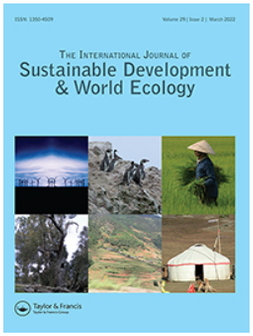

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The criticality of financial development and energy consumption for environmental sustainability in OECD countries: Evidence from dynamic panel analysis

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ABSTRACT

This study explored whether financial development and energy consumption affect environmental sustainability in Organization for Economic Cooperation and Development (OECD) countries. The empirical evidence used in this study was based on the standard fixed effects and the Arellano-Bover/Bundell Bond dynamic panel approach. Our empirical results demonstrated the importance of a financial development index and energy efficiency for reducing carbon emissions and promoting sustainability in the OECD. The mechanism through which financial development affects carbon emissions has been identified as energy consumption and foreign direct investment. Our study recommends that financial development be prioritised alongside investments in energy efficiency to promote environmental sustainability.

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Financial Development Index; Energy Consumption; Environmental Quality; Dynamic Panel Analysis; OECD Countries

1. Introduction

For decades, financial development has contributed substantially to investment opportunities in Organisation for Economic Co-operation and Development (OECD) (Lee et al. 2015; Madsen et al. 2018; Baloch et al. 2021). Furthermore, the increase in financial development has improved the economic performance of nearly all OECD members. However, the rise in financial development has also resulted in a steady rise in energy demand, raising environmental concerns among OECD countries. Therefore, this study examined the mechanism through which financial development affects carbon emissions, with the hope of providing new information that will help promote environmental sustainability.

Several factors justify the choice of OECD countries as potential candidates for this study. First, infrastructure scarcity is seen as a major environmental challenge in OECD countries. As a result, it is crucial to consider the link between financial development and carbon emissions, as this may lead to a solution to the problem and a direction toward more sustainable futures (Roller and Waverman 2001; Madsen et al. 2018; Shobande 2021a). Second, rapid population growth in the OECD has led to increased energy consumption, resulting in an increase in carbon emissions. Hence, it is uncertain whether fostering financial development will help OECD countries achieve a more sustainable future.

In the recent literature, it has been demonstrated that financial development can affect carbon emissions in a variety of ways. First, energy consumption has been identified as a mechanism through which financial development can influence the environment (Shobande and Shodipe 2019; Ozcan et al. 2020; Shobande 2020; Baloch et al. 2021). This is because financial development encourages investments in environmentally sustainable technologies and helps reduce carbon emissions. For example, the production of energy-saving appliances in homes can promote energy efficiency and sustainability (Karanfil 2009; Shobande and Ogbeifun 2021). However, financial development can also attract investments that increase energy consumption and thus have a negative effect on the environment. Second, an increase in trade flows has been identified as a potential mediating role between financial development and carbon emissions (Mujtaba and Shahzad 2021). For example, trade can trigger investment in green technology, which can help foster environmental sustainability. Third, foreign direct investment (FDI) can affect the environment. For example, FDI may also facilitate the exchange of information and expertise needed to enhance environmental quality through green technologies (Pantelopoulos 2021; Ahmad et al. 2021). Finally, the level of economic activity encouraged by financial development can influence the level of carbon emissions. This is the case when an increase in productivity through a spike in manufacturing activities increases emissions through waste disposal and the nature of the technology used.

This study makes four important contributions to existing literature. First, prior studies are limited to small countries. while the current analysis examines

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data from 24 OECD countries spanning 40 years. Second, prior studies inappropriately proxied financial development with financial access, but we correct this notion by using the financial development index. Third, our study makes important methodological contributions following the dynamic panel econometric approach proposed by Arellano-Bover/Bundell Bond to correct for potential endogeneity and measurement error. Our findings highlight the importance of financial development and energy consumption in promoting environmental sustainability. Similarly, we identified the potential mechanism through which financial development affects carbon emissions in OECD countries.

The remainder of this paper is organised as follows. Section 2 presents a brief literature review on the link between financial development and carbon emissions and the research question addressed in this study. Section 3 presents the data sources and descriptions of the variables. Section 4 presents the empirical results and discussion of the findings, while Section 5 concludes the paper with policy implications.

2. Literature review

This section presents a brief literature review of the study. It contains the theoretical framework, empirical literature and research questions the study seeks to address.

2.1 Theoretical framework

The economic insight explaining the link between financial development and the environment was established in the Environmental Kuznets Curve (EKC) proposed by Grossman and Krueger (1995). The original theory notes that economic growth is initially followed by environmental deterioration; however, as the economy exceeds a certain level of *per capita* income, environmental quality improves (Shobande and Enemona 2021; Shobande 2021a). While the EKC hypothesis has ignited a significant volume of empirical study, critics argue that it ignores the potential role of financial development in improving environmental quality (Shobande 2021b). Tamazian et al. (2009) suggested that a stable financial market has the ability to fund clean energy, which would be beneficial for the environment. Similarly, some studies have argued that the stock market will assist in environmental protection by providing financial access, lowering manufacturing costs, expanding financial networks, and mobilising the capital required to invest in environmentally sustainable infrastructure and ensure long-term viability. Some studies have shown that financial development can attract foreign direct investment and bring about the innovative research required to improve the environment (Frankel and Romer 1999; Shobande 2021a). Zhang (2011) argued that financial development can aid investment in energy conservation technology which can help promote environmental quality. In contrast, some studies have warned that increased financial development could lead to increased carbon emissions (Sadorsky 2010; Zhang 2011; Shobande and Shodipe 2019). Sadorsky (2010) argued that a sound financial system can help promote investment but can have adverse effects on the environment through an increase in energy use.

