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Environmental impact of financial Market's development in Australia

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ABSTRACT

Enhancing environmental quality has become one of the most commonly discussed topics in the modern world, particularly in response to the challenges posed by the increasing threats to climate change. The financial system is acknowledged as a crucial factor in achieving environmental quality by facilitating the flow of financial resources. This study aims to examine the impact of a unique aspect of the financial system—financial market development—on environmental quality in Australia. What sets this study apart from existing works is its comprehensive approach, capturing broader measures of financial market development, including financial market depth, access, efficiency, and stability. By employing the Autoregressive Distributive Lag (ARDL) model over the period from 1983 to 2021, our research demonstrates a positive impact of market-based financial development on Australia's environmental quality by reducing greenhouse gas emissions in the long run. Specifically, an opposing impact of financial market development on environmental quality is evident in the short run. Our findings highlight that financial market development degrades environmental quality in the short run by contributing to increased greenhouse gas emissions, which further emphasizes the importance of integrating both the positive and negative effects of financial market development in policymaking, particularly in the context of achieving Australia's environmental targets.

1. Introduction

Presently, the modern world is emphasizing sustainable development, aiming to balance economic, social, and environmental aspects. However, the rapid increase in greenhouse gases from every corner of the world poses a serious challenge to achieving environmental sustainability, leading to environmental pollution and climate change (Charfeddine and Khediri, 2016; Danish et al., 2018; Ahmad et al., 2020). Therefore, environmental quality has become a significant agenda among policymakers to mitigate environmental degradation and create a livable environment for human life. Environmental quality is considered essential for mitigating risks to human life (Habiba and Xinbang, 2022). Recently, research scholars have focused on studying the determinants of various variables in different economic settings to assist policymakers in making decisions aimed at enhancing the desired level of environmental quality (see examples: Shafik, 1994; Seker et al., 2015; Abdouli and Hammami, 2017; Chen et al., 2018; Danish et al., 2018; Danish and Wang, 2018; Ganda, 2021; Khalid et al., 2021; Zafar et al., 2022).

The role of the financial system in enhancing environmental quality has garnered increased attention from scholars in the last decade. The development of the financial system is noted to alter the production and consumption patterns of the economy, consequently affecting the global environmental landscape (Ashraf et al., 2022). An improved financial system provides easier access for individuals, corporations, and the government sector to financial facilities at a lower cost of financing. This, in turn, leads to changes in consumption and production patterns, exerting pressure on the environment (Sadorsky, 2011; Shahbaz and Lean, 2012; Çoban and Topcu, 2013; Kahouli, 2017; Habiba and Xinbang, 2022). Conversely, an improved financial system facilitates the availability of necessary funds for research and development activities, allowing the adoption of environmentally friendly technologies in the production system and providing financial assistance to environmentally friendly projects (Tamazian et al., 2009; Pan et al., 2019). Due to

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this controversial argument, the environmental impact of the development of the financial system has been extensively examined by scholars in various study contexts. (Refer to examples: Charfeddine and Khediri, 2016; Jiang and Ma, 2019; Ahmed et al., 2020; Bayar et al., 2020; Bui, 2020; Pata and Yilanci, 2020; Awosusi et al., 2022; Ehigiamusoe et al., 2022; Usman et al., 2023; Dhingra, 2023).

As a crucial element within the financial system, financial markets play a vital role in channelling funds from financial savers to financial deficit units (Aggarwal and Goodell, 2009). These markets provide access to finance through various means, such as equity financing and debt financing, which, in turn, can have implications for the environment through different channels, including sustainability, production, and consumption (Topcu, 2024). The sustainability channel suggests that the development of the financial market facilitates sustainable development, which subsequently leads to the reduction of emissions by ensuring the availability of financial resources for investing in sustainable projects and technologies. A well-developed financial market promotes rational investment decisions and investments in sustainable industries, balancing environmental, social, and governance factors with risk and return. This approach can reduce environmental damage and spillover green knowledge and technology among industries (Prempeh, 2023).

Next, the development of the financial market degrades environmental quality through the production channel. Financial market development ensures the availability of financial resources at the lowest cost, which can flow into the economy and expand business operations (Sadorsky, 2010, 2011). The expansion of the business environment demands more energy sources and other resource consumption, leading to increased emissions (Sadorsky, 2010, 2011). Finally, through the consumption channel, financial market development impacts the environment by enhancing consumer access to credit facilities and financial products. Financial market development increases access to credit and other financial products, which empowers individuals' purchasing ability (Sadorsky, 2010, 2011; Topcu, 2024). Ultimately, consumer demand for goods and services will increase, leading to higher energy consumption and resource extraction, which adds more toxic emissions to the environment (Sadorsky, 2010, 2011; Topcu, 2024). However, despite being a significant component of the financial system, the impact of financial market development has not been thoroughly examined by scholars. This study addresses this gap by examining the impact of market-based financial development on environmental quality in the Australian context. By delving into this aspect, we aim to contribute to the understanding of how financial market development may affect the environmental landscape, thereby providing valuable insights for both academia and policymakers.

The Australian economy, ranking as the world's 14th largest emitter, has its finance sector standing as the 3rd largest contributor to the economy (Commonwealth Scientific & Industrial Research Organization). With a robust financial market playing a significant role in shaping the economy, Australia serves as the ideal study context for this empirical work. Interestingly, despite the country's prominence in emissions and economic structure, there is a noticeable absence of country-specific empirical findings on the environmental impact of market-based financial development in the Australian context. This gap in the literature becomes particularly pertinent given Australia's commitment to achieving environmental targets by 2030. Consequently, there is a compelling need for policymakers to have access to specific insights that can inform the formulation of effective policies aligned with the country's environmental goals. This study addresses this need by providing a focused examination of the environmental impact of market-based financial development, offering a unique perspective compared to existing studies.

It is noteworthy that this study deviates from existing empirical works, which often simultaneously address the environmental impact of financial markets and financial institutions. In contrast, our study concentrates solely on the impact of financial market development, deliberately excluding the environmental impact of financial institutional development. This strategic decision arises from the recognition that not all financial facilities are uniform in their response to environmental challenges (Haas and Popov, 2019). The environmental impact of institution-based financial development will be explored in our next paper. Furthermore, the present study comprehensively explores all dimensions of financial market development by utilizing various proxies. These proxies are designed to encompass financial market access, financial market depth, financial market efficiency, and financial market stability. This approach distinguishes our study from existing empirical research within this domain, as it seeks to provide a more nuanced and in-depth analysis of the multifaceted aspects of financial market development. In accordance with our research objective, we utilized the Autoregressive Distributive Lag (ARDL) model to explore the research findings.

