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Impact of Financial Development on Greenhouse Gas Emissions in Indonesia: A Comprehensive Analysis (2000-2019)

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ABSTRACT

This study aims to comprehensively analyze the impact of financial development on greenhouse gas emissions in Indonesia during the period from 2000 to 2019. Using ordinary least squares with robust standard errors, the study revealed a positive and significant relationship between financial development and total greenhouse gas emissions. The study revealed a positive and significant relationship between financial development and total greenhouse gas emissions by employing utilizing a comprehensive financial development index. The findings indicate that higher levels of financial development by employing utilizing a comprehensive financial development index led to increased greenhouse gas emissions. Moreover, sector-specific analyses demonstrated that financial development significantly and positively influences emissions across various sectors, including the energy sector, agriculture, forest, and other land uses, peatland fires, and waste. However, intriguingly, financial development was found to have a significant and negative impact on greenhouse gas emissions in the industrial processes and product use sector, suggesting its role in promoting sustainable practices and contributing to emissions reduction in this specific domain.

Keywords: Financial Development, Greenhouse Gas Emissions, Environmental, Emerging Countries
JEL Classifications: G10, G20, Q01, Q20

1. INTRODUCTION

The issue of greenhouse gas emissions and its impact on global warming holds paramount importance in today's world. The escalating concentration of greenhouse gases, particularly carbon dioxide, in the atmosphere has been identified as a major driver of climate change and its associated consequences. As a result, it becomes imperative for scholars and policymakers to deeply explore the intricate relationship between economic growth and carbon emissions, taking into account the potential implications for environmental sustainability and human well-being.

One subject that has garnered extensive research interest is the impact of financial development on carbon emissions. Despite numerous studies, no consensus has been reached among researchers. Some academics argue that financial development could lead to an increase in carbon emissions, owing to the amplified funding for industrial expansion, resulting in higher pollutant emissions (Boutabba, 2014). Moreover, the promotion of consumer credit services may stimulate personal consumption, thereby contributing to a rise in carbon dioxide emissions. Conversely, a few researchers propose that financial development might actually have a positive effect on emissions reduction, although the underlying mechanisms remain incompletely understood. In contrast, some scholars maintain that financial development has no significant effect on carbon emissions, underscoring the complex and multifaceted nature of this relationship, which necessitates further investigation.

As studies have been conducted across various regions and time periods, they have generated contradictory findings concerning the impact of financial development on carbon emissions. For instance, Boutabba (2014) found that financial development had a long-term positive effect on carbon emissions in India, leading to environmental degradation. In contrast, Bui (2020) revealed a direct positive relationship between financial development and environmental degradation on a global scale. Tamazian and Bhaskara Rao (2010) demonstrated that financial liberalization could be detrimental to environmental quality, particularly in economies undergoing transition without robust institutions. Meanwhile, Hasan et al. (2021) identified a short-term effect of financial development on carbon emissions in Bahrain. These diverse outcomes underscore the need to consider specific economic and institutional contexts in research on the link between financial development and carbon emissions.

Extensive research has explored the relationship between financial development and carbon emissions in numerous countries and regions, yielding a broad spectrum of results. For example, Yang et al. (2023) discovered a significant positive influence of financial development, as measured by loans from financial institutions as a percentage of GDP, and industrial constitution upgrading on carbon emissions in 283 Chinese cities between 2006 and 2019. In contrast, Zaidi et al. (2019) found that globalization and financial development had a mitigating effect on carbon emissions in Asia Pacific Economic Cooperation (APEC) countries between 1990 and 2016. Furthermore, Sharma et al. (2019) observed that foreign aid and remittances led to a reduction in carbon emissions, while financial development and high economic prosperity contributed to increased carbon dioxide emissions in Nepal. Such diverse findings indicate that specific factors and contexts play crucial roles in shaping the relationship between financial development and carbon emissions in different regions.

Given the complexity and multidimensionality of financial development's impact on carbon emissions, recent research has sought a deeper understanding of this association. Studies by Habiba and Xinbang (2022) and Acheampong et al. (2020) have demonstrated that specific aspects of financial market development can lead to a reduction in CO_2 emissions in both developed and developing countries. However, other studies by Omri et al. (2015) and Dogan and Turkekul (2016) have found no direct causal relationship between economic growth and carbon emissions in certain regions, suggesting the influence of other factors. These complexities underscore the need for further investigation and a nuanced approach to comprehending the impact of financial development on carbon emissions in diverse contexts.

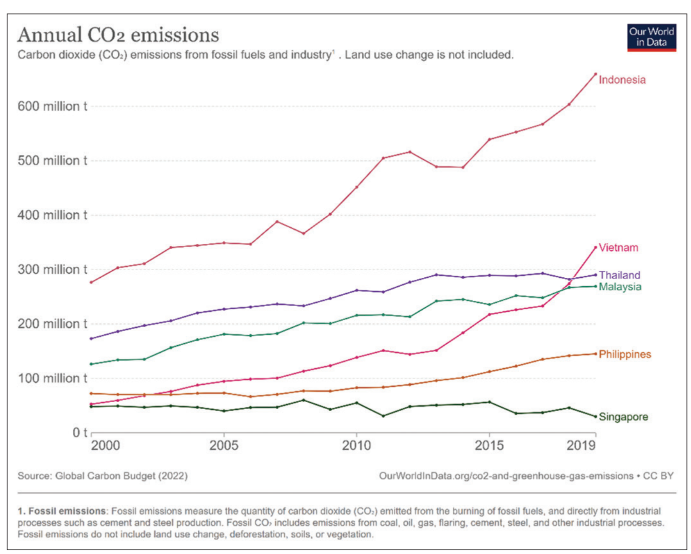
The aim of this study is to conduct a regression analysis to examine the impact of financial development on greenhouse gas emissions in Indonesia during the period from 2000 to 2019. Specifically, we analyze the impact of financial development on total greenhouse gas emissions. To measure financial development, we use a comprehensive index proposed by Svirydzenka (2016), derived from a Principal Component Analysis (PCA) of various variables, including stocks traded, domestic credit to the private sector by banks, market capitalization of listed domestic companies, broad money, and foreign direct investment. Furthermore, total greenhouse gas emissions encompass emissions from the energy sector, industrial processes and product use, agriculture, forest and other land uses, peatland fires, and waste (thousand tonnes of CO_2 equivalent). Additionally, we explore the dependent variables that form the total greenhouse gas emissions, including industrial processes and product use, agriculture, forest and other land uses, peatland fires, and waste. Through this investigation, we aim to contribute to a deeper understanding of the impact of financial development on greenhouse gas emissions in the context of Indonesia (Figure 1).

