



Do climate change policies, and environmental regulations affect the financial performance: policy-based analysis in context of green innovation

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Abstract

In these modern times, developed and developing economies use different means and strategies to attain economic growth and financial development. Still, environmental recovery instruments are not yet empirically explored in developed regions. The prime objective of this study is to unveil the nexus between electricity use, environmental policies, and financial development to report novel approaches through the lens of sustainable development. The present research examines the heterogeneous impacts of climate policies and ecological taxes on financial development. In doing so, the study has considered greener energy and institutional quality variables as policy factors for financial development. The authors employ the 29 OECD economies data from 1994 to 2020. This research gathered the data from authentic sources such as the OECD, the World Bank, and ICRG. The pre-estimation diagnostic (residual cross-section dependence, unit root, and cointegration) tests asserted cross-section dependence between countries, variables' stationarity, and cointegration between the variables. Due to the asymmetrical behaviour of data shown by the Jarque and Bera (Int Stat Rev 55:163–172, 1987) test, this study uses non-parametric panel quantile regression. It asserts environmental policies and green electricity use have a substantial yet mixed influence on financial development. In contrast, trade openness and GDP are the significant factors of economic development in the region. Overall, Environmental taxes adversely affect financial development in developed countries across quantiles. This study suggests promoting and improving green investment, trade, and efficient environmental policies to encourage financial development in developed countries without affecting ecological quality.

Keywords Green electricity · Financial development · Environmental policies · Environmental regulations · Environmental taxes · Sustainable development

Abbreviations

CSD	Cross-sectional dependence
FD	Financial development
OECD	Organization for Economic Co-operation and Development
GDP	Gross domestic product
ENPO	Environmental policies

ENT	Environmental taxes
REN	Green electricity
BQ	Bureaucratic Quality
TO	Trade openness
SDGs	Sustainable development goals

1 Introduction

The environmental concerns have attracted the attention of environmentalists and researchers to take strict actions to fight climate change. In this instance, several environmental recovery indicators (air/water quality, resource management, etc.) may affect the financial development of the economies. Monitoring these factors helps in resource preservation and substantial growth (Xu et al., 2022; Zeraibi et al., 2021). According to the World Bank, financial development is an inextricable part of economic development that stimulates growth by mobilizing resources, encouraging foreign capital, alleviating poverty, risk management, etc. In recent literature, few studies have scrutinized the nexus between the importance of sustainability and the environment (Shaheen et al., 2022; Sarkar et al., 2022). Besides that, financial development or financial indicators have also gained a significant position for the economy's expansion (Balsalobre-Lorente et al., 2018; Le et al., 2020)). However, the determinants of financial development from the perspective of sustainable environmental policies and regulation have remained an unexplored area academically.

Financial development is critical in mitigating emissions and accomplishing sustainability targets (World Bank, 2022). The increasing global rise in temperatures and ecological degradation have posed severe coercions for policymakers in sustainable development, especially in the financial sector (Awosusi et al., 2022). Therefore, the study determines the asymmetric influence of climatic policies on financial development. The uncertain climate change complicates businesses and adversely impacts economic and social life by aggravating environmental deterioration. Therefore, climate policies must adapt according to new information and technology to tackle the harmful impact of climate change on the economy. For that reason, researchers, policymakers, and environmentalists design climatic policies to ensure environmental and economic sustainability.

Correspondingly, the role of environmental taxes on sustainable development is essential for an eco-friendly economy (Envirotech, 2015). In the extant body of knowledge, the influence of ecological policies (ENPO) and environmental taxes (ENT) on financial development (FD) hasn't been explored beforehand. However, scholars emphasized that climate change influences financial progression and regulation, ultimately affecting the global economy (D'Orazio and Dirks, 2022). Hence, climate change policies and environmental taxes potentially influence economic development from the sustainable development perspective. A limited number of studies have shed some light on the importance of environmental policies (ENPO) and ecological taxes in terms of environmental quality (Doğan et al., 2022; Rafique et al., 2022; Li et al., 2020; Bashir et al., 2020). Based on the author's available knowledge, no prior research examined the impacts of climate policies and taxes on financial development. Therefore, the present study is significant in assessing the determinants of financial development from the perspective of sustainable development because a strong financial system and execution of policies are equally essential as they serve as tools for promoting a sustainable environment in the economy (D'Orazio & Dirks, 2022; Xie et al., 2024).

Grounded on the research needs, our research attempts to accomplish the following objectives. First, the study aims to investigate the role of climatic policies on financial development in the first model under the influence of greener energies, trade, economic growth, and bureaucratic quality in OECD. Second, the study aims to inspect the role of environmental taxes on financial development alongside the impact of greener energies, trade, Economic Growth, and bureaucratic quality in the second model as described in methodology Sect. 3. The study uses 29 OECD economies, data from 1994 to 2020, and conducts a comprehensive empirical analysis to accomplish these aims. In Fig. 1, the graphical analysis of financial development (FD), environmental taxes (ENT), and environmental policies (ENPO) are presented. The volatility of all three variables can be observed in the figure. The figure illustrates the three variables information of FD, ENT, and ENPO of OECD countries. Among financial development, taxation, and other factors, climate policies are more volatile than environmental taxes in the OECD. Because climatic policies are a multifactored and complex phenomenon and several actors, economic, financial, political, social, etc. impact them. Further, the uncertainty and knowledge gap in the individual while designing policies causes volatility, which can be visually observed in the diagram. Whereas the sample countries have shown significant financial development over the years, as illustrated in the graph below.

The motivation behind conducting this study is based on a few important points.

First, the study is significant in evaluating the influence of climatic policies, green electricity use, governance quality, and environmental regulation on financial development for the first time. Besides, OECD economies regard climate change as an essential issue and a danger to long-term sustainability. Countries like Australia, Canada, and the USA have legislated significant taxes and opted for sustainable practices to resolve these global concerns (Sadik-Zada & Ferrari, 2020). Still, further actions are mandatory to lessen climate change and harmful carbon emissions because the international community struggles to tackle both concurrently. The issue of environmental pollution and a sustainable economy are hot topics for every economy. The role of climatic policies and regulations hasn't been inspected from the perspective of sustainable financial development. Therefore, the study is prominent in investigating the affiliation between climatic policies and environmental regulations on financial development in OECD countries.

Second, carbon taxes and low-cost and energy-saving strategies limit harmful emissions, and a strong financial system plays a significant role in managing taxes and policy implications. Consequently, the present study intends to examine the nexus between environmental policies, regulations, green electricity, and sustainable development to signify the importance of policies and regulations as supplementary contributions to the academic literature. Sustainable development and green economy are two sides of the same coin. We need both simultaneously to achieve climate change goals. Hence, the study findings could be resourceful in overhauling environmental policies for sustainable development because green electricity reduces poverty and endorses development. Therefore, the transition towards green energy via financial development will meaningfully contribute to a sustainable environment.

Our study contributes to the literature in the following ways.