2.2 Empirical evidence

This section summarises empirical evidence on the relationship between financial development and carbon emissions, as well as the mechanisms that underpin it.

2.2.1 Related work

Financial development and carbon emissions

The results of research into the relationship between financial development and carbon emissions have remained mixed and inconsistent. For examples, a study by Vo and Zaman (2020) investigated the impact of energy demand on carbon emissions in the mediation of financial development across 101 countries for the period 1995 to 2018. The authors employed the generalised method of moments (GMM) and reported that financial development reduced carbon emissions in all countries studied. Zaidi et al. (2019) examined the dynamic linkages between financial development and carbon emissions for Asian Pacific Economic Cooperation countries between 1990 and 2016 using Westerlund cointegration techniques and a continuously updated bias-corrected approach. This study demonstrated that financial development significantly reduced carbon emissions. Piñeiro Chousa et al. (2017) investigated the linkages between financial development and environmental degradation for Brazil, Russia, Indonesia, and China (BRICs) for the period 1992 to 2004 and reported that financial development decreased environmental degradation. Tamazian et al. (2009) reported a negative relationship between financial development and carbon emissions for BRICs. Boutabba (2014) reported a positive contribution of financial development to environmental degradation in India. Shahbaz et al. (2016) investigated the asymmetric impact of financial development on environmental quality in Pakistan and reported that financial development degraded the environment.

Ozturk and Acaravci (2013) examined the causal link between financial development, trade, and carbon emissions in Turkey between 1960 and 2007 and found that financial development had no

significant effect on carbon emissions in the long run. Using a vector autoregressive model, Ziaei (2015) examined the link between financial development, energy consumption, and carbon emissions across 13 European and 12 East Asian and Oceania countries for the period 1989 to 2011 and reported that the stock market influenced energy consumption and affected the environment. Adams and Klobodu (2018) examined the determinants of environmental degradation with a bias toward financial development and reported that financial access is an important factor for carbon reduction in Africa. Rjoub et al. (2021) examined the moderating role of financial development in the determinants of carbon emissions using the Bayer and Hanck cointegration and canonical cointegrating regression and reported that financial development can promote environmental sustainability in Turkey. Usman et al. (2021) examined whether financial inclusion can explain ecological footprints in 15 of the highest-emitting countries using the augmented mean group approach and reported that financial development and renewable energy contributed significantly to environmental degradation. Khan et al. (2021) examined the impact of financial development and energy consumption on carbon emissions for 128 countries, between 1990 and 2017, using seemingly unrelated regression and GMM and reported that financial development positively impacted carbon emissions. Lv and Li (2021) investigated the spatial effects of financial development on carbon emissions across 97 countries, from 2000 to 2014, and reported that financial development has a negative effect on carbon emissions. Tahir et al. (2021) examined the impact of financial development on environmental quality in South Asian economies from 1990 to 2014 and reported that financial development contributed to carbon emissions.

2.2.2 Energy and carbon emissions nexus

Several studies have investigated the mediating role of energy consumption on finance-carbon emissions nexus with mixed evidence. For example, Karanfil (2009) shows that financial development can help reduce energy consumption. and promote sustainability. Kahouli (2017) examined the short and long run causality between energy consumption and financial development and reported that financial development unidirectionally Granger cause energy consumption. Alexander et al. (2019) argues that financial development can promote investment in green technology that can contribute to environmental sustainability. Using Autoregressive Distributed Lag Model, Jalil and Feridun (2011) examined the impact of financial development, economic growth and energy consumption in China for the period of 1953 to 2006 and reported that a financial development reduced environmental pollution. Shen et al. (2021) examined the potential of financial development for carbon emissions with mediating role of green investment and reported that financial development positively impacts on carbon emission through energy consumption. Al-Mulali and Sab (2012) investigate the impact of energy consumption on carbon emission with mediating role of financial development from 1980 to 2008 and reported that financial development encourage investment in energy saving projects and reduce potential threat to the environment. Islam et al. (2013) examined the financial and energy consumption nexus for Malaysia using a multivariate time series analysis and reported that consumption impacts on financial development both in the long and short run. Baloch et al. (2021) model the dynamic linkages between financial development, energy consumption, innovation and environmental degradation in OECD for the period 1990 to 2017 and reported that financial development tends to encourage energy innovation while also enhancing environmental quality. Ozcan et al. (2020) explores the dynamic of energy consumption, economic growth and environmental degradation for a panel of 35 OECD countries for the period 2000–2014 and reported that economic growth and energy use tend to be leading factors in environmental degradation in OECD countries.

Following the review, three major issues contribute to the lack of agreement among studies. The first is the use of inappropriate proxies for financial development, which leads to discrepancies in the reported results. The second is failure to identify the associated mechanism by which financial development can affect the environment. The third is a lack of endogeneity control, which contributes to reverse causality, sample bias, and measurement error.

2.3 Research questions

Based on our literature review, the following research questions were explored in this study.

Question 1

Is there a relationship between financial development index and carbon emissions in the OECD?

Question 2

What role does energy consumption have in explaining links between financial development index and carbon emissions in the OECD?

The answers to these research questions are crucial for OECD countries in several ways. (a) The research questions may aid in the formulation of financial incentives for OECD members to fix current infrastructure deficits, which may aid the promotion of a low-carbon economy; (b) addressing the second question can encourage OECD countries to invest in

energy-saving technologies to reduce carbon emissions.

3. Data and methodology

3.1 Data

Our dataset covers the period of 40 years from 1980 to 2019 for 24 OECD countries, i.e., Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Turkey, the United Kingdom, and the United States. Following Shobande (2020), CO_2 emission data were obtained from the OECD statistics database.