2. LITERATURE REVIEW

Researchers have not reached a consensus regarding the effect of financial development on carbon dioxide emissions. Financial development has experienced significant developments (Yudaruddin et al., 2023a; Kusumawardani et al., 2021b; Yudaruddin, 2023b; Abbasi et al., 2022). Financial innovation has not only driven financial development but economic growth (Yudaruddin, 2020; Yudaruddin, 2023a). Some academics believe that financial development will increase carbon emissions, citing the fact that enterprises will be able to acquire funds for investments in new production lines, expansion of production scale, and the purchase of heavy machinery and equipment, all of which will result in an increase in pollutant emissions. Another contributing factor is the promotion of consumer credit services through financial development, which encourages personal consumption of items such as automobiles, home appliances, and real estate, thereby contributing to an increase in carbon dioxide emissions. On the other hand, a few researchers hypothesize that financial development could reduce carbon emissions, although the precise mechanisms underlying this reduction remain unknown. A few academicians are of the opinion that financial development and carbon emissions have no significant effect, highlighting the complexity of this relationship and the need for additional study.

Studies investigating the effect of financial development on carbon emissions in various regions and time periods have produced contradictory results. For instance, Boutabba (2014) conducted

Figure 1: Annual CO_2 emissions in ASEAN Countries from 2000 to 2019



research in India and discovered that financial development has a long-term positive effect on carbon emissions, leading to deterioration in environmental quality. In contrast, Bui (2020) analyzed a global sample of 100 countries from 1990 to 2012 and demonstrated that financial development has a direct positive effect on environmental degradation. This suggests that financial development exacerbates the degradation of environmental integrity in various contexts. In addition, development of the financial system has been linked to an increase in energy demand, which in turn has led to an increase in pollutant emissions. Tamazian and Bhaskara Rao (2010) demonstrated that financial liberalization may be detrimental to environmental quality, particularly in economies in transition that lack robust institutions. In addition, Hasan et al. (2021) discovered that financial development had a short-term effect on carbon emissions in Bahrain from 1980 to 2018. These findings emphasize the diverse effects of financial development on carbon emissions and highlight the need to consider specific economic and institutional contexts when conducting such research.

Numerous studies have investigated the relationship between financia development and carbon emissions in numerous coutries and regions. For example, Yang et al. (2023) analyzed data from 283 Chinese cities between 2006 and 2019 and discovered that financial development, as measured by loans from financial institutions as a percentage of GDP, and industrial constitution upgrading have a significant positive influence on carbon emissions. In contrast, Zaidi et al. (2019) found that globalization and financial development reduce carbon emissions, whereas economic growth and energy intensity increase emissions in Asia Pacific Economic Cooperation (APEC) countries between 1990 and 2016. Notably, financial factors have a mitigating effect on emissions only after deregulation and financial sector expansion, and this effect is milder than that of rising per capita incomes (Abbasi and Riaz, 2016). According to Sharma et al. (2019), in Nepal, the receipt of foreign aid and remittances leads to a reduction in carbon emissions, but financial development and high economic prosperity lead to a rise in carbon dioxide emissions. In Egypt, India, Bangladesh, Pakistan, and the Philippines, Wang et al. (2021) observed that economic growth, inflow of remittance, and agriculture value added strongly affected in minimizing carbon emissions, financial stability, and industrial value added in the long term. In the short run, a rise in CO_2 emissions was caused by both the flow of remittances and the value added to agricultural products. Rahaman et al. (2022) investigated the influence that foreign direct investment inflow, tourism, energy consumption, and economic growth had on carbon dioxide emission emissions using times series data of Bangladesh throughout the period that spanned from 1990 to 2019. The data was collected over the course of the country's history. According to their results, foreign direct investment (FDI), economic expansion, and increased power consumption all have a beneficial effect on CO_2 emissions over the long run, leading to an increase in these emissions. Focus on 31 sub-Saharan African countries from 1996 to 2018, Mensah and Abdul-Mumuni (2023) showed remittances and financial development asymmetrically influence carbon emissions in the long run.

