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The impact of financial development and foreign direct investment on environmental sustainability in Sub-Saharan Africa: using PMG-ARDL approach

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ABSTRACT

This study is aimed at establishing the impact of foreign direct investment and financial development on carbon dioxide emission and clean energy using 44 countries in sub-Saharan Africa ranging from 1998 to 2017. Employing a second generation unit root test in conjunction with Pooled Mean Group, the study established that financial development have significant positive impact on clean energy consumption in sub-Saharan Africa. This was found to be consistent in both low-income and middle-income countries in sub-Saharan Africa. Financial development is however found to be significantly negative with carbon dioxide in sub-Saharan Africa and middle-income countries. This relationship is only positive in the low-income countries. Foreign direct investment does not have any significant impact on clean energy consumption in sub-Saharan Africa. A significant impact is noted after the decomposition of the sample into low-income and high-income countries. In low-income countries, foreign direct investment inflows impact positively on clean energy consumption. This relationship is however negative with middle-income countries. The link between foreign direct investment and carbon dioxide is significantly positive in the whole sample and also in low-income countries. These long-run relationships have been confirmed by the causality test.

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1. Introduction

Literature is awash with studies exploring the links between foreign direct investment (FDI) and energy consumption (see Azam et al., 2015; Çoban & Topcu, 2013; He et al., 2020; Sadorsky, 2011) or financial development (FSD) and energy consumption (see Rezagholizadeh et al., 2020; Sadorsky, 2011; Zheng-Zheng et al., 2020). This can be attributed to an earlier interest to make energy available to all so as to boast productivity in the world. This paradigm is however being shifted in recent times towards

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the use of clean energy in the world. The need to adopt clean energy is attributable to the advantages clean energy consumption has over dirty energy. For instance clean energy can assist in meeting the increasing demand for energy in the world. Besides, it can significantly reduce carbon dioxide (CO2) emission drastically (Paramati et al., 2016). As a result, developing countries are being compelled to reduce CO2 by focussing on the use of clean energy following Kyoto Protocol Summit in 1997 (Paramati et al., 2016). Despites this, globally developed countries are still found to have increased their consumption of clean energy more than developing countries (Shahbaz et al., 2018).

It is thus paramount to establish the impact of foreign direct investment and financial development on the use of clean energy and carbon dioxide emission. It is argued that the inflows of FDI has got positive impact on clean energy since most multinational corporations(MNCs) originate from advanced countries with much environmental awareness together with high compliance level on environmental laws and policies (Shahbaz et al., 2018). Besides, the inflows of FDI enhance the capital level of firms making them capable of acquiring very efficient technologies that support the production and use of clean energy (Musah et al., 2021). Empirical studies exist supporting this positive link between FDI and clean energy consumption (Kwakwa et al., 2021; Paramati et al., 2016). Contrary to this view, others believe that the inflows of FDI destroy the environment through the consumption of dirty energy and increase in CO2 emission. This view supports the Pollution Haven Hypothesis which posits that most firms migrate from advanced countries to developing countries as result of high cost of production due to high environmental compliance cost. With this aim to avoid cost, MNCs move with this mindset thus try to take advantage of less environmental laws to operate in developing countries with less care for the environment.

Financial development and environmental sustainability are argued to have a relationship which could be positive or negative. FSD is noted to have positive relationship with environmental quality through consumption of clean energy and reduction in CO2 as financial institutions assist businesses and individuals to embrace efficient innovative technologies. This is also done by way of boasting businesses and individuals financially to be able to adopt clean energy (Musah et al., 2021; Shahbaz et al., 2018). Evidence on this positive relationship between FSD and environmental quality exist (Jalil & Feridun, 2011; Musah et al., 2021; Zaidi et al., 2019). On the contrary, FSD destroys the quality of environment and thus leading to reduction in clean energy consumption and increase in CO2 emission. It is argued that most economic activities like industrialisation, expansion in infrastructure are financed by financial sector and these activities can reduce the quality of environmental sustainability (Khan et al., 2019; Mensah et al., 2020). Some evidence equally exist for this relationship (Al-Mulali & Ozturk, 2015; Shahbaz et al., 2018).