The paper's subsequent sections are organized as follows: Section 2 discusses the theoretical background, accompanied by an exploration of existing empirical evidence. Following this, Section 3 focuses on the study's methodological strategy, covering discussions on model construction, the econometric approach, and the data and variables employed in the analysis. In Section 4, we elaborate on the empirical findings derived from the data analysis. Finally, Section 5 concludes the study, drawing implications for policy considerations.

2. Theoretical underpin and empirical evidence

This section discusses the theoretical background and the existing empirical evidence on the relationship between financial market development and environmental quality. Theoretically, two distinct perspectives exist regarding the nexus between financial market development and environmental quality. The first perspective suggests that financial market development worsens environmental quality. Financial market development facilitates increased access to capital and efficient resource allocation, thereby stimulating economic growth. Accordingly, financial market development leads to the degradation of environmental quality through its impact on economic growth. In general, economic growth depends on how well the financial market of a particular economy is developed (Schumpeter, 1911). The supply-leading hypothesis explains the direction of the effect of financial market development on economic growth, suggesting that causality flows from finance to economic growth. This has been empirically demonstrated by Colombage (2009); Kolapo and Adaramola (2012); Puente-Ajovín and Sanso-Navarro (2015); Adeyeye et al. (2015); and Pradhan et al. (2019). However, economic growth induced by financial market development may come at the cost of the environment if financial flows are directed towards high-polluting industries. Additionally, financial intermediation theory emphasizes that the flow of funds into the economy through financial markets affects resource allocation, potentially leading to environmental pollution if investments prioritize short-term profits over long-term sustainability.

Additionally, economic growth induced by financial market development generates more wealth for households and business sectors, leading to increased energy demand that puts pressure on environmental quality in the economy (Sadorsky, 2011a, 2010a; Kahouli, 2017; Shahbaz et al., 2017; Acheampong, 2019). A well-developed financial market facilitates finance at the lowest cost and mitigates asymmetric information, thereby expanding business operations and consumption. However, this expansion hurts environmental quality due to increased energy consumption (Sadorsky, 2010, 2011). The second perspective asserts that the development of financial markets contributes to an enhancement in environmental quality. The development of financial markets facilitates the allocation of funds to research and development activities, leading to the creation of green technologies with spillover effects on the environment (Tamazian et al., 2009; Acheampong, 2019). Also, it provides funding for environmentally beneficial projects undertaken by both the government and the private sector at the lowest financing costs (Tamazian et al., 2009). Moreover, financial market development enables financial innovations for investors, such as green bonds, green indices, and green exchange-traded funds, to support environmental sustainability while diversifying their investment portfolios. Unlike financial development-environmental nexus, only a limited number of scholarly works have focused on analyzing the impact of financial market development on environmental quality. Acheampong et al. (2020) discovered that the nature of the effect of financial market development on environmental quality diverges in different economic settings. Accordingly, financial market development in developed economies and emerging economies improves environmental quality by reducing carbon intensity, while financial market development degrades environmental quality in frontier economies. Financial market development in standalone economies plays a neutral role in determining the level of environmental quality. Additionally, it is evident that sub-indices of financial market development also reveal distinctive impacts on environmental quality. Horobet et al. (2022) provided empirical evidence supporting the neutral role of financial market development in determining the environmental quality in European Union economies, aligning with the findings for standalone economies by Acheampong et al. (2020). Their study measured the development of financial markets using the IMF (International Monetary Fund) index of financial market development, which covers financial market access, depth, and efficiency.

A recent study by Habiba and Xinbang (2022) empirically highlights the fact that financial market development improves environmental quality in both developed and emerging economies by reducing carbon emissions. Additionally, contrary to the findings of Acheampong et al. (2020), all dimensions of financial development studied, including financial market access, depth, and efficiency, also confirm positive effects on environmental quality. Also, aligning with the findings of Acheampong et al. (2020), Ashraf et al. (2022) revealed that financial market development, with its dimensions, including depth, access, and efficiency have diverse relationships with environmental quality in global economies.

Interestingly, a study by Bădîrcea et al. (2023) explored the nexus between financial market development and environmental performances, employing individual measures for different dimensions of financial market development. Bădîrcea et al. (2023) confirmed that financial market access negatively affects environmental performance in Romania, while financial market depth and efficiency positively influence environmental performance. More importantly, Bădîrcea et al.'s (2023) study not only focused on the equity market but also comprehensively considered the dimensions of the debt market. Another study by Deng et al. (2023) empirically reveals that improvements in financial market efficiency in China and Japan lead to a reduction in carbon emissions over the long term. However, Deng et al.'s (2023) study overlooks the impact of financial efficiency on environmental quality, while also excluding consideration of other dimensions of financial market development. A study by Yu et al. (2023) confirmed diverse relationships between financial market development and environmental quality in both developed and developing countries. Notably, Yu et al.'s (2023) study considered broader measures of financial market development that were not covered by the existing body of literature. Significantly, they incorporated the stability of financial markets as a dimension of financial market development. However, Yu et al.'s (2023) study was limited to stock market measures.

The relationship between financial market development and environmental quality is not always linear; it can be nonlinear. This was demonstrated in the study by Li et al. (2022), which revealed that the linear relationship is positive. This implies that the deepening of financial markets negatively impacts environmental quality in BRICS economies. However, in non-linear estimations, positive shocks in financial market development increase the emissions while negative shocks in financial market development decrease emissions. Additionally, some studies have specifically focused on particular financial markets, such as the stock market, insurance market, bond market, etc., aiming to establish connections between these markets' development and environmental quality. The existing literature has identified either a positive, negative, or insignificant impact of stock market development in determining the level of environmental quality (see, example: Zafar et al., 2019; Sharma et al., 2021; Mhadhbi et al., 2021; Zhang et al., 2022; Habiba and Xinbang, 2022; Musah, 2023; Zhao et al., 2023). Similarly, insurance market development has been found to exhibit either a positive or negative effect on the changes in environmental quality in various economic settings (see, example: Altarhouni et al., 2021; Appiah-Otoo and Acheampong, 2021; Rizwanullah et al., 2022; Samour et al., 2022).