Additionally, research on specific countries has yielded diverse results. For instance, Tamazian et al. (2009) examined BRIC economies from 1992 to 2004 and found that financial openness and liberalization policies could reduce environmental degradation. Shahbaz et al. (2013) analyzed South Africa between 1965 and 2008 and found that while economic expansion increases energy emissions, financial development decreases them. In addition, Saidi and Mbarek (2017) provided evidence that financial development has a negative long-term impact on carbon emissions, implying that it reduces environmental degradation in emerging economies. Jiang and Ma (2019) adopted a global perspective and concluded that financial development increases carbon emissions substantially, with similar findings for emerging market and developing countries. In a similar vein, Cetin and Ecevit (2017) analyzed Turkey from 1960 to 2011 and discovered a positive long-term correlation between financial development and carbon emissions. From 1971 to 2010, Ali et al. (2019) examined the correlation between financial development, energy consumption, trade openness, economic growth, and carbon emissions in Nigeria. Their long-term estimations indicated that the expansion of the financial system is a significant contributor to pollution.

Due to the complexity and multidimensionality of financial development, recent studies have sought to gain a deeper understanding of its impact on carbon emissions. Financial market development and its sub-indices reduce CO_2 emissions in both developed and developing coutries, according to Habiba and Xinbang (2022). Similarly, Acheampong et al. (2020) examined 83 countries from 1980 to 2015 and demonstrated that financial market development and its sub-measures, such as financial market depth and efficacy, reduce carbon emission intensity in both developed and emerging economies. This suggests that particular aspects of financial development play a significant role in determining carbon emissions.

Other studies, however, have investigated the effect of specific factors on carbon emissions. For instance, Hou et al. (2021) found that an increase in FDI correlates with a decrease in carbon emissions in China from 1997 to 2018, highlighting the significance of foreign investment in the context of carbon emission reduction. However, research conducted by Omri et al. (2015) in 12 North African and Middle Eastern countries discovered no causal relationship between carbon dioxide emissions and economic development, suggesting that other factors may be more influential in these regions. Similarly, Dogan and Turkekul (2016) examined the United States from 1960 to 2010 and found no significant effect of economic growth on carbon dioxide (CO_2) emissions. Jamel and Maktouf (2017) also found no causal relationship between European financial development and carbon emissions in the context of Europe. Lastly, a study that analyzed data from 39 sub-Saharan African coutries from 2004 to 2014 found that financial development reduces CO_2 emissions without exception, indicating a potential positive impact in this region. Overall, the relationship between financial development and carbon emissions is complex and context-dependent, with numerous factors influencing the outcomes in various coutries and regions.

3. METHODS

This study investigates the relationship between financial development and greenhouse gas emissions. We obtain data on greenhouse gas emissions from central bureau of statistics of Indonesia. Unlike previous studies that used the total greenhouse gas emissions variable, we broke down the greenhouse gas emissions variables from several sources, namely greenhouse gas emissions of the energy sector, the industrial processes and product use, the agriculture, the forest and other land uses, the peatland fires, and the waste (thousand tonnes of CO_2 equivalent). Meanwhile, the data on financial development and control variables have been compiled from the World Bank. This study focuses on Indonesia by covering the period 2000-2019. The definitions and measurements of all variables are presented in Table 1 below:

The association between financial development variables and greenhouse gas emissions was evaluated using using a regression analysis. The regression equation is as follows:

$$GHGE_{,i,t} = \alpha_{,i,t} + \beta_1 FINDEV_{i,t-1} + \beta_2 INDS_{i,t-1} + \beta_3 POGR_{i,t-1} + \beta_4 CRIS_{i,t} + \varepsilon_{i,t} \quad (1)$$

The control variables used include industrial structure (INDS), population growth (POGR), and crisis (CRIS). The industry sector, including construction (INDS), has a significant impact on greenhouse gas emissions, which can be both positive and negative (Mahmoudi et al., 2021; Wei et al., 2007; Lin and Xie, 2014; Gao et al., 2022; Lestari et al., 2022; Amalia et al., 2022; Musviyanti et al., 2022). On the positive side, industrial growth contributes to economic development, job creation, and improved living standards. Technological advancements in the industry have led to increased efficiency and reduced emissions per unit of output, helping to mitigate greenhouse gas emissions. However, on the negative side, the expansion of industrial activities can lead to higher energy consumption, particularly from fossil fuel sources, resulting in increased greenhouse gas emissions.

Population (POGR) can have a complex impact on the increase or decrease of greenhouse gas emissions (Yahaya and Hussaini, 2020; Jamel and Maktouf, 2017; Wang et al., 2018; Heidari et al., 2015; Pujiati et al., 2023; Jebli et al., 2017). On one hand, population growth can lead to an increased demand for energy, food, and natural resources, potentially escalating greenhouse gas emissions due to fossil fuel consumption, deforestation, and intensive agriculture. Additionally, a larger population may result in increased industrial and transportation activities, contributing to overall greenhouse gas emissions. However, on the other hand, a larger population also presents opportunities for implementing more efficient technological innovations, such as renewable energy sources and sustainable agricultural practices. Moreover, growing environmental awareness within communities can foster collective efforts to reduce carbon footprints and contribute to the reduction of greenhouse gas emissions.

Crisis (CRIS) can have complex impacts on the increase or decrease of greenhouse gas emissions. The financial crisis has had a negative impact on the economy (Sadorsky, 2020; Defung and Yudaruddin, 2022; Yudaruddin, 2017a; Yudaruddin, 2017b; Ulfah et al., 2022). The same thing also arises from health crisis such as the COVID19 pandemic (Achmad et al., 2023; Lestari et al., 2021; Maria et al., 2022; Riadi et al., 2022a; Riadi et al., 2022b; Yudaruddin, 2022; Ulfah et al., 2022). In some cases, economic crises resulting in reduced industrial and transportation activities can lead to temporary decreases in greenhouse gas emissions (Aktar et al., 2021; Sadorsky, 2020; Jiang and Guan, 2017; Liu et al., 2023; Siddiqi, 2000). For instance, during the COVID-19 pandemic, many countries experienced emission reductions due to travel restrictions and lower economic activities, demonstrating how economic or health crises can have a positive impact in temporarily reducing emissions. However, negative impacts can also occur, especially if crisis responses prioritize rapid economic

