



## Research article

# The effect of renewable energy on carbon emissions through globalization

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## ABSTRACT

The sustainability of the environment debate cannot be addressed without considering the type of energy to use. The pace at which the world is industrializing, globalizing, and developing economically has prompted many researchers to investigate the kind of energy required to preserve the environment. In this regard, this study employs the mediation model to assess renewable energy's direct and indirect effects on carbon emissions through globalization. The data for the study is from 1990 to 2020. The study's findings showed that while renewable energy has no appreciable impact on trade openness, it directly and negatively affects carbon emissions. However, foreign direct investment has a direct and significant positive effect on carbon emissions, while trade openness has no significant effect. The indirect result revealed that renewable energy through foreign direct investment has a negative effect on carbon emissions; however, renewable energy through trade openness has a positive effect on carbon emissions. Policymakers are encouraged to restrict the trade sector to reduce the trading of high-emission technologies.

## 1. Introduction

As the world's population reaches 8 billion, energy consumption and production activities continue to rise, with the majority of energy consumption coming from nonrenewable sources. The perpetual use of nonrenewable energy has adversely affected the environment causing global warming [1]. It has been argued by Xu et al. [2] that carbon emissions from nonrenewable energy are an influential driver of climate change. Also, per the report of the International Panel on Climate Change's fifth assessment, activities of human are considered the primary sources of GHG emissions. These human activities, according the IPCC are result of the post-industrial revolution advancement in population and economy. Again, emphasis has been made by policymakers on the need to mitigate GHG emissions, which are detrimental to our planet. As a primary goal of the Paris Climate Agreement (COP21), expedited measures need to be taken to mitigate carbon emissions, or else the emissions of GHG could double up by 2035 from the level it used to be during the pre-industrial level [3,4]. To prevent planet earth from bypassing a crucial 1.5 °C to achieve net-zero goals, renewable energy sources have been identified as the answer, which is to emphasize that, the use of renewable energy helps to neutralize the effect of greenhouse gases [5] and gives a longer period of use than fossil fuels [6] hence its worldwide acceptance.

Globally, the combustion of fossil fuels is considered the highest emitter of greenhouse gases [7]. The environmental consequences of emissions have brought the world to a universal goal focus, thus the fight to replace fossil fuels with sustainable energy. Irrespective

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of the role fossil fuels play in the development of the economy in many countries especially developing countries, its threat to the environment has caused environmentalists, government bodies, non-state actors, and all concerned individuals to put measures in place to replace it [8].

Globalisation is also among the emitters of greenhouse gases, over the past years, most of the West African countries especially Ghana have received many foreigners because of globalization. As a means of protecting the environment, it is expedient to examine the effect of globalization on energy on carbon emissions. Ghana is blessed with abundant renewable resources however; the country is unable to utilize these resources to the fullest. The Major part of its economy still depends on fossil fuels for survival.

Ghana's energy supply has long relied on gas, biomass, and oil. Ghana's energy supply in 2019 was around 11,149ktoe, with oil contributing 38.3% of the total supply. Oil has since remained the most used primary energy supply within the Ghanaian economy since 2012 [9]. Ghana's renewable energy sector has experienced quite a slow growth. Between the years 2011 and 2017, the sector only grew by 15.39%. The country's renewable energy sector has remained undeveloped, although the government has attempted several initiatives towards the sector's development. As a renewable energy source, solar has only 0.3% of Ghana's energy supply [10]. Undoubtedly, this proves why CO<sub>2</sub> emissions have been a concern for the Ghanaian government. In a quest to address these issues of developing renewable energy to control CO<sub>2</sub> emissions, several studies have explored variables that will affect renewable energy use, and the majority of these studies identified globalization, among others, as an influential factor [2,11,12].

Recently, countries have become increasingly dependent on each other. Countries are more inclined to economic globalization. Economic globalization has several effects like spreading social values, culture, employment, economic growth, climate change, foreign investment, and trade openness [2]. In this 21st century, both developing and developed countries have benefited positively from economic globalization. Nonetheless, developing countries have experienced accompanying negative effects [13]. Globalization's influence on climate change has raised debate among scholars. Some school of thought believes globalization endangers the environment through GHG emissions [14]. Another school of thought also believes globalization has brought about advancement in technology which helps in reducing GHG emissions [15]. Globalization in the social and economic context increases carbon emissions, as opined by Destek [16], contrary to political globalization, which he believes has improved environmental quality in central and eastern Europe.

Globalization has always been a driver of economic growth in a broad sense. Foreign direct investment and trade openness as a factor of globalization are also contributing factors to economic growth. Most countries have declared their ports as import-free, while others have reduced tariffs to promote economic growth. Globalization has propelled the rate of urbanization and eventually, the demand for energy consumption has increased. Current research elucidates that the accelerated rate of urbanization must be accompanied by a corresponding energy demand [17]. In an attempt to meet this demand for energy, the majority of developing countries have resorted to eco-unfriendly fossil energy, which they consider affordable at the expense of renewable energy, which is environmentally friendly.

Several research has been done on globalization, the carbon emissions nexus and renewable energy, and mixed results have been established. Aziz et al. [18] in their study, conclude that globalization through foreign direct investment increases energy use (nonrenewable) which negatively affects the environment. Sun et al. [19] also reveal in their study that globalization increases carbon emissions. The study of Gyimah and Yao [20] reveals a reverse effect that globalization rather reduces carbon emissions through increased renewable energy use. However, this study is an addition to other literature in three extant phenomena. Firstly, among the studies that have tried to explore the effect of globalization on carbon emissions, none of them considered examining the indirect effect as well. Nevertheless, this study evaluates the indirect effect of renewable energy on carbon emissions through globalization since almost all the studies towards this direction focus on the direct effect thus creating a research direction awareness.