In summary, a limited number of studies have focused on the nexus between financial market development and environmental quality. Most existing studies have analyzed only a few measures of financial market development, treating them as a single aspect of financial development, and have not considered all measures of financial market development, including financial market access, depth, efficiency, and stability. To the best of the researchers' knowledge, there is a notable absence of country-specific empirical evidence regarding the relationship between financial market development and environmental quality in Australia.

3. Methodological strategy

In this section, we discuss the variable selection, model construction, data, and econometric strategy that were employed to enhance the study's objective.

3.1. Variable selection and model construction of empirical model

To empirically test the impact of market-based financial development on environmental quality in Australia, we employed the following general model presented in Equation (1). Where, EQ_t represents environmental quality, $FMD_{t,}$ denotes the financial market development and CV_t symbolizes the control variables that are considered in the model.

$$EQ_t = f\left(FMD_{t,} CV_t\right) \tag{1}$$

Financial market development refers to the process by which financial markets become more efficient, accessible, deep, and stable, thereby enhancing their ability to perform their essential functions. The key components of financial market development are financial market access, financial market depth, financial market efficiency, and financial market stability (Wijethunga et al., 2023; Čihák et al., 2012). Financial market depth refers to the market's ability to handle a large number of transactions without significant price volatility (Čihák et al., 2012). It ensures market liquidity, enabling the easy buying and selling of financial instruments. Financial market access pertains to the availability and ease with which different participants can engage in financial market transactions (Čihák et al., 2012). Greater access leads to higher levels of financial inclusion, allowing more participants to benefit from financial market activities. Financial market efficiency indicates the smooth functioning of financial markets, characterized by the absence of information asymmetry (Čihák et al., 2012). Efficient markets ensure the optimal allocation of financial resources and the reduction of transaction costs. Financial market stability is the market's ability to withstand economic shocks without leading to systemic crises (Čihák et al., 2012). Stability in financial markets fosters investor confidence and supports sustained economic progress. As we discussed in the theoretical underpinnings and empirical pieces of evidence on the nexus between financial market development and environmental quality, market-based financial development can either improve or degrade environmental quality (Tamazian et al., 2009; Sadorsky, 2010, 2011; Acheampong et al., 2020). Therefore, it is rational to expect either a positive or negative impact of market-based financial development on environmental quality in Australia. In addition to the development of the financial market, the model incorporates a set of control variables, including economic growth, energy consumption, and trade openness.

Theoretically, the relationship between economic growth and environmental quality is supported by the Environmental Kuznets Curve (EKC) proposed by Grossman and Krueger (1991). It predicts the level of environmental damage faced by a country in relation to its GDP growth. Subsequently, scholars have empirically tested this relationship between economic growth and environmental quality (see, example: Tamazian et al., 2009; Charfeddine and Khediri, 2016; Zaidi et al., 2019; Zakaria and Bibi, 2019; Rahman and Vu, 2020). Existing evidence in the Australian context, as revealed by Marques et al. (2018); and Rahman & Vu (2020), indicates that economic growth degrades environmental quality by increasing carbon emissions. Consequently, this study anticipates a negative impact of economic growth on environmental quality in the Australian economy, resulting in an increase in greenhouse gas emissions.

The energy-environment relationship is crucial in the modern economy for maintaining a livable environment. Generally, a higher level of energy consumption increases dependence on fossil fuels and natural gas, leading to increased environmental damage and resource depletion (Mirza and Kanwal, 2017; Munir and Riaz, 2020; Rahman et al., 2021). In contrast, the higher demand for energy in advanced economies motivates efficient energy utilization through the adoption of novel technologies that reduce emissions in those economies (Stern, 2006). Accordingly, this study forestalls either a positive or negative impact of energy consumption on environmental quality in the Australian context.

The discourse on the trade-environment relationship frequently turns around two distinct channels: the scale effect and the composition effect. In the context of the scale effect, trade plays a role in fostering economic growth, thereby inducing heightened levels of production and consumption, which may adversely affect the environment (Copeland, 2013). Nevertheless, the trade-environment relationship is more likely to be advantageous to the environment in developed nations, primarily owing to their rigorous environmental policies concerning trade (Copeland, 2013). Therefore, we foresee a positive influence of trade openness on environmental quality in Australia.

The general model presented in Equation (1) can be reformulated as Equation (2) by incorporating the control variables considered in this study.

$$EQ_t = \alpha + \beta_1 FMD_t + \beta_2 GDP_t + \beta_3 ENG_t + \beta_4 TO_t + \varepsilon_t \tag{2}$$

Where, FMD_t denotes financial market development while $GDP_t, ENG_t,$ *and* TO_t represent economic growth, energy consumption, and trade openness, respectively. β_1, β_2, β_3, and β_4 measure the coefficients of explanatory variable. ε_t symbolizes the error term of the model and t represents the time.

Finally, to address the exponential variances in the dataset under consideration in this study, log transformation is employed, and the model is reformulated as Equation (3).

$$\ln EQ_t = \alpha + \beta_1 lnFMD_t + \beta_2 lnGDP_t + \beta_3 lnENG_t + \beta_4 \ln TO_t + \varepsilon_t \tag{3}$$

3.2. Econometric approach

To empirically estimate the model presented in Equation (3), this study employs an Autoregressive Distributed Lag (ARDL) bound test approach, drawing inspiration from the empirical works of Deng et al. (2023). The ARDL approach is particularly suitable for statistical estimations with small samples, regardless of the individual regressors' different orders of integration—whether they are I(0), I(1), or a combination of both (Pesaran et al., 2001). Before initiating the ARDL approach, we conducted a stationarity test on the dataset using the Augmented Dickey-Fuller (ADF) test to ascertain the order of integration of the dataset. After confirming the order of integration, Equation (4) presents the estimated ARDL model. The optimal lag selection for the cointegration equation is determined based on the Akaike Information Criterion (AIC).

$$\Delta lnEQ_t = \beta_0 + \beta_1 lnEQ_{t-i} + \beta_2 lnFMD_{t-i} + \beta_3 lnGDP_{t-i} + \beta_4 lnENG_{t-i} + \beta_5 lnTO_{t-i} + \sum_{i=1}^{p} \delta_{1i}\Delta lnEQ_{t-i} + \sum_{i=1}^{p} \delta_{2i}\Delta lnFMD_{t-i} + \sum_{i=1}^{p} \delta_{3i}\Delta lnGDP_{t-i} + \sum_{i=1}^{p} \delta_{4i}\Delta lnENG_{t-i} + \sum_{i=1}^{p} \delta_{5i}\Delta lnTO_{t-i} + \varepsilon_t \tag{4}$$

