



The era of global warming mitigation: The role of financial inclusion, globalization and governance institutions

Justice Gyimah^a, Isaac Sam Hayford^{b, **}, George Nyantakyi^c, Philip Sarfo Adu^b, Sabastian Batasuma^{a, *}, Xilong Yao^a

^a College of Economics and Management, Taiyuan University of Technology, Taiyuan, 030024, China

^b School of Management Engineering, Zhengzhou University, Henan Province, China

^c Department of Accounting, Zhongnan University of Economics and Law, Wuhan, China

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ABSTRACT

Several efforts have been undertaken by environmentalists, nations, and various international organizations towards the fight against carbon emissions. The continuity of the environment has been one of the main concerns of the international system and state and non-state actors and government institutions are encouraged to play their roles effectively. Therefore, the study assesses the effect of financial inclusion, globalization, and government institutions on carbon emissions. The study used data from 1996 to 2021 and employed FMOLS model for the analysis. The findings of the study confirm the pollution halo hypothesis implying globalization promotes environmental sustainability. However, financial inclusion and government institutions have no significant effect on global warming mitigation. Nevertheless, institutional governance encourages global warming while political stability promotes the fight against global warming, the effect of economic governance is not significant. Renewable energy and economic growth exhibit positive and negative effect, respectively, on environmental sustainability. The findings suggest the encouragement of the rule of law, political stability, and an effective low carbon trading system as part of the policy implications.

1. Introduction

Climate change and global warming have been among the most significant challenges confronting the global community in this century. The rising concentration of greenhouse gases, primarily carbon dioxide, in the atmosphere is causing unprecedented changes in the Earth's climate system, including rising temperatures, alterations in the climate, and more frequent and intense extreme weather events. The resulting alterations pose imminent dangers to human societies and ecosystems worldwide, necessitating the development of effective mitigation strategies. The most devastating consequences are the disintegration of societal interactions, the breakdown of international order, and the outbreak of conflicts and wars [1–3]. Despite the critical need for effective global warming mitigation strategies, a significant gap in the global understanding of how financial inclusion, globalization, and governance institutions can be leveraged to address this critical issue.

* Corresponding author.

** Corresponding author.

E-mail addresses: gyimahjustice@gmail.com (J. Gyimah), samhayford92@gmail.com (I.S. Hayford), nyantakyi.george@gmail.com (G. Nyantakyi), adusarfophilip@yahoo.com (P.S. Adu), zsabastian7@gmail.com (S. Batasuma), xilongyao@163.com (X. Yao).

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While there is growing recognition of the importance of these factors, there is still much to be learned about their potential synergies, trade-offs, and implementation challenges. Addressing these complexities is critical to the development of effective and sustainable global warming mitigation strategies that can achieve the ambitious targets set out in the Paris Agreement and beyond [4,5]. In such might, this study examines the role of financial inclusion, globalization, and governance institutions in the era of global warming mitigation. Drawing on the most recent research and analysis, we explore how these factors can help promote sustainable economic development and reduce greenhouse gas emissions.

Financial inclusion is one of the key components of any successful strategy to mitigate global warming [6,7]. Financial inclusion is termed as the provision of affordable and accessible financial services to all members of society, including those who are traditionally underserved, such as low-income households and small and medium-sized enterprises [8]. By promoting financial inclusion, governments and institutions can help unlock the potential of these groups to participate in sustainable economic activities and reduce their carbon footprint [9,10]. A study conducted by the World Bank found that expanding access to finance for small and medium-sized enterprises (SMEs) in developing countries can have a significant impact on reducing greenhouse gas emissions. The study analyzed data from 24 countries and found that SMEs that had access to formal financial services were more likely to adopt energy-efficient technologies and practices, which in turn reduced their carbon emissions [11]. A recent study by Khan et al. [12] on the main factors influencing energy poverty in emerging economies include financial inclusion, the use of renewable energy sources for electricity, globalization, income, the human capital index, and energy investment and thus financial inclusion reduces energy poverty.

Globalization is another fascinating factor in the era of global warming mitigation [12,13]. The increasing interconnectedness of the world's economies and societies has created opportunities for the dissemination of new technologies and ideas and for the development of global markets for sustainable goods and services [14]. It has led to economic growth and technological advancements but also contributed to the depletion of natural resources and the emission of greenhouse gases. Finding a balance between economic growth and environmental sustainability through sustainable development practices is essential [3,15]. According to Pata [16] the long-term reactions show that globalization raises pollution indicators while renewable energy production significantly lowers the environmental burden in China. Again, the study shows that globalization raises CO₂ emissions, while Brazil's environmental quality is improved by renewable energy production. At the same time, in other studies, however, globalization has also contributed to the acceleration of greenhouse gas emissions through the rapid expansion of international trade and transport [17,18]. An empirical study in Southeast Asian nations examines the impact of important economic globalization factors on economic growth and environmental quality. Conversely, as the effects of economic globalization worsen, CO₂ emissions rise, but both over the long term and in most countries, over the short term, there is a decline in this ratio per unit of production [19]. Addressing the challenges of global warming will require finding ways to harness the potential benefits of globalization while mitigating its negative impacts on the climate. This study is an attempt to strike a balance between economic growth and environmental sustainability that globalization needs.

Finally, effective governance institutions are essential for successful global warming mitigation [20,21]. These institutions include international bodies such as the United Nations Framework Convention on Climate Change (UNFCCC), which provides a framework for global cooperation on climate action, as well as national and local institutions responsible for implementing climate policies and programs [22]. Strong and effective governance institutions are essential for ensuring that climate policies are well-designed, well-implemented, and responsive to changing circumstances [23]. Such as creating laws and regulations that, encourage environmentally friendly growth and lower carbon emissions [2,24]. Again, to significantly scale up low-carbon, resilient investments, it is necessary to take climate risks and opportunities into account across pertinent aspects of central banking, supervision, regulation, and market practices for making investment decisions. By Establishing legislative frameworks that support sustainable practices and lower carbon emissions, they make a greater contribution to mitigating global warming [22,25].