Table 1: Dependent, independent and control variables

Variables	Symbol	Definition and measure	Expected Sign
Dependent			
Greenhouse gas emissions	GHGE	Total greenhouse gas emissions (in thousand tonnes CO_2 equivalent)	
	ENRG	Greenhouse gas emissions of the energy sector (in thousand tonnes CO_2 equivalent)	
	IPPU	Greenhouse gas emissions of the Industrial Processes and Product Use (in thousand tonnes CO_2 equivalent)	
	AGRI	Greenhouse gas emissions of the agriculture (in thousand tonnes CO_2 equivalent)	
	FOLU	Greenhouse gas emissions of the forest and other land uses (in thousand tonnes CO_2 equivalent)	
	PEFI	Greenhouse gas emissions of the peatland fires (in thousand tonnes CO_2 equivalent)	
	WAST	Greenhouse gas emissions of the waste (in thousand tonnes CO_2 equivalent)	
Independent			
Financial development	FINDEV	A comprehensive index proposed by Svirydzenka (2016)	±
	FINDEV1	Stocks traded, total value (% of GDP)	±
	FINDEV2	Domestic credit to private sector by banks (% of GDP)	±
	FINDEV3	Market capitalization of listed domestic companies (% of GDP)	±
	FINDEV4	Broad money (% annual change)	±
	FINDEV5	Foreign direct investment, net inflows (BoP, current billions of US$)	±
Control			
Industrial structure	INDS	Industry (including construction), value added (% of GDP)	+
Population growth	POGR	Population (% annual change)	+
Crisis	CRIS	Dummy variable (1 from 2008 to 2009; 0 elsewhere)	-

recovery without considering environmental consequences. Economic crises often trigger recovery measures that rely on fossil fuel resources or large infrastructure projects, potentially increasing greenhouse gas emissions in the long run. Additionally, prolonged health crises may disrupt emission reduction efforts if governmental priorities shift from environmental issues to health and economic recovery.

Following Hadjaat et al. (2021), Kusumawardani et al. (2021a), Ulfah et al. (2021) and Yudaruddin, (2019), Ordinary Least Squares (OLS) with robust standard errors is utilized in this study. OLS with robust standard errors is a statistical method used in regression analysis to estimate the relationships between variables in a linear model. The OLS method aims to find the best-fitting line through the data points, minimizing the sum of squared differences between the observed and predicted values. Standard errors assume that the errors have constant variance, which might not hold in real-world datasets. Heteroscedasticity occurs when the variability of the errors changes across the range of independent variables, leading to biased standard errors and unreliable hypothesis tests (Wooldridge, 2009). To address this issue, robust standard errors are used, which allow for heteroscedasticity in the data and provide more accurate estimates of the coefficients' precision. The robust standard errors are calculated based on the residuals, adjusting for potential variations in the error terms. This adjustment provides more accurate confidence intervals, hypothesis tests, and P-values, making the estimates more robust to violations of homoscedasticity assumptions. To capture observable effects, we also include country dummy as control variable.

4. RESULTS AND DISCUSSION

In panel models, the problem of spurious regression is caused by non-stationary sequences of data, which further contributes to inaccuracies in predicting the findings. In order to steer clear of this predicament, we decided to investigate the data's stationarity by utilizing five widely utilized unit root tests (Im et al., 2003). Note that in order to conserve space, we will only present the results of the unit-root test and the co-integration test for the main regression (full sample). However, all of the other regressions have also passed these two tests, and the data are available from the authors upon request. The findings of the test to determine the unit root are presented in Table 2. There was not a single variable that did not have a stationary sequence. However, because some of the variables did not show significance in certain unit root tests, we decided to investigate the stationarity of the first-order difference of the variables. The results showed that all of the unit root tests were significant at the 1%, 5% and 10% level, which suggested that all of the variables were integrated at least at the order of one. Nevertheless, some of the variables did not show significance in certain unit root tests.

Table 3 presents the descriptive statistics for all variables in the study. The dataset contains 20 observations for most variables. The variables are categorized as Dependent, Independent, and Control. Among the Dependent variables, GHGE is the primary focus of the study. The mean value of GHGE is approximately 1164.9 thousand tonnes of CO_2 equivalent, with a standard deviation of 452.13.

Table 2: Panel unit root test

Variables	Im–Pesaran–Shin		Result
	t-Stat	Prob.	
GHGE	−6.7721***	0.0000	Stationary
ENRG	−3.8045**	0.0111	Stationary
IPPU	−10.333***	0.0000	Stationary
AGRI	−4.4698***	0.0029	Stationary
FOLU	−5.4865***	0.0004	Stationary
PEFI	−4.3117***	0.0043	Stationary
WAST	−7.3169***	0.0000	Stationary
FINDEV	−4.2095***	0.0053	Stationary
FINDEV1	−5.6867***	0.0003	Stationary
FINDEV2	−3.5351**	0.0199	Stationary
FINDEV3	−5.5068***	0.0004	Stationary
FINDEV4	−8.9072***	0.0000	Stationary
FINDEV5	−5.5626***	0.0003	Stationary
INDS	−5.5307***	0.0003	Stationary
POGR	−2.8413*	0.0735	Stationary

The values in parentheses are the P-values. ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively

Table 3: Descriptive statistics for all variables (n=20)