First, the study significantly contributes to the literature by examining the influence of Environmental Policy and Environmental Taxes on financial development in the long term. Previous studies emphasized achieving a sustainable environment (Batten et al., 2016; Doğan et al., 2022; D'Orazio & Dirks, 2022). However, no prior study explored the role of climatic policies and environmental regulations on financial development. The proper implementation of environmental policies and a strong financial system is equally essential

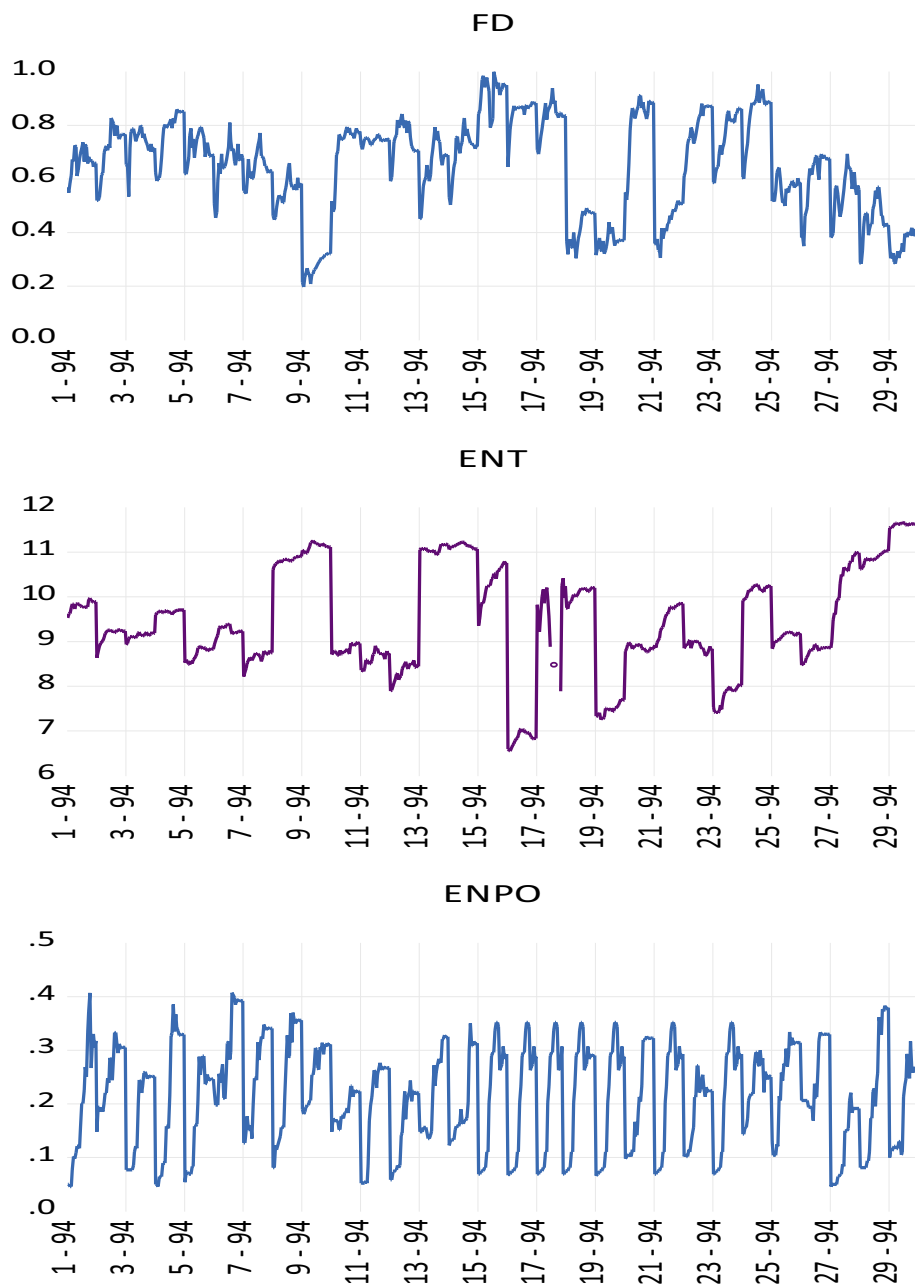


Fig. 1 Graphical presentation of FD, ENT, and ENPO

for sustainability. Besides, climatic policies and environmental regulations are significant tools for a sustainable environment and promoting financial development. A wide range of issues related to pollution can be substantially controlled through the implementation of

environmental taxes. Further, low carbon financing becomes more attractive, which ultimately aids in limiting emissions, as studies like (D’Orazio & Dirks, 2022; Rosiek, 2015; Yang et al., 2022) documented. Therefore, the present study is substantial in contributing to the empirical investigation of climatic policies and environmental regulations for attaining sustainable financial development in the OECD, a new input in the academic literature.

Second, the present study provides an additional share of empirical evidence on the determinants of financial development considering simultaneously green electricity, trade openness, GDP, and Bureaucratic Quality, as the available literature is scarce or has taken financial development as an explanatory factor for environmental development analysis (Doğan et al., 2022; Jakovac et al., 2021; Rafique et al., 2022; Samour et al., 2022; Usman et al., 2022; Zhou & Du, 2021). Since financial development helps in strategizing/financing environmental improvement and sustainable plans. Hence, the current study significantly contributes to the academic literature by examining the determinants of financial development by adding different variables from a sustainable development perspective.

Third, the present study significantly contributes to the empirical literature by investigating the influence of environmental policies and taxes on financial development in OECD economies and how these regulations impact these economies, which is a new input. The study extends the debate by providing a better understanding of environmental policies, taxes, and financial development through evidence-based recommendations. Further, it evaluates the effectiveness of climatic policies in promoting sustainable development in OECD economies in updated data (1994 to 2020) using long-term panel data analysis.

The rest of the study is organized in the following manner. The upcoming section briefs on the relevant literature on the variables under consideration. Section 3 deals with the data and methodology on which the study is based. Section 4 documents the results and discussion segment. Section 5 is about the conclusion and policy implications.

2 Literature review

The present study segment documents the empirical studies on financial development and explanatory variables nexus in the following sub-sections.

2.1 Influence of green energy and economic factors

Renewable financing is imperative to achieve climatic goals (Ahmed et al., 2021). Most of the studies examined the causal impact of financial development (FD) on renewable energy (REN) consumption as a dependent variable. They reported long-run associations between renewable Energy and financial development. For instance, Samour et al. (2022) investigated the positive impact of financial development on renewable energy consumption in the UAE because it averts financial risks and promotes renewable energy consumption in the economy. Similarly, Anton and Nucu (2020) employed panel data analysis to examine the finance-energy nexus. The empirical findings depicted the positive impact of financial development on promoting green and renewable energy consumption. Few recent studies highlighted the nexus between Energy and financial development, such as; Eren et al. (2019); Khan et al., (2020a, 2020b); Shahbaz et al. (2021); Alsagr and van Hemmen (2021), Shahbaz et al. (2022), Ahmad et al. (2023) among others. This study inspected the positive impact of financial development on renewable Energy, running from financial development to renewable Energy, because financial development triggers the demand for

green energy sources such as renewable Energy for a sustainable environment. Therefore, financial development increasingly affects renewable Energy with a causal association. Besides, financial sector development is critical in developing renewable and green Energy for cultivating environmental quality (Qin et al., 2021b; Xie et al., 2024). In contrast, Wang et al. (2021) analyzed the negative influence between financial development and renewable Energy with unidirectional causality flowing from renewable Energy to financial development in China in the long run. While the positive impact is observed in the short run.