Several studies have been done to explore the effects of foreign direct investment, trade liberalization, economic growth and other related variables on the environment. The purpose of these studies is to provide necessary policy implications from an empirical base for states and non-states in the fight against carbon emissions. Aside from the already highlighted relevance of this study, it further contributes to the literature in two folds; first although Gyimah and Yao [26] study analyze the effect of globalization on carbon emissions in Ghana using the same globalization variables but the data for that study is from 1990 to 2015. The data for the study is too old to explain the current influence of globalization on carbon emissions and to better appreciate the recent effect of globalization on improving environmental quality. Therefore, to build on that study, this study updated the data to 2021 to include post COVID data. This result will reflect the current nature of globalization's effect on carbon emissions. Secondly, studies like Acheampong et al. [27] focused on globalization and other control variables effect on carbon emissions but this study has involved government institutions and financial inclusion in the analysis. Expanding the field, financial inclusion has been added to the variables since most of the studies turn to focus on only economic growth. The study uses economic growth and financial inclusion differently and their measurement are also different. In addition, the position of government institutions is sometimes undermined but this study tries to assess their contribution to this global problem. This shows how the study is unique from other studies. The results will reveal government institutions' involvement in the fight against global warming and further help to either validate the pollution haven hypothesis or pollution halo hypothesis. The study reflects the current situation of Ghana and provides comprehensive policy implications based on the results.

A comprehensive strategy that incorporates financial inclusion, globalization, and efficient governance institutions is necessary for the era of global warming mitigation. These elements are supportive of sustainable economic growth, lowering greenhouse gas emissions, and increasing climate change resilience [1,10,28]. However, achieving these objectives will call for effective leadership, audacious policy moves, and a shared dedication to global cooperation [7]. Despite previous studies recommending urgent action to reduce greenhouse gas emissions and limit global warming, there remains a literature gap in ensuring that mitigation strategies are equitable, inclusive, and sustainable [20,21]. Therefore, this study seeks to contribute to the body of knowledge by creating new solutions to the complex and interconnected problems caused by climate change.

In the section on financial inclusion, the study examines the role of financial services in promoting sustainable economic development and reducing greenhouse gas emissions. We review the evidence on the impact of financial inclusion on key sectors such as agriculture, energy, and transport, and we discuss the potential for innovative financial products and services, such as green bonds and microfinance, to support sustainable economic growth.

In the section on globalization, this article looks at how global trade and investment can foster sustainable economic growth and reduce greenhouse gas emissions. We discuss how trade and investment policies might encourage the development of sustainable markets as well as the invention and uptake of clean technologies. We also take into account the challenges brought on by the expansion of global trade and transportation, as well as the possibility that emissions from trade could jeopardize efforts to combat global warming.

Finally, in the section on governance institutions, we examine the critical role played by local institutions in promoting global warming mitigation. The findings also make recommendations on the role of national and local institutions in implementing climate policies and programs and the potential for innovative governance models, such as climate clubs and public-private partnerships, to drive progress on global warming mitigation.

The summary of the findings of the study reveals that globalization has a negative effect on carbon emissions. Two hypotheses have been used in the literature to explain the effect of globalization on environment: thus the pollution haven hypothesis and pollution halo hypothesis. Our study has validated the pollution halo hypothesis, which emphasizes how globalization promotes environmental quality. The findings further reveal that renewable energy helps with carbon mitigation. Promoting environmental quality goes with sustainable energy. Renewable energy is argued to be the best substitute for fossil fuels since the impact of fossil fuels on the environment undermines its quality. However, economic growth causes carbon emissions. The Environmental Kuznets Curve Hypothesis argues that at the initial stage of development, economic growth deteriorates the environment due to unhealthy activities. These results of our study are relevant for future research and policymaking.

The rest of the paper is structured as section 2 literature review, section 3 methodology, section 4 results and discussion, and section 5 conclusion and policy implication.

2. Literature review

In the past few decades, the matter of global warming has gained urgency as scientists and researchers have issued dire warnings about its potentially catastrophic effects. As a result, there has been an increase in curiosity about researching how governance institutions, globalization, and financial inclusion can all help to lessen the effects of global warming. In order to determine the extent to which these factors may affect efforts to cut carbon emissions and advance sustainable development, this literature review examines the body of prior research on the subject, the difficulties and possibilities posed by global warming mitigation in the modern era. By synthesizing and analyzing the current body of literature on this subject, this review seeks to contribute to a better understanding of the challenges and opportunities associated with global warming mitigation in the contemporary era.

Over the years, the severity of the effects of climate change has been recognized by global communities since the mid-20th century, when scientists first began to warn about the probable consequences of the buildup of greenhouse gases in the atmosphere and have taken progressive steps to mitigate the effect. The compound CO₂ has been considered a significant contributor to global warming and climate change; hence, several studies on global warming mitigation have extensively focused on how to mitigate CO₂ emissions. The world's carbon emissions have grown on average over the decades, with 2019 recording 1.9% above 2018 [29]. In 2018, total greenhouse gas emissions growth was at a 2% rate (equivalent to 51.8 Gt of CO₂) with a yearly growth rate of about 1.3%. According to Cao et al. [30], the 2% increase in global GHG emissions in 2018 was mainly due to an increase in the world's fossil fuel combustion and non-combustion industrial processes. Hashimoto and Hashimoto [31] opine that since the onset of the Second Industrial Revolution, there has been a continuous increase in global CO₂ emissions until the present industrial revolution.

From the onset of the global warming mitigation era, much research has been conducted on the influential factors that could contribute to mitigating CO₂ emissions and the direct impact of these factors. While some studies have tried to investigate and test the pollution haven hypotheses, others have attempted the Environmental Kuznets Curve. Several others have also investigated the institution-environmental quality link, renewable energy-environmental quality link, and financial development-environmental quality link. The current research combines variables across these studied areas relevant to our study objectives.

2.1. Trade liberation and carbon emissions

The theoretical underpinning of the effect of trade liberation on the environment was earlier propounded by Copeland and Taylor [32] and Grossman and Krueger [33]. This theory categorizes trade liberation's impact on environmental quality into three segments: scale effect, composition effect, and technique effect. The scale effect argues that a rising income propels an increased effect on carbon emissions. Implying that as income keeps increasing, environmental quality continues deteriorate resulting from intense production. The composition effect relates to whether a nation has a more or less carbon-intensive production structure. It presupposes that nations with more carbon-intensive production structures will mainly contribute more to environmental pollution and vice-versa. In short, how a country's structures are set up and the nature of its industrial composition strongly reflect its environmental quality. On the other hand, the technique effect stresses environmental law enforcement, which puts the private sector in check by requiring them to adopt current and modern production processes that can mitigate carbon emissions. According to Kebede [34], the technique effect leads to improved environmental quality because of people's inclination for a clean environment and implementing more strict environmental standards as income rises.