A vast body of literature estimates financial development's impact on growth, inequality, and stability. These studies often proxy financial development with stock market capitalization to GDP or the ratio of private credit to GDP–the two commonly used measures for financial depth. However, these measures do not take into consideration the complex multidimensional nature of financial development. To correct this omission, this study uses the financial development index (FD) developed by the International Monetary Fund (IMF) to capture the role of financial development for carbon emissions. Trade openness (exports plus imports as a percentage of GDP) and energy consumption (using energy use as proxy) were sourced from WDI. Data on per capita income (using GDP per capita as a proxy), inflation (consumer price index), and unit labor cost were derived from the OECD statistics, whereas the human development index (HDI) is sourced from UNESCO Institute for Statistics. In line with existing literature (Ogbeifun and Shobande 2020, 2021), foreign direct investment inflows were sourced from the United Nations Conference on Trade and Development (UNCTAD) statistic, while data on institutional variables, including political stability and absence of violence, voice and accountability, the rule of law and control of corruption, and regulatory quality, were collated from the OECD Worldwide Governance Indicators.

For the subgroup's classification, the study follows Shobande and Ogbeifun (2021) such that countries classified as high-average production-based CO2 emitters consist of those whose carbon emissions average 510 million tonnes and above. Medium-average production-based CO2 emitters subgroups consist of countries whose carbon emissions range between 90 and 500 million tonnes, whereas the low-average production-based CO2 emitters subgroup consists of countries emitting carbon less than 90 million tonnes per annum. On the other hand, the demand-based CO2 emission subgroup consists of countries with carbon emissions of 500 million tonnes and above based on the demand-based computation of emission. See Table A of the Appendix for a comprehensive data description.

3.2 Methodology

The standard methodology employed in relevant literature is based on estimating a fixed-effects panel model for the countries under examination. In this study, the fixed effects panel model used to examine the effect of financial development (FD) on environmental sustainability proxy by CO2 emission is structured as follows:

$$CO2_{i,t} = \alpha_i + \beta_1 FD_{i,t} + \beta_2 EC_{i,t} + \beta_3 FDI_{i,t} + \beta_4 Z_{i,t} + e_{i,t} \quad (1)$$

For i = 1, …, N; t = 1, …, T. Where $CO2_{i,t}$ stands for carbon dioxide emission, $FD_{i,t}$ stands for financial development, and $FDI_{i,t}$ stands for foreign direct investment inward flows. We also test for the impact of other control variables ($Z_{i,t}$), which include per capita income proxy by GDP per capita (GDP), trade openness (TO), unit labor cost (ULC), human development index (HDI), inflation (INF), and several institutional variables.[1]

However, recent literature suggests the use of dynamic panel data model to examine the relationship in equation (1). Hence, we employ the Arellano-Bover /Blundell-Bond (Bover and Arellano 1997; Blundell and Bond 2000) dynamic panel model that accounts for serial correlation and endogeneity. The model is specified as follows:

$$CO2_{i,t} = \alpha_i + \beta_1 CO2_{i,t-1} + \beta_2 FD_{i,t} + \beta_3 EC_{i,t} + \beta_3 FDI_{i,t} + \beta_4 Z_{i,t} + e_{i,t} \quad (2)$$

Where α_i is a vector of individual effects, $e_{i,t}$ is a multivariate white-noise vector of residuals and the earlier definition for the other variables hold.

As a robustness test, we divide our sample into different groups based on the computation of CO2 emission–production-based and demand-based.[2] The first group is classified as the high production-based CO2 emitter, including the United States, Japan, Germany, Australia, Korea, Canada, and the United Kingdom. The second group is classified as the medium production-based CO2 emitter, which consists of Mexico, Italy, France, Spain, Turkey, Netherlands, Belgium, and Greece. The third group is classified as the low production-based CO2 emitter, including Denmark, Austria, Finland, Ireland, Portugal, Norway, Sweden, New Zealand, and Iceland. This categorization is useful in identifying whether the CO2 emission from different countries is affected by different determinants. Finally, we consider another group of particular interest classified as the high demand-based emitters of CO2 among the OECD countries, including the United States, United

Kingdom, Canada, France, Germany, Japan, Korea, and Italy.[3]

4. Empirical results

This section presents and discusses the empirical results of the standard fixed effect and Arellano-Bover /Blundell-Bond dynamic panel estimation. Table 1 reports the fixed effect panel estimation for the 24 OECD countries. The first column is the estimate from Equation (1), whereas subsequent columns showed the results when we included one or more control variables in the basic model.

From the basic model, the estimates show that an increase in the financial development (FD) index and the foreign direct investment inflows (FDI) reduces carbon emissions. A 1% in FD index and FDI reduce carbon emission by about 0.713 and 0.166 units, respectively. Our result supports the evidence of Paramati et al. (2020). On the other hand, energy consumption increases carbon emission such that a 1% increase in the amount of energy consumed leads to a 5.513 unit increase in the carbon emissions from the OECD countries. We further estimate the model and include other determinants of CO2 emission. The results suggest that per capita income (GDP), trade openness (TO), and human development index (HDI) are negative and statistically related to CO2 emission. This evidence confirms that as income grows, individuals tend to buy more energy-intensive products that contribute to more carbon emissions. As argued by Hu et al. (2020), the past few years have seen changing international trade policies among developed countries, which has led to importing goods that are energy and or carbon-intensive in their production stage. The new international trade approach has resulted in the decline of carbon emission across the OECD countries. On the contrary, a unit of labour cost, the institutional variable, political stability, and regulatory quality significantly impact CO2 emission, whereas inflation does not. We employ the Arellano-Bover/Blundell-Bond dynamic panel estimation technique to address the issues of endogeneity and serial correlation, and the results are presented in Table 2.