Next, the verification of the cointegration relationship among regressors was conducted through the bound test. The existence of a cointegration relationship among regressors is a prerequisite for estimating the long-run coefficients of the model. Therefore, the null hypothesis of H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$ is tested against its alternative hypothesis of H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$. Following that, to gauge the convergence of the model towards equilibrium, the Error Correction Model is estimated, and the ECM model is presented in Equation (5).

$$\Delta ln\, EQ_t = \delta_0 + \sum_{i=1}^{p} \delta_1 lnEQ_{t-i} + \sum_{i=1}^{p} \delta_2 \Delta lnFMD_{t-i} + \sum_{i=1}^{p} \delta_3 \Delta lnGDP_{t-i} + \sum_{i=1}^{p} \delta_4 \Delta lnENG_{t-i} + \sum_{i=1}^{p} \delta_5 \Delta lnTO_{t-i} + \psi ECT_{t-i} + \varepsilon_t \tag{5}$$

The presence of cointegration between environmental quality and its predictors indicates the potential for at least one-way causality between these variables. Consequently, we performed a Granger causality test, as outlined by Granger (1969), to investigate causality not addressed by the ARDL bound test approach. Equations (6) and (7) illustrate the causality models and test the null hypotheses that Y does not Granger-cause X and X does not Granger-cause Y.

$$Y_t = \varsigma_0 + \varrho_1 Y_{t-1} + \ldots\ldots + \varrho_k Y_{t-k} + \varepsilon_1 X_{t-1} + \ldots\ldots \varepsilon_k X_{t-k} + \omega_t \tag{6}$$

$$X_t = \zeta_0 + \vartheta_1 X_{t-1} + \ldots\ldots + \vartheta_k X_{t-k} + \xi_1 Y_{t-1} + \ldots\ldots \xi_k Y + \phi_t \tag{7}$$

Finally, various diagnostic tests are employed to evaluate the adequacy and reliability of the fitted Autoregressive Distributed Lag (ARDL) model in estimating the impact of market-based financial development on environmental quality in Australia. The stability of coefficients in the fitted model is assessed using the Cumulative Sum of Recursive Residuals (CUSUM) and CUSUM of squares tests. Furthermore, the Breusch-Godfrey Serial Correlation LM Test, Heteroscedasticity test, and normality test are applied to examine the presence of autocorrelation among residuals, constant variance, and normality in the residuals. Furthermore, for robustness checks, in line with Apergis (2016); Samargandi (2019); Nguyen et al. (2020); and Atsu et al. (2021), we re-estimated Equation (3) using the Fully-Modified OLS (FMOLS), Dynamic OLS (DOLS), and Canonical Cointegrating Regression (CCR).

3.3. Data

To empirically assess the econometric model, we utilized secondary data spanning from 1983 to 2021, guided by data availability. The data is predominantly collected on an annual basis, as the majority of the available data is provided in this format. The proxies of each variable and the corresponding data sources are presented in Table 1 below.

More importantly, this study addresses a notable gap in the existing body of literature by employing five proxies to measure market-based financial development comprehensively. Specifically, these proxies cover all dimensions of the financial market development, including financial market access, depth, efficiency, and stability. Additionally, the selected proxies also cover the development of the debt market, equity market, and insurance market. The IMF's sub-indices on financial market development assess financial access, depth, and efficiency within the debt and equity markets. Furthermore, to gauge the market stability of the equity market, stock price volatility was chosen as a proxy,

Table 1
Proxies of the study variables.

Variable	Measurement	Source of Data
EQ	Total greenhouse gas emissions [It includes Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), Sulphur Hexafluoride (SF6)]	World Bank Database National greenhouse gas emission inventories
FMD	Financial market access index Financial market depth index Financial market efficiency index Stock price volatility Gross insurance premium	International Monetary Fund Global financial development database Bloomberg database OECD database
GDP	GDP per capita	World Bank Database
ENG	Primary energy consumption per capita (kWh/person)	World Bank Database
TO	Total exports and imports of goods and services (% of GDP)	World Bank Database

aligning with the availability of data. In accordance with the approach suggested by Appiah-Otoo and Acheampong (2021), gross insurance premium was employed as a proxy to assess the development of the insurance market. Principal Component Analysis (PCA) was employed as a tool to construct the financial market development index from proxy variables, following the methodology outlined in the works of Shahbaz et al. (2016).

The time series plots of the proxy variables for the financial market development in Australia are depicted in Fig. 1. Similarly, the time series plots of the dependent variable and other exploratory variables that were considered in this study are graphically displayed in Fig. 2.

4. Empirical results and discussion

The descriptive statistics in Table 2 provide the main features of the dataset utilized in this study. The table summarizes the mean, median, maximum, minimum, standard deviation, skewness, kurtosis, and Jarque-Bera values for the log-transformed data series of each variable

