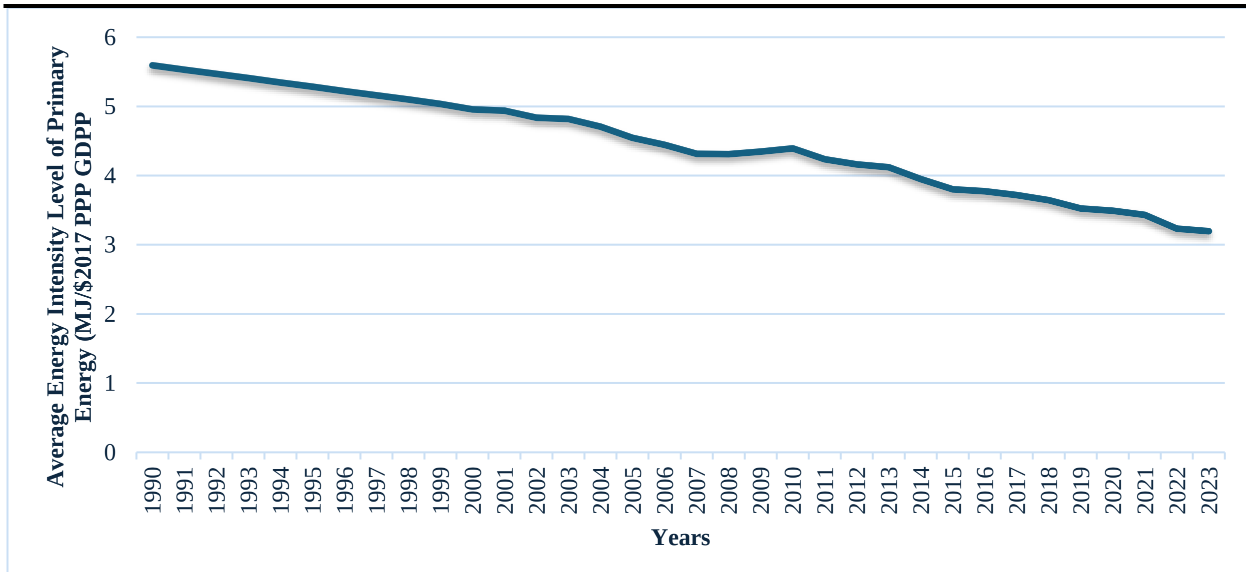


Source: OECD, 2023

Environmental governance is a critical driver of sustainable development. Insufficient investment in environmental protection can hinder the ability to achieve consistent growth in EAMFP. This raises the question that are current expenditures on environmental protection are adequate to support steady improvement in green growth (OECD, 2023).

Figure 2 shows the average energy intensity among OECD countries from 1990 to 2023. It reveals a gradual decline over the years, indicating a potential improvement in energy efficiency. Reducing energy intensity can contribute to sustainable development and a reduced environmental impact by lowering resource consumption and emissions. This trend aligns with global efforts to transition toward cleaner energy sources, implement energy-efficient technologies, and enforce stricter regulatory frameworks. However, the degree to which these factors collectively influence energy intensity across OECD countries remains a subject of investigation (WDI, 2023).

Figure 2: Average Energy Intensity Level of Primary Energy (MJ/$2017 PPP GDP) in OECD Countries



Source: WDI, 2023

The problem lies in understanding whether sufficient investment in environmental protection correlates with or directly drives improvements in energy intensity (WDI, 2023). While policy measures such as carbon pricing, subsidies for renewable energy, and efficiency standards may play a role, other economic and technological factors could also contribute to this decline. Structural changes in industrial processes, shifts in economic activities toward less energy-intensive sectors, and advancements in energy management practices could be influencing factors. Therefore, further analysis is required to assess the causal relationship between environmental governance and the observed decline in energy intensity within OECD countries.

The main objective of this study is to explore the impact of environmental governance on energy intensity in OECD countries. The rest of the paper is organized as follows: Section 2 gives literature review. Section 3 explains the specification of the model along with data and methodology. Section 4 exhibits results and discussion. Section 5 is based on conclusions and policy recommendations.