The study employed a mediation model for this analysis. In situations where there is not a clear direct correlation between renewable energy and carbon emissions, the mediation model recognizes the causal relationship that exists between them. This reveals the role some variables play in ensuring environmental sustainability. Secondly, to enrich extant literature on renewable energy and environmental sustainability nexus, the study further considers the direct effect of renewable energy on carbon emissions, the direct effect of renewable energy on globalization, and the indirect effect on carbon emissions.

The paper unfolds in a structured manner, with section two delving into the comprehensive literature review, section three elucidating the methodology employed, section four presenting the findings alongside a thoughtful discussion, and section five encapsulating the conclusive remarks, concluding with a discussion on policy implications.

## 2. Literature Review

Globalization impacts the growth of an economy by advancing a country's economic, social, and political attainment; however, globalization increases CO<sub>2</sub> emissions, giving rise to changes in the climate and environmental degradation [21]. As a result, the correlation between globalization and the environment is causing growing concern. Discovering such a long-standing relationship is critical for policymakers aiming for environmental sustainability and its development is contingent on environmental, social, and economic factors. As a natural outcome, globalization increases energy demand, which causes carbon emissions [22]. Carbon emissions (Loss and damage) were a major conservation at the Egypt Climate Conference 27 (COP27). It is accounted that most rich countries with significant numbers of globalization are responsible for 90 percent of the excess emissions that are causing climate breakdown. The significance of the study is to examine the mediating role of globalization on carbon emissions.

Globalization has far-reaching effects on CO<sub>2</sub> emissions, with three main areas of impact. Firstly, there is the influence on domestic and commercial energy consumption. Secondly, the construction industry plays a role, with energy-intensive activities aimed at improving transportation, infrastructure, and residential structures. Lastly, urban growth leads to forest alteration. The rise in

household appliance usage (such as air conditioners and heating systems), contributes significantly to energy consumption, exacerbating the overall impact on greenhouse gas emissions [23]. While the globalization implications on carbon emissions have been identified; there have been two widely held assumptions about the link between globalization and CO<sub>2</sub> emissions. Several researchers posit that globalization is to be held responsible for lesser CO<sub>2</sub> emissions [24–26]. Among others, Saud et al. [27] discovered an insignificant impact between globalization (natural resources) and CO<sub>2</sub> emissions in India, Brazil, and China; but again, globalization (natural resources) plays a vital role in CO<sub>2</sub> emission reduction in Russia. Muhammad and Khan [28] investigated 170 countries' environmental effects of globalization and discovered that economic globalization reduces CO<sub>2</sub> emissions. Whereas others assume that globalization would adversely cause environmental degradation if the current energy-producing system remained stable [21,29]. Furthermore, globalization is liable for a decline in natural resources, along with economic growth. Globalization has triggered several environmental effects, spanning everything from ozone depletion, resource overutilization, and forest destruction [30]. Globalization stimulates economic activity and energyconsumption, which increases carbon emissions. Globalization, on other instances can improve environmental quality by increasing the inflow of eco-friendly technologies [31,32]. The major contribution of the study to ascertain globalization as a mediating role for carbon emissions taking to account renewable energy, trade openness, economic growth and FDI.

Usually, multiple previous studies have looked into the environmental consequences of globalization employing a variety of methodological approaches that span both country-specific and cross-country analyses [27]. In this regard, the findings have all been questionable, as existing researchers have found both positive and negative environmental implications related to globalization. Globalization has been identified as the primary cause of the conversion of the most polluting industries from developing countries to developed ones. This stands out as the leading factor behind the surge in carbon emissions, suggesting a clear and significant correlation between the two variables. Countries like China, Japan, Brazil, South Africa, and Argentina demonstrate a trend where globalization leads to a reduction in carbon emissions [33–35]. Through the analysis of yearly time series data from 1980 to 2017, a research study examines how urbanization and globalization influence CO<sub>2</sub> emissions in South Africa. Following the confirmation of a cointegrating relationship, the ARDL model reveals that urban growth is a catalyst for CO<sub>2</sub> emissions, while globalization exerts a significant long-term influence on emissions [36]. In a research endeavor examining carbon emissions in Argentina, it was found that globalization, coupled with renewable energy consumption (REC), concurrently reduces emissions. However, the research findings indicated that when combined with the consumption of non-renewable energy sources, globalization contributes to an overall rise in CO<sub>2</sub> emissions, especially over extended periods [37].

Furthermore, a significant body of research also endeavored to examine the relationship between globalization and CO<sub>2</sub> emissions, with notable studies conducted by Khan and Ullah [38] in Pakistan, Sheraz et al. [39] in Malaysia Etokakpan et al. [40], in Turkey [41], India [42], China [43] and Ghana [44]. Specifically, in the case of Malaysia, the study utilizes the total trade with 10 TPP members as a gauge of globalization, analyzing its impact on carbon emissions. The findings depict a cointegrated among the variables

**Table 1**

The summary of the literature review.