In addition, few researchers explored the finance trade nexus, keeping financial development as an explanatory factor. Batten et al. (2016) investigated financial development's positive long-run and short-run influences on international trade in African economies. They demonstrated that when FD interacts with the digital economy, it significantly impacts trade. Thach et al. (2021) examined the ASEAN countries to assess the association between financial development and trade. The empirical findings established a positive and significant link between financial development and the sample countries' trade. In addition, Kim et al. (2010a) examined the negligible to no influence of financial development on Trade in OECD economies.

In contrast, Ibrahim and Sare (2018) analyzed the determinants of FD and found trade openness as a substantial factor in financial development. Earlier, Kim et al. (2010b) also assessed the positive impact of trade on financial development in the long run in 88 world economies. In contrast, a negative association is observed in the short-run analysis. In the case of China, Zhang et al. (2015) inspected the negative effect between financial development and trade as unfavourable in several regions and provinces of China. A significant association between trade policies and regional financial sector development was observed (Wang et al., 2022). Likewise, Ahmed et al. (2022) evaluated the prominent role of trade globalization in the renewable sector and the decarbonizing economy in the G7 economies.

Financial development happens at the expense of deteriorating environmental quality (Javid & Sharif, 2016). Therefore, in a few studies, GDP moderates the positive relationship between financial development and carbon emissions (Acheampong, 2019). In a recent study, Rani et al. (2022) analyzed that financial development substantially impacts the economy's GDP in achieving sustainable economic development. The results depicted a U-shaped relationship between GDP and financial growth. In another study, using GMM panel VAR analysis, Usman et al. (2022) inspected the feedback causal relationship between GDP and FD in 28 EU economies. In the case of China, Hao et al. (2020) investigated the significant association between GDP and FD. The results displayed that FD does not granger cause GDP; however, the impulse response approximations depicted a negative impact of financial development on the GDP of the Chinese economy. Likewise, Jakovac et al. (2021) discovered the adverse effects of FD on GDP in Croatia. In emerging markets, Nguyen et al. (2022) revealed that financial development positively impacts the GDP by paving the way toward progression. The novel studies estimate a positive impact on GDP and financial development in China and India (Lenka & Sharma, 2020; Li & Wei, 2021). Conversely, Ehigiamusoe et al. (2021) examined the positive impact of GDP on financial development in the panel analysis of 125 economies, which was later adversely moderated by inflationary pressure.

2.2 Nexus between bureaucratic quality and financial development

Bureaucratic quality is the proxy for institutional quality in the case of 'Belt and Road Initiative' economies (Islam et al., 2020). Bureaucratic quality is significant in formulating

the financial systems that attract foreign investments and attain sustainable development (Islam et al., 2020). According to Islam et al. (2020), the economy flourishes when the quality of institutions is high. The empirical results depicted financial development with significant interaction of institutional quality aids in economic development because the progression depends on the institution's quality (Kassie, 2021). Similarly, in another study, for the finance and growth nexus, Bureaucratic quality moderates the West African Economies (Olaniyi & Oladeji, 2021). Islam et al. (2020) analyzed that institutional quality plays a moderating role between FD and foreign direct investment in attracting FDI¹ in Belt and Road Initiative (BRI)² economies. Khan et al., (2020a, 2020b) found that bureaucratic quality and financial development show significant associations in 15 EAGLE economies. Moreover, quality institutions, as well as financial growth, significantly enhance environmental quality (Bashir et al., 2023; Qin et al., 2021a).

2.3 Effects of environmental policies and taxes

It has been widely known that financial regulators and institutions actively participate in climate mitigation policies to attain a sustainable environment. Environmentalists and policymakers have emphasized that climate change influences financial progression and regulation, ultimately affecting the global economy (D'Orazio and Dirks, 2022; Batten et al., 2016). According to the IMF, climate policies have a devastating impact on monetary policy; they not only slow down productivity and increase risks but also adversely impact financial institutions. But then again, mobilizing financial resources for climate mitigation and adaptation is a significant aid in improving the environment (IMF, 2019). In the extant body of knowledge, the influence of environmental policies (ENPO) on financial development (FD) is the least discussed area academically and pragmatically. Hence, ENPO has a potential impact on financial development from the sustainable development perspective. However, in a recent analysis of environmental regulations and development, Zhou and Du (2021) observed that environmental policies are affected by the financial developments in the country. Therefore, optimizing environmental policies is necessary to achieve sustainable development goals.

Environmental taxes are one of the potential instruments of environmental policies required for carbon mitigation and enhancing ecological quality (Doğan et al., 2022; Rafique et al., 2022). Similarly, there is limited to no evidence of environmental taxes' impact on financial development as a dependent variable in the prevailing pragmatic literature. Since the relationship between taxes and financial development has been ignored. Nevertheless, Bashir et al. (2020) inspected the negative impact of environmental taxes on environmental quality, stating that they significantly reduce emissions levels and that financial development plays a significant role. Li et al. (2020) explored the influence of environmental taxes and financial development on the green technological development of the Chinese economy. The empirical results demonstrated that climate taxes and financial development significantly improve green tech development.

On the other hand, when the environmental taxes grow stronger, the financial effect begins to differ across regions. Similarly, Khan et al. (2019) examined the impact of

¹ FDI: An investment, corporation, or government from another nation in a foreign enterprise or project.

² BRI: The Belt and Road Initiative, like the Silk Road, would build infrastructure from East Asia to Europe.

environmental taxes on CO₂ emissions and employed financial development as a controlled variable. The empirical findings demonstrated that environmental taxes and financial development are conducive to limiting harmful emission levels. Following these findings, the study of Jiang et al. (2022) demonstrates the importance of environmental R&D in environmental quality along with economic enhancement.

3 Summary and literature gap

Financial development is one of the influential determinants of sustainable development. The expansion of financial systems increases access to credits, enhances productivity, and has a significant part in environmental policymaking that enables the limit of harmful emissions (Alsagr & van Hemmen, 2021; D'Orazio & Dirks, 2022; Javid & Sharif, 2016; Rafique et al., 2022; Shahbaz et al., 2022). The prevalent studies in the available literature ignored the determinants of financial development, such as green electricity, trade openness, GDP, and bureaucratic quality. In the extant literature, quite a few studies assessed the relationships between the factors mentioned above and financial development, but the conclusions are ambiguous. Besides, financial development is employed as an explanatory variable. Therefore, due to the scarcity of empirical evidence considering our research aims, the study focuses on the determinants of financial development alongside the inclusion of two novel variables: environmental policy/policies and environmental taxes in two different specifications. Our study is significant in analyzing the association to cover the gap regarding the role of climate policies, regulations, and green energies on financial development. In this regard, the current research unveiled some novel policies in the context of sustainable development goals and financial development in developed countries.