Literature Review

This section focuses on studies exploring how energy intensity impacts environmental governance and assessing the effectiveness of regulatory frameworks. Table 1 provides the summary of the studies on energy intensity and environmental governance.

Table 1: Summary of the Studies on Energy Intensity and Environmental Governance

Author(s)	Country	Time Frame	Methodology	Main Findings
Long et al. (2024)	Vietnam	2018-2020	OLS	The research found that strong environmental regulations reduced energy use, though the impact varied by region. Notably, reduced energy intensity was linked to economic activity and a larger workforce, likely due to Vietnam's green initiatives and the expansion of its service sector.
Sackitey (2023)	35 OECD Countries	1995-2014	FMOLS and DOLS Methods	The findings from both models indicated that environmental taxes and financial development had a negative impact on energy consumption and energy intensity. On the other hand, urbanization and trade openness had a positive impact on energy consumption and energy intensity.
Ahmed et al. (2022)	4 Nordic Countries	1994-2020	FMOLS and POLS	A green tax contributed to a decrease in overall energy usage, as demonstrated by the results. It improved energy efficiency by encouraging businesses, governments, and individuals to support environmental technology innovation.
Bashir et al. (2021)	29 OCED Countries	1994-2018	DOLS and FMOLS	The findings from the energy consumption model indicated that environmental taxes negatively affected energy consumption, whereas all other independent variables had a positive influence. In the energy intensity model, environmental taxes and trade negatively impacted energy intensity, while the remaining explanatory variables showed a positive effect.
Adetutu et al. (2020)	UK	2001-2006	SFA method	The findings indicated that factor substitution and technological advancement were the two main company responses to the CCL, while energy efficiency was the least responsive.
Fang et al. (2013)	China	2000-2019	DID Model	The findings suggested that energy intensity was better managed as the carbon price rose, though it risked impeding economic expansion

Overall, the literature consistently shows that stronger environmental governance reduces energy intensity and improves energy efficiency. However, the effects vary across countries and are influenced by factors such as economic structure, technological progress, urbanization and trade openness.

Model Specification, Data and Methodology

The model is presented in the following functional form:

$$EI_{it} = f(E_nG, E_cG, E_cG^2, P_g, U_bP, F_dI, I_{nd}VA, TD) \quad (1)$$

The model is specified in the econometric equation as follows:

$$EI_{it} = \beta_0 + \beta_1 E_n G_{it} + \beta_2 E_c G_{it} + \beta_3 E_c G_{it}^2 + \beta_4 P_{git} + \beta_5 U_b P_{it} + \beta_6 F_d I_{it} + \beta_7 I_{nd} VA_{it} + \beta_8 TD_{it} + \varepsilon_{it} \quad (2)$$

This model examines the impact of environmental governance on energy intensity, along with other economic factors. The dependent variable, energy intensity, is defined as GDP per capita of energy consumption expressed in PPP dollars per kilogram of oil equivalent. The independent variables include environmental governance, GDP growth, squared GDP growth, population growth, urbanization, foreign direct investment (FDI), industrial value-added, and trade openness. Environmental governance is the key variable of interest, and it is included as a determinant of energy intensity. GDP and squared GDP are incorporated to model the Environmental Kuznets Curve (EKC) theory, which suggests an inverted U-shaped relationship between economic growth and energy intensity. According to this theory, economic growth initially increases energy intensity, but after reaching a certain level of development, further growth leads to a reduction in energy intensity due to technological advancements, efficiency improvements, and better governance. Population growth is included as a determinant of energy intensity because it increases the demand for energy as more people require housing, transportation, and basic services. This often leads to higher energy consumption, which can raise energy intensity, particularly in countries with limited infrastructure or technological advancements to improve efficiency.