	Year	Country	Method	Effect
Saud et al. [27]	1990 to 2014	N-11 countries	Panel estimation techniques	Globalization not carbon emissions (Brazil, India, China) Globalization reduces carbon emissions (Russia)
Muhammad and Khan [28]	1990 to 2018	170 countries	GMM and fixed effect model	Economic globalization reduces CO <sub>2</sub> emissions
Xiaoman et al. [34]	1980 to 2018	Middle East and North Africa (MENA) economies	Second-generation panel cointegration techniques continuously updated fully modified	Economic globalization reduces CO <sub>2</sub> emissions
Salahuddin et al. [36]	1980 to 2017	South Africa	continuously updated bias-corrected ARDL cointegration test	Globalization affects carbon emissions (long-term)
Yuping et al. [37]	1970 to 2018	Argentina	Autoregressive Distributed Lag model	Globalization and renewable reduce carbon emissions, globalization and nonrenewable cause carbon emissions (long term)
Khan and Ullah [38]	1975 to 2014	Pakistan	ARDL bound testing approach	Globalization increases carbon emissions
Sheraz et al. [39]	2003 to 2019	64 Belt and Road (BRI) countries	second-generation methodological approach	Globalization enhances negative environmental externality
Shahbaz et al. [41]	1970 to 2010	Turkey	VECM Granger causality	Economic globalization increases carbon emissions
Shahbaz et al. [42]	1970 to 2012	India	ARDL bounds testing	globalization increases carbon emissions
Acheampong [44]	1961 to 2016	Ghana	Stochastic Effect of Return to Population, Wealth, and Technology	Political globalization increases carbon emissions (long-term) Social globalization reduces carbon emissions (long-term)
Acheampong et al. [21]	1980 to 2015	Sub-Saharan African countries	Fixed and random effect	Globalization reduces carbon emissions
Yameogo et al. [46]	2002 to 2017	Sub-Saharan Africa countries	Generalized Methods of Moments	Economic globalization reduces carbon emissions

[45]. The Stochastic Effect of Return to Population, Wealth, and Technology (STIRPAT) model was used by Acheampong [44] to assess the influence of political, de facto economic, and social globalization on Ghana’s CO<sub>2</sub> emissions, employing a nonlinear autoregressive distributed lag model. The findings suggest that alterations in political globalization, regardless of being positive or negative, contribute to a long-term rise in CO<sub>2</sub> emissions. Conversely, fluctuations in social globalization, whether positive or negative, are linked to a reduction in CO<sub>2</sub> emissions.

Acheampong et al. [21] conducted a thorough examination of the effect of globalization on CO<sub>2</sub> emissions through panel regression. Their research reveals a noteworthy trend, indicating that globalization exerts a negative influence on environmental breakdown in Sub-Saharan Africa. In a similar research by Yameogo et al. [46] examines the relationship between economic globalization and environmental quality in Sub-Saharan Africa, considering institutions as a determining factor (SSA). The approach of GMM was used in a study to compare data from 2002 to 2017. The outcome of that shows that regulation quality positively impacts environmental degradation in SSA, whereas economic globalization and corrupt practices control negatively impact CO<sub>2</sub> emissions.

The summary of the literature review section has been presented in Table 1. The table shows the effect of globalization on CO<sub>2</sub> emissions presented in the literature review section.

### 3. Method and materials

#### 3.1. Theoretical background

As a mediating role, globalization has been one of the contributing factors left undiscussed in relation to its influence on foreign direct investment (FDI), economic growth, trade openness, carbon emissions, and renewable energy. The findings of Sheraz et al. [39] a second-generation method on retrieved data (2003–2019) from that of the 64 BRIC countries, records that globalization impacts socially negative and environmental externality associated with financial development, whereas institutional quality minimizes it. Moreover, globalization and the quality of institutions (FDI, trade openness) each contribute to the advantageous decrease in emissions from renewable energy sources. One of the existing studies by Mishkin [47] examined the empirical relationship of Globalization with FDI and Economic growth (i.e. GDP). From the results, globalization stands to be a primary contributor promulgating the financial system: debt finance reduction, giving rise to significant investments in concurrent projects and at the intersection of growth in GDP. Sheraz et al. [39] also concludes that globalization is directional in relationship with financial systems and GDP, but energy posed a hindrance to the manufacturing of goods and services, though it was the source of CO<sub>2</sub> emissions. In a country analysis using globalization as a mediating role, a new threshold analysis of Japan reveals Shahbaz et al. [48] globalization raises energy demand and CO<sub>2</sub> emissions, and that economic growth exacerbates environmental degradation via globalization. Likewise for Pakistan Khan et al. [49] using the ARDL method to demonstrate that in the short run, there was a positive relationship between trade openness, globalization, FDI and CO<sub>2</sub> emissions. This association persisted in the long run as well. According to the reviewed studies, proponents have examined various globalization-related factors such as trade openness, FDI, export, and import; however, neither of the research has looked at different aspects of globalization and assessed their impact on carbon emissions. As a result, by carrying out this study, we are able to bridge the gap.

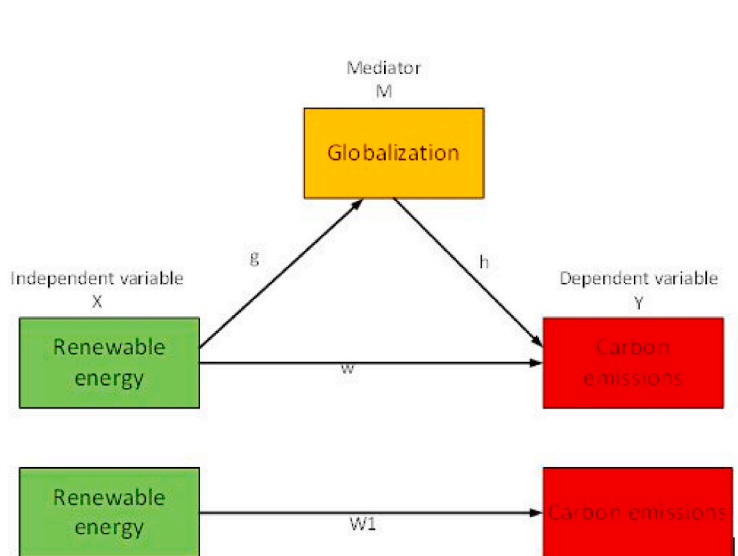


Fig. 1. Mediation pathways.