The empirical literature on trade liberation and carbon emission nexus continues to provide mixed results partly due to methodological differences or country-specific variables employed. Using panel data from 1990 to 2018 for G-7 countries, Ding et al. [35] employed the cross-section dependence test; augmented mean group, second-generation panel unit root test; panel causality test, Westerlund panel co-integration test and cross-sectional autoregressive distributed lag to analyze the data. The findings reveal that trade liberation helps improve environmental quality. Obiakor and Uche [36] conducted research for developing countries using a third-generation unit-root test with structural breaks to analyze the data gathered from 1990 to 2018. The study concluded that trade liberation significantly leads to high carbon emissions, which undermine the quality of the environment.

Khan and Ozturk [37] researched 88 developing countries using the environmental Kuznets curve framework. The study went ahead also to test the validity of the pollution haven hypothesis, and the results for trade liberation elucidate a significant positive association between trade liberation and CO₂ emissions for the 88 developing countries. In examining the growth of carbon emissions for 35 OECD economies, Lu et al. [38] used panel data from 1970 to 2019 to analyze how trade liberation has impacted carbon emissions. The finding reveals that for a more democratic state, trade liberation lessens the emissions of carbon dioxide. By employing the Generalized Method of Moments (GMM) and the Dumitrescu-Hurlin causality test for a panel data of 23 middle-income countries, Chhabra et al. [39] argues that for low middle-income countries, trade liberation leads to severe environmental deterioration as compare with upper middle-income countries.

2.2. Foreign direct investment, economic growth, financial inclusion, and carbon emissions

The current debate concerning FDI, EG, FI, and carbon emissions continues to grow across Africa and most developing Asian countries. FDI and FI contribute to poverty alleviation as they stimulate economic growth [40]. In Saudi Arabia, Ali et al. [41] used the quantile-on-quantile regression and quantile regression technique to empirically analyze the data collected between the period 1990 to 2020. The findings explicitly reveal that foreign direct investment relatively decreases carbon emissions intensity (CEI) for most quantiles. Gyiamh et al. [42] undertook a study on environmental sustainability in Ghana using the two-stage least squares, robustness least squares, and Generalize Method of Moments to analyze the data collected from 1990 to 2018. The results indicate a no relationship exists between economic growth and carbon emissions. For a sample of 107 countries grouped by income difference, the second-generation cointegration technique was employed to examine the research variables' long-term link. The study finds that foreign direct investment inflow increases environmental pollution for lower- and upper-middle-income sub-panel groups. The reverse effect of decreased environmental pollution is recorded for financial development, implying that an increase in financial development helps improve the quality of the environment [43]. Financial inclusion through the development and innovation of the financial sector provides a greater possibility to obtain new energy-efficient products and advanced technologies. These technologies influence the environment by reducing pollution levels in nations by efficiently utilization energy appliances. Financial inclusion also can worsen environmental quality in several dimensions. For instance, the growth of the financial sector can make credit readily available, which can be secured to acquire luxurious energy-inefficient appliances like second-hand refrigerators, cars, and washing machines. The usage of these appliances leads to increase environmental emissions. Zaidi et al. [40] examined the influence of financial inclusion on ecological footprints for OECD countries using the CS-ADRL technique to analyze the data. The outcome reveals that financial inclusion stimulates energy use, directly intensifying CO₂ emissions in OECD member countries. The study suggests intensifying renewable energy consumption through financial inclusion restructuring initiatives. A study using 30 selected provinces in China stresses the need for more financial inclusion as it helps alleviate pollution and CO₂ emissions [44]. In selected ASEAN-5 economies, Nasir et al. [45] researched to investigate how economic growth, financial development, and foreign direct investment help in carbon emissions mitigation. The study deployed the Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) to test the study hypothesis empirically. The findings demonstrate a statistically significant negative long-run relationship between economic growth, financial development, FDI, and carbon emissions. The study outcome confirms the EKC. The study undertaken by Shahbaz et al. [46] using a sample of 39 countries employed the second-generation econometrics technique for scale decomposition and technique effect. In the presence of structural breaks and cross-sectional dependence, the empirical findings reveal presence of cointegration among the model parameters. The summary analysis show that all three variables; financial development, economic growth and foreign direct investment are significantly related with renewable energy. The long-term effect is that, as these variable help increase renewable energy consumption through the use of clean and green energy source, the quality of the environment is improved. Hanif et al. [47] applied the Autoregressive Distributive Lag (ARDL) technique on dataset pulled from fifteen emerging Asian countries. For foreign direct investment, the empirical results confirm the pollution haven hypothesis that foreign direct investment contributes to carbon emissions. The study further reports that economic growth also fuels carbon emissions leading to environmental deterioration. Liu et al. [48] concluded in their studies the long-term adverse effect of economic growth on environmental quality.

2.3. Governance institutions, renewable energy, population growth, and carbon emissions

Mixed and inconclusive results continue to surface as studies on governance institutions, renewable energy, population growth-carbon emissions nexus keep unearthing. Concerning Southern Asia, Mehmood [49] used annual data from 1996 to 2019, the cross-sectional dependence test, Westerlund cointegration test, and cross-sectional autoregressive distributed lag techniques were adopted to confirm the research objective. The study outcome provided a series of positive feedback. For every 1 % increase in renewable energy, carbon emission is lowered by 13.95 %. The same trend was confirmed for governance, as a percentage increase in governance leads to a 7.68 % decrease in carbon emissions. Using 30 selected countries from Sub-Saharan Africa (SSA), the study employed data from 2000 to 2021 to investigate the effect of government institutional quality on climate change and sustainable

growth. The study's findings show that the rule of law, control of corruption, and regulatory quality are good governance attributes that substantially help reduce carbon emissions [50].

