The Influence of Financial Development on Ecological Footprint: A Panel Quantile Regression Modelling in OECD Countries

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Abstract. In the competitive landscape where Organisation for Economic Cooperation and Development (OECD) nations vie for investments and strive to maintain competitiveness, financial development, becomes a crucial factor not only in resource allocation but also in shaping the ecological footprint. The complex and varied nature of the relationship between financial development and ecological footprint in OECD nations may be oversimplified by conventional linear regression models. This study aims to model the effects of financial development on the ecological footprint of OECD countries using panel quantile regression. Analysing a sample of 36 countries within the OECD from 1995 to 2021 using a panel quantile regression framework with distributional heterogeneity, the study reveals a U-shape relationship between financial development and ecological footprint when the countries with high ecological footprint. Policymakers may promote eco-friendly financial practices, integrate green finance principles, and develop policies to manage environmental consequences of financial development. The originality of this research is evident in highlighting that the influence of financial development on ecological footprint differs among countries, contingent on their specific ecological footprint levels. This is achieved through the application of a panel quantile regression approach, providing policymakers with valuable insights.

1 Introduction

Since the onset of the industrial revolution, marked by rapid economic growth, urbanization, and mass production, environmental pollution resulting from extensive resource use and coal-burning went unnoticed until the recent Paris Agreement which triggered public awareness and discussions on the environmental impacts of human activities, fostering a growing consciousness of the need for environmental protection. The Paris Agreement,

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established in 2015, aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels. It endeavours to achieve even more stringent measures by striving to restrict temperature increases to 1.5 degrees Celsius [1].

OECD countries are described as nations with high levels of energy consumption, robust economic growth, and substantial greenhouse gas emissions. In 2019, their average per capita carbon dioxide emissions of 9.5 metric tons significantly exceeded the worldwide average of 4.9 metric tons. The Organization for Economic Cooperation and Development (OECD), comprising 37 nations from the Americas, Europe, and the Pacific, is dedicated to enhancing the economic well-being of its members, with environmental sustainability and green growth as primary objectives [2]. As some of the world's most developed economies, OECD members contributed a significant $53,415,405.02 million (measured in constant 2010 US dollars) to the world GDP in 2019, constituting 62.8% of the global GDP. In the meantime, OECD countries have had higher ecological footprints compared to the global average due to their high levels of resource consumption and industrialization.

The ecological footprint (EF) is a quantitative method revealing the extent of biological productive area utilized globally. EF quantifies the essential sea and land resources required for meeting societal resource demands and manage waste resulting from human activities [3]. Simultaneously, it forecasts whether the Earth's transport capacity limits have been exceeded, signifying humanity's reliance on the ecological system [4]. Financial development effects capital allocation across sectors and businesses. Financial institutions that favour ecologically sustainable projects and businesses can help to reduce the ecological imprint. On the other hand, financial institutions may invest in industries with significant environmental implications, such as heavy manufacturing, fossil fuel extraction, or intensive agriculture. This funding may aggravate ecological footprints by encouraging behaviours with serious environmental effects. The nexus between financial development and ecological footprint may not be linear in OECD countries as the ecological footprint in these countries vary from each other. The economic systems, degrees of industrialisation, and environmental regulations of these nations vary greatly. It is reasonable to speculate that there may be more variation in the relationship between ecological footprint and financial development as a result of this diversity. Panel quantile regression accounts for non-linear trends in the data, reflecting changes in influence across different levels of the ecological footprint distribution. The study raises the following research questions: Is the relationship between financial development and ecological footprint linear? Does the relationship between financial development and ecological footprint exhibit distinctions in environments characterized by low versus high ecological footprints? Therefore, the objective of this study is to examine the relationship between financial development and ecological footprint in OECD nations by using panel quantile regression model.

The contribution of this study lies in its exploration of the relationship between financial development and ecological footprint in OECD countries, considering the diverse ecological contexts within this group. This study introduces a novel analytical approach by employing a panel quantile regression model, which allows for the examination of non-linear trends and variations in the impact of financial development across different levels of the ecological footprint distribution. The empirical findings reveal a U-shaped relationship between financial development and ecological footprint specifically for countries with high ecological footprints. This insight challenges the assumption of a linear association and underscores the need for a more detailed understanding of the impact of financial development on ecological sustainability.