### 3.2. Method

Numerous studies have investigated the direct impact of the consumption of renewable energy on CO<sub>2</sub> emissions through various models. However, to improve on the current literature, this study emulates Gyimah et al. [50] to employ the Mediation Model to assess the indirect effect of renewable energy consumption on CO<sub>2</sub> emissions using trade openness and foreign direct investment as mediators. The mediation model is utilized when exploring the connection between an independent variable, a dependent variable, and an intermediary factor in a study. The mediation model can analyze both the direct impact of the independent variable on the mediators and the dependent variable. The model further helps to understand the existing relationship between the predictor and the outcome variable when they do not have an obvious direct connection. In other words, the model helps explain best if the influence from the predictor variable to the outcome variable is mediated by another variable and helps better understand the underlying mechanisms through which the influence from the predictor variable affects the outcome variable. Again, it broadens the understanding of the relationships that exist between the two variables (both direct and indirect relationships). Although, the model is not able to check selection bias, the preliminary tests done have helped address the issue making the data suitable for the study. With this, the data for the study is regarded as appropriate for the mediation analysis. For example, Qiu et al. [51] employed the mediation model to explain the direct and indirect effects of online risky behaviour on sleep quality. Gyimah et al. [50] also used the mediation model to investigate how renewable energy affect economic growth both directly and indirectly. In addition, Liu and Bah [52] also employed mediation model to assess the effects (direct and indirect) of renewable energy potential on poverty reduction.

Fig. 1 presents the pathway of the variable effects. The independent variable is renewable energy use (X), the mediator is globalization (M), and the dependent variable is the carbon emissions (Y). The authors have developed two equations (Equation (1) & 2) to estimate the indirect effect of X on Y as the general mediation estimation.

Equation (1) explains the mediator (M) which is specified as the linear function of the independent variable (X).

$$M = i_M + gX + e_M \quad (1)$$

Equation (2) shows how the dependent variable (Y) is specified as a linear function of independent variable (X) and the Mediator (M).

$$Y = i_Y + wX + hM + e_Y \quad (2)$$

From the figure, the product of path coefficients “g” and “h” will give the indirect effect. The coefficient “w1” is the direct effect. Equation (3) explains the total effect

$$TE = w1 + gh \quad (3)$$

### 3.3. Data

The research was undertaken in Ghana, and the data utilized is sourced from World Bank Indicators spanning from 1990 to 2020. Ghana was selected as the study area due to the implementation of measures in recent years aimed at promoting the utilization of renewable energy to mitigate emissions. The research variables are sourced from World Bank data and include renewable energy consumption (expressed as the total percentage of renewable energy consumption), carbon emissions (measured in kilotons), trade openness (represented as the percentage of Gross Domestic Product), and foreign direct investment (calculated as the total net inflow percentage of Gross Domestic Product). Descriptive statistics and the correlation between these variables are presented in Table 2 and Table 3, respectively. While Fig. 2 gives the general view of the trend of the variables for the study.

## 4. Results and discussion

### 4.1. Direct effect

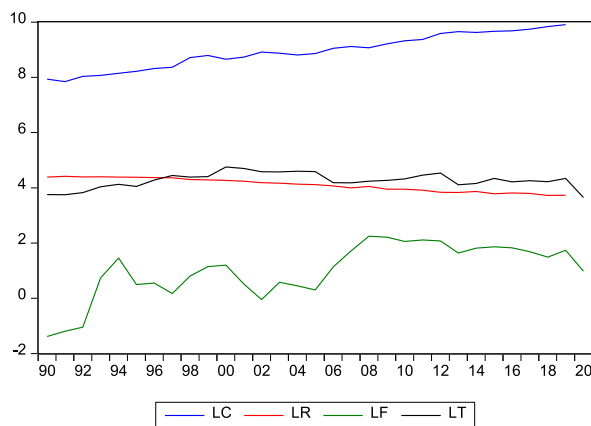
This section discusses the direct influence of the predictor variable on the mediators, the independent variable effect on the dependent variable, and the direct impact of the mediator on the dependent variable. The summary of the result is presented in Fig. 3. The results in Table 4 reveal renewable energy has a significant effect on foreign direct investment in a negative direction (−0.5323, p = 0.0021). Gyimah et al. [50] findings corroborate with this outcome. The study by Shahbaz et al. [53] reveals a reverse trend of a significant positive effect, while the study by Hagert and Marton [54] indicated a mixed significant relationship. Thus, it reduces and increases renewable energy in the short term and long term respectively. Appiah-Otoo et al. [55] indicated that the enhancement of

**Table 2**  
Descriptive statistics.

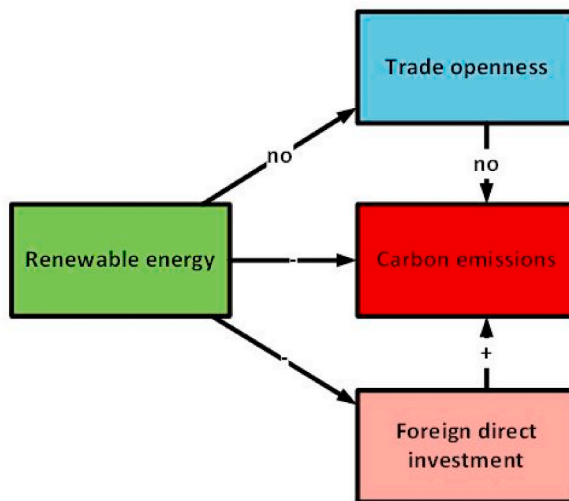
	ln c	ln r	ln f	ln t
Mean	8.937451	4.103692	1.012232	4.289963
Median	8.893375	4.125572	1.176193	4.275265
Max value	9.905486	4.417977	2.247777	4.754008
Mini value	7.847763	3.725211	−1.381074	3.749230
Std. Deviation	0.621547	3.725211	1.005142	0.256301

