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The adoption of renewable energy towards environmental sustainability: Evidence from Partial Least Square Structural Equation Modelling (PLS-SEM)

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Abstract

The effect of carbon emissions on the environment has made some of the Sustainable Development Goals difficult to achieve. Despite the efforts of international bodies, there is still a need to address the problem since the transition is not complete. Therefore, this study investigates the effect of globalization, economic growth, financial inclusion, renewable energy, and government institutions on carbon emissions from the period of 1998 to 2021. To be able to assess both the direct and indirect effects of the variables, the Partial Least Square Structural Equation Modelling is employed, where renewable energy serves as the mediator, and the Two-Stage Least Squares is employed as the robustness check. The findings of the study reveal that globalization promotes the use of renewable energy, but financial inclusion has a negative effect on renewable energy use. Renewable energy has a direct positive and significant effect on carbon emissions. Financial inclusion has an indirect negative and significant effect on carbon emissions. The results imply that more enlightenment on financial inclusion will help a smooth transition, and globalization should be embraced when all environmental regulations are enforced.

1. Introduction

The world's economy has grown significantly during the last few years as a result of industrialization and improvements in technology. Numerous environmental issues have been brought on by economic progress [1], most notably an increase in environmental pollution that has now reached a worldwide scale. The excess demand for energy for production has caused the increased use of coal and other related fossil fuels which is a threat to environmental quality [2]. According to Ritchie et al. [3], in the year 2022, the global emitted carbon is 17 times more than in 1900. The emission was over 34 billion and it is considered as a threat to human settlements. The severe nature of global warming has caused many international bodies to put policies and measures in place to reduce carbon emissions but all these policies and measures are still not successful because of insufficient planning and administration [4].

The overreliance on fossil fuels has caused high carbon emissions in many countries and led to global warming [5, 6]. The ideal auxiliary for non-renewable energy is renewable energy due to its potential to reduce carbon emissions, but it has a rate of reduction in productivity and negatively affects the economy if not properly used. Even though renewable energy resources are abundant and available in many nations, these resources continue to be untapped [7]. Hu et al. [4] specified in their studies that renewable energy allows the reduction of carbon emissions in the short run but increases carbon emissions in the long run. A study by Yu et al. [8] on China supported the argument that the rise in the use of renewable energy reduces carbon emissions, and Destek & Aslan [9] study on G-7 nations and Liu et al. [10] study on the UK economy, produced the same result. Cheng et al. [11], have shown that reducing the cost of carbon emissions will lead to increases in renewable energy consumption, which will mitigate global warming. Again, Xu & Buyya [12], revealed that carbon emissions can be lessened through renewable energy consumption. Wind and solar energy are required to mitigate environmental pollution and its consequences, such as climate change, through carbon emissions.

Sustainable energy supports carbon emission reductions [13]. Scott [14] also claims that renewable energy is the best solution for the pressures that fossil fuels put on the environment. Seeing the alarms about carbon emissions, climate change, and global warming, the OECD countries have increasingly highlighted different energy mixes as well as secure sources of energy supply [15]. The rise in population has resulted in limitless governments relying on unclean energies to carry out production to meet their desires and demands. This upsurge in population has led to the usage of more fossil fuels, which negatively affects the environment through the release of carbon emissions. Many studies carried out in both developed and developing countries from 1980 until now have revealed that renewable energy does not contribute to carbon emissions, but the majority of the world's population still depends on non-renewable energy. Our dependence on non-renewable energy has generated larger carbon emissions, and this carbon emission is one of the fundamental causes of the increase in the Earth's temperature and thus leads to global warming [16]. Even if this phenomenon stopped now, the effects of greenhouse gas emissions would continue to affect our unborn generations. The world has argued that the rate at which energy consumption, coupled with greenhouse gases is on the rise, has environmental consequences, and the desire for an alternate energy source in both developed and developing nations has a direct impact on climate change and, as such, need to be dealt with [17]. Despite all these studies done globally, there have been many climate change conferences and treaties to ensure environmental sustainability through the use of renewable energy, which does not contribute to carbon emissions. However, all these efforts by countries and governments to reduce the impact of global warming and ensure a sustainable environment have proved effortless. Again, only a few developed countries are using renewable energy, as the majority of the developing countries are still dependent on fossil fuels, which greatly pollute the environment. Even though issues of global warming are gradually taking shape, there has been a neglect of the roles that financial inclusion, globalization, and government institutions play in helping lower the impact of greenhouse gas effects and encourage a sustainable environment.

At present, the effect of globalization has gained more attention from the global system due to its contribution to global warming as argued by some researchers. Globalization's environmental effects have gained some concerns from a theoretical and policy perspective. From the policy point of view, exploring the consequences of globalization on the environment will enable us to adopt a more integrated open policy that will deal with the emissions of carbon. From an environmental angle of view, globalization can be seen from three main angles including; scale effect, technique effect, and composition effect [18]. The scale effect is the

influence of intercontinental trade which brings economic growth that is built on energy consumption as well as leads to environmental deterioration. Globalization promotes the free movement of environmentally friendly technology which turns to enhance environmental sustainability via trade openness and production. The composition effect is unclear whether globalization will bring positive or negative changes to the environment. Due to the technicality of globalization on the environment, some studies have turned their attention to this issue. However, the existing studies have not reached a clear conclusion [18].