By employing the Panel Quantile Regression (PQR), Feasible Generalized Least Square (FGLS), and variance decomposition analysis to test for the effect of institutional quality, renewable energy consumption, and economic growth on carbon emissions, the empirical results from the FGLS test show that a percentage increase in renewable energy consumption, institutional quality reduces carbon emissions by 0.144 % and 0.257 % respectively. Conversely, a percentage rise in the economy's growth and population growth increases carbon emissions by 0.961 % and 1.510 %, respectively [51]. The study of Mohsin et al. [52] examined the impact of population growth, renewable energy consumption, and economic growth on carbon emissions. The findings show that all variables contribute to carbon emissions within the terrain of the transport sector. Per the research of Wu et al. [53] in China, although per capita rural emissions increase resulting from increasing population, the overall emissions reduce, which could likely be an outcome of renewable energy intensity. The study further projected that emissions in China are likely to face future decline. In India, the empirical results from the study of Rehman and Rehman [54] reveal that population growth increases carbon emissions. The study of Tufail et al. [55] provide strong evidence of fiscal decentralization contributing to reduced CO₂ emissions. The study recommends how power transfer to local government will aid environmental friendliness.

The targets for sustainable development cannot be realized without well-functioning governmental institutions [56]. According to Fankhauser and Stern [57], growth and development in the economy are inextricably linked to concerns about global warming. The main driver of climate change is the release of greenhouse gases (GHGs). This occurs as a result of how climate change affects both the environment and human wellness (McMichael et al., 2008).

The nations of the Middle East and North Africa (MENA) are rich in natural resources, according to a study by Saidi et al. [58], but due to corruption and ad hoc structural changes, they were unable to fully utilize these resources or lower their carbon emissions levels. Again, research by Hasnisah et al. [59] on developing as well as emerging economies in Latin America and the Caribbean showed that the right institutional frameworks along with financial development and trade policies are the fundamentals of efficient renewable energy strategies to reduce global warming while promoting a sustainable development for the environment. Through initiatives like carbon taxes, feed-in tariffs, and the elimination of subsidies for fossil fuels, institutions can also have an impact on the environment [60]. By regulating free market regulations, institutional quality also has a substantial impact on the energy disparities between regions [61]. The relationship of greenhouse gas emissions and the effectiveness of government institutions has received a lot of attention recently [62,63]. The main systems through which institutions thrive and impact CO₂ emissions are those of energy consumption, trade openness, and financial development.

Economic growth and global climate change, such as ozone layer destruction, acid rain pollution, and global warming, have grown very serious and provide an imminent danger to human well-being and existence. In order to address, a number of countries introduced the concept of sustainable development with the intention of synchronizing the growth of the economic and the environment. Many other researchers have used the Environment Kuznets Curve (EKC), first proposed by Ref. [64], in their studies [65,66]. It presumes that there's a U-shaped curve that is inverted that links financial growth and environmental quality. According to previous studies [67, 68], the Kuznets curve for carbon emissions only exists when additional factors like financial development, trade openness, or government quality of institutions are present. Inflows of foreign direct investment (FDI) boost a country's economic activity and production while also promoting financial expansion. Although this is good for the economy, FDI damages the environment by causing more pollution due to the rise in uncontrolled industrial operations. Foreign investors frequently lend money to emerging nations with plenty of natural resources but lax environmental regulations.

Considering how these variables affect the environment, this study tries to provide empirical evidence on the effect each variable has on global warming. This is perceived as the gap in the literature which needs to be addressed because most of the studies on global warming mostly consider trade openness, economic growth, renewable energy, and FDI as the main variables but in this study, most of these variables are considered as control variables and the emphasis is placed on government institutions, globalization, and financial inclusion.

2.4. Theoretical framework

Many studies have demonstrated that global warming is a complex problem that necessitates an all-encompassing strategy. However, it is evident that globalization, financial inclusion, and governance can all significantly contribute to the reduction of greenhouse gas emissions, the promotion of sustainable development practices, and the availability of financing for renewable energy projects. Studies like Ali et al. [69] investigated the effect of these variables on ecological footprint in ECOWAS economies using Applied Augmented Mean Group, Common Correlated Mean Group, and Pooled Mean Group. The outcome revealed that financial inclusion and economic growth increase the ecological pressure, while economic governance institutions and renewable energy use reduce ecological footprints. Raihan's [70] study which employed Autoregressive Distributed Lag and FMOLS as robustness checks indicated that economic growth and energy have a positive effect on carbon emissions. Zhang et al. [71] study which employed Autoregressive Distributed Lag, DOLS, and FMOLS revealed that boosting green finance over time would help reduce carbon emissions. Zhang et al. [72] the study revealed that financial development increases carbon emissions. Raggad [73], study employed ARDL, FMOLS, and DOLS techniques and the result indicated that there is a positive interaction between economic growth, energy use and carbon emissions. A study by Ze et al. [74], employed OLS, FMOLS, and DOLS estimations revealed an inverted U-shape between economic growth and greenhouse gas emissions. Financial development reduces greenhouse gas emissions, while international trade causes greenhouse gas emissions. A study by Al-Barakani et al. [75] employed Stochastic Impacts and the result revealed that financial development positively influences ecological footprint use, economic growth and foreign direct investment increases ecological

footprint use, while globalization reduces it. A study by Gyimah et al. [76] revealed that renewable energy causes carbon emissions while economic growth is not significant. Another study by Ofori et al. [77] revealed that financial development has mixed environmental pollution effects depending on the type of indicator used. Financial development causes more environmental pollution as compared to foreign direct investment. Economic governance improves environmental sustainability through quality regulation, institutional governance causes carbon emissions through a weaker rule of law, and the pollution mitigation is supported by political governance through a voice of accountability. A study by Lin et al. [78] employed a novel econometric model in their estimation and the result revealed that carbon emissions are increased as the result of economic growth, trade, energy use, and foreign direct investment while carbon emissions are reduced by renewable energy use and financial development. Tang et al. [79] study revealed that institutional quality reduces negative environmental externality while globalization does otherwise. These previous studies show the effects of global warming factors on environmental quality, and the differences in results can be attributed to data, methodology, and geographical location.