4 Data and methodology

4.1 Data and modelling

Based on the critical analysis of the literature and the study's objectives, the present research tends to explore the factors affecting financial development (FD)³ in developed economies. In contemporary times, the existing literature asserts that the prime objective of the developed economies is to environmental hazards such as global warming and climate change. Therefore, several environmental sustainability factors are adopted, which could discourage the excessive use of energy-intensive products and services. In this sense, the present study uses environmental policies (ENPO), environmental tax (ENT), and green electricity (REN) in the empirical examination. Besides, to eradicate omitted variable biasedness issues of the estimation process, the present study also included gross domestic product (GDP), trade openness (TO), and bureaucratic quality (BQ) in the study model. Detailed specifications and data sources are now provided in Table 1. Apart from the mentioned variables, this study primarily focuses on the influence of green energies on FD, and the reason behind this is that it substitutes

³ The dataset contains nine indices that summarize how developed financial institutions and financial markets are in terms of their depth, access, and efficiency.

Table 1 Variables specifications and data source

Variable	Specification	Data Source
ENPO	Index based on environmental policies taken from OECD, (2022)	https://stats.oecd.org/
ENT	Constant US\$ 2010, millions	
FD	FD index is constructed via a standard three-step method on reducing multidimensional data into one summary index: (i) normalization of variables; (ii) aggregation of normalized variables into the sub-indices representing a particular functional dimension; and (iii) aggregation of the sub-indices into the final index	https://databank.world-bank.org/source/world-development-indicators#
REN	Percent of total green electricity use	World Bank, (2022)
TO	The ratio of trade to GDP	World Bank, (2022)
GDP	Constant US\$ 2010	World Bank, (2022)
BQ	Index, taken from ICRG, (2022)	https://www.prs-group.com/explore-our-products/icrg/

the negative consequences of traditional fossil fuels with substitutes that are better for the environment. Green energy, which is derived from natural resources, is most often renewable and clean, emitting no or minimal greenhouse gases, and is frequently accessible. Since developed economies are currently massively investing in this sector, these economies must explore its impact on overall financial development. In attaining environmental sustainability, environmental policies, environmental taxes, and bureaucratic quality also have a significant role (Shahzad et al., 2021), which could lead to fluctuations in various economic and financial activities. Hence, these variables could not be ignored in the empirical investigation of factors affecting financial development in the region.

Following the study of Zhou and Du (2021) and Li et al. (2020), the present research constructed the following two models:

Model-1

$$FD_{it} = \beta_0 + \gamma_1 ENPO_{it} + \gamma_2 REN_{it} + \gamma_3 TO_{it} + \gamma_4 GDP_{it} + \gamma_5 BQ_{it} + \varepsilon_{it} \quad (1)$$

From Model 1, it can be noted that FD is the function of ENPO, REN, TO, GDP, and BQ.

Model-2

$$FD_{it} = \beta_0 + \gamma_1 ENT_{it} + \gamma_2 REN_{it} + \gamma_3 TO_{it} + \gamma_4 GDP_{it} + \gamma_5 BQ_{it} + \varepsilon_{it} \quad (2)$$

From Model-2, it can be observed that financial development is the function of environmental taxes, green electricity, trade, GDP, and bureaucratic quality where β 's and γ 's in both the models are the intercepts and slopes, respectively. In addition, the vector ε in both models indicates the error of each model. Besides, the subscript " i " reveals the cross-sections, which is 29 OECD economies, and " t " represents the time period ranging from 1994 to 2020. Since numerous studies in the literature empirically examine various emerging economies, while developed economies, that are playing significant roles in the development of global policies remained out of focus. Therefore, this study particularly focuses on these economies to uncover the discussed and provide relevant and appropriate guidelines

for these economies. The data for the variables under consideration is extracted from different sources. The reason for opting for the two separate models is to avoid the multicollinearity issue as a result of considering both the climate policies and environmental taxes.

4.2 Estimation procedure

Before conducting an empirical inquiry, this research gives descriptive data for each variable being studied. Descriptive statistics are significant since they summarize all the information. The descriptive statistics employed in this instance are the mean value, median, and standard deviation—the divergence of observations from the mean value. In addition, descriptive statistics include the range values, defining the lowest and maximum values for each study variable. Conversely, descriptive statistics also offer the skewness and Kurtosis indices for each variable, which are necessary for examining the normality of data. To study the variables' normality comprehensively, the Jarque–Bera normality test developed by Jarque and Bera (1987) is used as an effective estimator. This test takes into account skewness and excess Kurtosis to determine if a time series is regularly distributed. Further, the test assumes that the skewness and excess Kurtosis equals zero—a null hypothesis. The Jargue-Bera calculation is based on the following formula:

$$JB = \frac{N}{6} \left(S^2 + \frac{(K - 3)^2}{4} \right) \quad (3)$$

where Eq. (3) indicates that JB is the Jargue-Bera statistic(s), N is the number of observations, S represents skewness, and K-3 is the excess Kurtosis.

Interdependence across individual countries is among the most challenging aspects of panel data investigation. This issue is referred to as cross-sectional dependency (CD). Cross-sectional dependence might result in ineffective test statistics as well as erroneous assessments (Wei et al., 2022). The Breusch–Pagan Lagrange multiplier (LM) test, the Pesaran scaled LM test, and the Pesaran CD test are often employed to examine cross-sectional dependence. Breusch–Pagan LM, the Pesaran scaled LM test, and Pesaran CD tests were used to examine cross-sectional dependence in this research. The fundamental hypothesis of the Breusch–Pagan LM test, the Pesaran scaled LM test, and the Pesaran CD test asserted that there is no cross-sectional dependence in the panel economies. However, the significant estimates could lead to the rejection of the null hypothesis.

After examining summary and normality statistics, this study examines the stationarity of each discussed variable. The testing of the unit root is essential for examining long-run predictions. This research utilizes a collection of 'five' unit root estimation methods, comprising Levin et al. (2002), Breitung (2001), Im et al. (1997), ADF-Fisher (Maddala & Wu, 1999), and Phillips and Perron (1988). These tests are applied to levelled and first-differenced data to provide a comprehensive view of stationarity. As the null hypothesis, the preceding tests show the presence of a unit root in the panel variable. In contrast, the null hypothesis may be rejected if statistical data are bigger than their respective critical values at the 1%, 5%, and 10% levels. In order to tackle the heterogeneity and cross-sectional dependence issue, this research also uses the second-generation CIPS test proposed by Pesaran (2007).

The second stage is to conduct panel cointegration tests for all the variables under consideration. In this study, we employed the Johansen-Fisher tests proposed by

Maddala and Wu (1999), which offered two statistics: the Fisher statistical values from the trace test and the Fisher statistical values from the maximum eigenvalue test. In such experiments, the lag order is set from 1 to 3. Concerning the null hypothesis, the test suggests there is no cointegrating link. However, there is at least one concerning the alternative hypothesis. Since this estimator is limited in tackling the issue of heterogeneity and cross-sectional dependence. Therefore, this study also uses the Westerlund (2007) cointegration test to tackle the stated issues.