Notwithstanding the fact that only a few studies have dealt directly on the impact of FDI and FSD on CE and CO2, mixed results are realised. These differences in results, are attributable to difference in economic methods, proxied employed, types of countries used, variations in the study periods. This lack of consensus in the previous literature implies more studies are needed to settle these links. This study is centred on SSA as a developing region since developing economics are found to be more vulnerable to environmental pollution than advanced countries (Musah et al., 2021). The region is unique for this study because it is the most lacking behind region in terms of inflows of FDI and financial development among the developing regions. As a result, its nations are putting in a lot of efforts now to attract more FDI and develop their financial sector. Despite of the benefits, that accompany FDI and financial development to countries, deleterious effects have also been noted with FDI and financial development in some countries. It is therefore imperative to examine whether or not the campaign to attract more FDI and develop the financial sector in SSA will not lead to a growth retardation through the destruction of the environment. The purpose of the study is to examine the links between foreign direct investment and financial development on one hand and environmental sustainability on the other hand. First, the study will specifically investigate the impact of foreign direct investment on clean energy consumption and carbon dioxide emission in SSA. Second, the study will explore the effect of financial development in the region on clean energy consumption and carbon dioxide emission. Finally the study will investigate the causal links among all the variables involved.

The study contributes to the literature in the following ways: first, it is the first study to examine the impact of FDI and FSD on CO2 and Clean energy consumption in SSA. The only study close to this study is that of Shahbaz et al. (2018). However, in Shahbaz et al. (2018), the sample countries used are the BRICS and the next 11 countries following the BRICS. In this sample, only 2 countries in SSA were found in their study. Again in their study, all the countries were lumped together without any decomposition. In this paper, the total sample is further decomposed into low-income and high-income countries. Secondly, in this paper, unlike many previous studies, second generation unit root test techniques (CIPS and CADF) in conjunction with cointegration are used to be able to account for cross-sectional inter-dependence which has the ability to distort results when not checked. Again with the use of Pooled Mean Group (PMG), the study is able to control for endogeneity and serial autocorrelation as well. Thirdly, the paper also examines the correlation relationship between all the variables using Dumitrescu and Hurlin (2012). This method apart from accounting for heterogeneity in data series, it is able to provide more reliable and robust results than the traditional Granger Causality test.

The rest of the paper is structured as follows: section 2 reviews the relevant literature for the study while section 3 examines the methodology of the work. The findings and discussions of the results are found in section 4. The conclusion and recommendation are on section 5 of the study.

2. Related literature

2.1. Foreign direct investment, financial development and clean energy consumption

Empirically a lot of studies exist on the link between FDI and energy consumption with a few delving into the link between FDI and clean energy consumption. For instance, Mohammad bin Mohamed (2016) examined the link between FDI and energy consumption and came to a conclusion that FDI inflows spur growth thus leading to the increase in energy consumption. Some others that also examined this link concluded that the inflows of FDI decrease energy consumption as it provides opportunities for a diffusion of efficient energy technology from rich and technology advanced economies to poor countries (Azam et al., 2015; Çoban & Topcu, 2013; Doytch & Narayan, 2016; He et al., 2020; Jiang et al., 2014; Sadorsky, 2011). Meanwhile other studies found no significant relationship between FDI and energy consumption (see Chang, 2015; Hüber & Keller, 2010; Lee, 2013; Sadorsky, 2010).

On the FDI-clean energy consumption nexus, there exist two theories that explain this link. First, is Pollution Haven Hypothesis (PHH) which argues that FDI mostly moves from advanced countries to developing world due to the stringent environmental laws and compliance cost that exist in advanced countries. The additional cost by way of environmental compliance cost pushes up the cost of production in the advanced countries which eventually affects profit margin negatively (Levinson & Taylor, 2008). This has made multinational corporations (MNCs) to look for locations where they can beat down their cost of production. MNCs that move into host countries with these as their main reasons certainly will explore the relaxed or non-existence of stringent environmental laws to their advantage. This thus means less consumption of clean energy thus reducing the consumption of clean energy in host countries.

Secondly, Pollution Halo Hypothesis is one of the theories which helps in explaining the FDI-clean energy nexus. This theory believes that the inflow of FDI on the contrary is supposed to encourage the consumption of clean energy since most of the MNCs are originating from advanced countries with much environmental awareness and standards together with efficient technologies. This theory believes that the inflow of FDI will automatically be accompanied with the adoption of very modern and internationally accepted standard of compliance in operations thus leading to the consumption of clean energy since they are already used to such practices. Besides, the inflow of FDI in firms make the firms more capitalised to be able to adopt best form of energy in its operations. Some empirical evidence are available to support the above theories.