Urbanization is considered a determinant of energy intensity based on the Malthusian Theory and the IPAT Equation. As cities grow, population density and economic activities increase, leading to greater demand for energy-intensive infrastructure, transportation, and industry. This results in higher energy consumption and can elevate energy intensity, especially in areas with limited energy efficiency improvements or infrastructure. FDI is included based on the Pollution Haven Hypothesis (PHH), which suggests that foreign investments can lead to higher energy consumption and environmental degradation, especially in countries with weaker environmental regulations. Industrial Value-Added (IVA) is taken based on the Environmental Kuznets Curve (EKC), which posits that industrial growth initially increases energy intensity, but as economies develop, technological advancements help reduce energy consumption per unit of output. Trade is included based on both the Heckscher-Ohlin Theory and the Pollution Haven Hypothesis (PHH). Trade can lead to the relocation of energy-intensive industries to countries with less stringent environmental regulations (PHH), while the Heckscher-Ohlin theory highlights how trade influences resource allocation and technological efficiency. The data description along with the unit of measurement and sources are given in Table 2.

Table 2: Variables Description, Measurement and Sources

Variables	Description	Measurement Units	Sources
E_nG	Environmental Governance	Public spending on environmental protection as percentage of GDP	GFS
E_cG	Economic Growth	Annual percentage	WDI
EI	Energy Intensity	As GDP per unit of energy use (PPP dollar per kg of oil equivalent)	
E_cG^2	Square of Economic Growth	Annual Percentage	
P_g	Population	Annual Percentage Growth	
U_bP	Urban Population	Percentage of the total population	
F_dI	Foreign Direct Investment (net inflows)	Percentage of GDP	
$I_{nd}VA$	Industry (including construction), Value Added	Percentage of GDP	
TD	Trade	Percentage of GDP	

The study used the panel data of 38 OECD countries from 1990-2023 and employed Method of Moment Quantile Regression (MM-QR) for analysis.
The models in the present study can be expressed in MM-QR form as follows:
The MM-QR equation can be expressed as:

$$Q_{EI_{it}}(\tau \mid \gamma_i, \delta_t, X_{it}) = \gamma_i + \delta_t + \eta_{1,\tau} E_n G_{it} + \eta_{2,\tau} E_c G_{it} + \eta_{3,\tau} E_c G^2{}_{it} + \eta_{4,\tau} P_{git} + \eta_{5,\tau} U_b P_{it} + \eta_{6,\tau} F_d I_{it} + \eta_{7,\tau} I_{nd} VA_{it} + \eta_{8,\tau} TD_{it} + \mu_{\tau,it} \quad (3)$$

At τ=0.25:

$$Q_{0.25}(EI) |= \gamma_{0.25} + \eta_{1,0.25} E_n G_{it} + \eta_{2,0.25} E_c G_{it} + \eta_{3,0.25} E_c G^2{}_{it} + \eta_{4,0.25} P_{git} + \eta_{5,0.25} U_b P_{it} + \eta_{6,0.25} F_d I_{it} + \eta_{7,0.25} I_{nd} VA_{it} + \eta_{8,0.25} TD_{it} + \mu_{0.25,it} \quad (4)$$

At τ=0.50:

$$Q_{0.50}(EI) |= \gamma_{0.50} + \eta_{1,0.50} E_n G_{it} + \eta_{2,0.50} E_c G_{it} + \eta_{3,0.50} E_c G^2{}_{it} + \eta_{4,0.50} P_{git} + \eta_{5,0.50} U_b P_{it} + \eta_{6,0.50} F_d I_{it} + \eta_{7,0.50} I_{nd} VA_{it} + \eta_{8,0.50} TD_{it} + \mu_{0.50,it} \quad (5)$$

At τ=0.75:

$$Q_{0.75}(EI) |= \gamma_{0.75} + \eta_{1,0.75} E_n G_{it} + \eta_{2,0.75} E_c G_{it} + \eta_{3,0.75} E_c G^2{}_{it} + \eta_{4,0.75} P_{git} + \eta_{5,0.75} U_b P_{it} + \eta_{6,0.75} F_d I_{it} + \eta_{7,0.75} I_{nd} VA_{it} + \eta_{8,0.75} TD_{it} + \mu_{0.75,it} \quad (6)$$

At τ=0.90:

$$Q_{0.90}(EI) |= \gamma_{0.90} + \eta_{1,0.90} E_n G_{it} + \eta_{2,0.90} E_c G_{it} + \eta_{3,0.90} E_c G^2{}_{it} + \eta_{4,0.90} P_{git} + \eta_{5,0.90} U_b P_{it} + \eta_{6,0.90} F_d I_{it} + \eta_{7,0.90} I_{nd} VA_{it} + \eta_{8,0.90} TD_{it} + \mu_{0.90,it} \quad (7)$$

Results and Discussion

Summary Statistics and Correlation Analysis

Table 3 and 4 show the summary statistics and correlation of the key variables for OECD countries (See Bibi and Farooq, 2025 for details).