2 Literature review

The Environmental Kuznets Curve (EKC) theory is often utilised to examine the relationship between economic factor and environmental degradation [5,6]. As illustrated in Fig 1, the EKC theory holds that environmental conditions decline in the early phases of industrialisation, but as a country's wealth grows, environmental deterioration reaches a tipping point and begins to improve [7,8]. In terms of the relationship between financial development and ecological footprint, during the early stages of financial development, there may be a larger ecological footprint. This could be due to rising industrialisation, resource-intensive activities, and an emphasis on economic expansion without prioritizing environmental concerns. As financial development advances, this hypothesis implies a tipping point at which the ecological footprint begins to decline. This tipping point could be linked to greater knowledge of environmental issues, the use of cleaner technologies in financial activities, and the introduction of environmental regulations. In the later stages of financial development, it is anticipated that nations or regions would see additional decreases in their ecological footprint. This might be the result of developments in environmentally friendly financial technologies, the incorporation of environmental factors into investment choices, and an overall move towards more environmentally friendly financial practices [4,9,10].

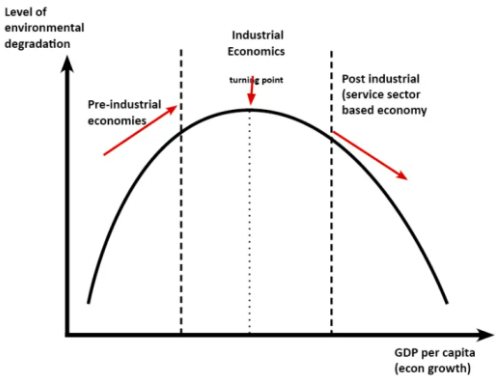

Fig. 1. Environmental Kuznets Curve (EKC)

The studies by [11–13] reach a consensus that financial development play an important role in influencing ecological footprint. They generally suggest that financial development induce harmful impact on ecological footprint. By utilising a panel consisting of 59 Belt and Road countries over the period from 1990 to 2016, [11] indicate that there is a positive association between financial development and ecological footprint. The finding suggests that central banks ought to impose limitations on financial institutions, preventing them from providing funds for projects that are not environmentally friendly. Furthermore, there is a need for the development of a check and balance mechanism to ensure that allocated financial resources are not invested at the expense of environmental quality. Similarly, within the context of emerging Asian countries utilising data spanning from 1985 to 2018, [12] reveals a positive correlation between financial development and EF based on the Cross-Sectionally Augmented Autoregressive Distributed Lag approach. It proposes that Asian nations should adopt a proactive green investment policy, channeling investments towards environmentally friendly projects rather than those with adverse ecological impacts. Opposite with the finding by [11,12], the evidence by [13] shows a mixed result based on a sample from G7 (Canada, France, Japan, Germany, Italy, the United Kingdom and the United States) countries over the period 1980–2015 by using threshold cointegration test with an endogenous structural break.

The result show that the ecological footprint (EF) is adversely affected by financial development in Japan only while other countries show insignificant results. The findings indicate that among G7 countries, globalisation is a more effective strategy than financial development in affecting the ecological footprint.

With the empirical studies by using a single country setting, [10,14–16] show inconclusive results. Singapore is positioned as having one of the most dynamic financial markets while concurrently holding the status of the country with the highest ecological deficit, the finding from Bayesian analysis reveals that financial development exerts a detrimental influence on the ecological footprint spanning the years 1980 to 2016 [16]. By examining a sample in Malaysia for the period 1984–2017, [14] shows that in the short run, financial development does not contribute to environmental degradation. Financial development increases ecological footprint but the moderating influence of institutional quality has reduced this impact in the long run. This suggests a synergistic connection between the development of the financial sector and the quality of institutions in alleviating environmental degradation. In an effort to validate the EKC hypothesis, [10] find EKC hypothesis is not valid in Pakistan, but the relationship between financial development and its impact on the environment is not the same when there are positive changes versus negative changes in financial development. When there is a positive change, it does not seem to have a significant effect on the environment. However, when there is a negative change in financial development, it appears to have a positive effect on the environment. In an effort to examine the impact of financial development on ecological footprint utilising the Quantile Autoregressive Distributed Lag model, the positive effect financial development on ecological footprint has been affirmed in Turkey over the period from 1986 to 2018 [15]. Drawing from these literature, majority of the studies support that financial development provide harmful impact on ecological footprint. They provide an interesting idea to explore the non-linear relationship between financial development and ecological footprint.