The issue of global warming has been addressed on several international platforms since it has become a global problem. Despite interventions and efforts by governments, international bodies, and other concerned entities, global warming continues to threaten the sustainability of the environment. Global warming upsurges outside water evaporation and changes rainfall patterns, adding to the frequency of negative disasters such as floods, droughts, etc. Global warming encourages the melting of glaciers and polar ice caps, resulting in a significant rise in sea level [19]. Global warming triggered by carbon dioxide, methane, and nitrous oxide gas emissions has developed to become a global concern that has gained much attention from both researchers and policymakers. This led to the formation of many conferences and agreements on climate change and global warming including; the Kyoto Protocol in 1997, the Paris Agreement reached in 2015 among others, and the recent United Nations (UN) Climate Change Conference [20]. These agreements represent significant global environmental agreements aimed at enhancing energy efficiency and promoting the use of renewable energy sources to reduce environmental degradation [21].

Climate change nowadays is seen as the number one environmental problem that needs more devotion and care in order to avert its impact on humanity as a result of the rise in greenhouse gases particularly carbon dioxide [22]. The emissions of these greenhouse gases continue to upsurge the possibility of terrible climate change in the world [23]. The climate is rapidly transmuting and for that matter the world is quickly heating up by day, supposedly exceeding the expected rise in temperature of 2˚C above levels [24]. Global warming is not only seen as a smaller factual threat to humanity in less developed nations but equally poses a notable problem for countries that are developing or developed including the UK, China, the US, etc. in the study by Kovats & Osborn [25]. The threats from global warming affect the whole world not only those living in less developed and developing countries. The situation is affecting developed nations as well especially the extreme rise in weather conditions which has affected the seasons as well.

Among the identified effects of climate change, globalization concerning the world economy is seen as the worst, even though other studies have claimed otherwise. Globalization in this context talks about the openness of markets through trade, foreign direct investment (FDI), and finance. Usually, globalization leads to a diminution in rates and taxes which aid in promoting production for economic development [26, 27]. Countless conflicting views were used to elucidate the connection between globalization and environmental degradation. Nevertheless, the literature has developed two hypotheses that explain the effect of globalization on the environment thus pollution halo and pollution haven hypotheses. The pollution haven theory talks about the circumstance that polluting entities in industrialized advanced countries always move to emerging economies with careless environmental rules and as a result contaminate the environment [28]. Contrary to this, the pollution halo theory says that trade and FDI have a direct connection between the economy and the environment via the transfer of management practices, ethics, and expertise which have efficient energy sources and reduce the level of carbon emissions [29]. Again, the halo effect theory claims that foreign direct investment or liberalization brings into existence environmentally friendly technologies. Some previous studies looked at the effect of liberalization on environmental degradation from three

dimensions including; the scale, technique, and composition effects. According to Acheampong et al. [30], trade openness promotes environmental value by lessening carbon emissions globally.

Economic globalization improves and increases productivity in energy sources, reduces energy costs, and creates a platform for technological advancement. The presence and dominance of trade liberation is one of the standard indicators of the influence of economic globalization. Trade liberation minimizes the use of energy by giving out imported expertise and encouraging environmental security [31–34]. Again, in the view of Copeland & Taylor [32] trade openness expands the per capita energy consumption of a nation. Cole [35] and Kearsley & Riddel [36] indicated that FDI will likely lead to an EKC pattern. According to the studies by these researchers, whenever there is an increase in FDI in a country, the economy of that country grows as well leading to a rise in demand for commodities that destroy the quality of the land. In this regard, the high level of productivity in a country will lead to a rise in the number of pollutants released. Depending on the level of development, FDI income can have a wide effect on environmental sustainability. Regarding the explanation of the scale effect, the effect of FDI on the environment and the economy are not the same thus it positively affects the economy and negatively affects the environment and as such does not promote environmental sustainability. The compositional effects cannot be ignored since it emphasizes how the presence of foreign direct investment in a country controls its industrial composition and encourages the establishment and growth of less polluting industries. The study by Eluwole et al. [37] on 37 developed countries revealed that FDI and carbon emissions have a correlation effect. The desire of nations to transition to new, more diverse forms of energy is backed by a variety of international organization policies, which creates a market for the use of renewable energy on a global scale. Diversification of energy is a critical and challenging aim for governments in ensuring energy efficiency. Therefore creating an energy policy is critical for ensuring economic advancement and change to a more sustainable energy use [38].

Money gained from economic and non-economic entities enables nations to develop their economy and judiciously use the scarce resources that they have [39]. Equally, providing money to finance the energy sector is crucial in encouraging environmental sustainability. The problem of global warming will continue to exist if governments and concerned individuals do not efficiently review energy financing policies or create energy-related regulations with strict enforcement. Observing the continuous growth and environmental challenges of financial development, numerous studies on energy financing mentioned that increased growth as a result of financial complexity and development is the sole factor of growing energy consumption [40–44]. From an academic point of view, financial development comes with a two-way outcome on pollution. First, the finance-owning prosperity effect may lead to degradation of the environmental quality [41, 42, 45–47]. For instance, a lesser capital may encourage industries to upsurge production and by so doing raise energy consumption levels [48]. The rise in the usage of energy turns to adulterates the environment and this deals with global warming [42, 45]. Secondly, monetary assistance to economies to regain environmental value through the importation of pollutants reduction technology [49–51]. That is to say, when business entities have access to loans, they turn to present green technologies to reduce CO2 emissions. By this, business entities turn to preserve the environment through the use of better-quality pollution control mechanisms. Numerous studies have tried to find the connection between financial development and carbon emissions, but their outcomes were ambiguous and inconsistent [11, 52, 53] and found that financial development improves rather than declines carbon emissions.