We employ the quantile regression method pioneered by Koenker and Bassett Jr. (1978) to comprehensively investigate the long-run influence of the study variables on financial development after doing the cross-sectional dependence and cointegration tests. For this reason, since the data under examination follows a non-normal distribution, we employ quantile regression instead of more conventional methods. Furthermore, this approach provides the estimated coefficient at each quantile selected to eliminate the over- and under-estimation biases prevalent in these typical methods. Panel quantile regression offers an informative insight into the investigated components since it considers both individualized and distributional variability (Cheng et al., 2019). Quantile regression also has more predictive power than the more common linear regression, which only provides an average effect of errors (Qin et al., 2021a). The above-mentioned estimator is also helpful because of its efficiency in dealing with the cross-sectional dependency issue (Amin et al., 2020). Panel quantile regression forms (Eqs. (4) and (5)) may be derived from the previously mentioned regression equations (Eqs. (1) and (2)).

$$Q_{FD_{it}}(\theta|\alpha_i, \varphi_t, X_{it}) = \alpha_i + \varphi_t + \varphi_{1,\theta}ENPO_{it} + \varphi_{2,\theta}REN_{it} + \varphi_{3,\theta}TO_{it} + \varphi_{4,\theta}GDP_{it} + \varphi_{5,\theta}BQ_{it} + \varepsilon_{it} \quad (4)$$

$$Q_{FD_{it}}(\theta|\alpha_i, \varphi_t, X_{it}) = \alpha_i + \varphi_t + \varphi_{1,\theta}ENT_{it} + \varphi_{2,\theta}REN_{it} + \varphi_{3,\theta}TO_{it} + \varphi_{4,\theta}GDP_{it} + \varphi_{5,\theta}BQ_{it} + \varepsilon_{it} \quad (5)$$

Here, θ in both equations is used for four quantiles (Q25, Q50, Q75, and Q90) to empirically assess the impact of environmental policies, green electricity, trade openness, and institutional quality on financial development in empirical models.

Apart from the primary estimators, this study also tested the robustness of both models. In this sense, this study uses robust regression to analyze the average impact of each explanatory variable on financial development. Traditional linear regression has various shortcomings that robust regression attempts to address. Ordinary least squares regression and other common forms of regressions offer valuable qualities provided their underlying assumptions hold. Still, they may produce inaccurate results (i.e., are not robust for the assumption violation). The goal of robust regression techniques is to mitigate the impact of processing assumptions being broken by the underlying data generation mechanism on the regression estimations.

5 Empirical results and discussions

This segment discusses the estimated results from the methodology described in the previous section. The results are illustrated in the respective tables with their graphical representation.

Table 2 Descriptive and normality analysis

Specification	FD	ENPO	REN	TO	GDP	BQ	ENT
Mean	0.650	2.162	63.72	87.400	10.384	3.569	9.467
Median	0.682	2.240	27.95	69.653	10.567	4.000	9.223
Maximum	1.000	4.070	749.379	416.389	11.625	4.000	11.662
Minimum	0.197	0.460	0.101	16.104	8.719	2.000	6.550
Std. Dev	0.179	0.947	106.863	57.790	0.641	0.571	1.170
Skewness	-0.455	-0.165	3.061	2.507	-0.610	-0.933	-0.092
Kurtosis	2.311	1.866	13.223	11.785	2.663	2.759	2.473
Jarque–Bera	39.409	42.091	4289.582	3091.290	48.489	106.941	9.310
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.009

5.1 Pre-estimation diagnostics

Starting with descriptive statistics of the data under consideration. In Table 2, the descriptive and normality analyses are presented. The mean values are nearly identical to the median values. The similarity between both statistics showed the balancing point of the information. They are leading to the standard deviation statistics illustrating data spread from the mean values. The skewness statistics of green electricity and trade show that the variable is positively skewed, while the remaining variables show negative skewness. Coming towards the Kurtosis analysis, the findings of the variables depict the peakedness of data, such that the variables follow the non-normal distribution as they are less or greater than 3. The Jarque Bera and probability statistics confirm the non-normal distributions. The overall analysis shows that the data is non-normal with skewed distribution.

5.2 Cross-section dependence analysis

Table 3 employs the residual cross-section dependence test after successful descriptive stats. Breusch-Pagan LM, Pesaran scaled LM, and Pesaran cross-sectional dependence tests are applied to examine dependence analysis. The results show significant values at a 1% level of significance in all applied tests, which can be shown in the table. The general interpretation of the results demonstrates the existence of underlying factors that impact the economies and influence during the estimation analysis and cause significant cross-sectional dependence across the panel. Thus, all factors in the cross-section are correlated. The study panel indicates that financial development, climate policies, taxes, green energies, economic growth, and trade are correlated with each other.

5.3 Unit root test

Now comes the unit root analysis, the results of which are illustrated in Table 4 below. The panel unit root summary of all variables at level $I(0)$ and the first difference $I(1)$ are presented. At this level, bureaucratic quality and trade showed significant values in all tests, while others showed significant and insignificant results. At first difference $I(1)$, all variables gave significant outcomes at a 1% significance level in all tests. The results reject the null hypothesis of no stationarity and show a strong presence of unit roots. After executing panel stationarity results, we move toward cointegration analysis for long-run associations

Table 3 Residual cross-section dependence test

Test	Statistic	Prob
Breusch-Pagan LM	2189.100***	0.0000
Pesaran scaled LM	62.57454***	0.0000
Pesaran CD	22.86190***	0.0000

The significance level is denoted by *** for 1%, ** for 5%, and * for 10%

between the variables under study. In order to tackle the issue of heterogeneity and cross-sectional dependence, this research uses the second-generation CIPS (Pesaran, 2007) test and the results asserted that all the variables are highly stationary at $I(1)$, which allows this research to analyze the long-run equilibrium relationship.

5.4 Cointegration analysis

The cointegration analysis is applied in both Models (1&2). Johansen Fisher Panel Cointegration Test is used for this purpose. There are significant results in both models 1 and 2, thereby rejecting the null hypothesis of 'no' long-run relationship. The analysis demonstrates that climate policies, green energies, economic growth, trade, and environmental taxes have significant long-run relationships with financial development in the case of 29 OECD economies from 1994 to 2020. This led us to employ regression analysis to analyze the association between the dependent and independent variables of the research. The results of the cointegration test are displayed in Table 5 in this section. Concerning the second-generation test, this research uses the Westerlund (2007) ECM test and the results are reported in the under-discussion table. It can be observed that both the models exhibit a significant cointegration in the long-run while accounting for the heterogeneity and cross-sectional dependence.