Paramati et al. (2016) using 20 emerging countries tested this link. With the use of ARDL and causality test, their study established that FDI has significant positive impact on the consumption of clean energy. Again in their work to establish the factors influencing the consumption of clean energy in 31 sub-Saharan Africa, Kwakwa et al. (2021) noted among other factors is FDI inflows into the region. Their study made use of fixed effect and random effect estimators and FMOLS. Lee (2013) examined the link between FDI and clean energy from 1971 to 2009 using G20 countries on fixed effect regression. This study realised no significant impact made by the inflows of FDI to clean energy consumption. Again in United Arab Emirates, Shia et al. (2014) studied this phenomena using quarterly data from 1975 to 2011 with the use of bound test and Granger causality test. They discovered bidirectional relationship between FDI and clean energy showing that the two variables are inter-dependent on each other. Using a comparative study of the BRICS countries and the next 11 countries following the BRICS, Shahbaz et al. (2018) also studied this link. With the help of ARDL model, their study realised that FDI does not have any significant impact on clean energy consumption.

On the financial development (FSD) and clean energy nexus, the story is not much different. A lot of earlier studies focussed more on FSD and energy consumption with just a few examining the nexus between FSD and clean energy consumption. It is argued that the advancement in the financial sector spurs up production and consumption thus increasing the use of energy (Zhang, 2011). Again it is contended that as financial sector increases, there is greater liquidity and cheaper access to credit facilities by households and this makes them able to procure household items such as vehicles, electrical gadgets and many more which certainly require more energy to function (Chang, 2015; Sadorsky, 2010). A number of studies exist to support this positive link of FSD and energy consumption (see Islam et al., 2013; Le, 2016; Rezagholizadeh et al., 2020; Sadorsky, 2011; Zheng-Zheng et al., 2020). The contrary argument that exist in the financial development and energy consumption nexus is that as a country get developed financially, it will have the means to be able to innovate and use energy efficient technology that will reduce the consumption of energy at the end (Ouyang & Li, 2018; Shahbaz et al., 2013, 2017, 2018; Tamazian et al., 2009).

Relating this to the clean energy consumption, it is plausible to infer from this that as a country get developed financially, it will be in the position to be able to acquire clean sources of energy for use. Shahbaz et al. (2018) studied this link in the BRICS countries and the next 11 countries following the BRICS. They concluded that financial development hampers clean energy consumption. Based on the above I hypothesised that:

$H_{1.}$ Foreign direct investment correlates with clean energy consumption

$H_{2.}$ Financial development correlates with clean energy consumption

2.2. Foreign direct investment, financial development and carbon dioxide emission

Foreign direct investment (FDI) and carbon dioxide (CO2) emission nexus has been very mixed. While it is argued that the inflows of FDI increases economic activities in an economy thus leading to an attended hazards caused to the environment. Besides, using the Pollution Haven Hypothesis, it is believed that MNC moves into host countries with the mindset of reducing environmental compliance cost end up exploring cheaper means of production which can also be hazardous to the environment. Thus the inflow of FDI leads to more CO2 emission. Shahbaz et al. (2018) for instance studied the relationship between FDI and CO2 in BRICS and the next 11 countries following BRICS. They realised that the inflow of FDI leads to high emission of CO2 in the host countries. Bukhari et al. (2014) studied this link in Pakistan using ARDL-ECM on a data spanning from 1974 to 2010. Their study discovered that FDI inflows increases CO2 thus reducing environmental quality in Parkistan. Employing Granger causality and error correction model in Turkey, Gökmenoğlu and Taspinar (2016) examined the environmental Kuznets Curve Hypothesis. After validating the existence of PHH, their study discovered a bidirectional relationship between FDI and CO2 implying that the two variables depend on each other. Using another country study, Mukhtarov et al. (2021) investigated this link in Azabaijan from 1996 to 2013. This study made use of structural time series model and realised also that the inflow of FDI increases environmental pollution. In a very recent study by Jafri et al. (2022) in China, similar results were uncovered using both ARDL and non-ARDL models.