Cross-Sectional Dependence Test

The results of the Cross-Sectional Dependence (CD) test presented in Table 5 indicate significant interdependence among most variables in the analysis (See Bibi and Farooq, 2025 for details). Energy intensity (EI) also exhibits strong cross-sectional dependence.

Table 3: Cross-Sectional Dependence Test

Variable	CD-test
EI	104.087***

Slope Homogeneity Tests

Slope Homogeneity Test in Table 4 consistently indicates slope heterogeneity.

Table 4: Slope Homogeneity Test

	Delta Test	HAC Robust Adjusted Delta Test
Adjusted	-3.926***	-9.358***
Un-Adjusted	-1.866**	-4.447***

Unit Root Analysis

Table 5 presents the results of the unit root analysis. The findings show a mixed order of integration (See Bibi and Farooq, 2025 for other variables).

Table 5: Unit Root Analysis

CSDIPS Unit Root Test				
	Without Trend		With Trend	
Variables	**Lags**	**Zt Statistics**	**Lags**	**Zt Statistics**
EI	0	-4.206***	0	-1.048*

Panel Cointegration Tests

Table 6 exhibits the results of the panel cointegration analysis. The results show the rejection of the null hypothesis and it indicates strong evidence of cointegration in the panel.

Table 6: Panel Cointegration Tests

Westerlund Test	**Gt**	**Ga**		**Pt**	**Pa**
	-2.101***	-7.665***		-12.840***	-5.902***
Kao Test	**Modified Dickey-Fuller**	**Dickey-Fuller**	**Augmented Dickey-Fuller**	**Unadjusted Modified Dickey**	**Unadjusted Dickey-Fuller**
	-2.480***	-3.06***	0.187	-7.855***	-5.664***
Pedroni Test	**Modified Phillips-Perron**		**Phillips-Perron**	**Augmented Dickey-Fuller**	
	-0.244		-2.443***	-3.858***	

Source: Author's calculations
Note: *** p<0.01, ** p<0.05, * p<0.1

MM-QR Estimates

This section presents the estimates based on the MM-QR method that analyzed the impact of environmental governance on energy intensity along with the other variables. The dependent variable is energy intensity. On the other hand, the explanatory variables are environmental governance, GDP growth, squared of GDP growth, population growth, urban population growth, foreign direct investment, industrial value added and trade openness. The results of MM-QR estimates are shown in Table 7.

The result shows that environmental governance positively correlates with energy intensity in OECD countries. An increase in the expenditures on environmental protection increases the energy intensity for several reasons. Firstly, increased expenditures on environmental protection often lead to a reduction in energy intensity due to the promotion of energy-efficient technologies. Investment in cleaner and more advanced technologies enables industries to produce the same level of output using less energy. For example, the adoption of energy-efficient machinery or processes in manufacturing significantly lowers the energy consumption per unit of production, thereby decreasing energy intensity. These technological advancements are often incentivized by environmental regulations or subsidies associated with environmental protection expenditures (Bashir et al., 2021).

Another reason is the shift toward renewable energy sources, which typically have a lower energy intensity compared to fossil fuels. Expenditures directed at environmental protection often support the development and integration of renewable energy infrastructure, such as solar, wind, or hydropower systems. These sources not only reduce carbon emissions but also enhance energy efficiency by providing cleaner and more sustainable alternatives. As economies transition to greener energy solutions, the energy consumed relative to economic output diminishes, reflecting a decline in energy intensity (Peng et al., 2022).