5.5 Quantile regressions

Quantile regressions provide reliable estimates of the non-normal linear information (Koenker and Bassett, 1978). Table 6 shows the quantile estimates of Model 1, and Table 7 shows estimates of Model 2. First, green electricity, trade, and bureaucratic quality depicted significant results in all quantiles. However, green electricity showed adverse effects at first, consistent with Wang, Zhang, and Zhang (2021), and then became positively associated with financial development in the last quantiles. They indicate asymmetric associations in Model 1. Trade is positively related to economic development, depicting their increasing relationship. Trade openness promotes significant financial development. Bureaucratic quality is negatively related to financial development in Model 1, indicating that increasing bureaucratic quality will decrease the financial effect in OECD countries. Then, GDP is positively associated with financial development in all quantiles, demonstrating economic growth's positive and increasing impact on financial development. Finally, environmental policies are positively but insignificantly related to financial development in maximum quantiles, indicating that increasing climate policies is resourceful in promoting financial growth in the sample

Table 4 Unit root empirics

Variable	Levin, Lin & Chu t*	Breitung t-stat	Im, Pesaran and Shin W-stat	ADF—Fisher Chi-square	PP—Fisher Chi-square	CIPS I(0)
Panel Unit Root Summary [I(0)]						2nd Gen Test
FD	-4.782***	0.229	-2.775***	87.783***	323.567***	-2.906***
ENPO	2.874	-1.476*	3.800	24.093	26.608	-3.027***
ENT	-2.836***	0.419	-1.438*	74.561*	92.254***	-2.834***
REN	0.793	7.488	2.640	51.350	85.889**	-3.146***
TO	-3.935***	-5.552***	-3.667***	101.098***	94.397***	-2.199
GDP	-2.824***	3.118	1.365	47.614	24.844	-1.994
BQ	-4.247***	-1.351*	-4.670***	65.396***	42.005**	-1.102
Panel Unit Root Summary [I(1)]						I(1)
FD	-5.307***	-11.361***	-9.872***	200.186***	436.813***	-5.198***
ENPO	-4.894***	-12.598***	-8.434***	175.117***	390.057***	-5.338***
ENT	-10.086***	-9.322***	-9.373***	193.943***	558.720***	-4.732***
REN	-8.992***	-4.361***	-12.090***	251.340***	2477.30***	-5.354***
TO	-13.439***	-15.301***	-11.477***	229.386***	1201.34***	-4.218***
GDP	-10.530***	-11.276***	-8.791***	180.714***	313.604***	-3.284***
BQ	-16.087***	-6.964***	-13.432***	203.462***	441.079***	-2.783**

The significance level is denoted by *** for 1%, ** for 5%, and * for 10%

economies. Despite the specific influence of each regressor, it can be observed that the magnitude of the influence of ENPO and REN is increasing from lower to upper quantile, while reduces for the TO, GDP, and BQ. The overall, interpretation of Model 1, demonstrates that environmental policies, green electricity, and trade are essential determinants that promote financial development. The graphical presentation of all variables' quantile coefficients is displayed in Fig. 1 below. The graphs show explanatory variables' positive and negative impacts on financial development, as described earlier.

In Model 2, bureaucratic quality shows significant but negative results in all quantiles, indicating the negative impact of bureaucratic quality on financial development. Environmental taxes, green electricity, and GDP illustrated effective results in maximum quantiles. Environmental taxes are negatively associated with economic development in all quantiles. They are indicating that an increase in ecological taxes decreases financial development. In a more recent study, Doğan et al. (2022) argued that environmental taxes reduce carbon emissions, energy use, and natural resources in G7 economies. In addition, green electricity is positively associated with financial development under environmental taxes in maximum quantiles. The results further show that GDP is positively related to financial development, displaying a positive connection between financial development and economic growth in all quantiles. Lastly, trade positively impacts the financial development of the sample economies in all quantiles. Regarding the magnitude of the variables across quantiles, it must be noted that the coefficients' magnitude for REN and TO is increasing from lower to upper quantiles, while reduces for ENT, GDP, and BQ. The general interpretation of Model 2 demonstrates that economic growth and trade openness are essential determinants that promote financial development in OECD economies. The graphical illustration of positive and negative associations of environmental taxes, green electricity, trade openness, and bureaucratic quality with financial products is presented in Fig. 2 as interpreted above.

Table 5 Cointegration test

Johansen Fisher Panel Cointegration Test (Model-1)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob	Fisher Stat.* (from the max-eigen test)	Prob
None	442.7***	0.0000	262.9***	0.0000
At most 1	218.6***	0.0000	119.6***	0.0000
At most 2	121.9***	0.0000	73.42***	0.0000
At most 3	69.13***	0.0000	44.74***	0.0063
At most 4	44.37***	0.0069	34.91*	0.0698
At most 5	48.76***	0.0020	48.76***	0.0020

Westerlund (2007) ECM

Stats	Value	Prob
G_t	-4.487***	0.000
G_a	-20.093***	0.000
P_t	-15.155***	0.000
P_a	-20.803***	0.000

Model-2

None	469.4***	0.0000	282.3***	0.0000
At most 1	216.0***	0.0000	126.8***	0.0000
At most 2	111.2***	0.0000	73.56***	0.0000
At most 3	56.45***	0.0001	40.12**	0.0105
At most 4	35.09**	0.0379	25.73	0.2633
At most 5	38.89**	0.0145	38.89**	0.0145

Westerlund (2007) ECM

Stats	Value	Prob
G_t	-3.579***	0.000
G_a	-16.093***	0.000
P_t	-11.155***	0.000
P_a	-17.803***	0.000

The significance level is denoted by *** for 1%, ** for 5%, and * for 10%.

Combining the results of both Models 1 and 2, the regression results are consistent with the following strands of literature. First, green electricity showed a negative and positive relationship with financial development which is consistent with the findings of (Wang, Zhang, and Zhang, 2021; Samour et al., 2022). However, the result is novel, considering financial development as a dependent variable. Second, trade mentioned positive associations with economic development in both Models, in line with the relationship described by Daniel, (2021), ignoring the direction of the results. Third, GDP demonstrated a positive impact on financial development, which is also consistent with the findings of (Ehigiamusoe et al., 2021). Fourth, bureaucratic quality is negatively associated with economic development in both Models, a novel contribution to the prevailing literature. Similarly, environmental taxes and climate change policies negatively and positively impacted financial

Table 6 Quantile estimates (Model-1)

Variable	Q0.25	Q0.50	Q0.75	Q0.90
ENPO	-0.071 (0.083)	0.102 (0.088)	0.067 (0.074)	0.018 (0.089)
REN	-0.019** (0.008)	-0.027*** (0.007)	0.027*** (0.006)	0.013* (0.007)
TO	0.111*** (0.014)	0.088*** (0.010)	0.061*** (0.008)	0.021** (0.008)
GDP	0.130*** (0.018)	0.031 (0.021)	0.011 (0.017)	0.042*** (0.010)
BQ	-0.168*** (0.014)	-0.096*** (0.022)	-0.083*** (0.023)	-0.132*** (0.025)
Constant	-0.301** (0.152)	0.588*** (0.159)	0.864*** (0.125)	0.847*** (0.094)

The significance level is denoted by *** for 1%, ** for 5%, and * for 10%. The parenthesis shows the standard error value

Table 7 Quantile estimates (Model-2)

Variable	Q0.25	Q0.50	Q0.75	Q0.90
ENT	-0.084*** (0.009)	-0.076*** (0.012)	-0.026 (0.016)	-0.007 (0.012)
REN	0.853 (0.574)	-0.569 (0.659)	3.321*** (0.632)	1.368** (0.610)
TO	0.764 (1.361)	0.323 (1.555)	3.495* (1.899)	1.147 (1.470)
GDP	0.172*** (0.015)	0.081*** (0.022)	0.018 (0.014)	0.045*** (0.010)
BQ	-0.226*** (0.016)	-0.156*** (0.020)	-0.076*** (0.019)	-0.127*** (0.020)
C	0.342*** (0.131)	1.081*** (0.169)	1.046*** (0.172)	0.867*** (0.172)

The significance level is denoted by *** for 1%, ** for 5%, and * for 10%

development in the OECD economies. These significantly contribute to the empirical literature on sustainability because no study has traced the relationships (Fig. 3).