Variables	Mean	SD	Min	Max
GHGE	1164.9	452.13	461.47	2374.4
ENRG	456.51	94.674	317.61	638.81
IPPU	44.320	7.8983	35.910	60.175
AGRI	107.67	8.0875	97.124	127.50
FOLU	226.68	251.68	−144.33	742.84
PEFI	237.37	201.76	12.512	822.74
WAST	92.353	19.885	64.832	134.12
FINDEV	0.3226	0.0317	0.2683	0.3712
FINDEV1	10.624	3.7993	5.4352	21.960
FINDEV2	26.945	5.1262	18.156	33.127
FINDEV3	36.370	12.665	14.334	51.268
FINDEV4	11.980	4.0814	4.7000	19.300
FINDEV5	11.124	10.013	−4.5504	25.121
INDS	43.712	3.2071	38.952	48.061
POGR	1.4000	0.2176	1.0000	1.9000
CRIS	0.1000	0.3078	0.0000	1.0000

The minimum and maximum values of GHGE are 461.47 and 2374.4 thousand tonnes of CO_2 equivalent, respectively. GHGE is also broken down into specific sectors such as ENRG, IPPU, AGRI, FOLU, PEFI, and WAST. As for the Independent variables, FINDEV is represented by five indicators, namely FINDEV1, FINDEV2, FINDEV3, FINDEV4, and FINDEV5. The mean value of FINDEV is approximately 0.3226, with a standard deviation of 0.0317. The range of FINDEV lies between 0.2683 and 0.3712. Lastly, the Control variables include INDS, POGR, and CRIS. CRIS is a binary variable with a mean value of 0.1, indicating their presence only during specific periods (2008-2009). Overall, the descriptive statistics in Table 3 provide an overview of the data distribution for each variable, serving as a basis for further analysis and interpretation of the study's findings.

Table 4 presents the correlation matrix of the independent variables involved in the analysis. The correlation matrix serves to depict the linear relationship between the variables within the dataset. Upon observing the table, it becomes evident that the correlation values between all pairs of independent variables are quite low, indicating minimal or no issues of multicollinearity. According to Field (2009), a correlation >0.80 indicates no multicollinearity within the data. The low correlation values suggest that the variables have weak or negligible linear associations with each other. As such, the results can be considered robust, and the independent variables appear to be relatively independent of each other, ensuring the validity of the subsequent analyses.

In this study, we conducted a regression analysis to examine the impact of financial development on greenhouse gas emissions in Indonesia. In Table 5, we present the impact of financial development on total greenhouse gas emissions. The financial development variable is measured using a comprehensive index proposed by Svirydzenka (2016). This index is the result of a Principal Component Analysis (PCA) of the variables stocks traded, domestic credit to private sector by banks, market capitalization of listed domestic companies, broad money, and foreign direct investment. Meanwhile, total greenhouse gas emissions are the total of greenhouse gas emissions from the energy sector, the industrial processes and product use, the agriculture, the forest and other land uses, the peatland fires, and the waste (thousand tonnes of CO_2 equivalent). Furthermore, in Tables 6-11, we present more specifically the dependent variables forming the total greenhouse gas emissions (the industrial processes and product use, the agriculture, the forest and other land uses, the peatland fires, and the waste).

Table 4: Correlation matrix

Variables	FINDEV	FINDEV1	FINDEV2	FINDEV3	FINDEV4	FINDEV5	INDS	POGR	CRIS
FINDEV	1.0000								
FINDEV1	0.2262	1.0000							
FINDEV2	0.7752	0.1447	1.0000						
FINDEV3	0.4238	0.4562	0.7657	1.0000					
FINDEV4	−0.2027	0.5914	−0.2322	0.0560	1.0000				
FINDEV5	0.5990	0.1828	0.8316	0.7418	−0.0717	1.0000			
INDS	−0.5047	0.2494	−0.7178	−0.5607	0.4296	−0.5570	1.0000		
POGR	−0.5442	0.1830	−0.4849	−0.3546	0.6701	−0.2694	0.6545	1.0000	
CRIS	0.2256	0.4307	−0.0900	−0.1829	0.1651	−0.1375	0.4419	0.1571	1.0000

Table 5: Financial Development and Total Greenhouse Gas Emissions

Variables	Dependent variable: GHGE (Total greenhouse gas emissions)					
	(1)	(2)	(3)	(4)	(5)	(6)
FINDEV	9925.6** (2.95)					
FINDEV1		22.624 (0.82)				
FINDEV2			83.619*** (4.66)			
FINDEV3				15.709 (1.62)		
FINDEV4					2.3031 (0.08)	
FINDEV5						36.857*** (4.31)
INDS	−38.913 (−1.01)	−87.902** (−2.81)	18.905 (0.65)	−49.567 (−1.29)	−90.970*** (−3.45)	−8.3397 (−0.35)
POGR	313.92 (0.78)	−176.41 (−0.32)	−125.15 (−0.48)	−149.75 (−0.36)	−130.49 (−0.25)	−550.07 (−1.30)
CRIS	−339.11 (−1.48)	4.1058 (0.01)	−131.12 (−0.83)	−79.111 (0.21)	196.33 (0.80)	19.145 (0.13)
Constant	−720.45 (−0.32)	5038.05*** (4.19)	−1704.4 (−1.19)	2984.6 (1.72)	5299.6*** (4.96)	1926.9** (2.22)
F-Statistic	5.36	4.52	7.69	5.94	6.42	10.51
Prob > F	0.0079	0.0149	0.0017	0.0052	0.0038	0.0004
R-Square	0.5616	0.3716	0.7453	0.4804	0.3542	0.7667
Obs.	19	19	19	19	19	19