In supporting the PH hypothesis, others believe that the inflows of FDI lead to the transfer of technology that encourages investment in clean energy and adoption of activities that are supportive of environmental cleanliness (Paramati et al., 2017). Hao and Liu (2014) using 29 Provinces in China realised that FDI reduces the emission of CO2 in the country. A follow up study in China using the same provincial data by Yu and Xu (2019) while employing PCSE estimator, they also noted that FDI reduces carbon dioxide emission thus improving environmental quality in the country. Demena and Afesorgbor (2020) also examined this phenomena by using meta-analysysis on 65 primary studies. They equally realised that FDI improves environmental quality thus validating the Pollution Halo Hypothesis. Besides, other studies discovered no significant impact of FDI on CO2 emission. Using Turkey's economy, Haug and Ucal (2019) realised that in the long run FDI has no impact on CO2 in the country. Similarly, Mahmood et al. (2020) established identical findings using fixed effect and random effect estimators.

African countries have not been left out from these studies. For instance Joshua et al. (2020) examined this relationship in South Africa using ARDL bound test and Granger causality approach and came to the conclusion that FDI increases CO2 emission through its contribution to economic expansion in South Africa. With the use of GMM and panel Granger causality test, Shahbaz et al. (2019) discovered that the inflows of FDI into Middle East and North Africa reduces environmental quality in the region. Similar results were realised when Ssali et al. (2019) used panel ARDL-PMG on 7 countries in SSA. Again Musah et al. (2021) investigated this link but using only West African countries and arrived at the same conclusion. Contrary to these findings, other studies in the continent have different outcomes. Ojewumi and Akinlo (2017) noted that inflows of FDI enhances environmental quality as it reduces CO2. Their study focussed on 33 SSA countries using panel VAR and panel VEC from 1980 to 2013. Their study however failed to consider the issue of cross-sectional dependency issues in the model and that can lead to spurious results. Related to their study are the findings of Asongu and Odhiambo (2020) using GMM. They equally discovered that FDI enhances environmental quality in SSA. Their study was not able to examine the causal relationship among all the variables.

The relationship between financial development and CO2 is not different from the link between FDI and CO2 in its forms. Varied findings have also been found. Jalil and Feridun (2011) studied the link between FSD and CO2 in China using ARDL from 1953 to 2006. They realised from their findings that FSD reduces environmental pollution. Similar findings were uncovered by Shahbaz et al. (2013) using the Indonesian economy. Using ARDL and VECM from 1975 to 2011, they realised an inverse relationship between FSD and CO2. Another study that discovered negative relationship between FSD and CO2 is Salahuddin et al. (2015) in Gulf Cooperation Council countries from 1980 to 2012. Again the studies of Zaidi et al. (2019) from Asia Pacific Economic Cooperation noted a negative relationship between FSD and

CO_2. Positive findings are also found between FSD and CO_2. Shahbaz et al. (2013) using ARDL structural breaks on Malaysia realised a positive long run relationship between FSD and CO_2. In a very recent study, Musah et al. (2021) studied FSD and CO_2 in the 16 West African countries using CS-ARDL. Their study uncovered that FSD leads to an increase in CO_2. Inferring from the literature, I hypothesised that:

$H_{3.}$ Foreign direct investment correlates with carbon dioxide emission

$H_{4.}$ Financial development correlates with carbon dioxide emission

3. Methodology and data

3.1. Data sources

To investigate the impact of both financial development and foreign direct investment inflows on clean energy use and carbon dioxide emission in Sub-sahran Africa (SSA), the study employed data sourced from World Bank Database specifically making use of World Development Indicators. The data used ranges from 1998 to 2017. As a result of data availability, 44 countries from SSA were used as panel. To further understand these links properly, this study decomposed the region into low income countries and middle income countries per the World Bank rankings. While there are 21 low income countries in the sample, the middle income countries are made up of the 23 countries. The details of these countries are shown below in Table 1. The two dependent variables in this study are clean energy consumption and carbon dioxide emission while the main independent variables are financial development and foreign direct investment. Following the works of Shahbaz et al. (2018) economic growth has been included as control variable in the study. The full description of these variable are shown in the table below.

Table 1. Details of variables and sample countries.