3. Methodology

3.1. Method

Globalization has gained attention due to its economic and environmental impact. Two hypotheses have been proposed to define its impact on the environment thus, pollution haven and pollution halo hypothesis. Government institutions also play a major role in the fight against global warming. Strong institutions are required to maintain and enforce environmental policies. In this regard, this study emulates Gyimah and Yao [26] and Acheampong et al. [27] to examine the effect of globalization, financial inclusion, and government institutions on carbon emissions. The study uses FMOLS model in the analysis although the emulated studies used GMM. The purpose of the study is to examine the long term effect of these variables on environmental sustainability.

Globalization is perceived as one of the major factors in global development. However, it has an effect on the environment which makes it important to consider its environmental effects alongside its economic effects. In this study, trade liberalization and foreign direct investment are the variables used to represent globalization. The primary three factors, size effect, technology effect, and composition effect can be used to summarize the environmental implications of globalization. The scale effect is the result of global trade’s influence on production, which encourages energy-based economic growth and leads to environmental deterioration. Globalization makes it easier to spread green technologies and tightens environmental regulations, which raises the standard of the environment—a technique effect. Trade opening up contributes to globalization by changing the structure and methods of production. The composition effect is meant by this. Therefore, it is uncertain if globalization has a positive or harmful impact on the environment. In general, the strength of composition, method, and scale influences determine how globalization affects the environment. Numerous researches have focused on this topic due to the complicated effects of globalization on the environment. However, the current research does not come to a definitive conclusion.

According to Azimi [80], financial intermediaries are necessary to advance technical innovations in businesses to ensure stable economic growth is the foundation of the literature that is currently available on the relationship between finance and growth. An economy can expand by boosting the distribution of ecologically harmful goods thanks to financial inclusion. Nevertheless, increased productivity resulted in more toxins being produced. Depending on the level of development in the nation, this money may have a significant impact on environmental sustainability. The scale effect states that FDI does not support environmental sustainability since it has a beneficial impact on the economy but a negative impact on the environment. Another circumstance is the composition impact, which emphasizes how FDI affects the industrial composition and permits the development of either more environmentally harmful or less environmentally friendly sectors. The scale effect states that FDI does not support environmental sustainability since it has a beneficial impact on the economy but a negative impact on the environment. Another circumstance is the composition impact, which emphasizes how FDI affects the industrial composition and permits the development of either more environmentally harmful or less environmentally friendly sectors.

By encouraging accountability, transparency, and involvement in decision-making processes, good governance helps reduce global warming. In order to address the difficulties posed by global emissions, inclusive governance is investigating how global government may be redesigned. A key component of progress on complex, linked global challenges must be greater inclusiveness, which must go beyond symbolism. A wider spectrum of non-state actors must be meaningfully included, and states must participate more fairly. It is past time that multilateral organizations and global governance frameworks became powerful agents of change in the modern world.

The equations (Eq. 1 and Eq. 2) below give a mathematical presentation of the effects the study seeks to address.

$$lco_{2it} = \beta_0 + \beta_1 lf_{it} + \beta_2 lt_{it} + \beta_3 lfi_{it} + \beta_4 lg_{it} + \beta_5 lr_{it} + \beta_6 le_{it} + \beta_7 lp_{it} + \varepsilon_{it} \tag{Eq1}$$

$$lco_{2it} = \beta_0 + \beta_1 lf_{it} + \beta_2 lt_{it} + \beta_3 lfi_{it} + \beta_4 lig_{it} + \beta_5 lpg_{it} + \beta_6 leg_{it} + \beta_7 lr_{it} + \beta_8 lp_{it} + \beta_9 le_{it} + \varepsilon_{it} \tag{Eq2}$$

The first equation (Eq (1)) examines the effect of globalization, financial inclusion, government institutions and the control variables on carbon emissions. However in equation two (Eq (2)), government institutions indicators have been split to examine each institution’s effect on carbon emissions in addition to financial inclusion, globalization and the control variables. From the two equations, $i = 1-26$, t is the period (1996–2021), $\beta_0 - \beta_9$ represents the coefficients and the error term is represented by ε .

3.2. Econometric technique

The aim of the study is to examine the effects of globalization, financial inclusion and government institutions in the fight against global warming. The study adopted FMOLS estimation to establish this long term among the variables. In order to check the suitability of the variables, the first Augmented Dickey-Fuller unit root test is employed to examine the stationary of the variables and the econometric model is presented in Equation (3). For the variables to be stationary, they must be insignificant at levels and significant at the first difference. Second, the cointegration relationship among the variables is tested. Johansen Cointegration test is employed for this test. When the variables are cointegrated, it the variables are suitable for the FMOLS test. The variables after the preliminary tests showed that they were suitable for the study, therefore the FMOLS was tested.

$$\Delta x = \gamma_0 + \gamma_1 x_{t-1} + \sum_{k=1}^n w_k \Delta x_{tk} + \varepsilon_t \tag{Eq3}$$

x_t stands for the time, Δ stands for the first difference, and ε_t stands for error term

Then the study further uses Johansen Cointegration Test to assesses the cointegration relationship among the variables and the econometric model is presented in Equation (4)&5

$$R_t = \alpha + Q_t R_{t-1} + \dots + Q_a R_{t-a} + \varepsilon_t \tag{Eq4}$$

R_t is the variable integrated of order 1 having $p \times 1$ dimensions. Below is the vector autoregression

$$\Delta R_t = \alpha + \beta R_{t-1} + \sum_{i=1}^{z-1} w_i \Delta R_{t-i} + \varepsilon_t \tag{Eq5}$$

$\beta = \sum_{i=1}^z Q_i$ and $w_i = - \sum_{j=1+1}^z Q_j$, to determine the existence and the non-existence of cointegration among the variables, Trace statistics and Eigen are the two statistics to consider

The study employs FMOLS econometric model to examine the effect of globalization, financial inclusion, and government institutions on carbon emissions. The FMOLS approach is originally introduced by Philips and Hansen in 1990, and was used due to its suitability for assessing small sample sizes and its superiority over models in examining a combination of I(1) series with a single cointegration equation and make the outcome empirically more robust. FMOLS model considers a $n + 1$ -dimensional time series vector process (Y_t, X_t) with a cointegrating equation presented in Equation (6)&7

$$Y_t = \theta_0 X_t + \beta D_{it} + \vartheta_{it} \tag{Eq6}$$

$D_t = D_{1t}, D_{2t}$ and X_t is the Stochastic regressor of N variable

$$X_t = \gamma_{21} D_{1t} + \gamma_{22} D_{2t} + \varepsilon_t \tag{Eq7}$$

and $\Delta \varepsilon_{2t} = \vartheta_{2t} A1$

According to Danish et al. [81] FMOLS is highly recommendable when dealing with endogeneity and serial correlation among the independent variables. The FMOLS employs non-parametric approach.