*sig. at 10%, **sig. at 5%, and ***sig. at 1%

Table 6: Financial Development and Greenhouse Gas Emissions of The Energy Sector

Variables	Dependent variable: ENRG (Greenhouse gas emissions of the energy sector)					
	(1)	(2)	(3)	(4)	(5)	(6)
FINDEV	1648.3*** (3.13)					
FINDEV1		11.713** (2.69)				
FINDEV2			12.980*** (5.03)			
FINDEV3				3.9182** (2.95)		
FINDEV4					1.1948 (0.24)	
FINDEV5						5.9761*** (4.27)
INDS	−12.570 (−1.72)	−19.394*** (−3.49)	−4.1670 (−0.73)	−10.833* (−1.96)	−20.981*** (−3.14)	−7.8200 (−1.46)
POGR	28.670 (0.30)	−80.077 (−0.78)	−43.959 (−0.47)	−52.584 (−0.73)	−56.336 (−0.51)	−113.04 (−1.75)
CRIS	−77.556 (0.30)	−92.459 (−1.47)	−39.335** (−2.48)	−18.891 (−0.31)	7.0585 (0.20)	−17.318 (−0.99)
Constant	455.03 (1.09)	1315.4*** (7.69)	367.65 (1.39)	876.44*** (3.57)	1450.8*** (7.13)	907.95 (4.13)
F-Statistic	21.42	17.57	33.43	19.30	9.31	27.89
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000
R-Square	0.7264	0.7002	0.8224	0.7817	0.5795	0.8592
Obs.	19	19	19	19	19	19

*sig. at 10%, **sig. at 5%, and ***sig. at 1%

Table 7: Financial Development and Greenhouse Gas Emissions of The Agriculture

Variables	Dependent variable: AGRI (Greenhouse gas emissions of the agriculture)					
	(1)	(2)	(3)	(4)	(5)	(6)
FINDEV	162.51*** (4.28)					
FINDEV1		0.6883 (1.45)				
FINDEV2			1.3481*** (8.04)			
FINDEV3				0.2681* (1.80)		
FINDEV4					0.1884 (0.36)	
FINDEV5						−0.3449 (1.40)
INDS	−0.8601 (−1.30)	−1.6098** (−2.49)	0.0587 (0.16)	−1.0052 (−1.30)	−1.6690** (−2.33)	−0.9437 (−0.92)
POGR	7.9523 (1.10)	−1.1676 (−0.13)	0.7697 (0.11)	0.3245 (0.04)	−1.4037 (−0.13)	−3.0289 (−0.39)
CRIS	−8.6444*** (−3.29)	−5.8973 (−0.87)	−5.1534** (−2.79)	−1.8869 (−0.31)	−0.6762 (−0.14)	−1.4501 (−0.44)
Constant	−83.390** (−2.43)	173.84*** (6.24)	69.045*** (3.27)	142.43*** (3.89)	181.24*** (6.45)	150.47*** (3.16)
F-Statistic	13.52	3.82	16.72	4.93	2.06	6.70
Prob > F	0.0001	0.0265	0.0000	0.0108	0.0144	0.0037
R-Square	0.5916	0.4608	0.7446	0.5291	0.4109	0.5269
Obs.	19	19	19	19	19	19

*sig. at 10%, **sig. at 5%, and ***sig. at 1%

Table 8: Financial Development and Greenhouse Gas Emissions of The Forest and Other Land Uses

Variables	Dependent variable: FOLU (Greenhouse gas emissions of the forest and other land uses)					
	(1)	(2)	(3)	(4)	(5)	(6)
FINDEV	0.3449 (1.40)					
FINDEV1		4679.6*** (3.20)				
FINDEV2			−18.913 (1.35)			
FINDEV3				42.403*** (5.17)		
FINDEV4					10.594** (2.59)	
FINDEV5						7.3339 (0.50)
INDS	−0.9437 (−0.92)	−30.255 (−1.56)	−51.992*** (−3.45)	0.9423 (0.09)	−26.742* (−1.97)	−52.998***(−3.34)
POGR	−3.0289 (−0.39)	39.760 (0.22)	−219.73 (−0.93)	−168.19 (−1.46)	−189.20 (−1.47)	−225.93 (−0.99)
CRIS	−1.4501 (−0.44)	−35.099 (−0.32)	52.199 (0.28)	50.857 (0.92)	135.81 (0.87)	184.23 (1.43)
Constant	150.47*** (3.16)	−11.836 (−0.01)	2603.7*** (4.86)	−725.68 (−1.24)	1263.0* (2.01)	2796.6*** (5.28)
F-Statistic	6.70	10.96	11.04	27.83	20.64	9.39
Prob > F	0.0031	0.0003	0.0003	0.0000	0.0000	0.0007
R-Square	0.5269	0.6573	0.5404	0.8454	0.6964	0.5043
Obs.	19	19	19	19	19	19

*sig. at 10%, **sig. at 5%, and ***sig. at 1%

Table 9: Financial Development and Greenhouse Gas Emissions of The Peatland Fires