Despite the efforts and the campaigns by international and national bodies on energy transition, there is still a lot to be done considering the pace of the transition in particularly

developing countries. Although various factors have been examined in the literature coupled with a lot of recommendations, the vital roles of government institutions and globalization in this transition have not been adequately examined. Adding knowledge to the already existing knowledge on how to mitigate carbon emissions, Acheampong et al. [30] examine the effect of globalization and renewable energy on carbon emissions. However, what makes this study different and adds new knowledge is that in previous studies, the indicators used to represent globalization were independently assessed, but this study has put the proxies for globalization together and further assessed their independent effects. Previous studies assessed the effect of FDI and trade openness on carbon emissions independently, although these variables were used to represent carbon emissions. This study assessed the effect of these two variables from two perspectives (1) the variables were assessed as independent variables, and (2) the variables were put together as one variable. In addition, previous studies examined the long-run direct effect of globalization on carbon emissions [7, 54] while this study examines the indirect effect of globalization on carbon emissions through renewable energy use and further examines how globalization helps promote the use of renewable energy. This study not only concentrates on the direct effect of globalization on carbon emissions but further assesses the indirect effect on carbon emissions as well. Again, Gyimah et al. [55] study used renewable energy as the independent variable, economic growth as the dependent variable, and globalization proxies as mediators to find how renewable energy use indirectly affects economic growth, but this study aims at assessing the effect of globalization, economic growth, financial inclusion, and government institutions on carbon emissions through renewable energy use. Therefore, this study will add new knowledge to the already existing literature by developing past studies to provide recommendable policy implications on the subject of global warming.

In all the studies that have been done on the relationship between economic growth, renewable energy, FDI, trade openness, financial development, and carbon emissions, these studies have captured contradictory relationships for the variables. For instance, Gyamfi et al. [56] study on E7 countries revealed that the use of renewable energy improves air quality while economic growth and the use of fossil fuels undermine environmental quality. Kirikkalelin et al. [57] research revealed that economic growth and globalization harm the ecosystem. Additionally, the study of Dingru et al. [58] on BRICS economies revealed that the impact of financial development is insignificant, while the use of renewable energy has a negative effect on carbon emissions. Altinoz and Dogan [59] study revealed that there is a significant decrease in carbon emissions at 1% use of renewable energy. The study of Behera et al. [60] revealed that renewable energy and control of corruption in both the short and long term help in carbon mitigation. Furthermore, Xie et al. [61] study revealed that economic growth deteriorates the environment through the increase of carbon emissions and renewable energy promotes environmental sustainability through carbon mitigation. Similarly, Mujtaba et al. [62] revealed that a 1% increase in renewable energy use is expected to reduce carbon emissions by 0.2%, while a 1% increase in fossil fuel use is expected to increase carbon emissions by 1.08%. Therefore, this study is done to test the two hypotheses that explain the impact of globalization on the environment, government institutions contribution to environmental sustainability, economic growth and financial inclusions influence on global warming, and the effect of renewable energy on carbon emissions.

1.1 Theoretical background

The literature that explains the factors that affect carbon emissions is extensive [63–67]. These studies tried to assess the influence these factors have on carbon emissions. Zhang et al. [68] employed fixed effect regression to examine the energy efficiency of buildings in 54 cities in

China. Gyimah [69] used the Generalized Method of Moments to investigate the impact of financial inclusion and good governance on carbon neutrality in West Africa. Nyantakyi et al. [70] applied the Generalized Method of Moments (GMM), fixed effect, and pooled Ordinary Least Squares (OLS) models to explore the influence of environmental tax and economic growth on the use of renewable energy in West Africa. Zhang et al. [71]·examined the impact of revenue allocation on carbon reduction.

The most commonly used econometric model for this assessment is the Linear Econometric Model [72] which has been employed in both time series and panel data study [73]. Examining the effect of trade openness on environmental sustainability in 182 countries, the outcome revealed that within high-income and upper-middle-income countries, trade openness promotes environmental sustainability by decreasing carbon emissions [74]. Using threshold regression to examine the effects of FDI and trade openness on India's industrial sector, the findings revealed that for the sectors of the economy with low carbon intensity, foreign trade openness encourages carbon emissions, while industrial carbon emissions are harmed by FDI [75]. Employing the ARDL bounds testing approach to examine the causal relationship between FDI, trade openness, energy demand, economic growth, and carbon emissions, the results revealed that FDI, trade openness, and carbon emissions reduce energy demand [76]. A study by Hayford et al. [77] indicated that the use of clean fuel for cooking and renewable energy help in carbon emissions mitigation while trade and population deteriorate the environment in E7 economies. Again, Shang et al. [78] study on China revealed a U-shaped relationship between renewable energy and carbon emissions in the long-term but promotes environmental quality through carbon emissions mitigation in the short-term. The results further indicated that FDI deteriorates the environment, and economic growth increases carbon emissions in the long-term. Another study by Wang et al. [79] revealed that nonrenewable energy and the economy increase carbon emissions while renewable energy reduces carbon emissions. Liu et al. [80] study indicated that renewable energy use promotes environmental sustainability through carbon intensity and per capita carbon emissions mitigation.

A study by Kwakwa [81] on 32 African countries using the Fully-Modified OLS regression method indicated that trade openness and urbanization encourage carbon emissions while renewable energy improves environmental sustainability by reducing carbon emissions. The results further indicated that the variables for institutional quality (rule of law, voice and accountability, political stability and absence of violence, control of corruption, government effectiveness, regulatory quality, and institutional index) help in carbon mitigation. Haldar and Sethi [82] study on 39 developing countries revealed that institutional quality and renewable energy have a negative and significant effect on carbon emissions. Their result implies that both variables promote environmental quality. Using Driscoll–Kraay, the Generalised linear model, and the Prais-Winsten test to examine the relationship between financial inclusion and carbon emissions, the outcome revealed an inverted U-shape for their relations [83]. A study by Hussain et al. [84] further indicated that the relationship between financial inclusion and carbon emissions is nonlinear and changes from an inverted U-shape to a U-shape. Therefore, considering all these findings, this study tries to improve on the existing literature by assessing the indirect effect of these factors on carbon emissions through renewable energy.