3.3. Data

The data used for the study is from 1996 to 2021, and the data is extracted from World Governance Indicators, International Monetary Fund, and World Development Indicators. The study covers this period because of data availability. The variables for the study are; foreign direct investment and trade liberation to represent globalization, economic governance, political governance, and institution governance which represent government institutions, financial inclusion, population growth, renewable energy, economic

Table 1
Data description.

Variable		Measurement	Source
Carbon emissions	<i>lco2</i>	Carbon Emissions Per Capita	World Development Indicators
Foreign direct investment	<i>lf</i>	Percentage of Foreign Direct Investment net inflow	World Development Indicators
Trade liberation	<i>lt</i>	Trade percentage of GDP	World Development Indicators
Economic growth	<i>le</i>	GDP Per Capita	World Development Indicators
Government institution	<i>lg i</i>	Institution, economics and political governance	World Governance Indicators
Renewable energy	<i>lr</i>	Total percent of Renewable Energy	World Development Indicators
Financial inclusion	<i>lfi</i>	Financial Development Index	International Monetary Fund
Population growth	<i>lp</i>	Total percentage of population growth	World Development Indicators
Institution governance	<i>lig</i>	Rule of law and control of corruption	World Governance Indicators
Political governance	<i>lpg</i>	Voice of accountability and political stability	World Governance Indicators
Economic governance	<i>leg</i>	Regulation quality and government effectiveness	World Governance Indicators

growth, and carbon emissions. Table 1 gives the variables and its sources and the statistical description and correlation has been presented in Tables 2 and 3 respectively.

4. Results and discussion

4.1. Augmented Dickey-Fuller unit root test outcome

The results presented in Table 4 show the outcome of the stationary test. Augmented Dickey-Fuller is employed for the test. The results reveal that the variables are not significant at levels but significant at first difference (Δ). The outcomes imply that the variables are stationary and cointegration can be tested. To further ensure the accuracy of the results Phillips-Perron (PP) test is employed as a robustness check and the outcome is presented in Table 5. The test confirmed that the variables are stationary.

4.2. Johansen Cointegration Test outcome

The cointegration test results are presented in Table 6. The results reveal that the variables for the study are cointegrated.

4.3. FMOLS estimation and discussion

The findings from Table 7 are the result of the FMOLS model 1. The model is to examine the effect of the independent variables on carbon emissions since the objective of the study is to establish how these variables affect the environment in the long run. There are two variables that are used to represent globalization thus foreign direct investment and trade liberation. The outcome of the study indicates that globalization helps in carbon emissions mitigation. Foreign direct investment and trade liberation have negative and significant effects on carbon emissions. The result of the study is supported by Raihan [82], whose study revealed that globalization in the long term helps maintain environmental sustainability through carbon mitigation. Al-Barakani et al. [75] study also revealed that the presence of globalization is important for carbon mitigation to improve environmental sustainability.

The world has developed into an era where each country depends on the other for support. However, some studies argue that the existence of globalization has threatened the safety of the environment. The existing studies have proposed two hypotheses that define the effect of globalization on the environment. The first is the pollution halo hypothesis where globalization helps promote the quality of the environment because of the movement of low emission technologies, and experts to facilitate the development of renewable energy transitions. The second is the pollution haven hypothesis where globalization is considered a threat to the environment especially in underdeveloped and developing countries where environmental regulations are flexible with weak institutions [83]. A recent study by Gyimah and Yao [26], examined the impact of trade liberation and foreign direct investment on carbon emissions in Ghana. The study found that while trade liberation had a negative effect on carbon emissions, foreign direct investment had a positive effect on carbon emissions. However, the findings of this study indicate that both variables have a negative effect on carbon emissions. The difference in the results can be attributed to the time period studied, with the previous study using data from 1990 to 2015 and the new study using data from 1996 to 2021. Notably, the COVID-19 pandemic occurred during this time gap, affecting foreign direct investment and leading to significant changes in the post-COVID-19 era. Further research is needed to fully understand the complex relationship between trade, investment, and carbon emissions in the context of Ghana's economy.

Financial inclusion and government institutions have no significant effect on carbon emissions in Ghana. There have been many studies that explain the effect of financial inclusion on the environment which do not support our findings. According to Hussain et al. [84], financial inclusion reduces environmental degradation through carbon mitigation. Again, Fareed et al. [85] study revealed that financial inclusion promotes environmental sustainability in Eurozone. However, a study by Ali et al. [86] revealed that financial inclusion in both short and long terms increases carbon emissions. The disparities could be as the result of geographical location and data used. Regarding the effect of government institutions on the environment, several studies have produced different results. According to the study by Ofori et al. [77], Economic governance improves environmental sustainability through quality regulation, institutional governance causes carbon emissions through a weaker rule of law, the pollution mitigation is supported by political governance through the voice of accountability. In addition, a study by Ali et al. [69] revealed that economic government which is one of the government institutions reduces ecological footprint. Despite these findings, Ghana has struggled with weak government institutions in recent years, which has hindered the country's overall development. Specifically, the government has had difficulties implementing policies, which has led to concerns voiced by public opinion leaders and pressure groups across various platforms. Unfortunately, these concerns are yet to bring about any significant changes. The impact of these weak government institutions has

Table 2
Statistical description.

	lco_2	lf	lt	lfi	$lg i$	lr	le	lp
Mean	9.2372	1.4027	4.3619	-2.0271	5.8526	3.9931	7.2172	0.8993
Median	9.2113	1.6843	4.3225	-2.0543	5.8653	3.9495	7.1749	0.9004
Max	9.9055	2.2478	4.7540	-1.7455	5.9032	4.3673	7.5917	1.0110
Mini	8.3163	-0.0453	4.1069	-2.2568	5.7688	3.7252	6.8585	0.7367
Std. Dev	0.4483	0.6986	0.1804	0.1739	0.0425	0.1940	0.2399	0.0754

Table 3
Correlation.