There is a positive and significant relationship between CO2 emission, and the one lagged CO2 emission. The coefficients sign and significance of the dependent variables and most of the control variables are quite similar to the results obtained in the fixed effects estimation, with slight changes in the magnitude.

We also examine the different country subgroups based on the method of computing CO2 emissions. To begin with, we present the results from high-average production-based CO2 emitter in Table 3. As in the whole sample, the lagged coefficient of CO2 emission is positive and significant. The result demonstrates that more FDI net inflow into these countries increases the CO2 emission, although not significant. For the control variables, an increase in the income per capita, trade openness, and HDI will significantly decrease carbon emission. An increase in unit labour cost, institutional

Table 1. Fixed effects panel data estimations for 24 OECD countries, yearly data (1980–2019).

	Basic model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Constant	−34.91***	−29.66***	−32.11***	−42.98***	−35.47***	−31.79**	−35.53***	−34.75***	−34.10***	−12.32***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)
FD_t	−0.713**	1.276***	−0.369	−0.470	−0.671**	2.144***	−0.1839***	−0.688	−2.175***	2.671***
	(0.010)	(0.000)	(0.208)	(0.243)	(0.016)	(0.000)	(0.004)	(0.314)	(0.001)	(0.000)
EC_t	5.513***	6.049***	5.465***	6.319***	5.567***	6.215***	5.465***	5.289***	5.267***	4.956***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI_t	−0.166***	−0.0546*	−0.135***	−0.0248	−0.159***	0.0044	−0.0515	−0.0505	−0.0448	0.0311
	(0.054)	(0.082)	(0.000)	(0.561)	(0.000)	(0.899)	(0.257)	(0.257)	(0.320)	(0.451)
GDP_t		−1.178***								−2.332***
		(0.000)								(0.000)
TO_t			−0.707***							−0.786*
			(0.001)							(0.056)
ULC_t				0.0417***						0.0225
				(0.003)						(0.170)
INF_t					0.049					−0.0021
					(0.104)					(0.942)
HDI_t						−14.54***				3.181
						(0.000)				(0.492)
$INST_t$							0.126**			0.292**
							(0.036)			(0.019)
PS_t								0.744***		−0.160
								(0.000)		(0.391)
RQ_t									0.799***	0.597**
									(0.001)	(0.045)
Obs.	820	820	820	546	820	590	453	451	451	419
F	281.3	244.8	216.8	76.05	212.1	122.3	43.71	47.21	44.96	35.18

Note: FD counts for financial development index; EC counts for energy consumption; FDI counts for foreign direct investment inflows; GDP counts for GDP per capita; TO counts for trade openness; ULC counts for unit labor cost; INF counts for inflation; HDI counts for human development index; INST counts for the sum of the institutional variables Voice and Accountability, Government Effectiveness, Rule of Law and Control of Corruption; PS counts for Political Stability and Absence of Violence; RQ counts for Regulatory Quality. . The table presents the coefficient estimates and their p-values in the parenthesis for the period 1980–2019. *, **, *** denotes level of significance at 10%, 5% and 1% respectively.

Table 2. Arellano–Bover/Blundell–Bond dynamic panel data estimations for 24 OECD countries, yearly data (1980–2019).

	Basic model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Constant	−6.989***	−5.007***	−6.731***	−6.893***	−7.056***	−7.031***	−5.645***	−5.516***	−5.486***	−0.994
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.589)
$CO2_{t-1}$	0.821***	0.786***	0.794***	0.867***	0.821***	0.761***	0.789***	0.812***	0.813***	0.769***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FD_t	−0.466**	1.000***	0.0639	−0.421*	−0.455**	1.112***	−0.392	−0.554	−0.436	0.964**
	(0.010)	(0.000)	(0.745)	(0.087)	(0.013)	(0.000)	(0.265)	(0.133)	(0.204)	(0.044)
EC_t	1.077***	1.576***	1.371***	1.015***	1.084***	1.606***	0.935***	0.920***	0.905***	1.432***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI_t	−0.0094	0.0123	−0.0101	−0.0083	−0.0093	−0.0032	−0.0141	−0.0087	−0.0075	0.0022
	(0.594)	(0.481)	(0.561)	(0.720)	(0.598)	(0.876)	(0.559)	(0.713)	(0.752)	(0.929)
GDP_t		−0.682***								−0.771***
		(0.000)								(0.008)
TO_t			−0.675***							−0.0102
			(0.000)							(0.966)
ULC_t				−0.0018						−0.0183*
				(0.144)						(0.061)
INF_t					0.0007					−0.0235
					(0.775)					(0.154)
HDI_t						−5.714***				−1.804
						(0.000)				(0.499)
$INST_t$							0.0189			−0.0904*
							(0.436)			(0.094)
PS_t								−0.0642		−0.136
								(0.446)		(0.226)
RQ_t									−0.0381	0.513***
									(0.721)	(0.003)
Obs.	796	796	796	542	796	590	453	451	451	419
Wald chi2	7004.9	7482.1	7260.5	5461.9	6996.4	3955.2	2222.6	2350.7	2349.3	2355.9

Note: FD counts for financial development index; EC counts for energy consumption; FDI counts for foreign direct investment inflows; GDP counts for GDP per capita; TO counts for trade openness; ULC counts for unit labor cost; INF counts for inflation; HDI counts for human development index; INST counts for the sum of the institutional variables Voice and Accountability, Government Effectiveness, Rule of Law and Control of Corruption; PS counts for Political Stability and Absence of Violence; RQ counts for Regulatory Quality. . The table presents the coefficient estimates and their p-values in the parenthesis for the period 1980–2019. *, **, *** denotes level of significance at 10%, 5% and 1% respectively.

Table 3. Arellano–Bover/Blundell–Bond dynamic panel data estimations for high-average CO2 producer subgroup (seven OECD countries), yearly data (1980–2019).