Lastly, expenditures on environmental protection encourage structural economic changes that lower energy intensity. For instance, these expenditures promote a transition from energy-intensive industrial activities to less energy-demanding service-oriented sectors. Environmental policies and funding often incentivize research, innovation and the growth of sustainable industries, reducing the overall reliance on high-energy-consuming practices. Over time, such changes contribute to a more energy-efficient economy with lower energy intensity (Ernawati et al., 2024). Our results are in line with the following studies (Fang et al., 2013; Bashir et al., 2021; Peng et al., 2022; Shahzad, 2022; Sackitey, 2023; Ernawati et al., 2024).

The findings revealed that an increase in GDP growth tends to raise energy intensity, while a higher value of the squared term of GDP growth leads to a reduction in energy intensity in OECD countries. An increase in GDP growth tends to raise energy intensity for several reasons. First, during the early stages of economic growth, countries often expand energy-intensive sectors, such as heavy industry and manufacturing, which leads to an increase in energy consumption relative to GDP. As economies grow, industrialization and urbanization usually require more energy inputs, especially if energy efficiency measures are not implemented in parallel. This aligns with the Environmental Kuznets Curve (EKC), which suggests that environmental degradation, including energy intensity, increases in the initial stages of economic development but eventually decreases as income levels rise and cleaner technologies are adopted (Mahmood and Ahmad, 2018).

Second, as GDP grows, consumption increases, which typically leads to a higher demand for energy. People’s standards of living rise, leading to greater use of energy for transportation, heating, and electricity. This increase in energy demand may outpace improvements in energy efficiency, thus raising energy intensity. This relationship is often observed in the early stages of economic development when growth is heavily tied to energy-consuming sectors like construction, manufacturing, and transportation (Chen et al., 2022).

On the other hand, the squared term of GDP growth, which reflects diminishing returns to growth at higher levels of economic development, is associated with a reduction in energy intensity. As economies mature and reach higher levels of income, there is a shift towards more energy-efficient industries and services, which generally consume less energy per unit of output. This process is in line with endogenous growth theory, which highlights the role of technological innovation in driving sustainable growth. Technological advancements in energy efficiency, green technologies, and renewable energy sources contribute to a decoupling of energy use from economic growth. The neo-classical growth theory also supports this view, suggesting that as economies develop, they tend to invest more in capital that promotes energy efficiency, reducing overall energy consumption relative to GDP (Díaz et al., 2019).

Finally, a higher level of GDP growth often encourages governments to implement stricter environmental regulations and invest in cleaner technologies. At this stage, the economy benefits from a shift away from traditional, energy-intensive sectors, leading to lower energy intensity. This reflects the idea of green growth, where long-term growth is achieved by balancing economic expansion with environmental sustainability (Zhou et al., 2021). The findings of the study are consistent with the following studies (Mahmood and Ahmad, 2018; Díaz et al., 2019; Zhou et al., 2021; Chen et al., 2022; Zhang et al., 2022; Shokoohi et al., 2022).

The outcome of the study indicates that energy intensity is negatively associated with population growth in OECD countries. First, population growth is typically associated with a shift towards more energy-efficient urban living. As populations increase, there is often greater urbanization, which tends to be more energy-efficient compared to rural areas. Urban environments are typically designed to optimize infrastructure, including public transportation, energy-efficient housing, and