Variable name	Description
Carbon dioxide emission (CO2)	It refers to carbon dioxide emission released from the usage of oil, gas and other fuels. It is measured as kg per 2010 US$ of GDP
Financial development (FSD)	It is proxied by domestic credit issued to private sector. It is taken as the percentage of GDP
Foreign direct investment (FDI)	It is the net inflows taken as percentage of GDP
Economic growth (GDPG)	It is proxied by gross domestic product growth (annual %)
Clean energy consumption (CE)	It is measured by the access to clean fuels and technologies for cooking (percentage of population)

Sample of Sub-Saharan African countries (SSA)
Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe
Low income countries (SSA-LI)
Burkina Faso, Burundi, Central African Republic, Chad, Congo, Dem. Rep., Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Sudan, Togo and Uganda
Middle income countries (SSA-MI)
Angola, Benin, Cabo Verde, Cameroon, Congo, Rep., Cote d'Ivoire, Gambia, Ghana, Kenya, Lesotho, Mauritania, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Tanzania, Zambia, Zimbabwe, Botswana, Equatorial Guinea, Gabon, Mauritius, Namibia and South Africa

Source: Author's construct (2021).

3.2. Basic estimation technique

To investigate the link between financial development and foreign direct investment on one hand and clean energy consumption and carbon dioxide emission on the other hand, the following panel equations have been employed.

$$CE_{it} = \alpha_0 + \alpha_1 FSD_{it} + \alpha_2 FDI_{it} + \alpha_3 GDPG_{it} + \alpha_4 CO2_{it} + \mu_{it} \tag{1}$$

$$CO2_{it} = \alpha_0 + \alpha_1 FSD_{it} + \alpha_2 FDI_{it} + \alpha_3 GDPG_{it} + \alpha_4 CE_{it} + \mu_{it} \tag{2}$$

where CE, CO2, FSD, FDI and GDPG represent clean energy consumption, carbon dioxide emission, financial development, foreign direct investment and GDP growth respectively. μ also refers to the residual or error terms while the subscripts i represents cross-section and t shows the time period.

3.3. Cross-sectional dependency and unit root tests

In examining the long-run relationship between the variables it is imperative to first determine whether or not there is any cross-sectional dependence. Panel co-integration models that ignore cross-sectional dependence have the tendency of producing unreliable outcomes (Shahbaz et al., 2018). It is again documented that unobserved common factors such as global epidemics, climate change, global financial crises, global technological progress, spread of diseases and cross-border pollution between nations over time could result in dependencies in residual terms which have the ability to generate spurious outcomes in econometric models if they are not controlled (Musah et al., 2021; Talib et al., 2021). This paper investigated this using Pesaran's (2004) cross-sectional dependence (CD) test. Below is the equation used in this investigation.

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{n-1} \sum_{j=i+1}^{N} (p_{ij})\, N(0,1) \tag{3}$$

where N and T are the cross-section dimension and time period respectively p_{ij} also represents the sample estimate of the pairwise correlation of the errors.

To check for the unit root, CADF and CIPS developed by Pesaran (2007) which considers the cross-sectional dependence in the data thus making it better and superior to the first generation unit root test as far as cross-sectional dependency is concerned. Equations for the two are shown below:

$$\Delta Y_{it} = \alpha_1 + piY_{it-1} + \beta_i y_{it-1} + \sum_{j=0}^{k} Y_{ij}\Delta y_{it-1} + \sum_{j=0}^{k} \delta_{ij} Y_{it-1} + \varepsilon_{it} \tag{4}$$

$$CIPS = \left(\frac{1}{N}\right) \sum_{i=1}^{N} t_i(N,T) \tag{5}$$

where α_i is a deterministic term k is the lag order, y_t is the cross-sectional mean of time t.

3.4. Panel regression model

This paper made use of panel mean group autoregressive distributed lags (PMG-ARDL) model proposed by Pesaran et al. (1999). This model is used when the variables are stationary at I(0) or I(1) or the combination of the two but not I(2). This has therefore become appropriate in this study as shown in our unit root tests results in Table 5 where we have either the variables being stationary at levels or at first difference or the combination of the two. Besides, this model has the advantage of being able to explore both long-run and short-run effects among variables. One of the benefits of this model over others is that it is able to overcome endogeneity, heteroscedasticity, autocorrelation and multicollinearity problems in models (Wang et al., 2021).The panel PMG-ARDL model has three options; panel mean group (PMG), mean group(MG) and dynamic fixed effect (DFE). After performing Hausman test, the paper settled on the PMG to estimate the long-run relationship. The empirical equations for the PMG are shown here