	Basic model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Constant	−6.960***	−6.861***	−6.380***	−11.09***	−6.109***	−10.78***	−18.74***	−17.84***	−17.85***	−20.36***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$CO2_{t-1}$	0.880***	0.812***	0.868***	0.844***	0.888***	0.812***	0.781***	0.799***	0.792***	0.656***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FD_t	−0.442*	1.829***	−0.156	−0.270	−0.633**	1.066**	−1.112*	−1.023*	−1.257*	0.518
	(0.076)	(0.000)	(0.594)	(0.330)	(0.026)	(0.010)	(0.067)	(0.097)	(0.051)	(0.542)
EC_t	1.013***	2.095***	1.071***	1.548***	0.918***	2.085***	2.616***	2.531***	2.518***	4.055***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI_t	0.0191	0.0368	0.0196	0.0087	0.0230	−0.0340	−0.0324	−0.0310	−0.0311	−0.0299
	(0.495)	(0.172)	(0.482)	(0.766)	(0.413)	(0.274)	(0.457)	(0.483)	(0.477)	(0.513)
GDP_t		−1.010***								−2.167***
		(0.000)								(0.000)
TO_t			−0.300*							−0.564*
			(0.066)							(0.082)
ULC_t				0.0012						−0.0153
				(0.910)						(0.417)
INF_t					−0.0181					0.0836**
					(0.143)					(0.025)
HDI_t						−5.799***				15.59***
						(0.000)				(0.006)
$INST_t$							0.0725			0.0713
							(0.238)			(0.478)
PS_t								−0.0675		−0.0261*
								(0.636)		(0.094)
RQ_t									0.234	0.322
									(0.215)	(0.271)
Obs.	233	233	233	200	233	174	133	133	133	133
Wald chi2	8764.7	9615.3	8814.6	7292.1	8662.6	6642.7	3951.8	3873.9	3906.5	4122.8

Note: FD counts for financial development index; EC counts for energy consumption; FDI counts for foreign direct investment inflows; GDP counts for GDP per capita; TO counts for trade openness; ULC counts for unit labor cost; INF counts for inflation; HDI counts for human development index; INST counts for the sum of the institutional variables Voice and Accountability, Government Effectiveness, Rule of Law and Control of Corruption; PS counts for Political Stability and Absence of Violence; RQ counts for Regulatory Quality. . The table presents the coefficient estimates and their p-values in the parenthesis for the period 1980–2019. *, **, *** denotes level of significance at 10%, 5% and 1% respectively.

variable, and regulatory quality significantly impacts carbon emission.

Table 4. shows the results of the second subgroup, the medium-averaged production-based CO2 emitter. The lagged coefficient of CO2 indicates its dynamic nature, whereas the positive impact of energy consumption and the negative impact of financial development and FDI is also confirmed. For the control variables, per capita income, trade openness, and HDI are negative and statistically significantly related to carbon emissions.

Table 5. presents the results for low-average production-based CO2 emitter. The positive and statistical significance of the lagged coefficient of CO2 is also confirmed. The coefficients of energy consumption are quite smaller in magnitude compared to those in other subgroups. It is worth mentioning that only inflation, institutional variable, and political stability have a significant impact on CO2 emission amongst the control variables. Our results indicate that financial development promotes environmental sustainability the most in regions with lower production-based CO2 emissions, suggesting that the listed firms in the stock markets in this subgroup might be engaging in more environmentally friendly activities due to the stringent regulations on carbon emission cap and environmental laws.

Finally, we consider another subgroup of countries classified as high demand-based emitters of CO2, and the estimates are presented in Table 6.

The results show that lagged CO2 emission, FDI inflow, and energy consumption positively affect CO2 emission, whereas financial development negatively affects CO2 emission. On the other hand, all the control variables except the institutional variable and the regulatory quality have an adverse effect on CO2 emission.

5. Conclusion and policy implications

Various multidisciplinary debates have raised concerns about the need to promote financial development to reduce carbon emissions. However, critics argue that financial growth comes at a cost to the environment because it has the potential to increase carbon emissions. This study examined the role of financial development in promoting environmental sustainability among OECD countries. By controlling for confounding factors, this study made inferences concerning causal links among factors and identified the mechanism through which financial development can affect carbon emissions. Our methodological approach began with a standard fixed-effects estimation. However, to address the problem of reverse causality and measurement error, this study employed the dynamic panel approach developed by Arellano-

Table 4. Arellano–Bover/Blundell–Bond dynamic panel data estimations for medium-average CO2 producer subgroup (eight OECD countries), yearly data (1980–2019).

	Basic model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Constant	−7.621***	−6.858***	−7.692***	−4.990***	−7.532***	−8.522***	−8.631***	−9.827***	−6.810***	−10.70***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$CO2_{t-1}$	0.761***	0.760***	0.767***	0.845***	0.761***	0.752***	0.742***	0.740***	0.746***	0.667***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FD_t	−0.375***	−0.151	−0.349***	−0.0486	−0.377***	−0.114	−1.069***	−1.238***	−0.988***	−0.592
	(0.076)	(0.381)	(0.003)	(0.827)	(0.001)	(0.602)	(0.000)	(0.000)	(0.000)	(0.212)
EC_t	1.202***	1.254***	1.260***	0.745***	1.195***	1.542***	1.383***	1.563***	1.106***	2.550***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI_t	−0.0139	−0.0045	−0.0122	0.0042	−0.0162	−0.0340	−0.0054	−0.0114	−0.0002	−0.0167
	(0.335)	(0.771)	(0.398)	(0.867)	(0.275)	(0.858)	(0.812)	(0.615)	(0.993)	(0.533)
GDP_t		−0.139*								−0.402
		(0.079)								(0.333)
TO_t			−0.111							0.0787
			(0.159)							(0.694)
ULC_t				0.0039						−0.0060
				(0.635)						(0.640)
INF_t					−0.0006					0.0035
					(0.536)					(0.877)
HDI_t						−2.417***				−3.458
						(0.001)				(0.355)
$INST_t$							0.0153			−0.200***
							(0.648)			(0.003)
PS_t								−0.0557		−0.0703
								(0.404)		(0.495)
RQ_t									0.334**	0.604***
									(0.016)	(0.007)
Obs.	273	273	273	150	273	202	154	154	154	122
Wald chi2	9448.1	9511.4	9347.9	2776.1	9430.0	5742.9	4171.2	4197.3	4117.4	2726.4