centralized energy distribution systems. These factors can reduce the overall energy consumption per capita, which ultimately lowers energy intensity (Beteryeb, 2016).
Second, with population growth, there is often an increase in demand for cleaner energy technologies. As the population grows, the pressure to address environmental concerns, such as pollution and energy scarcity, intensifies. Governments and industries may respond by investing in renewable energy sources like solar, wind, and hydroelectric power, which are less energy-intensive compared to traditional fossil fuels. This can result in a reduction in energy intensity, especially as these cleaner sources of energy become more prevalent in meeting the demands of a larger population (Otsuka and Goto, 2018).
Finally, population growth can foster innovation and technological progress, which can lead to improvements in energy efficiency. Larger populations can stimulate the development of new technologies, systems, and methods that improve energy consumption per unit of output. For example, in response to growing populations and their needs, there may be more investments in energy-efficient appliances, building materials, and industrial processes. Such innovations contribute to reducing energy intensity over time, as economies become more productive while consuming less energy (Sun et al., 2022). The outcome of the study matched with the following studies (Beteryeb, 2016; Otsuka and Goto, 2018; Sun et al., 2022).
An increase in urbanization or urban population growth tends to reduce energy intensity for several key reasons, often linked to more efficient use of resources, technological innovations, and changes in consumption patterns. First, urban areas are generally more energy-efficient than rural areas due to economies of scale in infrastructure and service delivery. In cities, energy distribution systems, such as electricity grids, are typically more centralized and optimized for higher population densities. Urbanization leads to the development of more efficient transportation systems, including public transit networks that reduce individual reliance on energy-consuming vehicles. The compactness of urban areas allows for more efficient land use, reducing the per capita energy needed for activities such as transportation, heating, and cooling (Belloumi and Alshehry, 2016).
Second, urbanization often encourages the adoption of cleaner technologies and renewable energy sources. In cities, the higher concentration of people and economic activity creates a stronger incentive for innovation and the deployment of energy-efficient technologies. For example, buildings in urban areas are more likely to be retrofitted with energy-efficient systems such as LED lighting, energy-efficient appliances, and smart energy management systems. Moreover, urbanization leads to a higher demand for sustainable infrastructure, such as green buildings and renewable energy projects like solar panels and wind turbines, which help lower energy intensity compared to traditional fossil fuel-based energy sources (Bilgili et al., 2017).
Finally, as urban populations grow, there tends to be a shift away from energy-intensive industries like agriculture and heavy manufacturing toward services and high-tech industries, which are generally less energy-intensive. Services such as finance, education, healthcare, and information technology typically require less energy input compared to traditional industries. As economies urbanize, the structure of the economy moves towards sectors with lower energy consumption per unit of output, which reduces overall energy intensity (Zhu et al., 2021). The result of the study is in line with the following studies (Belloumi and Alshehry, 2016; Elliott et al., 2017; Bilgili et al., 2017; Lv et al., 2018; Chen and Zhou et al., 2021; Zhu et al., 2021).

Table 7: MM-QR Estimates

Variables	Location	Scale	Q 0.25	Q 0.50	Q 0.75	Q 0.90
EG	-0.333***	-0.104	-0.388**	-0.306***	-0.245***	-0.333***
	(0.122)	(0.133)	(0.171)	(0.0825)	(0.0436)	(0.122)
GDPG	0.188**	0.0118	0.178	0.190***	0.197***	0.207**
	(0.0753)	(0.0590)	(0.111)	(0.0706)	(0.0625)	(0.0829)
$GDPG^2$	-0.128**	-0.136***	-0.0289	-0.127*	-0.257***	-0.325***
	(0.0625)	(0.0398)	(0.0771)	(0.0657)	(0.0600)	(0.0740)
POPG	-3.901**	-2.172	-2.331***	-2.857***	-5.618*	-9.030
	(1.739)	(2.034)	(0.448)	(0.808)	(3.151)	(5.968)
URBAN	-3.112**	-1.589	-1.964***	-2.348***	-4.367*	-6.863
	(1.373)	(1.606)	(0.357)	(0.641)	(2.515)	(4.792)
FDI	-0.635***	-0.0151	-0.646***	-0.635***	-0.621***	-0.613***
	(0.0605)	(0.0386)	(0.0751)	(0.0607)	(0.0587)	(0.0664)
IVA	0.861***	0.159	0.982***	0.828***	0.723***	0.659***
	(0.167)	(0.129)	(0.224)	(0.156)	(0.152)	(0.186)
TRADE	-0.00368	-0.0461	-0.0370***	-0.0259**	-0.0328	-0.105
	(0.0279)	(0.0326)	(0.00691)	(0.0128)	(0.0484)	(0.0887)
Constant	6.482**	1.613	5.316***	5.706***	7.757	10.29
	(2.592)	(3.033)	(0.704)	(1.236)	(4.981)	(9.721)

Source: Author's calculations
Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Energy intensity is negatively impacted by foreign direct investment net inflows in OECD countries for several reasons. First, FDI often brings advanced technologies and practices that improve energy efficiency. Multinational companies, which are the primary sources of FDI, typically have access to the latest energy-efficient technologies and processes. When foreign firms invest in a country, they often bring with them cutting-edge technologies and management practices that allow for more efficient use of energy. These technologies can be particularly valuable in sectors like manufacturing and infrastructure, where energy efficiency improvements can significantly reduce energy consumption per unit of output. Over time, the diffusion of these technologies across the domestic economy can lead to lower energy intensity (Elliott et al., 2013; Wang and Hwang, 2014).