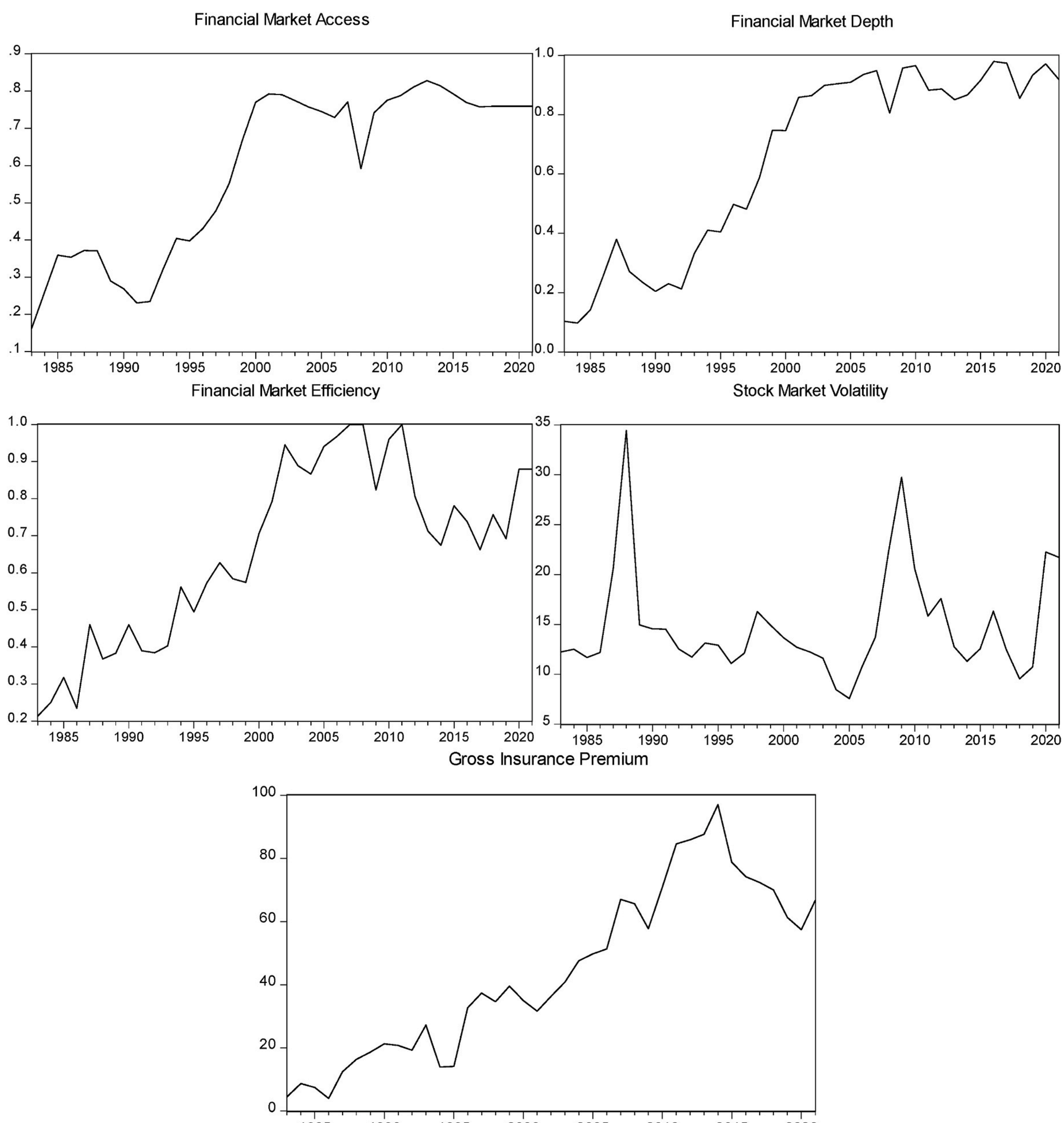

Fig. 1. Time series plots of the proxy variables for the financial market development.

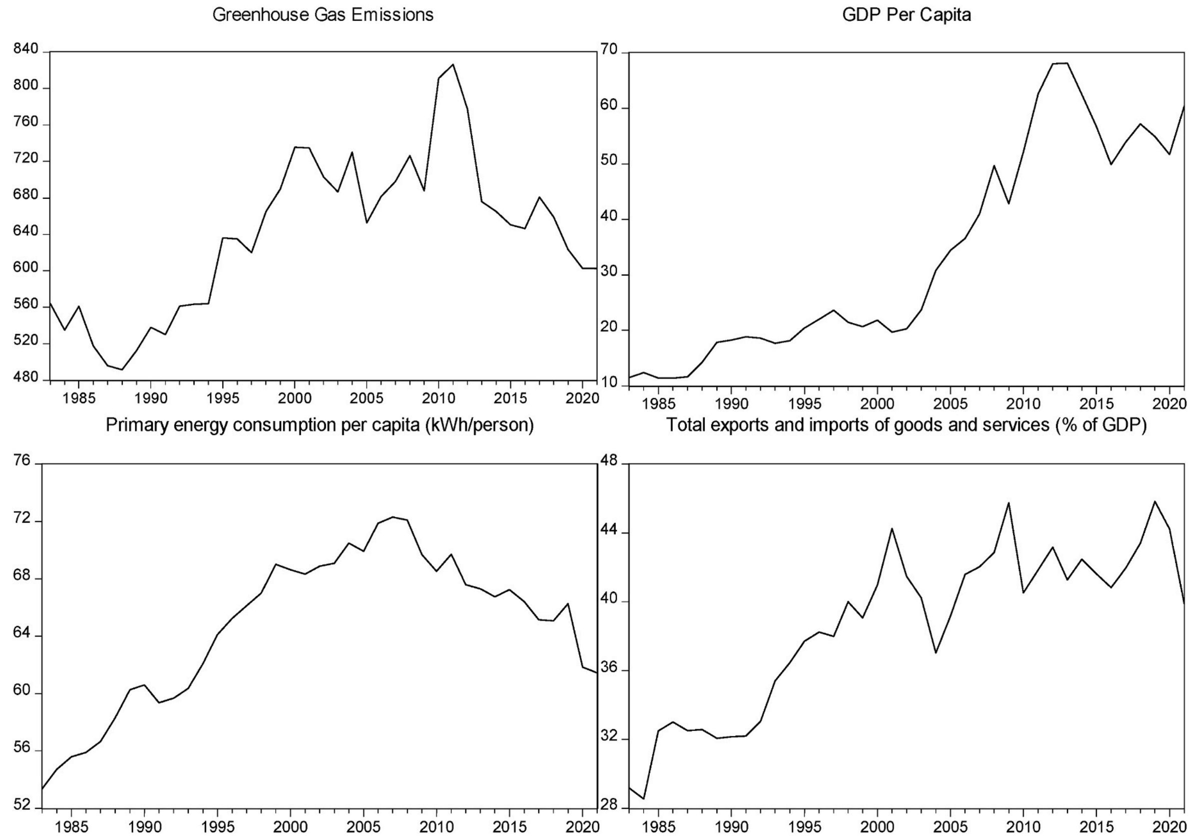

Fig. 2. Time series plots of the dependent variable and other variables used.

Table 2
Descriptive statistics.