5.6 Robustness check

After regression scrutiny, we applied robustness analysis, and the results are displayed in Tables 8 and 9 for Model 1 and Model 2, respectively. Except for climate policies and green electricity in Model 1, all variables show significant results demonstrating reliable results at a 1% level of significance. in Model 2, all variables show substantial outcomes illustrating reliable results except for green electricity.

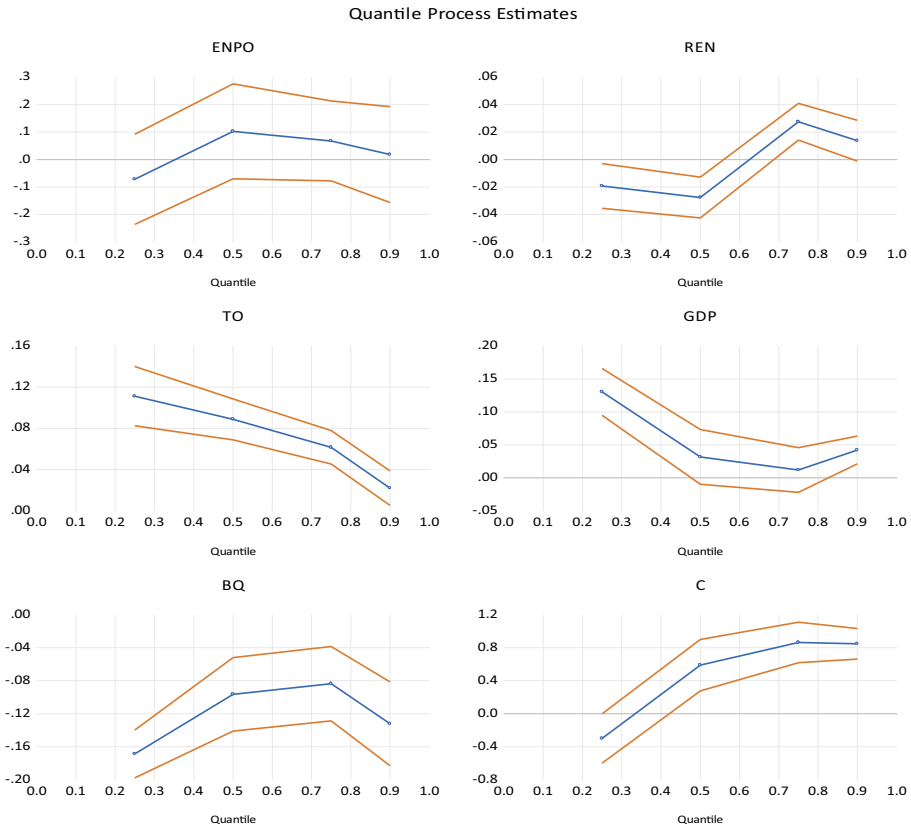


Fig. 2 Graphical representation of quantile coefficients model 1

5.7 Discussion of findings

The determinants of financial development have shown asymmetric responses through Quantile regressions such as the prevailing studies have shown heterogeneous affiliations between financial development, green Energy, economic growth, taxes, and environmental quality (D’Orazio & Dirks, 2022; Halliru et al., 2020; Saqib et al., 2024; Sharif et al., 2020). However, the following literature backed these results by providing insights into the relationship between the dependent and independent study factors (Wang, Zhang, and Zhang, 2021; Samour et al., 2022; Ehigiamusoe et al., 2021). The study delivers novel findings on the determinants of financial development in OECD economies. Starting with the signs of the coefficients in quantile regressions, green electricity has shown asymmetric associations with financial effect in Model 1.

Notably, the current study endorses the narrative of Makhdum et al. (2022) and Usman and Balsalobre-Lorente (2022), as they also mentioned institutional quality, financial development, and greener energy factors are significant to containing the pollution level. It can be inferred that in the initial stages of progression, green electricity negatively influences financial development due to increasing costs and later becomes positive and significantly promotes financial development. However, a positive association is observed in model 2,

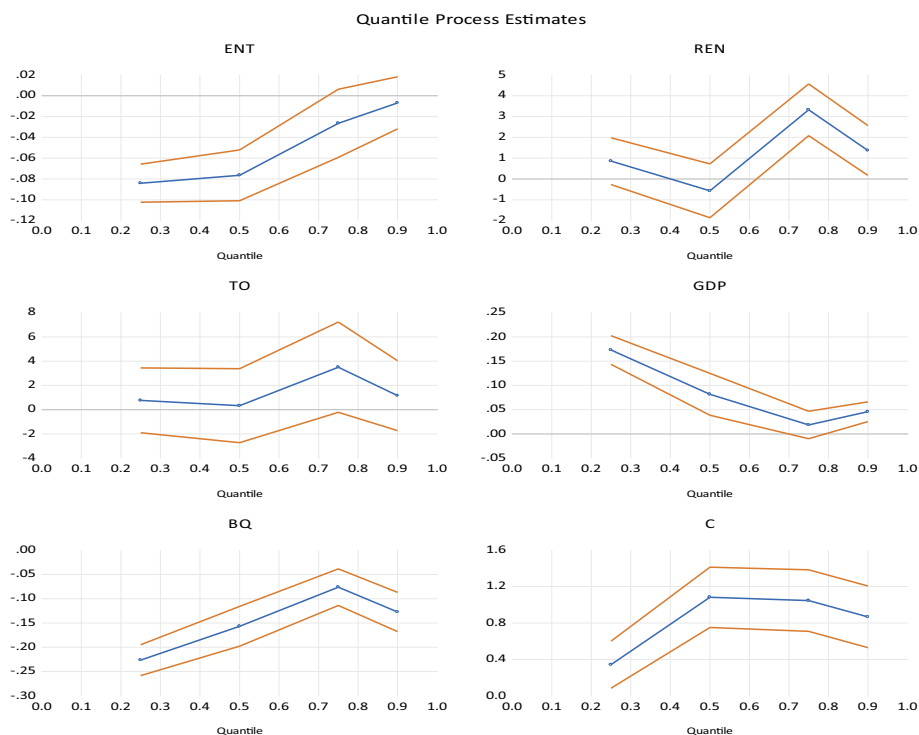


Fig. 3 Graphical representation of quantile coefficients model 2

Table 8 Robustness test (Model-1)

Robust regression				
Variable	Coefficient	Std. Error	z-Statistic	Prob
ENPO	0.116	0.072	1.599	0.109
REN	-0.688	0.675	-1.018	0.308
TO	0.097***	0.012	7.771	0.000
GDP	0.058***	0.016	3.563	0.004
BQ	-0.130***	0.016	-7.695	0.000
C	0.407***	0.125	3.260	0.001

The significance level is denoted by *** for 1%, ** for 5%, and * for 10%

so it can be implied that green energies stimulate financial development by creating new businesses and investment opportunities for a higher level of low-carbon financing in the OECD. Therefore, for long-term progression, green electricity is necessary. The nexus outcome relates to SDG 7 of affordable and sustainable Energy for all. The coefficients of economic growth and trade on financial development are positive.