Variables	Dependent variable: PEFI (Greenhouse gas emissions of the peatland fires)					
	(1)	(2)	(3)	(4)	(5)	(6)
FINDEV	16.806*** (3.63)					
FINDEV1		2991.7 (1.33)				
FINDEV2			−9.8362 (−0.87)			
FINDEV3				23.922* (1.78)		
FINDEV4					−5.5481 (−0.39)	
FINDEV5						12.730* (2.10)
INDS	−17.129 (−1.18)	8.5985 (0.40)	−8.9139 (−0.50)	24.331 (0.97)	−8.8902 (−0.47)	21.478 (1.07)
POGR	−360.60** (−2.42)	249.89 (0.86)	159.28 (0.53)	117.95 (0.47)	202.02 (−0.54)	−30.379 (−0.09)
CRIS	136.73** (2.15)	−204.36 (−1.25)	49.586 (0.34)	−136.46 (−1.04)	−9.8938 (−0.07)	−104.71 (−0.97)
Constant	1288.7* (2.13)	−1430.1 (−1.20)	506.21 (0.65)	−1619.1 (−1.32)	414.22 (0.53)	−781.03 (−1.11)
F-Statistic	15.35	5.55	3.32	0.91	0.17	1.30
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-Square	0.7943	0.7022	0.8583	0.4824	0.0230	0.2669
Obs.	19	19	19	19	19	19

*sig. at 10%, **sig. at 5%, and ***sig. at 1%

Table 5 presents the results of the analysis on the relationship between financial development, total greenhouse gas emissions, and control variables. The findings indicate a positive and significant impact of financial development on total greenhouse gas emissions. Specifically, there is a positive and significant effect observed for financial development variables, such as domestic credit to the private sector by banks and foreign direct investment. These results suggest that higher levels of financial development lead to increased total greenhouse gas emissions. These findings are consistent with previous empirical studies conducted by Boutabba (2014), Bui (2020), Tamazian and Bhaskara Rao (2010), and Hasan et al. (2021). On the other hand, Rahaman

Table 10: Financial Development and Greenhouse Gas Emissions of The Waste

Variables	Dependent variable: WAST (Greenhouse gas emissions of the waste)					
	(1)	(2)	(3)	(4)	(5)	(6)
FINDEV	359.58*** (4.59)					
FINDEV1		1.8180* (1.79)				
FINDEV2			2.8732*** (6.68)			
FINDEV3				0.7109** (2.46)		
FINDEV4					−0.0962 (−0.09)	
FINDEV5						1.0557*** (3.15)
INDS	−2.5079* (−1.90)	−4.1181*** (−3.90)	−0.6196 (−0.85)	−2.5141** (−2.18)	−4.4456*** (−3.70)	−2.0319 (−1.64)
POGR	−4.1815 (-0.28)	−25.373 (−1.23)	−20.039* (−1.83)	−21.440 (−1.45)	−17.803 (−0.92)	−32.059* (−2.04)
CRIS	−8.4392 (−1.28)	−5.0274 (−0.39)	−0.2704 (−0.10)	5.5432 (0.46)	11.911 (1.59)	5.9756 (1.46)
Constant	95.520 (1.40)	292.10*** (7.62)	72.967* (1.91)	208.74*** (3.88)	314.47*** (7.51)	217.08*** (4.20)
F-Statistic	21.39	13.48	30.23	19.59	8.59	19.71
Prob > F	0.0000	0.0001	0.0000	0.0000	0.0010	0.0000
R-Square	0.7844	0.6925	0.8941	0.7766	0.6271	0.8228
Obs.	19	19	19	19	19	19

*sig. at 10%, **sig. at 5%, and ***sig. at 1%

Table 11: Financial Development and Greenhouse Gas Emissions of The Industrial Processes and Product Use

Variables	Dependent variable: IPPU (Greenhouse gas emissions of the industrial processes and product use)					
	(1)	(2)	(3)	(4)	(5)	(6)
FINDEV	83.828* (1.82)					
FINDEV1		−0.6733 (−1.67)				
FINDEV2			0.0927 (0.34)			
FINDEV3				−0.1641* (−2.02)		
FINDEV4					−0.7672* (−2.08)	
FINDEV5						−0.0574 (−0.71)
INDS	−1.3177** (−2.88)	−1.8740*** (−6.72)	−1.6404*** (−3.17)	−2.2027*** (−6.82)	−1.9847*** (−4.39)	−1.8928*** (−5.26)
POGR	−8.1753 (−1.64)	−9.3488* (−2.02)	−11.689** (−2.22)	−11.127 (−2.20)	−1.0456 (−0.14)	−10.957* (−2.03)
CRIS	−5.0051 (−1.69)	5.7043 (1.35)	−0.7564 (−0.35)	0.9729 (0.69)	3.6993 (1.24)	−0.0846 (−0.04)
Constant	87.577** (2.65)	146.62*** (12.02)	130.73*** (4.79)	162.82*** (11.09)	142.19*** (11.27)	143.78*** (10.95)
F-Statistic	38.96	31.03	20.45	31.75	56.15	21.99
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-Square	0.8247	0.8271	0.7776	0.8214	0.8424	0.7794
Obs.	19	19	19	19	19	19

*sig. at 10%, **sig. at 5%, and ***sig. at 1%

et al. (2022) discovered that foreign direct investment (FDI), economic expansion, and increased power consumption all have a beneficial effect on CO_2 emissions in the long run, leading to a rise in these emissions.

In the next tables, we present a breakdown of greenhouse gas emissions variables. Tables 6-10 examine the impact of financial development on greenhouse gas emissions in various sectors, namely the energy sector, agriculture, forest and other land uses, peatland fires, and waste. The analysis reveals a positive and significant influence of financial development on greenhouse gas emissions in all of these sectors. Specifically, Table 6 demonstrates that financial development proxies, such as variables stocks traded, domestic credit to the private sector by banks, market capitalization of listed domestic companies, and foreign direct investment, have a positive and significant effect on greenhouse gas emissions in the energy sector.