**Table 3**  
Correlation.

	$\ln c$	$\ln r$	$\ln f$	$\ln t$
$\ln c$	1			
$\ln r$	-0.9763	1		
$\ln f$	0.7757	-0.7379	1	
$\ln t$	0.3370	-0.1200	0.3383	1



**Fig. 2.** The trend of the variables.



**Fig. 3.** Summary of the direct effect.

**Table 4**  
Direct effect.

Direct Effect	Coefficient	Prob
$r \rightarrow f$	-0.5323	0.0021
$r \rightarrow t$	0.0872	0.6409
$r \rightarrow c$	-0.2800	0.0960
$f \rightarrow c$	0.4945	0.0050
$t \rightarrow c$	0.1693	0.2292

foreign direct investment encourages the adoption of renewable energy, fostering economic growth. REC has no significant effect on trade (0.0872,  $p = 0.6409$ ). Our findings corroborate with the study of Gyimah et al. [50] whose results revealed that renewable energy has no significant impact on trade openness. In the study by Hussain et al. [56], the findings revealed that an increase in trade openness encourages renewable energy investment. The study of Zhongwei and Liu [57] further revealed that trade openness enhance the adoption of renewable energy use. However, the result is contradicted by the study by Zhang et al. [58] whose results indicated that trade openness and renewable energy use have a strong nonlinear relationship. Renewable energy has a negative and significant effect on CO<sub>2</sub> emissions ( $-0.2800$ ,  $p = 0.0960$ ). The use of renewable energy helps reduce carbon emissions to promote environmental sustainability. Li et al. [59] study supports the findings of our study. Their findings indicated that improving renewable energy helps alleviate environmental pressure. In addition, Wang et al. [60] study revealed that renewable energy development helps to curb carbon emissions in countries like Canada, Finland, Russia, Slovenia, South Korea, and the UK. The findings of Hussain et al. [61] also indicated that renewable energy promotes environmental sustainability in five polluted economies. Foreign direct investment has a positive and significant effect on CO<sub>2</sub> emissions (0.4945,  $p = 0.0050$ ). The result implies that FDI causes carbon emissions which do not help in the mitigation process. Derindag et al. [62] study supports the findings of our study. Their findings indicated that foreign direct investment positively affects industrial carbon emissions. In addition, a study by Bui et al. [63] revealed that foreign direct investment causes carbon emissions. However, Yi et al. [64] study revealed a negative correlational effect between foreign direct investment and carbon emissions. Lastly, trade openness does not have any effect on CO<sub>2</sub> emissions (0.1693,  $p = 0.2292$ ). Wang and Zhang [65] study on trade openness and carbon emissions revealed that the improvement of trade openness reduces carbon emissions in both high-income and upper-middle-middle countries however, an insignificant effect was captured for lower-middle-income countries, and increased CO<sub>2</sub> emissions in low-middle-income countries. In addition, Abokyi et al. [66] study indicated that in the short and long term, trade openness has a positive relationship with carbon emissions.

#### 4.2. Indirect effect

Table 5 presents the indirect effect outcome. The table indicates that REC through foreign direct investment has a negative significant effect on carbon emissions ( $-0.2633^*$ ). The findings suggest that when FDI acts as the intermediary, renewable energy exhibits a negative indirect impact on CO<sub>2</sub> emissions. However, renewable energy consumption through trade openness positively and significantly affects CO<sub>2</sub> emissions (0.0148\*). This means that renewable energy causes carbon emissions if trade openness serves as the mediator.

### 5. Conclusion

Demand for energy is rising because of the increased industrial revolution and globalization. Globalization has caused an amazing rise in energy demand that has an effect on the environment. We found two main perceptions surrounding the effect of globalization on the environment. One group argues that globalization is not environmentally friendly since it causes carbon emissions and the second group argues that globalization is environmentally friendly because it exposes a country to clean technologies and other factors to promote environmental quality. As an augmentation to the current body of knowledge, this study employs the Mediation Model to investigate the direct and indirect influence of renewable energy on CO<sub>2</sub> emissions mediated by globalization. The study utilizes trade openness and foreign direct investment as proxies for globalization (the mediators). The findings reveal that renewable energy exhibits a negative influence on foreign direct investment and a negative impact on carbon emissions. However, renewable energy does not significantly affect trade openness. Nevertheless, foreign direct investment is found to contribute to carbon emissions, while trade openness shows no significant effect on carbon emissions. Regarding the indirect effects, renewable energy, mediated through foreign direct investment, demonstrates a negative indirect impact on carbon emissions, while it exhibits a positive indirect effect on carbon emissions through trade openness. The results imply that, factors of globalization have mixed effects on environmental sustainability depending on the recipient country.

Foreign investors are promoting environmental quality in Ghana. In this respect, much attention is to be given to the FDI to accommodate them and make them promote clean energy use in Ghana. In addition, there should be strict measures to control the flow of these foreign investors to avoid the abuse of given freedom to maintain their negative mediation role towards carbon emissions. Again, the results indicate that renewable energy through trade openness has a positive indirect effect on carbon emissions. The trade openness has caused easy possession of high emissions technologies in the country. There should be rigid laws regulating the trading system in Ghana. More attention should be shifted to the trade sector to restrict the trading of high-emissions technologies.