Prior research overlooks the non-linear and diverse impact of financial development on the ecological footprint within OECD countries based on variations in ecological footprint distribution. When the factors of interest exhibit varying effects at different segments of the conditional distribution of the dependent variable, employing a quantile regression model becomes pertinent [17]. Given that the influence of financial development on ecological footprint may vary across countries based on their developmental stages and the non-linear relationship may exist, this study addresses the literature gap by employing a panel quantile regression model to explore the non-linear relationship between financial development and ecological footprint in OECD countries.

3 Data and methodology

The current study examines yearly data spanning from 1995 to 2021, encompassing 36 OECD countries. The chosen starting year of 1995 aligns with the commencement of available tourism data. Conversely, 2021 provides the most recent ecological footprint data. The outcome variable in this study is ecological footprint (EF) as recommended by the literature [18]. The primary variable of interest, financial development index (FD) utilised as a proxy for financial development. Additionally, control variables encompass economic growth (gross domestics products per capita, GDP), and international tourism measured by the number of arrivals (TOUR).

In the current research, we employ the EKC hypothesis which has solidified its place in studies pertaining to environmental economics. The quantile regression method considers the effects of independent variables such as, financial development, economic growth and tourism variables on the outcome variables' (Ys) dynamics by considering that the conditional ∂.quantile of Ys change distribution (y_t) [19–21]. The outcome variable of this

study is ecological footprint (EF), so $EF_y(\partial|x)$ is being affected by the impacts of independent variables. Hence, the ∂^{th} quantile function under specific conditions of y is given as Equation (1) [22].

$$Q_y(\partial|x) = \inf\{\Upsilon|F_y(\Upsilon|x) \geq \partial\} = \sum_h \alpha_h(\partial)x_h = x\alpha(\partial) \quad (1)$$

The value of $\alpha(\vartheta)$ for $\vartheta \in [0,1]$ determines the dependence of the y's structure. The coefficients of $\alpha(\vartheta)$ for a given ϑ can be assessed through minimize the independent and dependent variables' weighted absolute deviations.

$$\hat{\alpha}(\partial) = argmin \sum_{t=1}^{T} (\partial - 1_{\{y_t < x_t\alpha(\partial)\}})|y_t - x_t\alpha(\partial)| \quad (2)$$

In Equation (2), $1_{\{y_t<x_t\alpha(\partial)\}}$ gives the usual characteristic function. To determine the standard errors for the estimated coefficients, pair bootstrapping procedure will be implemented. This method provides standard errors that are progressively accurate under misspecifications and heteroscedasticity of the Quantile Regression function. The linear conditional quantile function for the linear dependency of an exogenous variables $(\boldsymbol{X})$ vector is derived as below:

$$Q(\partial|x) = \theta(\partial) + \sum_h \Upsilon_h(\partial)x_h \quad (3)$$

The estimation of the EKC hypothesis on the interaction between ecological footprint and economic are given in Equation (4).

$$EF_{it} = \beta_0 + \beta_1 FD_{it} + \beta_2 FD_{it}^2 + \beta_3 lnGDP_{it} + \beta_4 lnTOUR_{it} + \epsilon_{it} \quad (4)$$

FD_{it} denotes country i's financial development index in year t, while FD_{it}^2 gives the square of the country i's financial development index. GDP_{it} denotes country i's GDP per capita in year t and $TOUR$ represents the number of international tourist arrivals in country i in year t.

To apply Equations 1-3 to Equation 4, the process involves estimating the coefficients $\beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4$ in Equation 4 through panel quantile regression. This involves estimating the quantile functions for each quantile level (∂) using the methodology described in Equations 1-3.

4 Results and Interpretations

Table 1 displays the descriptive statistics for the variables. The dataset comprises a total of 778 observations, encompassing 36 countries over a span of 27 years. The mean of the ecological footprint (EF) is 5.66. Significant disparities are evident in the ecological footprint (EF) data, with a notable contrast between the maximum (17.78) and minimum (1.86). This indicates a substantial gap among the countries. Luxembourg is the nation with the highest reported EF. The plausible reason is that Luxembourg is a major financial center, hosting numerous international banks and financial institutions. The financial sector often involves significant resource consumption and energy use, contributing to environmental impact. Colombia has the lowest reported ecological footprint among nations. The agricultural sector in Colombia is strong, and compared to certain other countries where agricultural techniques are more resource-intensive, the production of specific crops or livestock may have a smaller ecological impact.

Table 1. Descriptive Statistics.