Economic activity is seen as the number one factor in carbon emissions. Economic growth is crucial for the betterment of people's lives. The idea of the Environmental Kuznets Curve (EKC) suggests that, as time goes on, people with a decent salary and environmental knowledge will demand better environmental conditions. This environmental condition is beneficial for both advanced economic growth as well as the quality of human life. The evidence for the EKC suggestion is best explained in diverse ways according to [85–89]. Some studies have revealed the role of economic growth not only in the EKC modeling basis but also from the

angle of decision-making on climate change and sustainability. Several kinds of research done to verify the EKC hypothesis have given different results, and Apergis [85] confirmed it using a panel sample of 15 countries. Onafowora & Owoye [87], used time series data for 8 countries and got varied results. Two of these countries' results gave an inverted U and the other six countries gave an N-shaped EKCs. Such varied outcomes may be due to the differences in developmental levels and also in the energy mix (renewable or non-renewable) in those countries. Özokcu & Özdemir [88], carried out a panel study in 26 OECD and 52 emerging economies, and the results demonstrated an inverted N-shaped relationship between growth and environmental degradation for those emerging economies. Based on the N-shaped result obtained, they then argue that economic growth on its own may not be enough to improve environmental quality. According to Sadorsky [90], economic development increases the use of renewable energy. Again, the author confirms that a 1% rise in economic development would lead to an 8.44% rise in renewable energy use. The economic importance of renewable energy cannot be undermined in trying to mitigate carbon emissions. With regards to the EKC, attaining additional economic growth will help limit the level of environmental deterioration if a convincing level of economic development has already been attained. Investigating renewable energy in G7 nations by Chen et al. [91] and Cheng et al. [11], the study showed that the main drivers of renewable energy use in these nations are GDP per capita and per capita carbon emissions. The effect of per capita income on renewable energy usage is positive and significantly supports the argument. The result implies that the rise in economic growth is crucial for the transition to renewable energy use.

The rest of the study is structured as section 2 methodology, section 3 results and discussion, and section 4 conclusion and policy implications.

2. Methodology

2.1 Method

Several studies with different variables have been done to analyze the effect of foreign direct investment, trade liberation, renewable energy use, and economic growth on carbon emissions. Studies like Acheampong et al. [30] and Gyimah & Yao [7] used the same variables to examine the effect of globalization on carbon emissions. However, all these studies have not assessed the indirect effects of government institutions and globalization on carbon emissions. The study further examines the proxies for both globalization and government institutions to analyze the direct and indirect effect of each proxy on carbon emissions. The study employs the Partial Least Squares Structural Equation Modelling to examine these path effects. The model does not provide the global measurement of model fit or examine model parameter's significance using standard errors. However, the model can overcome the problem of small a sample size and it is very useful in situations where other methods cannot be used. In addition, the model can be used to estimate very complex models with many latent and manifest variables. It has less stringent assumptions about the distribution of variables and error terms. Regarding the issue of endogeneity where the independent variable may be influenced by the dependent variable or the two variables may be influenced by an unmeasured third party, which will result in biased estimation, Two-Stage Least Squares is employed as the robustness check to deal with the problem. The issue of endogeneity is caused by the omission of variables, and when the observed sample is not random. Endogeneity results in a biased outcome which negatively influences the conclusion that will be drawn from the results. It is recommended to use the instrumental variable method to resolve the problem of endogeneity which Two-Stage Least Squares is considered to have.

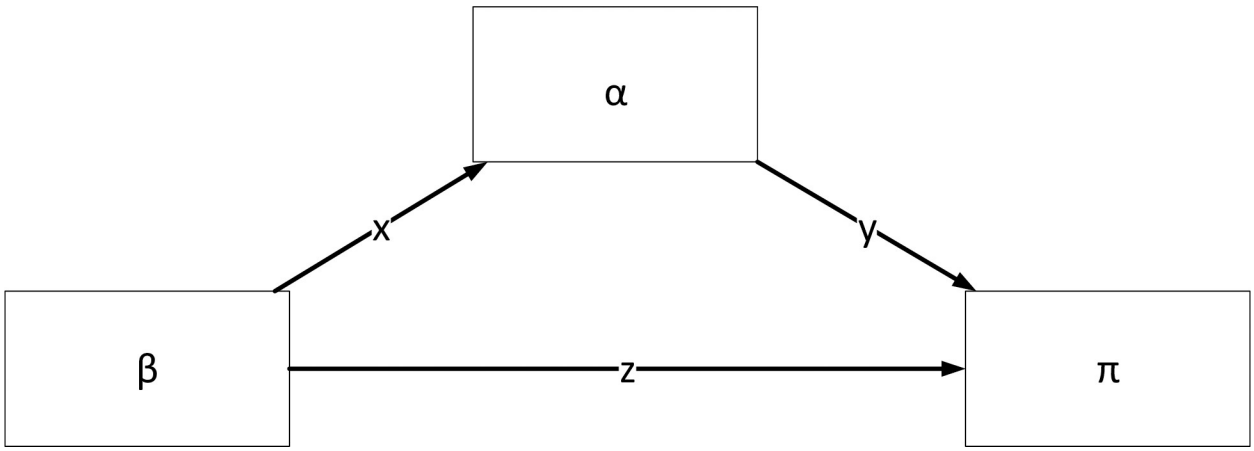

Fig 1. Direct and indirect pathways.