In spite of the relevance of this study to the ongoing deliberations on globalization and carbon emissions, there are some areas that future research could work on. Future research can add more variables to the globalization variables to enlarge the scope. Variables like capital formation and tourism. The authors could not add these variables to the study because of the objective behind the study. Again, future research can include more countries and even research on the regional or continental level. The authors restricted the study to only Ghana because of the current rise in globalization issues in the country.

#### Data availability statement

The data are available upon demand by request to the corresponding author.

**Table 5**  
Indirect.

Indirect Effect	Coefficient
$r \rightarrow f \rightarrow c$	-0.2633 <sup>a</sup>
$r \rightarrow t \rightarrow c$	0.0148 <sup>a</sup>
Total effect	-0.5285 <sup>a</sup>

<sup>a</sup> denotes a 1% significant.

### Ethics approval

Not applicable.

### Consent to publish

Not applicable.

### Consent to participate

Not applicable.

### Funding

Not applicable.

### CRedit authorship contribution statement

**Gyimah Justice:** Formal analysis, Data curation, Conceptualization. **George Nyantakyi:** Writing – review & editing, Writing – original draft. **Sam Hayford Isaac:** Writing – review & editing, Visualization, Methodology.

### 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.

### References

- [1] S.A. Sarkodie, S. Adams, P.A. Owusu, T. Leirvik, I. Ozturk, Mitigating degradation and emissions in China: the role of environmental sustainability, human capital and renewable energy, *Sci. Total Environ.* 719 (2020) 137530.
- [2] L. Xu, X. Wang, W. Guo, Does renewable energy adaptation, globalization, and financial development matter for environmental quality and economic progress? Evidence from panel of big five (B5) economies, *Renew. Energy* 192 (2022) 631–640.
- [3] M. Sheraz, X. Deyi, J. Ahmed, S. Ullah, A. Ullah, Moderating the effect of globalization on financial development, energy consumption, human capital, and carbon emissions: evidence from G20 countries, *Environmental Science Pollution Research* 28 (26) (2021) 35126–35144.
- [4] T. Matsumoto, D. Allain-Dupré, J. Crook, A. Robert, An Integrated Approach to the Paris climate Agreement: the Role of Regions and Cities, 2019.
- [5] N. Stern, A. Valero, Innovation, growth and the transition to net-zero emissions, *Res. Pol.* 50 (9) (2021) 104293.
- [6] E.S. Obobisa, Achieving 1.5° C and net-zero emissions target: the role of renewable energy and financial development, *Renew. Energy* 188 (2022) 967–985.
- [7] E. Abokyi, P. Appiah-Konadu, F. Abokyi, E.F. Oteng-Abayie, Industrial growth and emissions of CO<sub>2</sub> in Ghana: the role of financial development and fossil fuel consumption, *Energy Rep.* 5 (2019) 1339–1353.
- [8] J. Gyimah, U.A. Nwigwe, E.O. Opoku, X. Yao, Promoting environmental sustainability in Africa: the position of globalization, renewable energy, and economic growth, *SN Business & Economics* 3 (8) (2023).
- [9] G.E. Commission, National Energy Statistics, 2000–2019, Ghana Energy Commission, Accra, Ghana, 2020.
- [10] E.B. Ali, E.B. Agyekum, P. Adadi, Agriculture for sustainable development: a SWOT-AHP assessment of Ghana's planting for food and jobs initiative, *Sustainability* 13 (2) (2021) 628.
- [11] T. Tahir, T. Luni, M.T. Majeed, A. Zafar, The impact of financial development and globalization on environmental quality: evidence from South Asian economies, *Environ. Sci. Pollut. Res.* 28 (7) (2021) 8088–8101.
- [12] A.M. Awan, M. Azam, I.U. Saeed, B. Bakhtyar, Does globalization and financial sector development affect environmental quality? A panel data investigation for the Middle East and North African countries, *Environ. Sci. Pollut. Res.* 27 (36) (2020) 45405–45418.
- [13] M.B. Khan, H. Saleem, M.S. Shabbir, X. Huobao, The effects of globalization, energy consumption and economic growth on carbon dioxide emissions in South Asian countries, *Energy Environ.* 33 (1) (2022) 107–134.
- [14] S.S. Akadiri, A.A. Alola, U.V. Alola, C.S. Nwambe, The role of ecological footprint and the changes in degree days on environmental sustainability in the USA, *Environ. Sci. Pollut. Res.* 27 (20) (2020) 24929–24938.
- [15] G. Justice, P. Seth, N. George, A.S. Philip, S.H. Isaac, Do globalization and economic development promote renewable energy use in Ghana? *International Journal of Advanced Engineering, Management Science* 7 (2021) 4.
- [16] M.A. Destek, Investigation on the role of economic, social, and political globalization on environment: evidence from CEECs 27 (27) (2020) 33601–33614.
- [17] S. Williams, M. Short, Electricity demand forecasting for decentralised energy management, *Energy Built Environment* 1 (2) (2020) 178–186.
- [18] N. Aziz, A. Sharif, A. Raza, K. Jermisittiparsert, The role of natural resources, globalization, and renewable energy in testing the EKC hypothesis in MINT countries: new evidence from Method of Moments Quantile Regression approach, *Environ. Sci. Pollut. Res.* 28 (11) (2021) 13454–13468.
- [19] Y. Sun, A. Anwar, A. Razaq, X. Liang, M. Siddique, Asymmetric role of renewable energy, green innovation, and globalization in deriving environmental sustainability: evidence from top-10 polluted countries, *Renew. Energy* 185 (2022) 280–290.