Variable	Source	Obs	Mean	Std. Dev.	Min	Max
EF	Global Footprint Network [23]	778	5.664063	2.174536	1.858995	17.7778
FD	International Monetary Fund [24]	778	0.602748	0.21504	0.095064	1
GDP	World Development Indicators [25]	778	34049.75	22078.72	4801.068	111968.4
TOUR (million)		778	14.6	18.4	0.5	86.8

Table 2 displays the outcomes of the non-linear association between FD and EF across various levels of EF based on equation 4. Model 1 represents the results at the 10th percentile, and subsequent models increase in increments of 10%, reaching up to the 90th percentile in Model 9. To obtain the quantile regression results for Models 1 to 9, representing the 10th to 90th percentiles respectively, Stata software would conduct separate quantile regression analyses for each desired percentile. Firstly, it conducts quantile regression analysis where the dependent variable is EF, and the independent variables are FD, FD^2, lnGDP and lnTOUR. Then, it conducts another quantile regression analysis with the same independent variables but set the quantile level to 20%. This process is repeated until the quantile level to 90%.

Higher quantiles refer to the quantiles at the upper end of the distribution of the dependent variable, which in this case is the ecological footprint (EF). Specifically, the models 5 to 9, which represent the 50th to 90th percentiles of the conditional distribution of EF. At the higher quantiles, the results show that the relationship between FD and EF is U-shape as the coefficient for FD is negative and statistically significant with EF and the coefficient for FD2 is positive and statistically significant with EF. At higher quantiles (models 5 to 9), the results indicate a U-shaped relationship between FD and EF as depicted in Fig 2. The coefficient for FD is negative and statistically significant with EF, while the coefficient for FD2 is positive and statistically significant with EF. This outcome goes against the literature endorsing the Environmental Kuznets Curve (EKC) hypothesis, which suggests an inverted U-shaped pattern to elucidate the correlation between economic variables and environmental performance [9]. These findings imply that ecological footprint drops in the early stages of financial development but increases as financial development matures. The plausible reason is that early on in the financial development process, old resource-intensive economic activities may give way to less ecologically damaging and more service-oriented businesses. Then, financial development is often accompanied by technological advancements and innovation. These advancements can lead to more efficient resource utilization and cleaner production processes, thereby reducing environmental impact and contributing to lower ecological footprints. Furthermore, as financial systems mature, governments may implement stricter environmental regulations and policies aimed at mitigating environmental degradation. These regulations can incentivize businesses to adopt cleaner technologies and practices, leading to reductions in ecological footprint. However, because of rising demand or shifting economic priorities, resource-intensive businesses may resurface as financial development advances. Hence, with rising earnings and a more affluent society, there may be a greater demand for goods and services that are naturally more resource-intensive. This could include a resurgence in demand for manufactured goods and increased energy use with greater environmental impact. Subsequently, advanced financial systems can facilitate infrastructure development projects, such as urbanization and industrialization, which may have significant environmental implications. Rapid urbanization and industrial expansion can lead to habitat destruction, increased pollution, and higher ecological footprints.

Table 2. Results for Panel Quantile Regression

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
FD	-0.96 (-0.80)	0.49 (0.35)	-0.20 (-0.14)	-3.44* (-2.18)	-7.21*** (-4.94)	-7.84*** (-4.49)	-11.2*** (-4.20)	-17.4*** (-6.41)	-16.8** (-3.00)
FD2	-0.57 (-0.62)	-1.85 (-1.77)	-1.37 (-1.23)	1.78 (1.49)	5.23*** (4.74)	6.18*** (4.67)	9.21*** (4.57)	13.6*** (6.61)	12.7** (2.99)
lnGDP	1.78*** (17.90)	1.82*** (16.07)	1.99*** (16.54)	2.082*** (16.06)	2.18*** (18.21)	2.29*** (15.93)	2.50*** (11.42)	2.99*** (13.39)	3.74*** (8.12)
lnTOUR	-0.08* (-2.05)	-0.15*** (-3.40)	-0.19*** (-3.94)	-0.21*** (-4.01)	-0.20*** (-4.22)	-0.28*** (-4.87)	-0.31*** (-3.62)	-0.29** (-3.28)	-0.35 (-1.94)
Constant	-11.8*** (-10.5)	-11.2*** (-8.74)	-11.9*** (-8.73)	-11.6*** (-7.89)	-11.5*** (-8.52)	-11.2*** (-6.88)	-11.6*** (-4.69)	-14.4*** (-5.70)	-20.1*** (-3.87)
Obs	778	778	778	778	778	778	778	778	778