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Fig 1 explains the directional paths that have been analyzed in the study. The paths are the direct and indirect effects. The direct effect is from $\beta \rightarrow \alpha$ and $\alpha \rightarrow \pi$. Eqs 1 & 2 represent the indirect effect and total effect respectively. $\beta\alpha\pi$ shows the indirect pathway from $\beta \rightarrow \alpha \rightarrow \pi$. It gives a clear explanation of the direct effect from β (the symbol for the independent variable) to π (the symbol for the dependent variable) through α (the symbol for the mediator). The path from $\beta \rightarrow \alpha$ is indicated as βx and the path from $\alpha \rightarrow \pi$ is indicated as αx. The equation $T\beta$, π indicates the total path effect. The equation represents the total effect $\beta \rightarrow \pi$.

$$\beta\alpha\pi = \beta x \times \alpha y \tag{1}$$

$$T\beta, \pi = \beta x + \sum_{i=1}^{n} \beta\alpha\pi \tag{2}$$

Fig 2 below shows how the variables have been presented in the diagram. The figure shows the position of independent variables (government institutions, economic growth,

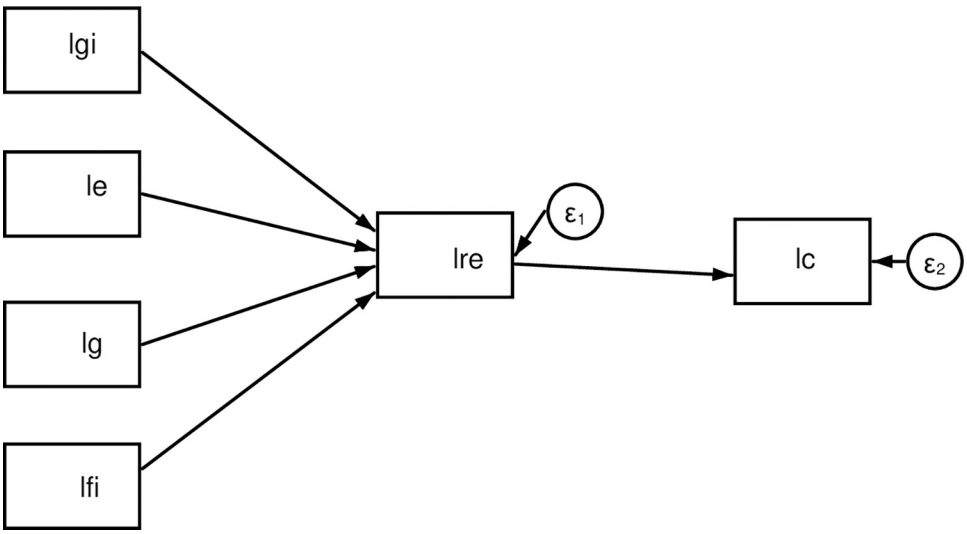

Fig 2. Path directions of the variables.

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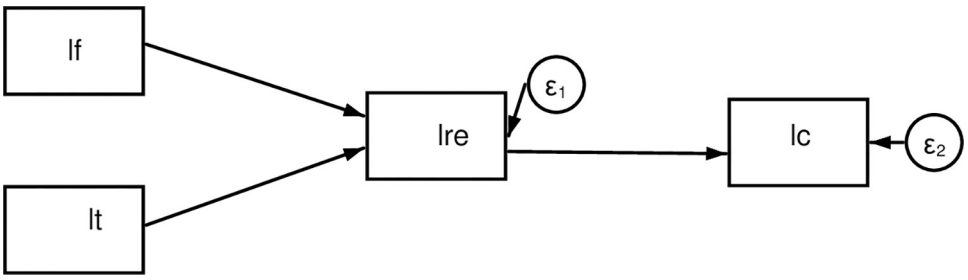

Fig 3. Globalization path analysis.

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globalization, and financial inclusion), mediator (renewable energy consumption), and the dependent variable (carbon emissions) in the diagram. The indication of the head of the arrows shows where the effect is running. Several studies have investigated this effect and provided empirical results to explain its effects. Haldar and Sethi [82] studied the effect of institutional quality on carbon emissions. Hussain et al. [84] explored the relationship between financial inclusion and carbon emissions. Sadorsky [90] investigated the effect between renewable energy and economic growth, and the study result revealed that economic growth improves the use of renewable energy. The direct effect is represented by government institutions on renewable energy (lg*i*→*lre*) and renewable energy use on carbon emissions (*lre*→*lc*). The indirect effect shows the flow from government institutions as the independent variable to renewable energy as the mediator to carbon emissions as the dependent variable (lg*i*→*lre*→*lc*), the movement of economic growth through renewable energy use to carbon emissions (*le*→*lre*→*lc*), the movement of globalization through renewable energy use to carbon emissions (lg→*lre*→*lc*), and the movement from financial inclusion through renewable energy use to carbon emissions (*lfi*→*lre*→*lc*).