Note: FD counts for financial development index; EC counts for energy consumption; FDI counts for foreign direct investment inflows; GDP counts for GDP per capita; TO counts for trade openness; ULC counts for unit labor cost; INF counts for inflation; HDI counts for human development index; INST counts for the sum of the institutional variables Voice and Accountability, Government Effectiveness, Rule of Law and Control of Corruption; PS counts for Political Stability and Absence of Violence; RQ counts for Regulatory Quality. . The table presents the coefficient estimates and their p-values in the parenthesis for the period 1980–2019. *, **, *** denotes level of significance at 10%, 5% and 1% respectively.

Table 5. Arellano–Bover/Blundell–Bond dynamic panel data estimations for low-average CO2 producer subgroup (nine OECD countries), yearly data (1980–2019).

	Basic model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Constant	−6.986***	−5.958***	−6.760***	−4.063***	−6.292***	−5.370***	−4.475**	−3.379	−2.568	−1.357
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.047)	(0.121)	(0.246)	(0.712)
$CO2_{t-1}$	0.819***	0.817***	0.818***	0.816***	0.803***	0.806***	0.793***	0.817***	0.830***	0.754***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FD_t	−0.800**	−0.372	−0.747*	−1.191**	−1.230***	−0.389	−1.772**	−0.456	−1.326*	−0.300
	(0.036)	(0.514)	(0.081)	(0.040)	(0.003)	(0.578)	(0.012)	(0.532)	(0.059)	(0.729)
EC_t	1.059***	1.148***	1.067***	0.791***	1.036***	1.126***	0.768***	0.539**	0.569**	0.881***
	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.004)	(0.031)	(0.026)	(0.002)
FDI_t	−0.0159	−0.0055	−0.0144	−0.0551	−0.0158	−0.0278	−0.0616	−0.0497	−0.0416	−0.0186
	(0.620)	(0.870)	(0.660)	(0.222)	(0.621)	(0.519)	(0.165)	(0.252)	(0.348)	(0.681)
GDP_t		−0.204								−0.710
		(0.306)								(0.183)
TO_t			−0.0726							0.429
			(0.802)							(0.359)
ULC_t				−0.0217						−0.0153
				(0.189)						(0.346)
INF_t					−0.0269**					0.0498*
					(0.011)					(0.087)
HDI_t						−2.515				−0.518
						(0.230)				(0.903)
$INST_t$							0.169**			−0.200
							(0.000)			(0.145)
PS_t								−0.719**		0.274
								(0.011)		(0.433)
RQ_t									0.127	0.0380
									(0.598)	(0.909)
Obs.	290	290	290	192	290	214	166	164	164	164
Wald chi2	1669.7	1682.0	1671.4	931.4	1698.7	1043.8	833.3	801.4	773.6	862.4

Note: FD counts for financial development index; EC counts for energy consumption; FDI counts for foreign direct investment inflows; GDP counts for GDP per capita; TO counts for trade openness; ULC counts for unit labor cost; INF counts for inflation; HDI counts for human development index; INST counts for the sum of the institutional variables Voice and Accountability, Government Effectiveness, Rule of Law and Control of Corruption; PS counts for Political Stability and Absence of Violence; RQ counts for Regulatory Quality. . The table presents the coefficient estimates and their p-values in the parenthesis for the period 1980–2019. *, **, *** denotes level of significance at 10%, 5% and 1% respectively.

Table 6. Arellano–Bover/Blundell–Bond dynamic panel data estimations for high-average CO2 demand-based subgroup (United States, United Kingdom, Canada, France, Germany, Japan, Korea, and Italy), yearly data (1980–2019).

	Basic model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Constant	−7.195***	−8.066***	−6.533***	−15.05***	−6.422***	−15.23***	−26.00**	−27.62***	−25.41***	−29.71***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.00)	(0.00)	(0.000)
$CO2_{t-1}$	0.883***	0.799***	0.870***	0.817***	0.892***	0.760***	0.716***	0.702***	0.719***	0.533***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FD_t	−0.636**	1.514***	−0.366	−0.569***	−0.779***	1.171***	−1.318**	−1.999***	−1.522**	−0.571
	(0.011)	(0.000)	(0.189)	(0.031)	(0.005)	(0.004)	(0.016)	(0.000)	(0.010)	(0.441)
EC_t	1.007***	2.240***	1.058***	2.019***	0.921***	2.723***	3.578***	3.840***	3.485***	5.42****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.031)	(0.000)	(0.000)
FDI_t	0.0436	0.0687***	0.0433	0.0355	0.0424	−0.0005	0.0184	0.0128	0.0080	0.0088
	(0.101)	(0.007)	(0.102)	(0.196)	(0.114)	(0.987)	(0.641)	(0.739)	(0.838)	(0.681)
GDP_t		−1.025***								−1.909***
		(0.000)								(0.000)
TO_t			−0.301**							−0.954***
			(0.036)							(0.000)
ULC_t				−0.0047						−0.0045
				(0.680)						(0.791)
INF_t					−0.0163					0.0919***
					(0.680)					(0.004)
HDI_t						−6.977***				14.32***
						(0.000)				(0.007)
$INST_t$							0.0641			−0.156*
							(0.225)			(0.054)
PS_t								−0.333**		−0.482***
								(0.012)		(0.000)
RQ_t									0.0546	0.656***
									(0.745)	(0.009)
Obs.	233	233	233	200	233	174	133	133	133	133
Wald chi2	11,145.4	12,545.3	11,224.6	10,884.0	10,958.5	8833.2	5775.6	5921.7	5720.8	6566.4