Description	LnEQ	LnFMD	LnENG	LnGDP	LnTO
Mean	20.267	−4.10E-16	11.074	10.257	3.645
Median	20.293	1.231	11.101	10.079	3.688
Maximum	20.532	2.294	11.188	11.129	3.824
Minimum	20.012	−3.584	10.884	9.340	3.351
Std. Dev.	0.135	1.919	0.083	0.591	0.127
Skewness	−0.148	−0.469	−0.660	0.026	−0.685
Kurtosis	2.241	1.580	2.370	1.612	2.371
Jarque-Bera	1.076	3.710	3.484	3.134	3.692
Probability	0.583	0.194	0.175	0.208	0.157
Sum	790.427	−2.78E-14	431.887	400.025	142.166
Sum Sq. Dev.	0.694	140.074	0.262	13.274	0.614
Observations	39	39	39	39	39

Source: Authors' calculations

under investigation. Notably, all variables demonstrate a leftward skew, except for the log-transformed GDP series, which exhibits a rightward skew. Furthermore, each of the data series follows a normal distribution. Additionally, the correlation matrix is summarized in Table 3. As indicated, all explanatory variables exhibit positive correlations with greenhouse gas emissions. Also, the observed weak relationships between explanatory variables confirm the absence of collinearity among them.

Table 3
Correlation matrix.

Variable	LnEQ	LnFMD	LnGDP	LnENG	LnTO
LnEQ	1.000000				
LnFMD	0.817003	1.000000			
LnGDP	0.657086	0.085627	1.000000		
LnENG	0.853560	0.241365	0.156256	1.000000	
LnTO	0.774687	0.307416	0.201585	0.432446	1.000000

Source: Authors' calculations

Before applying time series analysis, it is imperative to determine the order of integration for each data series under consideration in this study. The results of the unit root test are presented in Table 4. All data series are non-stationary at the level series, except for LnFMD. However, all series demonstrate stationarity at the first difference, thereby satisfying the requirements for the ARDL procedure. Next, the ARDL approach is employed to investigate the existence of cointegration among variables, facilitating the subsequent estimation of long-run and short-run dynamics. The optimal lag selection for the ARDL approach—1, 3, 4, 3, 0 (corresponding to LnEQ, LnFMD, LnGDP, LnENG, and LnTO, respectively) — is determined using the Akaike Information Criteria (AIC).

First, we tested the presence of cointegration among the variables to estimate the long-run coefficients and investigate the impact of market-based financial development on greenhouse gas emissions. As presented in Table 5, the bound test F statistic surpasses the critical value at the 1% significance level, confirming a long-run association among LnEQ and the explanatory variables LnFMD, LnGDP, LnENG, and LnTO.

The estimated long-run coefficients are presented in Table 6. As indicated, all the variables are statistically significant except for LnTO.

Table 4
The results of the unit root test.

Variable	Level	1st difference	Order of Integration
LnEQ	−1.465364	−6.255530***	I(I)
LnFMD	−3.131061**	−5.244885***	I(0)
LnGDP	−0.894155	−4.564953***	I(I)
Ln ENG	−2.526416	−4.973197***	I(I)
LnTO	−2.246824	−6.091941***	I(0)

Note: *** & ** indicate significance at 1% and 5% level, respectively.
Source: Authors' calculations

Table 5
The results of the long-run bound test.

F-statistic	5.346[a]	Critical Values	I (0)	I (1)
		10%	2.2	3.09
		5%	2.56	3.49
		1%	3.29	4.37

Note.
[a] indicates significance at the 1% level.
Source: Authors' calculations.

Table 6
The long-run coefficients.

Variable	Coefficient	Std. Error	t-Statistic	P-value
LnFMD	−0.096971	0.031457	−3.082621	0.0061**
LnGDP	0.206999	0.068087	3.040231	0.0067**
LnENG	3.163244	0.551949	5.731042	0.0000***
LnTO	−0.352407	0.300032	−1.174566	0.2547
C	−15.61706	6.108697	−2.556528	0.0193

R-squared 0.9479, Adjusted R-squared 0.9067, F-statistic 23.049 (0.000)***.
Note: *** & ** indicate significance at 1% and 5% level, respectively.
Source: Authors' calculations.

More significantly, market-based financial development has a negative impact on greenhouse gas emissions in Australia, signifying a reduction in emissions. Statistically, a 1% change in Australia's financial market development leads to a 0.096% reduction in greenhouse gas emissions, contributing to an improvement in environmental quality. This aligns with the findings of Acheampong et al. (2020); and Habiba and Xinbang (2022) confirming that Australia's capital market and insurance market channel financial resources towards sustainable avenues, ensuring environmental quality. It shows that in the long run, sustainability is prioritized over profitability. Additionally, in the long run, the regulatory framework governing financial market activities encourages industries to comply with regulations that improve environmental quality.

Additionally, LnGDP and LnENG positively impact greenhouse gas emissions, suggesting degradation in environmental quality in Australia. According to the long-run coefficients, a 1% improvement in the Australian economy leads to a 0.20% increase in greenhouse gas emissions, contributing to the degradation of environmental quality. This finding is consistent with existing Australian empirical evidence from Marques et al. (2018); and Rahman & Vu (2020). Furthermore, a 1% change in primary energy consumption in the Australian economy contributes to a 3.16% increase in emissions, weakening environmental quality, in line with the empirical findings of Mirza and Kanwal (2017); Munir and Riaz (2020); and Rahman et al. (2021).

As indicated in Table 7, a short-run association exists between greenhouse gas emissions and all regressors in the model, confirming the necessity of estimating short-run coefficients. The estimates of the short-run coefficients are provided in Table 8. In the context of our analysis, we include lagged variables to capture the short-term dynamics and assess the extent to which past values of financial development and other explanatory variables influence current environmental quality. As shown in Table 8, the error correction term is negative and statistically significant, suggesting that greenhouse gas emissions return to equilibrium after a variation in financial market development and other tested variables at a speed of 74.49%.

Table 7
The results of the short-run bound test.

F-statistic	5.346[a]	Critical Values	I (0)	I (1)
		10%	2.2	3.09
		5%	2.56	3.49
		1%	3.29	4.37

Note.
[a] indicates significance at the 1% level.
Source: Authors' calculations.

Table 8
The short-run coefficients.