Fig 3 shows how the variables for globalization thus trade liberation and foreign direct investment are presented in the diagram. Shahbaz et al. [76] studied the impact of trade openness and FDI on energy demand, and their results revealed that the two variables reduce energy demand. Therefore, this section tries to examine if the mediation role of renewable energy can influence the effect of these variables on carbon emissions. The movement is from trade liberation to renewable energy use and to carbon emissions (*lt*→*lre*→*lc*) and from foreign direct investment to renewable energy consumption and carbon emissions (*lf*→*lre*→*lc*)

Fig 4 shows how the indicators for government institutions are presented in the diagram. This section is motivated by the study of Ofori et al. [92], whose study investigated these government indicators on carbon neutrality. As presented in the diagram, the effect runs from

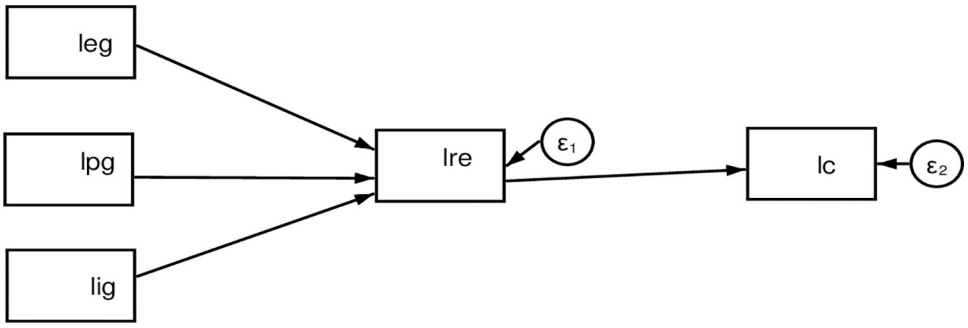

Fig 4. Government institutions path analysis.

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economic governance to renewable energy use and carbon emissions (*leg→lre→lc*), from political governance to renewable energy use and carbon emissions (*lpg→lre→lc*), and from institutional governance to renewable energy use and carbon emissions (*lig→lre→lc*).

2.2 Data

The data for the study is from World Development Indicators (https://databank.worldbank.org/source/world-development-indicators), World Governance Indicators, and the International Monetary Fund and the data is from 1998 to 2021 (26 observations). The variables for the study are renewable energy use which is the mediator, globalization (FDI and Trade openness), government institutions (economic governance, political governance, and institutional governance), economic growth, and Financial inclusion which are independent variables, and carbon emissions which is the dependent variable. Renewable energy has the potential to reduce carbon emissions. It is considered the best substitute for fossil fuels due to its impact on the environment. Lack of financial inclusion is seen as one of the factors contributing to energy poverty. It causes people to consider cheaper energy sources that are harmful to the environment. Government institutions are responsible for protecting the environment, hence making policies that would help mitigate carbon emissions. Globalization, depending on the environmental regulations in a country, can deteriorate the environment. The variables for the study were selected based on their influence on promoting a sustainable environment. Table 1 gives the source and definition of the variables. Tables 2 and 3 show the descriptive statistics and correlations of the variables respectively.

2.2.1 Dependent variable. The dependent variable for the study is carbon emissions. As a result of industrial activities, construction, and agricultural activities, carbon dioxide is released into the atmosphere [69]. The constant release of carbon dioxide affects the sustainability of the environment. Since the state of the environment affects the ecosystem, it is important to examine how the situation can be controlled.

2.2.2 Mediator. Renewable energy is the mediation variable for the study. Renewable energy is considered the best substitute to replace fossil fuels [55]. Its effect on the environment has drawn much attention to the energy. It is used as the mediator to examine the intermediate role it can play in fostering environmental sustainability.

2.2.3 Independent variable. The independent variables for the study are globalization, government institutions, economic growth, and financial inclusion. As the world has reached

Table 1. Data source and definition.

Variables	Sign	Definition	Source
Carbon emissions	*lc*	Carbon emissions per capita	WDI
Globalization	lg	Trade openness and foreign direct investment	WDI
Government institutions	lg*i*	Economic governance, political governance, and institutional governance	WGI
Financial inclusion	*lfi*	Financial development index	IMF
Renewable energy	*lre*	Total renewable energy consumption	WDI
Economic growth	*le*	GDP per capita	WDI
Foreign direct investment	*lf*	Net FDI inflow	WDI
Trade liberation	*lt*	Export and import	WDI
Economic governance	*leg*	Regulation quality and government effectiveness	WGI
Political governance	*lpg*	Voice and accountability and political stability	WGI
Institutional governance	*lig*	Rule of law and control of corruption	WGI

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Table 2. Statistical description.

	Mean	Median	Max	Mini	Std. Dev
lg*i*	5.852610	5.865316	5.903154	5.768808	0.041180
lg	4.399791	4.414852	4.782293	3.718314	0.217000
lc	-0.705031	-0.814358	0.633599	-1.473123	0.534056
lre	4.030917	4.023875	4.367283	3.725211	0.208635
lfi	-2.038330	-2.107881	-1.745514	-2.256770	0.178368
le	0.766642	0.952318	2.424809	-1.446538	1.044212

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an era of globalization, it is important to examine its impact on environmental sustainability. Foreign direct investment and trade openness are the proxies for globalization. The impact of FDI and trade cannot be undermined when considering carbon mitigation [93]. Government institutions have a role to play in environmental sustainability as the governance system is controlled by these institutions. Six proxies are used to represent government institutions, voice and accountability, regulation quality, rule of law, control of corruption, political stability, and government effectiveness. The level of economic development of a country has a crucial role in deciding the type of energy to use. Therefore, it is important to investigate the direct effect of economic growth on renewable energy and the indirect effect on carbon emissions. Lastly, financial inclusion is very relevant in deciding the level of development in a country which significantly influences the type of energy to use.