Note: FD counts for financial development index; EC counts for energy consumption; FDI counts for foreign direct investment inflows; GDP counts for GDP per capita; TO counts for trade openness; ULC counts for unit labor cost; INF counts for inflation; HDI counts for human development index; INST counts for the sum of the institutional variables Voice and Accountability, Government Effectiveness, Rule of Law and Control of Corruption; PS counts for Political Stability and Absence of Violence; RQ counts for Regulatory Quality. . The table presents the coefficient estimates and their p-values in the parenthesis for the period 1980–2019. *, **, *** denotes level of significance at 10%, 5% and 1% respectively.

Bover/Bundell Bond which helps to properly correct for endogeneity in the analysis. The evidence indicated that financial development could help reduce carbon emissions, but not without an increase in energy consumption. This raises serious concerns about the need to encourage energy efficiency through investment in clean technologies among OECD countries.

Based on the analysis, the study recommends the following:

(a) OECD countries need to stop carbon lock-in and make sustainability the standard in financing infrastructure decisions through rethinking planning at all levels of government.
(b) The OECD can improve environmental quality among its members by employing proper financial policies, implementing targeted innovation policies, and speeding up the deployment of existing technologies.
(c) The OECD needs to urgently fix the financial system to account for long-term climate threats and opportunities by resolving distorted incentives, capacity gaps, and insufficient climate risk transparency and pricing, which currently prevent funds from being allocated to low-emission, resilient infrastructure.
(d) OECD countries can set financial incentives for producers to invest in productivity with customers and 'green' ability, as well as environmentally friendly technology, to meet demand through a carefully planned change in the power market. Similarly, new policy frameworks to promote private investment in renewable energies and energy conservation are required.

Future studies can examine the potential of monetary policy towards climate change in OECD countries.

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No potential conflict of interest was reported by the author(s).

References

Adams S, Klobodu EKM. 2018. Financial development and environmental degradation: do political regime matter? J Clean Prod. 197:1472–1479. doi:10.1016/j.jclepro.2018.06.252.

Ahmad M, Khan Z, Rahman ZU, Khattak SI, Khan ZU. 2021. Can innovation shocks determine CO2 emissions (CO2e) in the OECD economies? A new perspective. Econ Innovation New Technol. 30(1):89–109. doi:10.1080/10438599.2019.1684643.

Alexander J, Nassiry D, Barnard S, Lindfield M, Teipelke R, Wilder M. 2019. Financing the sustainable urban future: scoping a green cities development bank. London: Overseas Development Institute.

Al-Mulali U, Sab CNBC. 2012. The impact of energy consumption and CO2 emission on the economic growth and financial development in the Sub-Saharan African countries. Energy. 39(1):180–186. doi:10.1016/j.energy.2012.01.032.

Baloch MA, Ozturk I, Bekun FV, Khan D. 2021. Modelling the dynamic linkage between financial development, energy innovation, and environmental quality: does globalization matter? Business Strategy Environ. 30(1):176–184. doi:10.1002/bse.2615.

Blundell R, Bond S. 2000. GMM estimation with persistent panel data: an application to production functions. Econ Revi. 19(3):321–340. doi:10.1080/07474930008800475.

Boutabba MA. 2014. The impact of financial development, income, energy and trade on carbon emissions: evidence from the Indian economy. Econ Model. 40:33–41. doi:10.1016/j.econmod.2014.03.005.

Bover O, Arellano M. 1997. Estimating dynamic limited dependent variable models from panel data. investigaciones econ. 21(2):141–165.

Frankel JA, Romer DH. 1999. Does trade cause growth? Am Econ Rev. 89(3):379–399. doi:10.1257/aer.89.3.379.

Hu G, Can M, Paramati SR, Doğan B, Fang J. 2020. The effect of import product diversification on carbon emissions: new evidence for sustainable economic policies. Econ Anal Policy. 65:198–210. doi:10.1016/j.eap.2020.01.004.

Islam F, Shahbaz M, Ahmed AU, Alam MM. 2013. Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis. Econ Model. 30:435–441. doi:10.1016/j.econmod.2012.09.033.

Jalil A, Feridun M. 2011. The impact of growth, energy and financial development on the environment in China: a cointegration analysis. Energy Econ. 33(2):284–291. doi:10.1016/j.eneco.2010.10.003.

Kahouli B. 2017. The short and long run causality relationship among economic growth, energy consumption and financial development: evidence from South Mediterranean Countries (SMCs). Energy Econ. 68:19–30. doi:10.1016/j.eneco.2017.09.013.

Karanfil F. 2009. How many times again will we examine the energy-income nexus using a limited range of traditional econometric tools? Energy Policy. 37(4):1191–1194.

Khan S, Khan MK, Muhammad B. 2021. Impact of financial development and energy consumption on environmental degradation in 184 countries using a dynamic panel model. Environ Sci Pollution Res. 28(8):9542–9557.

Lee JM, Chen KH, Cho CH. 2015. The relationship between CO2 emissions and financial development: evidence from OECD countries. Singapore Econ Rev. 60(5):1550117.

Lv Z, Li S. 2021. How financial development affects CO2 emissions: a spatial econometric analysis. J Environ Manage. 277:111397.