Moving on to Table 7, financial development, represented by domestic credit to the private sector by banks and market capitalization of listed domestic companies, also shows a positive and significant impact on greenhouse gas emissions in the agriculture sector. For greenhouse gas emissions in the forest and other land uses (Table 8), an increase in financial development measured by variables stocks traded, market capitalization of listed domestic companies, and broad money leads to higher emissions. Similarly, Table 9 reveals that greenhouse gas emissions from peatland fires are influenced by an increase in financial development, measured by market capitalization of listed domestic companies and foreign direct investment. Finally, Table 10 indicates that an increase in financial development proxies, such as variables stocks traded, domestic credit to the private sector by banks, market capitalization of listed domestic companies, and foreign direct investment, will also result in higher greenhouse gas emissions in the waste sector. These findings underscore the significant role of financial development in shaping greenhouse gas emissions across various sectors.

In Table 11, a significant and negative impact is found on the variable of financial development on greenhouse gas emissions of industrial processes and product use. Despite an increase in financial development measured by market capitalization of listed domestic companies and broad money, there is no corresponding rise in greenhouse gas emissions of industrial processes and product use. These results suggest that financial development reduces greenhouse gas emissions in this particular sector.

One of the key reasons for this reduction in greenhouse gas emissions is the promotion of sustainable practices driven by financial development. As financial markets grow and mature, investors and stakeholders increasingly prioritize environmental sustainability. Companies seeking capital investment and maintaining a positive reputation are incentivized to adopt greener approaches to their operations. This push towards sustainability often leads to the adoption of cleaner and more energy-efficient technologies in industrial processes and product development. Moreover, financial development facilitates the flow of resources towards environmentally friendly projects. As investors become more conscious of climate risks, they direct their funds towards businesses that prioritize sustainability. This access to green financing enables companies to invest in eco-friendly initiatives and upgrade their infrastructure to lower carbon emissions.

Additionally, financial development encourages innovation and research in green technologies. Increased access to funding allows businesses to invest in R&D efforts focused on developing cleaner and more sustainable industrial processes. The resulting technological advancements play a crucial role in reducing greenhouse gas emissions within the sector. These findings are in line with previous studies conducted by Zaidi et al. (2019), Abbasi and Riaz (2016), Sharma et al. (2019), Wang et al. (2021), Saidi and Mbarek (2017), and Acheampong et al. (2020), highlighting the positive impact of financial development on environmental sustainability.

5. CONCLUSION

This study comprehensively analyzed the impact of financial development on greenhouse gas emissions in Indonesia from 2000 to 2019. The study revealed a positive and significant relationship between financial development and total greenhouse gas emissions by employing a regression analysis and utilizing a comprehensive financial development index. The findings indicate that higher levels of financial development, including domestic credit to the private sector by banks and foreign direct investment, lead to increased greenhouse gas emissions. Moreover, sector-specific analyses demonstrated that financial development significantly and positively influences emissions across various sectors, including the energy sector, agriculture, forest, and other land uses, peatland fires, and waste. However, intriguingly, financial development was found to have a significant and negative impact on greenhouse gas emissions in the industrial processes and product use sector, suggesting its role in promoting sustainable practices and contributing to emissions reduction in this specific domain.

The positive and significant relationship between financial development and greenhouse gas emissions in Indonesia highlights the importance of integrating environmental considerations into financial policies and strategies. Policymakers should focus on promoting green investments and technologies by incentivizing businesses that prioritize sustainability. Creating a conducive environment for green financing and providing financial support to environmentally friendly projects can effectively reduce greenhouse gas emissions across various sectors. Additionally, policymakers should collaborate with financial institutions to develop and implement green finance initiatives that encourage the adoption of cleaner and more energy-efficient technologies.

One of the key implications of the study's findings is the need for sustainable finance frameworks that align financial development with environmental objectives. Implementing policies that integrate environmental risks and opportunities into financial decision-making processes can steer investments towards low-carbon and climate-resilient projects. By incorporating environmental factors into risk assessments and disclosure requirements, financial institutions can be better equipped to assess the environmental impact of their investments and channel funds towards sustainable projects. Developing green bond markets and sustainable investment products can also attract capital towards environmentally friendly initiatives, contributing to emission reductions in the long run.

While this study offers valuable insights into the relationship between financial development and greenhouse gas emissions in Indonesia, there are several limitations that warrant consideration in future research. Firstly, the study's focus on Indonesia as a single country may limit the generalizability of the findings to other regions or countries. Conducting cross-country studies that examine the impact of financial development on emissions in diverse economic contexts can provide a broader understanding of the relationship. Moreover, the study covered the period from 2000 to 2019, which might not fully capture the effects of more recent economic changes or crises on greenhouse gas emissions. Extending the research to include more recent years or specific periods of economic turbulence could reveal additional insights into the impact of financial development on emissions reduction strategies during challenging times. Additionally, further investigation into the underlying mechanisms driving the observed relationship between financial development and greenhouse gas emissions is essential. Exploring the role of financial policies, regulatory frameworks, and institutional arrangements can provide valuable insights for designing targeted and effective policy interventions to promote sustainable development. Lastly, considering other variables that may influence the relationship between financial development and emissions, such as energy efficiency policies, technological advancements, and demographic factors, can enhance the understanding of the complex interactions between financial development and emissions dynamics. In conclusion, this study's findings emphasize the significance of incorporating environmental considerations into financial development strategies to address greenhouse gas emissions in Indonesia. By leveraging financial policies and regulatory frameworks to promote sustainable practices and green investments, policymakers can contribute to emission reductions and environmental sustainability in the long term. However, future research should consider the study's limitations and explore additional factors to gain a more comprehensive understanding of the relationship between financial development and greenhouse gas emissions.

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