3. Results and discussion

The PLS-Structural Equation Modelling helps examine the direct and indirect paths of the variables thus from the independent variables to the mediator (direct effect), from the mediator to the dependent variables (direct effect), and from the independent variable to the mediator and the dependent variable (indirect effect). The results presented in Table 4 show both direct and indirect effects of the variables as presented in Fig 2. The findings indicate that government institutions have no significant effect on promoting renewable energy. Government institutions in Ghana's role in promoting the use of renewable energy is considered insignificant. The institutions understudy thus economic, political, and institutional governance efforts towards enhancing the transition from traditional energy (fossil fuel) to modern energy (renewable energy) are not felt. In the same regard, the indirect effect of government institutions on carbon emissions through renewable energy is not significant. The result contradicts the study of Towah [94] whose findings indicated that the rule of law, regulations, and effective governance compel firms to maintain and promote environmentally friendly measures. In addition, Cao et al. [95] revealed that institutional quality is crucial and needed for promoting environmental quality through carbon emissions mitigation. Hunjra et al. [96] revealed that

Table 3. Correlation.

	lc	*le*	lg*i*	lg	*lre*	*lfi*
lc	1					
le	0.1879	1				
lg*i*	0.5432	0.4091	1			
lg	-0.3956	0.0676	-0.2110	1		
lre	-0.9603	-0.2555	-0.6154	0.4094	1	
lfi	0.8606	0.1165	0.3342	-0.3146	-0.8761	1

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Table 4. Direct and indirect effects estimation.

	Direct effect	Indirect effect	Interpretation
lg*i*→*lre*	-.0683601		Not Significant
lg*i*→*lre*→*lc*		-.0002592	Not Significant
le→*lre*	.0385002		Not Significant
le→*lre*→*lc*		.0149225	Nott Significant
lg→*lre*	.2977643***		Significant
lg→*lre*→*lc*		.1154124	Not Significant
lfi→*lre*	-.6112909 **		Significant
lfi→*lre*→*lc*		-.2369341 **	Significant
lre→*lc*	.3875964**		Significant

***, **, and * indicate 1%, 5%, and 10% respectively

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institutional quality motivates people to advocate for sustainable development, which in the long-run helps in carbon mitigation.

Again, economic growth does not affect renewable energy use. The result of the study contradicts that of Gyimah et al. [55], whose findings indicated a feedback causal effect between economic growth and renewable energy consumption. Although Chen et al. [91] argued that economic growth and renewable energy usage are correlated, meaning the rise in economic growth will cause the rise in renewable energy use, however, the case of Ghana is different. The level of economic development in the country is not strong enough to promote the use of renewable energy. The indirect effect of economic growth on carbon emissions through renewable energy use is also insignificant. The result of the study is supported by Gyimah et al. [97] whose findings indicated that economic growth is irrelevant to explain carbon emissions. This implies that economic growth does not affect either direct or indirect renewable energy use and carbon emissions, respectively.

Globalization is considered to be one of the main drivers of renewable energy use, although there have been two hypotheses that explain its presence. The findings of the study show that globalization promotes the use of renewable energy in Ghana. The pollution hallo hypothesis explains how globalization promotes environmental quality through the promotion of environmentally friendly technologies. The result implies that foreign direct investment and trade liberation, which are indicators of globalization, must be encouraged in the country. Trade liberation provides a platform for people to trade environmentally friendly technologies without stress, and the FDI encourages local industries to use environmentally friendly technologies by investing in these local industries. The outcome is supported by Wang and Zhang [74] whose study revealed how trade openness, one of the globalization indicators promotes environmental sustainability. However, the indirect effect of globalization on carbon emissions through renewable energy use is insignificant.

Financial inclusion is argued to be one of the measures that need to be considered for the transition from traditional energy (fossil fuel) to modern energy (renewable energy). From our results, financial inclusion has a negative and significant effect on renewable energy use. The finding implies that the state of financial inclusion in the country is reducing the use of renewable energy instead of increasing it. This can be attributed to financial regulations and the financial institution's attitude toward encouraging the use of renewable energy. However, our results indicate that financial inclusion has a negative and significant indirect effect on carbon emissions through renewable energy. Financial inclusion through renewable energy helps promote environmental sustainability. Although Le et al. [98] revealed that financial inclusion

Table 5. Direct and indirect estimation of globalization.

	Direct effect	Indirect effect	Interpretation
lt→lre	.5888687***		Significant
lt→lre→lc		.2282434*	Significant
lf→lre	-.1911672		Not Significant
lf→lre→lc		-.0740957	Not Significant
lre→lc	.3875964**		Significant

***, **, and * indicate 1%, 5%, and 10% respectively

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causes carbon emissions, Saidi and Mbarek [99] study indicated that financial inclusion helps in carbon mitigation. This difference in results could be attributed to geographical locations and data availability.

Finally, renewable energy use has a positive and significant effect on carbon emissions. The finding contradicts the study of Gyimah et al. [64] whose findings revealed that renewable energy mitigates carbon emissions in both the short and long term. Renewable energy is argued to be the best substitute for fossil fuels due to its effect on the environment [100]. It is considered to help in carbon emissions mitigation. Various studies have supported this argument with their empirical results [97]. However, other studies have also recorded that renewable energy contributes to carbon emissions if the required measures are not put in place. The findings of this study support the fact that renewable energy contributes to carbon emissions. The result reflects the current attitude of developing countries towards the use of renewable energy.

Table 5 assesses the direct and indirect effects of trade liberation and foreign direct investment on renewable energy and carbon emissions, respectively. These are the two variables used to represent globalization in the study. The result shows that trade liberation promotes the use of renewable energy. Trade liberation is perceived to have a positive effect on the use of sustainable energy. However, trade liberation has a positive and significant indirect effect on carbon emissions. Trade liberation is argued to have either a positive or negative effect on environmental quality. The findings of the study reveal that trade liberation indirectly deteriorates environmental quality. However, foreign direct investment has no significant direct or indirect effect on renewable energy use and carbon emissions, respectively.