Table 9 Robustness test (Model-2)

Robust regression				
Variable	Coefficient	Std. Error	z-Statistic	Prob
ENT	-0.054***	0.007	-7.676	0.000
REN	0.877	0.674	1.301	0.192
TO	0.038***	0.014	2.701	0.006
GDP	0.106***	0.015	7.000	0.000
BQ	-0.172***	0.016	-10.551	0.000
C	0.632***	0.129	4.885	0.000

The significance level is denoted by *** for 1%, ** for 5%, and * for 10%

Simply put, it depicts that higher economic growth expands the financial access for sustainable financial expansion during the study period. As well as trade openness is crucial for achieving financial development as it will attract foreign investments and international market access, ultimately benefiting economic sustainability and growth. The role of Bureaucratic quality in the present study is negative on financial development. This signifies a need to improve the quality of the institutions in the OECD economies for a prosperous economy because good governance and quality institutions are essential elements of a sustainable economy. Poor bureaucratic quality delays government approval for licenses and permits in businesses and creates financial risks besides discouraging investment in the economy, which harms economic development.

Environmental policies improve environmental quality and help combat climate change, implying that a sustainable environment promotes financial growth. Further, the sign of ecological policies on financial development exhibited a positive impact in promoting financial development. It can be inferred that if sustainable finance is fruitful in limiting pollution, then the significant influence of environmental policies helps promote economic development because optimizing environmental policies is obligatory for sustainability. The positive impact of climatic policies suggests that the negative externalities of the environment are reduced due to effective policies, and energy efficiency and sustainable development are promoted. This is a significant contribution to the empirical literature on sustainability and relates to SDG 13 of climatic sustainability. Lastly, the impact of environmental taxes on financial development is inversely related, indicating poor tax reforms during the study period in OECD economies. This implies that inadequate tax reforms lessen government revenues and undermine fiscal stability, significantly affecting economic and financial development.

The general points inferred from the study are the economies need significant climatic policies for sustainable development environmentally and financially. Implementing green energy and climatic policies is crucial for attaining sustainable goals. Economic productivity, considering green and efficient energies, contributes to sustainable development. Since trade attracts investments, trade openness can be regarded as a tool for promoting sustainable finance to mitigate environmental degradation. Hence, environmental and economic policymakers must consider the importance of green electricity, trade, and environmental regulations for sustainable development.

6 Conclusion and policy implications

The study's primary objective was to investigate the role of environmental policies and taxes on financial development in OECD economies from 1994 to 2020. We started with descriptive statistics, which showed non-normal information to execute the aims. Then, cross-sectional analysis and unit root tests are applied to examine the cross-sectional dependence and stationarity of the data. Upon this, we performed the cointegration analysis to move toward regression approximations. After confirmation of long-run relationships, Quantile regressions for panel data are applied due to information asymmetry and non-linearity.

First, Green electricity showed a negative influence initially, then a positive relationship with financial development, suggesting the costs must be high, negatively affecting the development and investment initially. Later, the infrastructure and green progression positively contributed to the financial economy. However, the result is novel, considering financial development as a dependent variable. Second, Trade and economic growth are positively associated with financial development in both Models. Such findings imply that higher economic growth and trade expand financial access nationally and internationally, ultimately benefiting economic growth. Third, bureaucratic quality is negatively related to financial development in both Models, a novel input in the empirical body of knowledge. The negative association indicates poor institutional quality during the sample period. Fourth, environmental policies are significant in promoting financial development because optimizing environmental policies is obligatory for sustainability.

Meanwhile, ecological taxes and policies negatively and positively impacted financial development in the OECD economies, respectively. Meanwhile, the impact of environmental taxes on financial development is adversely related during the study period, indicating poor economic tax reform systems. The nexus between climatic policies and taxes with economic development is a novel practical contribution in the context of a sustainable environment.

Therefore, the following policy insights can be implied for the improvement of financial development in the region:

Green electricity is resourceful in promoting environmental sustainability. Therefore, the transition towards renewable Energy and green electricity requires financial solid systems for businesses to have easy financial access and contribute towards a sustainable environment. The endorsement of tariffs and subsidies by governmental institutions increases investments in green and renewable Energy. Besides, private and public green investment projects must be initiated to attain climate targets. International financial institutions and markets can play a crucial role as they provide financial protection via insurance companies or any other risk-managing mechanisms. Collaborations or partnerships with the World Bank and other international organizations help promote green projects.

Moreover, transparency and efficient bureaucratic quality help promote the financial sector. Meanwhile, the financial sector further coordinates the supply of finance for environmental regulation and the execution of ecological policies. Here, the negative association indicates the poor quality of institutions. Therefore, a strong foundation of institutions is necessary for sustainability. Inadequate policies hamper the growth and progression of the economy. Therefore, proper and efficient climate policies related to financial development, resource management, and environmental reforms are needed since the enhanced bureaucratic quality attracts businesses and promotes the business environment. These

sample economies need to revamp their economic policies and adopt those policies that will increase economic productivity and be fruitful for financial development.

Additionally, trade openness increases economic progression, which is beneficial for financial development through increasing financial market depth, which is significant in boosting any economy. Therefore, international trade must be promoted to attract foreign investment. Besides, upgrading technological advancements and utilizing those innovations for environmental regulations can reduce environmental degradation.

6.1 Limitations and future prospects

The prior literature hasn't focused on the present study determinants of financial development. Thus, this study provides additional practical evidence for a relative analysis of climatic policy revamping. The study is significant in assessing the complex relationship between climatic policies and regulations on financial development. The interaction of variables may vary from country to country. However, the study is restricted to the 29 OECD economies with a limited data period, and data is extracted from different institutions, so there might be chances of measurement uncertainties. Hence, examining the study variables on other economies, such as developed and developing economies, is suggested for a comprehensive view of evidence-based environmental policies. In addition, the present research can be extended for the identification of other financial and economic sectors development, including foreign direct investment, green economic growth, and trade openness. This will describe a more exclusive impact of climatic policies and taxes on the overall sustainable development. Besides, helping policy enthusiasts with effective policy outlines based on study findings. Secondly, including other variables besides these study factors would benefit a detailed financial sustainability analysis. Therefore, the role of technological innovation and green innovation should be considered in future research targeting financial development. Lastly, the present explanatory factors can be assessed on different financial indicators for in-depth analysis and would be a novel contribution to the pragmatic literature.

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Data availability Data are available upon request from the first or corresponding author.

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