- [20] J. Gyimah, X. Yao, Globalization and renewable energy impact on carbon emissions in Ghana, *Int. J. Glob. Warming* 28 (2) (2022) 113–121.
- [21] A.O. Acheampong, S. Adams, E. Boateng, Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? *Sci. Total Environ.* 677 (2019) 436–446.
- [22] U. Mehmood, S. Tariq, Globalization and CO2 emissions nexus: evidence from the EKC hypothesis in South Asian countries, *Environ. Sci. Pollut. Control Ser.* 27 (29) (2020) 37044–37056.
- [23] A. Raihan, D.A. Muhtasim, S. Farhana, M.I. Pavel, O. Faruk, M. Rahman, et al., Nexus between carbon emissions, economic growth, renewable energy use, urbanization, industrialization, technological innovation, and forest area towards achieving environmental sustainability in Bangladesh, *Energy and Climate Change* 3 (2022) 100080.
- [24] L.-S. Lau, C.-K. Choong, C.-F. Ng, F.-M. Liew, S.-L. Ching, Is nuclear energy clean? Revisit of Environmental Kuznets Curve hypothesis in OECD countries, *Econ. Modell.* 77 (2019) 12–20.
- [25] H. Zhu, L. Duan, Y. Guo, K. Yu, The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: evidence from panel quantile regression, *Econ. Modell.* 58 (2016) 237–248.
- [26] Z. Li, N. Xu, J. Yuan, New evidence on trade-environment linkage via air visibility, *Econ. Lett.* 128 (2015) 72–74.
- [27] S. Saud, M.A. Baloch, R.N. Lodhi, The nexus between energy consumption and financial development: estimating the role of globalization in Next-11 countries, *Environ. Sci. Pollut. Control Ser.* 25 (19) (2018) 18651–18661.
- [28] B. Muhammad, M.K. Khan, Foreign direct investment inflow, economic growth, energy consumption, globalization, and carbon dioxide emission around the world, *Environ. Sci. Pollut. Control Ser.* 28 (39) (2021) 55643–55654.
- [29] H. Haberl, M. Fischer-Kowalski, F. Krausmann, J. Martinez-Alier, V. Winiwarter, A socio-metabolic transition towards sustainability? Challenges for another Great Transformation, *Sustain. Dev.* 19 (1) (2011) 1–14.
- [30] M. Ahmad, P. Jiang, M. Murshed, K. Shehzad, R. Akram, L. Cui, et al., Modelling the dynamic linkages between eco-innovation, urbanization, economic growth and ecological footprints for G7 countries: does financial globalization matter? *Sustain. Cities Soc.* 70 (2021) 102881.
- [31] A. Jahanger, M. Usman, M. Murshed, H. Mahmood, D. Balsalobre-Lorente, The linkages between natural resources, human capital, globalization, economic growth, financial development, and ecological footprint: the moderating role of technological innovations, *Resour. Pol.* 76 (2022) 102569.
- [32] B. Doğan, S. Ghosh, D.P. Hoang, L.K. Chu, Are economic complexity and eco-innovation mutually exclusive to control energy demand and environmental quality in E7 and G7 countries? *Technol. Soc.* 68 (2022) 101867.
- [33] S. Yang, How globalization is reshaping the environmental quality in G7 economies in the presence of renewable energy initiatives? *Renew. Energy* 193 (2022) 128–135.
- [34] W. Xiaoman, A. Majeed, D.G. Vasbieva, C.E.W. Yameogo, N. Hussain, Natural resources abundance, economic globalization, and carbon emissions: advancing sustainable development agenda, *Sustain. Dev.* 29 (5) (2021) 1037–1048.
- [35] A. Haseeb, E. Xia, Danish, M.A. Baloch, K. Abbas, Financial development, globalization, and CO2 emission in the presence of EKC: evidence from BRICS countries, *Environ. Sci. Pollut. Control Ser.* 25 (31) (2018) 31283–31296.
- [36] M. Salahuddin, J. Gow, M.I. Ali, M.R. Hossain, K.S. Al-Azami, D. Akbar, et al., Urbanization-globalization-CO2 emissions nexus revisited: empirical evidence from South Africa, *Heliyon* 5 (6) (2019) e01974.
- [37] L. Yuping, M. Ramzan, L. Xincheng, M. Murshed, A.A. Awosusi, S.I. Bah, et al., Determinants of carbon emissions in Argentina: the roles of renewable energy consumption and globalization, *Energy Rep.* 7 (2021) 4747–4760.
- [38] D. Khan, A. Ullah, Testing the relationship between globalization and carbon dioxide emissions in Pakistan: does environmental Kuznets curve exist? *Environ. Sci. Pollut. Control Ser.* 26 (15) (2019) 15194–15208.
- [39] M. Sheraz, X. Deyi, A. Sinha, M.Z. Mumtaz, N. Fatima, The dynamic nexus among financial development, renewable energy and carbon emissions: moderating roles of globalization and institutional quality across BRI countries, *J. Clean. Prod.* 343 (2022) 130995.
- [40] M.U. Etokakpan, S.A. Solarin, V. Yorucu, F.V. Bekun, S.A. Sarkodie, Modeling natural gas consumption, capital formation, globalization, CO2 emissions and economic growth nexus in Malaysia: Fresh evidence from combined cointegration and causality analysis, *Energy Strategy Rev.* 31 (2020) 100526.
- [41] M. Shahbaz, I. Ozturk, T. Afza, A. Ali, Revisiting the environmental Kuznets curve in a global economy, *Renew. Sustain. Energy Rev.* 25 (2013) 494–502.