Table 6 examines the direct and indirect effects of economic governance, political governance, and institutional governance on renewable energy and carbon emissions, respectively. These are the variables used to represent government institutions. The findings reveal that

Table 6. Direct and indirect estimation of financial inclusion.

	Direct effect	Indirect effect	Interpretation
leg→lre	2.386486***		Significant
leg→lre→lc		.9249934*	Significant
lig→lre	-1.023431		Not Significant
lig→lre→lc		-.396678	Not Significant
lpg→lre	-1.827396**		Significant
lpg→lre→lc		-.7082919	Not Significant
lre→lc	.3875964**		Significant

***, **, and * indicate 1%, 5%, and 10% respectively

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Table 7. Two-Stage Least Squares estimation.

	Coefficient	t-statistics
lre→*lc*	-1.1395***	-4.6796
lg*i*→*lc*	0.7124***	6.9673
lg→*lc*	0.0137	0.0936
lfi→*lc*	0.2595	1.0034
le→*lc*	-0.0263	-0.8664
R^2	0.9165	
Adjusted R^2	0.8943	

***, **, and * indicate 1%, 5%, and 10% respectively

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economic governance promotes the use of renewable energy. The level of economic involvement in a country has a say in its renewable energy transition. The people desire more sustainable energy for production when the population is allowed to participate in economic activities in the country which our results confirm. However, economic governance has a positive and significant indirect effect on carbon emissions through renewable energy use. The level of economic participation through renewable energy in the country causes carbon emissions despite the positive influence of renewable energy use. The findings further show that institutional governance has neither a significant direct nor indirect effect on renewable energy use and carbon emissions, respectively. Nevertheless, political governance has a significant negative effect on renewable energy use. The result implies that political governance reduces the use of renewable energy. The level of the political atmosphere in the country is negatively affecting the transition from traditional energy (fossil fuel) to modern energy (renewable energy). However, it has no significant effect on carbon emissions through renewable energy.

3.1 Robustness check

The result presented in Table 7 is the outcome of the Two-Stage Least Squares estimation. The results indicate the effect of the independent and the mediators on carbon emissions. The results indicated that renewable energy use has a negative and significant effect on carbon emissions. The result implies that renewable energy use promotes environmental quality. The result supports that of the result from the PLS-SEM estimation. The result further revealed that government institutions cause carbon emissions. Although, this effect is not estimated in the PLS-SEM estimation. The rest of the variables have no effect on carbon emissions. The results presented in Table 8 show the effect of the mediators on renewable energy. The results

Table 8. Two-Stage Least Square estimation of the mediators effect on renewable energy use.

	Coefficient	t-Statistics
lg→*lre*	0.2618*	1.9303
lg*i*→*lre*	0.1758*	1.8446
lfi→*lre*	-0.9156***	-6.8093
le→*lre*	-0.0473	-1.6364
R^2	0.7937	
Adjusted R^2	0.7550	

***, **, and * indicate 1%, 5%, and 10% respectively

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revealed that globalization and government institutions have a positive effect on renewable energy use. However, financial inclusion has a negative effect on renewable energy use, but economic growth has no effect on renewable energy use. Except for government institutions that have a positive effect on renewable energy use, the rest of the results confirm the results from the PLS-SEM estimation.

4. Conclusion and policy recommendation

4.1 Conclusion

Renewable energy has gained much recognition as the best substitute for fossil fuels due to its potential to help mitigate carbon emissions. Researchers, policymakers, and all concerned corporations are making efforts to improve the use of renewable energy around the world. Adding to the already existing literature, this study employs PLS-SEM to analyze the direct and indirect effects of globalization, economic growth, financial institutions, and government institutions on renewable energy and economic growth respectively, and further employed Two-Stage Least Squares as the robustness check. The study aims to establish the best way to improve renewable energy use to control carbon emissions. The findings of the study reveal that globalization promotes the use of renewable energy. Globalization has a direct and significant effect on renewable energy. The result implies that globalization creates a platform to enhance the development and use of renewable energy. However, financial inclusion has a negative and significant effect on renewable energy, meaning financial inclusion reduces the use of renewable energy. Renewable energy causes carbon emissions. The development of renewable energy in the country is not strong enough to reduce carbon emissions. Finally, financial inclusion through renewable energy has a significant and negative effect on carbon emissions. Financial inclusion with the help of renewable energy helps to maintain environmental sustainability by controlling carbon emissions.

4.2 Policy recommendations

Based on the results of the study, these policies are recommended for the development of renewable energy and the control of carbon emissions to maintain environmental quality. The results indicate that globalization helps improve the use of renewable energy. Since trade liberation and foreign direct investment are used to represent globalization, developing countries should create a political atmosphere to welcome foreign investors. Governments in developing countries should set economic standards that would attract foreign investors into their countries. Environmental and trade regulations that encourage the use of renewable energy should have incentives that attract foreign investors. However, those in authority should not compromise environmental regulations for these investors. The results further show that financial inclusion reduces the use of renewable energy, but renewable energy helps mitigate carbon emissions. A lot of attention should be shifted toward creating financial awareness for the public. Financial institutions should be encouraged to help infant industries trying to use renewable energy in their production by providing loans with low interest rates. Individual households should have access to financial support and be motivated to use this available support for sustainable energy.

Although the objective of the study was achieved, future studies can expand the scope by addressing this issue. For the study, only two variables are used to represent globalization (trade liberation and foreign direct investment), but future research can add additional variables to these two. Recommended variables are migration rate and tourism because these two factors involve people moving from one country to another.

Supporting information

S1 Data.
(XLSX)

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