	<i>lco₂</i>	<i>lf</i>	<i>lt</i>	<i>lfi</i>	<i>lg i</i>	<i>lr</i>	<i>le</i>	<i>lp</i>
<i>lco₂</i>	1							
<i>lf</i>	0.656	1						
<i>lt</i>	-0.476	-0.512	1					
<i>lfi</i>	0.892	0.514	-0.362	1				
<i>lg i</i>	0.563	0.794	-0.330	0.340	1			
<i>lr</i>	-0.984	-0.691	0.487	-0.884	-0.612	1		
<i>le</i>	0.981	0.666	-0.486	0.931	0.548	-0.974	1	
<i>lp</i>	-0.593	-0.404	0.415	-0.665	-0.196	0.559	-0.681	1

Table 4
Augmented Dickey-Fuller unit root test.

	Critical value	t-statistics	Prob
<i>lco₂</i>	-3.7880	0.1762	0.9640
Δlco_2	-4.4679	-8.0246	0.0000
<i>lf</i>	-3.7241	-1.7056	0.4163
Δlf	-2.6649	-4.6798	0.0001
<i>lt</i>	-3.7241	-2.5397	0.1186
Δlt	-4.3943	-6.6870	0.0001
<i>lfi</i>	-3.7696	-0.0434	0.9443
Δlfi	-4.4407	-6.1044	0.0003
<i>lg i</i>	-4.5326	-2.6737	0.2563
$\Delta lg i$	-3.8574	-6.3747	0.0001
<i>lr</i>	-3.7880	-1.2123	0.6489
Δlr	-4.4679	-7.1291	0.0000
<i>le</i>	-3.7241	0.3074	0.9739
Δle	-3.7379	-3.3167	0.0254
<i>lp</i>	-3.7696	-1.1751	0.6660
Δlp	-2.6797	-1.9617	0.0496

Table 5
Phillips-Perron (PP) test.

	Phillips-Perron (PP) Test			
	Levels		First difference	
	Critical value	t-statistics	Critical value	t-statistics
<i>lc</i>	-3.752946	-1.086469	-3.769597	-7.392090***
<i>lf</i>	-3.724070	-1.705686	-3.737853	-4.628278***
<i>lt</i>	-3.724070	-2.539703	-3.737853	-7.818708***
<i>lfi</i>	-3.737853	-0.278954	-3.752946	-8.329520***
<i>lg i</i>	-3.831511	-3.090542	-3.857386	-6.449147***
<i>lr</i>	-3.752946	-1.019805	-3.769597	-15.95635***
<i>le</i>	-3.724070	0.152843	-3.737853	-3.316685
<i>lp</i>	-3.724070	0.181659	-3.737853	-1.695048

Table 6
Johansen cointegration test.

	Trace Statistics	Critical value 0.05	Prob
None	148.5043	125.6154	0.0010
At most 1	96.75110	95.75366	0.9426
At most 2	67.37016	69.81889	0.0772
At most 3	44.78148	47.85613	0.0945
At most 4	26.32573	29.79707	0.1192
At most 5	10.59607	15.49471	0.2376
At most 6	1.582880	3.841466	0.2083

also affected financial institutions, which may help to explain the lack of significant effect of these two variables on the environment. Further research is necessary to better understand the relationship between government institutions, financial inclusion, and carbon emissions in Ghana, as well as to develop strategies for addressing weak institutions and promoting sustainable development.

Table 7
FMOLS estimation.

Variable	Coefficient	t-Statistics
<i>lf</i>	-0.0390**	-2.2083
<i>lt</i>	-0.0877*	-1.8502
<i>lfi</i>	-0.2523	-1.6134
<i>lgi</i>	-0.0230	-0.0587
<i>lr</i>	-1.0001 ^a	-4.1161
<i>le</i>	1.3495 ^a	6.5927
<i>lp</i>	0.2516	1.0587
<i>R</i> ²	0.9899	
Adjusted <i>R</i> ²	0.9820	
S.D. dependent var	0.3650	

^a , **, * , represent 1 %, 5 %, and 10 %, respectively.

Renewable energy consumption has a negative and significant effect on carbon emissions. The finding is supported by Lin et al. [78] whose study revealed that the use of renewable energy helps in carbon mitigation which promotes environmental sustainability. In addition, a study by Liu et al. [87] revealed that the rise in renewable energy use reduces carbon emissions. Meaning, as the use of renewable energy increases, environmental sustainability increases. However, a study by Mohsin et al. [52] revealed that renewable energy contributes to carbon emissions. A lot of concerns have been raised locally and internationally on the best energy source to use in order to promote the continuity of a friendly environment. Many studies have argued against the traditional energy (fossil fuel) and branded it as one of the main causes of global warming because of its high emissions [88]. Over the past years, fossil fuel has been the major source of energy for many developing and developed countries. It has helped in building many economies and impacting many developmental projects [89]. However, its contribution towards environmental sustainability has raised the concern of finding a possible replacement. Since renewable energy’s effect on the environment is recommendable, it is considered as the best replacement for fossil energy. Although, some studies have recorded that renewable energy contributes to environmental degradation in some countries and the reason is attributed to the level of development in these areas.

Economic growth promotes environmental degradation. The level of Ghana’s GDP is not strong to support its fight against global warming. This result of the study is supported by Lin et al. [78] who revealed the rise in carbon emissions is as the result of a rise in economic growth. In addition, a study by Al-Barakani et al. [75] revealed that the rise in economic growth causes ecological footprint to rise. The Environmental Kuznets Curve theory is used to explain how economic development affects the environment with time. The theory explains that at the initial stage of economic development, environmental degradation is inevitable but at the threshold point, economic development will start to contribute to environmental sustainability [76]. The result of this study is supported by Ridzuan et al. [90] who stated that economic growth contributes to environmental degradation.