Second, FDI inflows can drive structural changes in the economy, leading to a shift away from energy-intensive industries. In many cases, FDI tends to be directed toward industries such as high-tech manufacturing, services, and knowledge-based sectors, which generally consume less energy compared to traditional, energy-intensive sectors like mining, heavy industry, and agriculture. As FDI promotes the development of these less energy-consuming industries, the overall energy intensity of the economy decreases. This shift in economic structure can help decouple economic growth from energy use, aligning with the principles of green growth and sustainable development (Xin-gang et al., 2019).

Lastly, FDI can lead to improvements in the regulatory environment and infrastructure that support energy efficiency. Foreign investors often require stable and efficient energy supply systems to operate effectively. This demand can incentivize domestic governments to improve energy infrastructure and implement policies that promote energy efficiency. For example, FDI might encourage investment in renewable energy, energy-efficient buildings, and modernized power grids, which collectively help lower energy intensity in the long term. Additionally, the presence of foreign firms can encourage the adoption of global best practices in energy management, further reducing the energy required to produce a given amount of economic output (Cao et al., 2020). The findings of the study are consistent with the following studies (Elliott et al., 2013; Wang and Hwang, 2014; Li et al., 2019; Xin-gang et al., 2019; Cao et al., 2020; Petrović and Lobanov, 2022). An increase in industrial value-added leads to an increase in the energy intensity in OED countries for several reasons. First, industrial sectors, especially heavy manufacturing and production-based industries are often more energy-intensive compared to other sectors like services or agriculture. As industrial production increases, there is a higher demand for energy inputs, such as electricity, fuel, and raw materials. Industries like steel, cement, chemicals, and mining require significant amounts of energy for production processes, and as their value-added contribution to GDP rises, so does the total energy consumption required to support this growth. As a result, the energy intensity tends to increase as industrial activity expands (Freeman et al., 1997).

Second, the nature of industrialization often involves a growth in energy-intensive sectors, which can offset the efficiency gains made in other parts of the economy. While some industries adopt energy-efficient technologies over time, many industrial processes still rely on traditional, energy-demanding methods, particularly in developing or transitioning economies. As industries expand and contribute more to GDP, the energy consumed by these sectors increases faster than any improvements in energy efficiency, leading to an overall rise in energy intensity. The concentration of energy use in high-demand industries, such as manufacturing and construction, can outpace gains in energy efficiency, thus increasing energy intensity (Zheng et al., 2011).

Lastly, the demand for energy in industrialized economies is often linked to a greater reliance on fossil fuels, which are typically more energy-intensive compared to renewable sources. Industries that contribute significantly to GDP value-added, such as those in the manufacturing and energy sectors, are often heavily dependent on coal, oil, and gas. This reliance on fossil fuels can drive up energy consumption per unit of economic output, especially if there is insufficient investment in energy efficiency or cleaner technologies. Thus, as the share of industry in the economy increases, energy intensity also tends to rise unless there is a significant shift toward more sustainable and energy-efficient production processes (Wang et al., 2018). The outcome of the study matched with the following studies (Freeman et al., 1997; Zheng et al., 2011; Wang et al., 2018).

Trade, measured as a percentage of GDP, tends to lower energy intensity in OECD countries for several reasons that are linked to both structural changes in the economy and the influence of international market dynamics on energy efficiency. First, trade opens up access to more efficient technologies and practices. As countries engage in international trade, they often import goods, services, and technologies from foreign markets. Many of these imports are produced using advanced, energy-efficient technologies. For instance, industrial machinery, consumer goods, and energy-efficient appliances are often sourced from countries with high standards of technological innovation. The influx of such goods helps domestic industries adopt more energy-efficient practices and technologies, thus reducing the energy required to produce the same output. This diffusion of technology and knowledge helps lower the overall energy intensity of the economy (Kander et al., 2017).