Madsen JB, Islam MR, Doucouliagos H. 2018. Inequality, financial development and economic growth in the OECD, 1870–2011. Eur Econ Rev. 101:605–624.

Mujtaba G, Shahzad SJH. 2021. Air pollutants, economic growth and public health: implications for sustainable development in OECD countries. Environ Sci Pollution Res. 28(10):12686–12698.

Ogbeifun L, Shobande OA. 2020. Causality Analysis of Disaggregated FDI Inflows on Sectorial Growth in OECD Area. Studia Universitatis Vasile Goldi? Arad, Seria ?tiin?e Economice. 30(4):92–110.

Ogbeifun L, Shobande OA. 2021. A reevaluation of human capital accumulation and economic growth in OECD. J Public Aff. e02602.

Ozcan B, Tzeremes PG, Tzeremes NG. 2020. Energy consumption, economic growth and environmental degradation in OECD countries. Econ Model. 84:203–213.

Ozturk I, Acaravci A. 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ. 36:262–267.

Pantelopoulos G. 2021. Higher education, gender, and foreign direct investment: evidence from OECD countries. Industry and Higher Education. 1–8. doi: 10.1177/0950422221997274

Paramati SR, Mo D, Huang R. 2020. The role of financial deepening and green technology on carbon emissions: evidence from major OECD economies. In: Finance Research Letters. p. 101794. doi: 10.1016/j.frl.2020.101794

Piñeiro Chousa J, Tamazian A, Vadlamannati KC. 2017. Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. Energy Policy. 37(1):2009.

Rjoub H, Odugbesan JA, Adebayo TS, Wong WK. 2021. Sustainability of the moderating role of financial development in the determinants of environmental degradation: evidence from Turkey. Sustainability. 13(4):1844.

Roller LH, Waverman L. 2001. Telecommunications infrastructure and economic development: a simultaneous approach. Am Econ Rev. 91(4):909–923.

Sadorsky P. 2010. The impact of financial development on energy consumption in emerging economies. Energy Policy. 38(5):2528–2535.

Shahbaz M, Shahzad SJH, Ahmad N, Alam S. 2016. Financial development and environmental quality: the way forward. Energy Policy. 98:353–364.

Shen Y, Su ZW, Malik MY, Umar M, Khan Z, Khan M. 2021. Does green investment, financial development and natural resources rent limit carbon emissions? A provincial panel analysis of China. Sci Total Environ. 755:142538.

Shobande OA. 2020. The effects of energy use on infant mortality rates in Africa. Environ Sustain Indicators. 5:100015.

Shobande OA. 2021a. Decomposing the Persistent and Transitory Effect of Information and Communication Technology on Environmental Impacts Assessment in Africa: evidence from Mundlak Specification. Sustainability. 13(9):4683.

Shobande OA. 2021b. Is climate change a monetary phenomenon? Evidence from time series analysis. Int J Sustainable Dev World Ecol. 1–13.

Shobande OA, Enemona JO. 2021. A Multivariate VAR Model for Evaluating Sustainable Finance and Natural Resource Curse in West Africa: evidence from Nigeria and Ghana. Sustainability. 13(5):2847.

Shobande OA, Ogbeifun L. 2021. Has information and communication technology improved environmental quality? A dynamic analysis. Int J Sustainable Dev World Ecol. 1–11.

Shobande OA, Shodipe OT. 2019. Carbon policy for the United States, China and Nigeria: an estimated dynamic stochastic general equilibrium model. Sci Total Environ. 697:134130.

Tahir T, Luni T, Majeed MT, Zafar A. 2021. The impact of financial development and globalization on environmental quality: evidence from South Asian economies. Environ Sci Pollution Res. 28(7):8088–8101.

Tamazian A, Chousa JP, Vadlamannati KC. 2009. Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. Energy Policy. 37(1):246–253.

Usman M, Makhdum MSA, Kousar R. 2021. Does financial inclusion, renewable and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries. Sustainable Cities Soc. 65:102590.

Vo XV, Zaman K. 2020. Relationship between energy demand, financial development, and carbon emissions in a panel of 101 countries: "go the extra mile" for sustainable development. Environ Sci Pollution Res. 27(18):23356–23363.

Zaidi SAH, Zafar MW, Shahbaz M, Hou F. 2019. Dynamic linkages between globalization, financial development and carbon emissions: evidence from Asia Pacific Economic Cooperation countries. J Clean Prod. 228:533–543.

Zhang YJ. 2011. The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy. 39(4):2197–2203.

Ziaei SM. 2015. Effects of financial development indicators on energy consumption and CO2 emission of European, East Asian and Oceania countries. Renewable Sustainable Energy Rev. 42:752–759.

Appendix

Table A. Data description.

Variable	Description	Sources
CO2	Gross direct emissions from fuel combustion only (measured in tonnes/capita)	OECD statistics
EC	Energy use (kg of oil equivalent per capita)	World Bank's World Development Indicators
FD	Financial development index	IMF
FDI	Foreign direct investment inward (U.S. dollar at current price in millions)	UNCTAD statistics
GDP	GDP per capita (current U.S. dollars)	
TO	Trade openness (measured as exports plus imports as a percentage of GDP)	World Bank's World Development Indicators
ULC	Unit labor cost measure the average cost of labor per unit of output.	OECD statistics
INF	Inflation (measured as consumer price index)	OECD statistics
HDI	Human Development Index	UNESCO Institute for Statistics.
INST	Institutional variable computed as the sum Voice and Accountability, Government Effectiveness, Rule of Law and Control of Corruption	OECD Worldwide Governance Indicators
PS	Political Stability and Absence of Violence	OECD Worldwide Governance Indicators
RQ	Regulatory Quality	OECD Worldwide Governance Indicators