$$CE_{it}\,\alpha_i + \sum_{J=1}^{p} \beta_{ij} CE_{it-j} + \sum_{J=1}^{q} \delta_{ij} Z_{it-j} + \varepsilon_{it} \tag{6}$$

$$CO2_{it}\,\alpha_i + \sum_{J=1}^{p} \beta_{ij} CE_{it-j} + \sum_{J=1}^{q} \delta_{ij} Z_{it-j} + \varepsilon_{it} \tag{7}$$

where

$$Z_{it} = (FDI,\, FSD,\, GDPG,\, CO2)$$

in Equation (6)

$$Z_{it} = (FDI,\, FSD,\, GDPG,\, CE)$$

in Equation (7)α_i represents the country fixed effects, β_{ij} shows parameter estimates of lagged CE or CO2; δ_{ij} indicates the coefficients of the lagged explanatory variables while ε_{ij} represents the stochastic error term.

3.5. Panel causality test

To examine the links that exist among all the variables, the paper conducted causality test using Dumitrescu and Hurlin (2012) panel test developed from Granger Causality test. The choice of this method against other methods is that it produces consistent results in case of both small samples and cross-sectional dependence (Shahbaz et al., 2018). It is also very suitable for unbalanced panels and panels with different lag order for each individual. The empirical equation for this causality test is shown as follows.

$$Y_{it} = \sum_{j=1}^{d} \alpha_i(d) Y_{it-d} + \sum_{j=1}^{d} \beta_i(d) X_{it-d} + \varepsilon_{it} \quad (8)$$

where both Y and X refer to FSD, FDI, GDPG, CO2 and CE, d represents lagging lengths, $\alpha_i(d)$ is autoregressive coefficients, $\beta_i(d)$ is coefficient which allows for differences across the section.

4. Findings and discussions

4.1. Descriptive statistics

Table 2 shows the summary statistics of the variables starting with the full sample. From the full sample, the highest standard deviation is recorded on financial development in the region while the least is observed in carbon dioxide emission. This implies that there is great disparities in the financial sector development in SSA with high homogeneity in carbon emission in the region. In term of skewness, all the variables show positive skewness. In low income countries, however, while CO2 emission is noted as the least in terms of standard deviation, the highest standard deviation here is recorded by FDI implying that there is great variation in the inflows of FDI into these countries. It is however very instructive to observe that the standard deviation across all the variables have reduced drastically showing the higher deviations in the full sample is basically caused by the combination of countries of vast differences in economic and income levels. Here too with the exception of economic growth all the variables are positively skewed. On the disparities among countries, it is noted again that CO2 emission is still the lead in terms of standard deviation with FSD leading again in the middle income countries category. With this category, though it is similar to the full sample, here the highest standard deviation as recorded by the FSD is higher as compared with the full sample. It shows that much disparities exist among the middle income countries. The correlation matrix is presented in Table 3 and which shows that there is no problem with multi-collinearity issues among the variables.

4.2. Results of cross-sectional dependence and unit root test

Being mindful that the ignorance of cross-sectional dependencies in models can give spurious results (Musah et al., 2021; Talib et al., 2021), this study first and foremost examined this phenomena in the study. To be able to find out whether countries in SSA are cross-sectionally dependent on each other, CD test was performed and the results are reported in Table 4. From the results, the null hypothesis of cross-sectional independence is clearly rejected in all the three categories of the sample. It therefore means countries in SSA are cross-sectionally dependent on each other and any shock in any one country can easily be transmitted into other countries within the region.

In examining the long-run relationship in this paper, it is crucial to determine the integration properties of the variables. Having already established from the results of the CD test that there is cross-sectional dependencies in the model, conventional

Table 2. Summary statistics.