Variable	Coefficient	Std. error	t-statistic	P-value
D(LnFMD)	0.0611	0.0249	2.4530	0.0240**
D(LnFMD(-1))	0.0686	0.0238	2.8782	0.0096***
D(LnFMD(-2))	−0.0266	0.0188	−1.4114	0.1743
D(LnGDP)	0.2582	0.0668	3.8648	0.0010***
D(LnGDP(-1))	0.1609	0.0772	2.0833	0.0510*
D(LnGDP(-2))	0.1741	0.0728	2.3896	0.0274**
D(LnGDP(-3))	−0.1022	0.0700	−1.4607	0.1604
D(LnENG)	1.5254	0.4661	3.2723	0.0040***
D(LnENG(-1))	1.0403	0.4502	2.3103	0.0323**
D(LnENG(-2))	0.2572	0.3232	0.7959	0.4359
CointEq(-1)*	−0.7449	0.1170	−6.3656	0.0000***

R-squared: 0.7456, Adjusted R-squared: 0.6397.
Note: ***, **, and * indicates significance at the 1%, 5% and 10% level, respectively.
Source: Authors' calculations.

Additionally, Australia's financial market development has a short-run impact on environmental quality. In contrast to its long-run effects, the short-run impact of financial market development suggests a negative influence on environmental quality. This is evident in the illustration that a 1% improvement in Australia's market-based financial development leads to a 0.06% increase in greenhouse gas emissions in the short run, consequently degrading environmental quality. Furthermore, the short-run elasticity of market-based financial development is found to be less than its long-run elasticity. The short-run impact contradicts the long-run impact for several reasons. The immediate effect of financial market development leads to a surge in economic activities that prioritize profitability over sustainability, resulting in increased toxic emissions. However, in the long run, financial market development promotes economic diversification, making economies more diverse and resilient to environmental damage. This shift involves increased investments in sustainable industries, ultimately creating a healthier environment. These contradictory long-run and short-run findings are similar to those reported in Deng et al. (2023), which also observed differing impacts for some studied economies. The immediate effects of economic growth and energy consumption in the short run also contribute to increased greenhouse gas emissions in Australia, posing challenges to environmental quality. Nevertheless, it is noteworthy that the short-run elasticities of both economic growth and energy consumption are smaller than their respective long-run elasticities. Moreover, the R-squared values of the tested long-run and short-run models are 94.7% and 74.5%, respectively, indicating that the total variation in environmental quality can be jointly described by the regressors employed in this study.

The results of the Granger causality test are presented in Table 9. Further reinforcing the cointegration findings observed in the study, the Granger causality test reveals unidirectional causality from financial market development, GDP, and energy consumption to environmental quality in Australia. However, trade openness does not show any causality with environmental quality in Australia.

Furthermore, various diagnostic tests are applied to evaluate model residuals, aiding in the assessment of model adequacy. Accordingly, the Correlation LM test, Heteroskedasticity test, and Jarque-Bera statistics are used along with the CUSUM test and CUSUM of Square test. The results of the Correlation LM test, Heteroskedasticity test, and Jarque-Bera statistics are summarized in Table 10. The Breusch-Godfrey Serial Correlation LM test statistics validate the absence of serial correlation in residuals, and the Heteroskedasticity Test: Breusch-Pagan-Godfrey confirms homoscedasticity in the residuals. Jarque-Bera statistics confirm the normal distribution of the residual series. Further, the stability of the applied time series analysis in both the short run and long run is confirmed by the CUSUM test and CUSUM of Square test, as the

Table 9
The results of the Granger causality Test.

Null Hypothesis	F- statistic	Decision
LnFMD does not Granger Cause LnEQ	3.2205* [0.0532]	Unidirectional causality from LnFMD to LnEQ
LnEQ does not Granger Cause LnFMD	0.8961 [0.4181]	
LnGDP does not Granger Cause LnEQ	3.4711** [0.0285]	Unidirectional causality from LnGDP to LnEQ
LnEQ does not Granger Cause LnGDP	0.1462 [0.8645]	
LnENG does not Granger Cause LnEQ	4.6496** [0.0169]	Unidirectional causality from LnENG to LnEQ
LnEQ does not Granger Cause LnENG	0.1653 [0.8483]	
LnTO does not Granger Cause LnEQ	0.8299 [0.4452]	No causality
LnEQ does not Granger Cause LnTO	0.6864 [0.5207]	

Source: Authors calculations. Note: ***, ** & * indicates significance at 1%, 5%, and 10% level, respectively.

Table 10
The results of diagnostic tests.

Breusch-Godfrey Serial Correlation LM Test	1.4202 [0.2689]
Heteroskedasticity Test: Breusch-Pagan-Godfrey	1.2661 [0.3086]
Jarque-Bera	1.3313 [0.6952]

Parenthesis "[.]" indicates the probability values.

statistics remain within the 5% confidence bounds. The graphical representation of the CUSUM test and CUSUM of Square test is illustrated in Figs. 3 and 4.

In addition to the aforementioned diagnostic tests, we conducted robustness checks by re-estimating Equation (3) using FMOLS, DOLS, and CCR. The estimation results are presented in Table 11, and these estimates are compared with the long-run estimates corresponding to the ARDL model, as given in Table 6. Interestingly, the estimates obtained through FMOLS, DOLS, and CCR are similar to the ARDL estimates. Similar to the ARDL long-run estimates, financial market development, economic growth, and energy consumption exhibit a significant impact on greenhouse gas emissions, while trade openness demonstrates an insignificant impact under the three considered estimation techniques used for robustness checks. Additionally, financial market development contributes to an improvement in environmental quality by reducing greenhouse gas emissions. The changes in economic growth and energy consumption lead to an increase in greenhouse gas emissions, thereby deteriorating environmental quality in Australia.

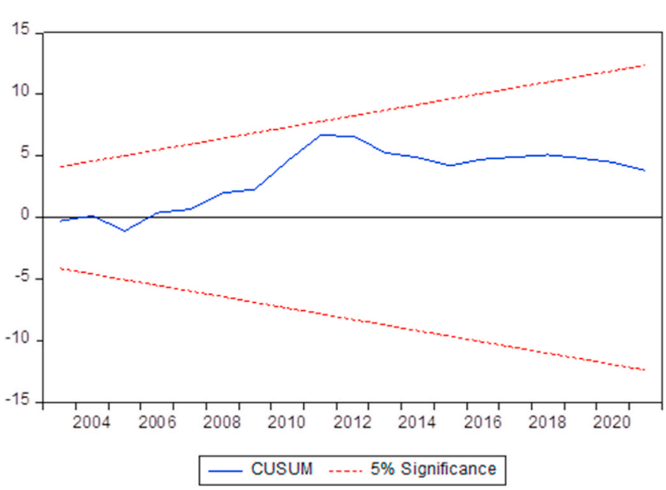

Fig. 3. Plots of CUSUM test.