Second, trade often leads to a shift in economic structure towards less energy-intensive industries. When countries open up to international trade, they tend to specialize in sectors where they have a comparative advantage. In many cases, this leads to a shift away from energy-intensive industries like heavy manufacturing and towards sectors like services or high-tech industries, which generally consume less energy. For example, countries that specialize in knowledge-based industries, such as information technology or finance, tend to have lower energy intensity because these sectors rely less on physical energy inputs. As trade increases, economies can decouple economic growth from energy consumption by focusing on sectors with lower energy requirements, leading to a reduction in energy intensity (Pan et al., 2019).

Finally, trade encourages competition and efficiency improvements. Increased exposure to global markets forces domestic firms to become more competitive, often through the adoption of more efficient production methods. In an open trade environment, companies are incentivized to reduce costs, including energy costs, by adopting energy-saving technologies, optimizing supply chains, and improving production processes. This pressure to stay competitive can lead to improvements in energy efficiency, which in turn lowers energy intensity. Moreover, international trade can lead to the specialization of countries in producing goods and services that are less energy-demanding, further contributing to a decrease in energy intensity (Chen et al., 2022). The findings of the study are consistent with the following studies (Keho, 2016; Kander et al., 2017; Pan et al., 2019; Chen et al., 2022; Rahman et al., 2023; Mahmood et al., 2024).

BS-QR Estimates

This section provides the results from the Bootstrap technique, used to evaluate the robustness of the MM-QR estimates. Table 8 presents the BS-QR estimates, which align with the MM-QR results, thereby confirming the robustness of the findings across various quantile regression methods.

Table 8: BS-QR Estimates

Variables	Q 0.25	Q 0.50	Q 0.75	Q 0.90
EG	-0.600***	-0.605***	-0.702***	-0.830***
	(0.0739)	(0.145)	(0.194)	(0.191)
GDPG	0.970***	0.682***	0.741***	1.013***
	(0.162)	(0.205)	(0.212)	(0.131)
GDPG^2	-0.265**	-0.0964	-0.0975***	-0.0713
	(0.108)	(0.123)	(0.0295)	(0.0447)
POPG	-0.138	-0.160***	-0.148***	-0.193***
	(0.124)	(0.0579)	(0.0479)	(0.0501)
URAB	-1.195***	-1.261***	-1.300***	-1.087***
	(0.227)	(0.135)	(0.121)	(0.132)
FDI	-1.037***	-1.036***	-1.137***	-1.028***
	(0.225)	(0.248)	(0.149)	(0.124)
IVA	0.198	0.126	0.121***	0.133***
	(0.166)	(0.156)	(0.0374)	(0.0458)
TARDE	-0.0378***	-0.0399***	-0.00605	-0.101***
	(0.00646)	(0.00434)	(0.0468)	(0.0322)
Constant	3.808***	4.637***	4.417**	6.304***
	(0.643)	(1.698)	(2.107)	(2.246)

Source: Author's calculations

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

The variables of environmental governance, squared of GDP growth, population growth, foreign direct investment and trade have a negative impact on energy intensity. On the other hand, GDP growth and industry value added have a positive impact on environmental performance.

Conclusion

This study examines the influence of environmental governance on energy intensity, utilizing panel data from 38 OECD countries spanning 1990 to 2023. The analysis employs the Method of Moments Quantile Regression (MM-QR) to derive the primary results, followed by Bootstrap Quantile Regression (BS-QR) to validate the robustness of the MM-QR findings. The study employs the MM-QR method to estimate the results. The dependent variable is the energy intensity while the independent variables are environmental governance measured by expenditures on environmental protection, economic growth measured by GDP growth, squared of GDP growth, population growth, urban population growth, foreign direct investment, industry value added including construction and trade openness. The variables of environmental governance, squared of GDP growth, population growth, foreign direct investment and trade have a negative impact on energy intensity. On the other hand, GDP growth and industry value added have a positive impact on environmental performance. The results from the BS-QR method are consistent with those obtained from the MM-QR, confirming the robustness of the findings across different quantile regression techniques.

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