	CE	CO2	FSD	FDI	GDPG
SSA					
Mean	19.84498	0.336802	23.32981	4.763536	4.425520
Median	6.485000	0.289422	13.90505	2.594325	4.456502
Maximum	93.34000	1.241422	257.1810	103.3374	63.37988
Minimum	0.150000	0.059074	0.402581	−8.703070	−36.39198
Std. Dev.	24.73333	0.213934	35.89524	8.756754	5.487163
Skewness	1.423053	1.951054	4.290403	5.828848	0.750078
Kurtosis	4.091768	7.125997	23.77729	48.83807	27.15169
Jarque-Bera	348.4603	1209.386	18949.73	83888.66	21958.30
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	17860.48	303.1218	20996.83	4287.183	3982.968
Sum Sq. Dev.	549952.2	41.14537	1158333.	68935.98	27067.95
Observations	900	900	900	900	900
SSA-LI					
Mean	3.461333	0.233501	11.86372	4.755409	4.483582
Median	1.390000	0.223389	10.79625	2.602825	4.777073
Maximum	41.29000	0.872440	46.47670	103.3374	33.62937
Minimum	0.150000	0.059074	0.402581	−4.845830	−36.39198
Std. Dev.	5.933879	0.114832	7.822366	9.940643	5.432070
Skewness	4.007512	1.404550	1.228573	6.239690	−1.931723
Kurtosis	20.96849	6.734217	5.053231	50.51874	19.79765
Jarque-Bera	6774.375	382.1198	179.4332	42240.89	5199.027
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	1453.760	98.07029	4982.763	1997.272	1883.104
Sum Sq. Dev.	14753.37	5.525103	25638.36	41404.06	12363.59
Observations	420	420	420	420	420
SSA-MI					
Mean	32.92085	0.427931	33.05036	4.830857	4.380923
Median	28.80500	0.342819	16.56380	2.683108	4.297892
Maximum	93.34000	1.241422	257.1810	74.12390	63.37988
Minimum	0.840000	0.126851	2.013640	−8.703070	−17.66895
Std. Dev.	26.60478	0.237702	46.48213	7.558384	5.588366
Skewness	0.773819	1.664684	3.098331	4.587724	2.850556
Kurtosis	2.524037	4.979031	13.01616	33.00802	32.17940
Jarque-Bera	52.43450	300.0250	2774.441	19693.40	17678.80
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	15802.01	205.4069	15864.17	2318.812	2102.843
Sum Sq. Dev.	339043.1	27.06466	1034922.	27364.87	14959.09
Observations	480	480	480	480	480

Source: Author's construct (2021).

Table 3. Pairwise correlation matrix.

	CE	CO2	GDPG	FDI	FSD
CE	1.000				
CO2	0.4457*	1.000			
GDPG	−0.0649	−0.0783	1.000		
FDI	0.0350	0.0656*	0.1810*	1.000	
FSD	0.4392*	0.3397*	−0.0773*	−0.0194	1.000

Note: * denote significance level of 10%.
Source: Author's construct (2021).

stationary test estimators are not appropriate as they could lead to erroneous results (Musah et al., 2021; Dao, 2020). This paper thus used the second generation unit root test techniques which results are shown in Table 5. From the results, all the variables in all the categories are I(1) with the exception of CE alone under SSA-MI using the CADF which is only I(0). This shows that the variables are all stationary either at levels or at the first difference. This is an indication of long-run relationship thus serving as justification for cointegration analysis carried out by this paper.

Table 4. Cross-sectional dependence.

	SSA		SSA-LI		SSA-MI	
Variable	CD-test	Correlation	CD-test	Correlation	CD-test	Correlation
CE	68.526***	0.87	21.093***	0.92	39.717***	0.76
FSD	65.717***	0.62	27.801***	0.64	34.313***	0.58
FDI	6.991***	0.26	5.589***	0.28	1.707*	0.25
CO2	−2.32**	0.41	1.939*	0.42	−1.975**	0.39
GDPG	7.944***	0.21	1.676*	0.18	4.069***	0.23

Note: ***, **, * denote significance level of 1%, 5% and 10% respectively.
Source: Author's construct (2021).

Table 5. Unit root tests results.