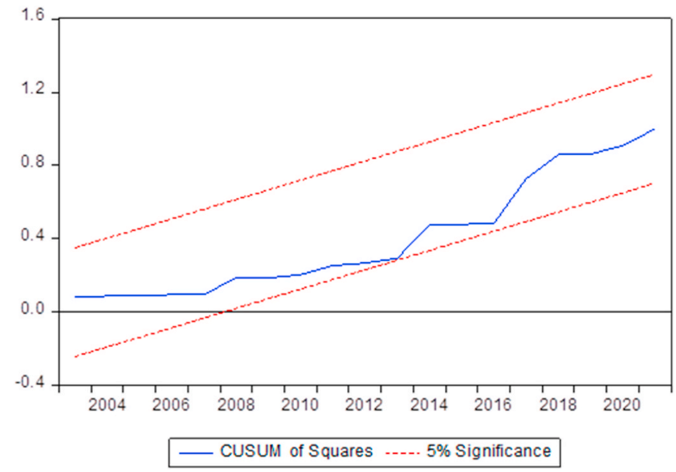

Fig. 4. Plots of CUSUM of squares test.

Table 11
Estimates of FMOLS, DOLS and CCR.

Variable	FMOLS	DOLS	CCR
LnFMD	−0.056 [0.002] ***	−0.049 [0.012] **	−0.068 [0.025] **
LnGDP	0.215 [0.010] ***	0.242 [0.049] **	0.238 [0.036] **
LnENG	1.561 [0.000] ***	1.775 [0.002] ***	1.656 [0.000] ***
LnTO	−0.246 [0.689]	−0.220 [0.426]	0.325 [0.411]
C	12.957 [0.000] ***	−12.028 [0.080] *	−12.570 [0.000] ***
R^2	0.816	0.895	0.743
Adj. R^2	0.788	0.797	0.712

Note: ***, **, and * indicates significance at the 1%, 5% and 10% level, respectively.
Source: Authors' calculations.

Moreover, the R-square values of all estimated models confirm that the total variation in greenhouse gas emissions is well-explained by the considered variables in the model.

5. Conclusion and policy implications

As a crucial component of the financial system, the financial market exerts an impact on environmental quality by influencing production and consumption scales. Consequently, this study is primarily dedicated to examining the impact of financial market development on environmental quality in Australia, addressing an existing empirical gap. To achieve this objective, we applied the ARDL bound testing approach and utilized secondary data from 1983 to 2021. Additionally, this study comprehensively covers various dimensions of financial market development, including financial market access, depth, efficiency, and stability. The empirical results reveal that financial market development significantly reduces greenhouse gas emissions in Australia, contributing to an improvement in environmental quality over the long run. However, the long-run impact of economic growth and energy consumption is reported as positive on greenhouse gas emissions, thereby worsening environmental quality in Australia. In contrast, the short-run impact of financial market development exacerbates environmental quality issues in Australia, opposing the long-run impact. This highlights the need for policies to address the adverse immediate effects of financial market development. Moreover, the short-run impact of economic growth and energy consumption mirrors their long-run counterparts.

The empirical findings of this study yield several policy implications for Australia and other developed countries aiming to enhance environmental quality. Market-based financial development exhibits different impacts in the long run and short run. Hence, policymakers can utilize financial market development to improve environmental quality by effectively managing the flow of financial resources through strategic and balanced policies. Strengthening short-term environmental regulations is essential. Implementing tighter environmental regulations and enforcement can help mitigate the adverse impact of financial market development, particularly by restricting financial resources flowing to high-pollutant industries. The Australian government should focus on new investment projects by tightening environmental assessments. Additionally, incentivizing green investments through tax reliefs and financial incentives can significantly direct financial market activities toward sustainable avenues. This includes channeling funds to environmentally friendly initiatives to balance the immediate adverse effects on environmental quality. Following the example of the United States, Australian policymakers can enhance environmental quality by implementing tighter environmental regulations for the financial market alongside incentives for green investments. Promoting and facilitating sustainable financial products, such as green bonds and green investment funds, can also help strategically enhance environmental quality. Policymakers should implement a monitoring mechanism to regularly assess the activities of financial markets, as short-term priorities often favor profitability over sustainability. This will allow policymakers to manage financial flows in the economy and ensure both short-term and long-term environmental targets are met. Furthermore, increasing the awareness of financial market participants about the environmental impact of their activities can encourage them to reconfigure their investment portfolios towards environmentally healthy investments. This shift is crucial for redirecting investments from pollutant sectors to sustainable industries. Moreover, policymakers ought to incentivize industries with high pollution levels to embrace environmentally sustainable production methods, integrate cutting-edge energy-saving technologies, and channel investments into renewable energy sources. This entails enhancing the provision of renewable energy and offering financial support to both industries and individuals, fostering the widespread adoption of renewable energy sources and consequently mitigating environmental pollution.

This study focused on the period up to 2021, given the data availability within the study's context. However, this leaves room for future scholars to explore the latest data in order to re-examine the objectives of this study. Notably, the present study relies on the IMF Financial Market Development Index, which measures financial access, depth, and stability. Additionally, financial market stability is captured through a variable representing the equity market due to data availability, while other financial markets such as the debt market and insurance market are neglected in this study due to data constraints. Similarly, the study uses one variable to represent insurance market development due to data unavailability. Therefore, future scholars have a potential research pathway to re-evaluate market-based financial development by considering broader measures that represent each component of the financial market. This study's findings provide valuable insights into the relationship between financial market development and environmental quality in Australia. However, it is important to acknowledge that these findings may not be directly generalizable to other developed economies with different economic structures, financial systems, and environmental policies. Australia has a diversified economic structure but is highly reliant on natural resource extraction, which differs from other developed economies. Therefore, countries heavily reliant on manufacturing and the service sector may experience different environmental impacts from their financial market development. Similarly, the maturity level and regulatory mechanisms of the Australian financial market differ from those in other developed countries, and Australia faces unique environmental challenges. Consequently, comparative studies with developed economies with different economic and financial settings are needed to fully understand the generalizability of these findings.

CRediT authorship contribution statement

Ambepitiya Wijethunga Gamage Champa Nilanthi Wijethunga: Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Mohammad Mafizur Rahman:** Writing – review & editing, Supervision. **Tapan Sarker:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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