To further examine the effect of government institutions and financial inclusion on carbon emissions, the various institutions used to represent government institutions have been expanded and the outcome has been presented in Table 8. This is to effectively assess each institution’s contributions to environmental sustainability. The institutions are economic governance, political governance, and institutional governance. The outcome presented in Table 5 shows that foreign direct investment as one of the globalization variables has a negative and significant effect on carbon emissions. The findings of the study are supported by Ali et al. [41] study that revealed that foreign direct investment decreases carbon intensity. In addition, Gyimah et al. [91], revealed that renewable energy consumption in both short and long terms promotes environmental sustainability. However, a study by Hanif et al. [47] revealed otherwise that foreign direct investment causes carbon emissions which validates the pollution haven hypothesis. However, trade liberation is insignificant in affecting carbon emissions in this equation. Institutional governance contributes to carbon emissions. Over the past years, most of the institutions in Ghana have been ineffective with their duties especially regarding implementing environmental policies. Most of the institutions are most easily influenced by individuals or groups to weaken some environmental policies in their

Table 8
The effect of government institutions indicators on carbon emissions.

Variable	Coefficient	t-Statistics
<i>lf</i>	-0.0510***	-3.1883
<i>lt</i>	0.0330	0.5637
<i>lfi</i>	-0.1788	-1.3016
<i>leg</i>	0.0159	0.0697
<i>lig</i>	0.6814**	2.5135
<i>lpg</i>	-0.7014*	-2.0989
<i>lr</i>	-0.7150***	-3.1044
<i>le</i>	1.4117***	7.3470
<i>lp</i>	-0.0905	-0.3909
<i>R</i> ²	0.9910	
Adjusted <i>R</i> ²	0.9794	
S.D. dependent var	0.3650	

***, **, * , represent 1 %, 5 %, and 10 %, respectively.

favor. These actions have caused the nation to lose some of its forest reserves to activities that put the environment at risk. The institutions are to be allowed to work without influence from either the ruling government or state actors to ensure the rule of law. Political governance promotes environmental sustainability. Ghana, since the fourth republic, has enjoyed political stability until now. The political governance can maintain orderliness and peace in the country and this atmosphere helps promote environmental sustainability. The reason is that, the peaceful atmosphere attracts foreign investors to invest in the infant and mature industries. These investors mostly provide the capital and encourage these local industries to use renewable energy. Most of the investors also transfer their skills needed for the transition and some import low emission technologies into the country. Therefore, the state of political governance is very instrumental in building a sustainable environment especially in developing countries. However, economic governance as the last indicator for government institutions has no significant effect on carbon emissions. Ghana has experienced a fall in its economic growth since the era of the pandemic. Many economic activities in the country have been slowed down. The result of the government institutions can be compared to that of Ofori et al. [77], which revealed that economic governance through quality regulation helps in carbon mitigation, institutional governance through weaker rule of law deteriorates the environment, and political governance through the voice of accountability supports the pollution mitigation. Lastly, renewable energy consumption has a negative and significant effect on carbon emissions while economic growth has a positive effect on carbon emissions. The result is supported by a study by Ali et al. [69] which revealed that the rise in renewable energy use reduces ecological footprint. Renewable energy is argued to be the best replacement for fossil fuels due to its impact on the environment [92,93]. It helps in carbon mitigation, which is one of the main concerns of the international community.

4.4. Robustness check

To further confirm the relationship between the independent variables and the dependent variable, the Robust Least Squares is employed as the robustness check. The outcome of the robustness check is presented in Table 9. The results confirm the results of the main estimation except the effect of financial inclusion on carbon emissions. From the main estimation results presented in Table 7, financial inclusion has no significant effect on carbon emissions. In addition, despite the slight changes in the values, the sign for each effect is maintained. Foreign direct investment negatively affects carbon emissions at 10 % significance, trade openness at 1 % significance reduces carbon emissions, renewable energy use at 5 % significance reduces carbon emissions, financial inclusion causes carbon emissions, and economic growth at 10 % significance causes carbon emissions.

5. Conclusion and policy implication

Carbon emissions mitigation has been a major concern to environmentalists, governments, state and non-state actors since the continuity of human existence depends on it. A lot of measures have been put in place to protect the environment. Therefore, this study examines the effect of globalization, government, and financial inclusion on carbon emissions. The study uses the FMOLS model for the analysis. The outcome of the analysis shows that globalization encourages global warming mitigation meaning the pollution halo hypothesis has been supported by this study. Financial inclusion and government institutions have no effect on carbon emissions. Renewable energy consumption reduces global warming through carbon emissions mitigation while economic growth contributes to global warming. However, the results from the second equation indicate that various institutions have different effect on carbon emissions.

Based on the findings of the study, government institutions should be given the supremacy to implement and enforce environmental policies. The interference of government actors and influential stakeholders mostly undermines the effectiveness of government institutions when making and implementing environmental policies. This situation is mostly found in developing and underdeveloped countries. The condition exposes the environment to high-emissions technologies. In this regard, rule of law is to be ensured in order to promote environmental sustainability by government institutions. Since ensuring rule of law will give governments and institutions responsible for environmental policies to make decisions without fear or interference. Governments should take advantage of the positive impact of globalization to improve renewable technologies usage. Since trade liberalization and foreign direct investment promote environmental sustainability, policy makers should capitalize on that to enhance low emissions technology trade, and provide incentives for foreign investors to invest in low emissions technologies.

The study addresses the issue of global warming in relation to financial inclusion, globalization, and government institutions impact. However, the authors would like to recommend that future studies can add more variables like tourism and migration to globalization variables to cover more, since only trade liberalization and foreign direct investment limit the scope of globalization. The authors are not able to factor these variables due to data availability.

Additional information

No additional information is available for this paper.

Data availability statement

The data for the study is from World Governance Indicators, International Monetary Fund, and World Development Indicators.

Table 9
Robust least squares estimation.

	Coefficient	t-statistics
<i>lf</i>	−0.083725*	−1.892749
<i>lt</i>	−0.382000***	−3.378232
<i>lfi</i>	1.041742***	6.836139
<i>lg i</i>	−0.255387	−0.942441
<i>lr</i>	−0.654005**	−2.428984
<i>le</i>	0.031264*	1.131476
<i>lp</i>	0.279160	1.015669

***, **, *, represent 1 %, 5 %, and 10 %, respectively.

CRedit authorship contribution statement

Justice Gyimah: Writing – original draft, Methodology, Data curation, Conceptualization. **Isaac Sam Hayford:** Validation, Data curation. **George Nyantakyi:** Writing – original draft, Methodology. **Philip Sarfo Adu:** Software, Data curation. **Sabastian Batasuma:** Writing – review & editing, Visualization. **Xilong Yao:** Supervision, Conceptualization.

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.

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