Note: Standard errors in parenthesis. The asterisk indicates p-value significance level where *** p<0.01, ** p<0.05, * p<0.1

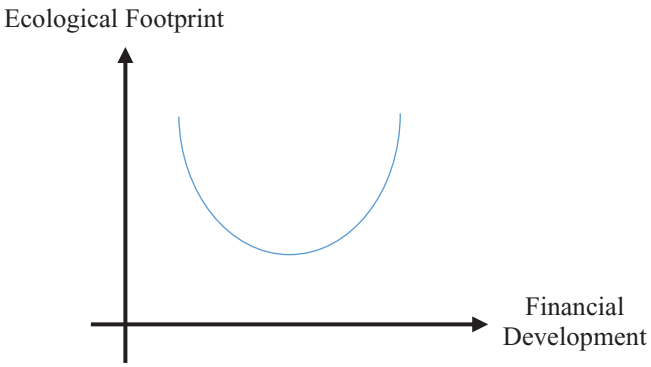

Fig. 2. Environmental Kuznets Curve (EKC): U-shaped relationship between Financial Development and Ecological Footprint

For the control variable, the coefficients for GDP in all nine models consistently indicate a positive and significant impact on ecological footprint. This positive connection means that more economic activity leads to a bigger demand for resources and energy, resulting in a larger ecological footprint [3]. The coefficients for TOUR in models 2 to 7 consistently indicate a negative and significant impact on the ecological footprint. This result implies that tourism activity reduces the ecological footprint in countries with a moderate level of ecological footprint. Tourism has the potential to greatly boost a country's economy. Tourism may provide income and economic growth in countries with moderate ecological footprints while without significantly worsening environmental stress. It shows that countries with moderate ecological footprints may be more likely to promote sustainable tourism practices. This could include attempts to reduce environmental impact, encourage conservation, and participate in environmentally friendly tourism projects [26].

Following the quantile regression analysis, we conducted assumption checking to ensure the validity of our findings. The results are free from independence of errors and normality of residuals.

In summary, the empirical findings from quantile regression affirm our hypothesis regarding the validity of the Environmental Kuznets Curve. However, our findings indicate a U-shaped relationship between financial development and ecological footprint, which differs from the literature that proposes an inverted U-shaped relationship.

5 Conclusions and Implications

The study addresses the complex relationship between financial development and ecological footprint within OECD countries, acknowledging the varying ecological footprints, economic systems, industrialization degrees, and environmental regulations across these nations. Financial institutions play a pivotal role in capital allocation, potentially influencing ecological sustainability positively by supporting environmentally friendly projects or negatively by funding industries with substantial environmental implications. The non-linear nature of this relationship is explored through panel quantile regression, allowing for an examination of differing impacts across various levels of the ecological footprint distribution.

This study uses a panel quantile regression approach to investigate the link between financial development and ecological footprint in OECD nations covering the period from year 1995 to 2021. Contrary to typical linear regression models, our results support Environmental Kuznets curve hypothesis and show a U-shaped connection, indicating that as financial growth proceeds, the ecological footprint decreases initially before increasing, particularly in nations with high ecological footprints. This discovery highlights the complexities of financial development's impact on environmental sustainability and challenges the simplistic assumptions of traditional ordinary least square models.

For the implications of the study, policymakers should advocate for and reward financial firms to use environmentally friendly practices. This could be done by encouraging investments in sustainable projects and businesses can help reduce the environmental impact of financial development. Furthermore, the use of green finance principles is critical. Financial policies and frameworks should include environmentally sustainable criteria to help guide investment decisions. This involves supporting programmes and efforts that promote environmental preservation and resource conservation. In addition, recognising the uniqueness of OECD countries, policymakers should develop adapted solutions based on ecological footprint levels. Countries with high ecological footprints may require different strategies than countries with moderate or low footprints to meet their specific environmental concerns.

For the limitations of this study, it focuses on OECD countries, and the conclusions may not be immediately applicable to non-OECD countries. Future research should look into the dynamics of financial development and environmental footprint in various global contexts. Moreover, the study considers financial development as a single variable. Future research should dive deeper into certain components of financial development, such as investment kinds or banking procedures, to gain a better understanding of their environmental repercussions. For future research direction, researcher may use dynamic modelling to evaluate the long-term effects of policy actions. This could assist policymakers better determine the long-term effectiveness of various policies.

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