- [42] M. Shahbaz, H. Mallick, M.K. Mahalik, N. Loganathan, Does globalization impede environmental quality in India? *Ecol. Indic.* 52 (2015) 379–393.
- [43] B. Yan, F. Wang, M. Dong, J. Ren, J. Liu, J. Shan, How do financial spatial structure and economic agglomeration affect carbon emission intensity? Theory extension and evidence from China, *Econ. Modell.* 108 (2022) 105745.
- [44] A.O. Acheampong, The impact of de facto globalization on carbon emissions: evidence from Ghana, *International Economics* 170 (2022) 156–173.
- [45] S.A. Solarin, U. Al-Mulali, P.K. Sahu, Globalization and its effect on pollution in Malaysia: the role of Trans-Pacific Partnership (TPP) agreement, *Environ. Sci. Pollut. Control Ser.* 24 (29) (2017) 23096–23113.
- [46] C.E.W. Yameogo, J.A. Omojolaibi, R.O.S. Dauda, Economic globalization, institutions and environmental quality in Sub-Saharan Africa, *Research in Globalization* 3 (2021) 100035.
- [47] F.S. Mishkin, Globalization and financial development, *J. Dev. Econ.* 89 (2) (2009) 164–169.
- [48] M. Shahbaz, S.J.H. Shahzad, M.K. Mahalik, Is globalization detrimental to CO2 emissions in Japan? New threshold analysis, *Environ. Model. Assess.* 23 (5) (2018) 557–568.
- [49] M.K. Khan, J.-Z. Teng, M.I. Khan, M.O. Khan, Impact of globalization, economic factors and energy consumption on CO2 emissions in Pakistan, *Science of the total environment* 688 (2019) 424–436.
- [50] J. Gyimah, X. Yao, M.A. Tachea, I. Sam Hayford, E. Opoku-Mensah, Renewable energy consumption and economic growth: new evidence from Ghana, *Energy* (2022) 248.
- [51] W.F. Qiu, J.P. Ma, Z.Y. Xie, X.T. Xie, C.X. Wang, Y.D. Ye, Online risky behavior and sleep quality among Chinese college students: the chain mediating role of rumination and anxiety, *Curr. Psychol.* (2022) 1–11.
- [52] Y. Liu, Z. Bah, Enabling development impact of solar mini-grids through the community engagement: evidence from rural Sierra Leone, *Energy Pol.* (2021) 154.
- [53] M. Shahbaz, A. Sinha, C. Raghutla, X.V. Vo, Decomposing scale and technique effects of financial development and foreign direct investment on renewable energy consumption, *Energy* 238 (2022).
- [54] M. Hagert, C. Marton, The Effects of FDI on Renewable Energy Consumption, Lund University, 2017.
- [55] I. Appiah-Otoo, X. Chen, J.D. Ampah, Exploring the moderating role of foreign direct investment in the renewable energy and economic growth nexus: evidence from West Africa, *Energy* (2023) 281.
- [56] J. Hussain, K. Zhou, F. Muhammad, D. Khan, A. Khan, N. Ali, et al., Renewable energy investment and governance in countries along the belt & Road Initiative: does trade openness matter? *Renew. Energy* 180 (2021) 1278–1289.
- [57] H. Zhongwei, Y. Liu, The role of eco-innovations, trade openness, and human capital in sustainable renewable energy consumption: evidence using CS-ARDL approach, *Renew. Energy* 201 (2022) 131–140.
- [58] M. Zhang, S. Zhang, C.-C. Lee, D. Zhou, Effects of trade openness on renewable energy consumption in OECD countries: new insights from panel smooth transition regression modelling, *Energy Econ.* (2021) 104.
- [59] R. Li, Q. Wang, I. Li, Does renewable energy reduce per capita carbon emissions and per capita ecological footprint? New evidence from 130 countries, *Energy Strategy Rev.* 49 (2023).
- [60] Q. Wang, J. Guo, R. Li, X.T. Jiang, Exploring the role of nuclear energy in the energy transition: a comparative perspective of the effects of coal, oil, natural gas, renewable energy, and nuclear power on economic growth and carbon emissions, *Environ. Res.* 221 (2023) 115290.
- [61] M. Hussain, T. Lu, Y. Chengang, Y. Wang, Role of economic policies, renewable energy consumption, and natural resources to limit carbon emissions in top five polluted economies, *Resour. Pol.* 83 (2023).
- [62] O.F. Derindag, A. Maydybura, A. Kalra, W.K. Wong, B.H. Chang, Carbon emissions and the rising effect of trade openness and foreign direct investment: evidence from a threshold regression model, *Heliyon* 9 (7) (2023) e17448.

- [63] T. Bui Minh, T. Nguyen Ngoc, Bui, H. Van, Relationship between carbon emissions, economic growth, renewable energy consumption, foreign direct investment, and urban population in Vietnam, *Heliyon* 9 (6) (2023) e17544.
- [64] J. Yi, Y. Hou, Z.Z. Zhang, The impact of foreign direct investment (FDI) on China's manufacturing carbon emissions, *Innovation and Green Development* 2 (4) (2023).
- [65] Q. Wang, F. Zhang, The effects of trade openness on decoupling carbon emissions from economic growth - evidence from 182 countries, *J. Clean. Prod.* 279 (2021) 123838.
- [66] E. Abokyi, P. Appiah-Konadu, K.F. Tangato, F. Abokyi, Electricity consumption and carbon dioxide emissions: the role of trade openness and manufacturing sub-sector output in Ghana, *Energy and Climate Change* 2 (2021).