	SSA CIPS		SSA-LI CIPS		SSA-MI CIPS	
Variable	Level	First difference	Level	First difference	Level	First difference
CE	−2.424***	−3.958***	−2.856	−4.875***	−0.122	−3.290***
FSD	−1.886	−3.877***	−2.109	−4.113***	−1.567	−3.965***
FDI	−3.216***	−5.196***	−2.920	−4.802***	−3.147***	−5.454***
CO2	−1.746	−4.347***	−1.886	−3.859***	−2.329***	−4.534***
GDPG	−3.41***	−5.487***	−3.638***	−5.456***	−3.318***	−5.595***
	CADF		CADF		CADF	
	Level	First difference	Level	First difference	Level	First difference
CE	−2.125***	−2.263***	−2.401***	−3.657***	−2.316***	−1.778
FSD	−1.780	−2.916***	−2.040***	−3.028***	−1.362	−2.761***
FDI	−2.471***	−3.731***	−2.389***	−3.166***	−2.051***	−3.544***
CO2	−1.781	−3.315***	−1.825	−2.822***	−2.107***	−3.311***
GDPG	−2.610***	−4.086***	−2.659***	−3.890***	−2.527***	−4.116***

Note: *** shows the rejection of null hypothesis. Constant and trend were included as suggested by Pesaran (2007). Critical values of CIPS for 1% significance level is −2.250, −3.510, −2.130 for SSA, SSA-LI and SSA-MI respectively while for CADF 1% significance level is −2.012, −1.958, −2.001 for SSA, SSA-LI and SSA-MI respectively.
Source: Author's construct (2021).

4.3. Cointegration test results

Having observed that all the variables across all the categories are stationary at levels or first difference, this paper proceeded to test for cointegration to determine whether long-run equilibrium relationship exist among the variables of interest. This study made use of the Pedroni (1999) which is known for its ability to deal with heterogeneity and inter-dependence (Wang et al., 2021). Pedroni (1999) test for cointegration presents two main results. First, it has the within-dimension which is made up of panel v-statistic, panel-rho statistic, panel-PP-statistic and panel ADF-statistic. The second option known as the between dimension has three outcomes; group-rho-statistic, group-PP-statistic and group-ADF-statistic. The results are presented in Table 6. The null hypothesis here is that there is no cointegration against two alternative hypothesis of existing cointegration among the variables. From the results shown in the table, the null hypothesis about no cointegration has been rejected in all the categories in respect of both dependent variables (CE and CO2).

In the full sample (SSA) using clean energy as the dependent variable, four out of the six statistics are significant at 1% while three out of the six statistics are significant at 1% with carbon dioxide emission being the dependent variable. After

Table 6. Results of Pedroni panel co-integration test.

CE as dependent variable					CO2 as dependent variable			
				SSA				
Alternative hypothesis: common AR coefs. (within-dimension)					Alternative hypothesis: common AR coefs. (within-dimension)			
	Statistic	Prob.	Weighted statistic	Prob.	Statistic	Prob.	Weighted statistic	Prob.
Panel v-Statistic	−1.256064	0.8955	9.305872	0.0000	−1.552427	0.9397	−3.246730	0.9994
Panel rho-Statistic	4.693222	1.0000	2.924493	0.9983	2.978023	0.9985	3.108239	0.9991
Panel PP-Statistic	1.372479	0.9150	−4.977415	0.0000	−1.406625	0.0798	−3.414968	0.0003
Panel ADF-Statistic	1.400037	0.9192	−6.416428	0.0000	−1.789202	0.0368	−4.455559	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)					Alternative hypothesis: individual AR coefs.(between-dimension)			
	Statistic	Prob.			Statistic	Prob.		
Group rho-Statistic	4.322859	1.0000			4.634383	1.0000		
Group PP-Statistic	−3.840256	0.0001			−3.284842	0.0005		
Group ADF-Statistic	−3.955844	0.0000			−3.291692	0.0005		
				SSA-LI				
Alternative hypothesis: common AR coefs. (within-dimension)					Alternative hypothesis: common AR coefs. (within-dimension)			
	Statistic	Prob.	Weighted statistic	Prob.	Statistic	Prob.	Weighted statistic	Prob.
Panel v-Statistic	57.47041	0.0000	7.675773	0.0000	−0.474504	0.6824	−1.596946	0.9449
Panel rho-Statistic	2.564448	0.9948	1.771056	0.9617	0.564745	0.7139	3.046036	0.9988
Panel PP-Statistic	−4.986607	0.0000	−6.337381	0.0000	−7.120415	0.0000	−0.316619	0.3758
Panel ADF-Statistic	−5.274496	0.0000	−6.364575	0.0000	−10.49210	0.0000	−1.956692	0.0252
Alternative hypothesis: individual AR coefs. (between-dimension)					Alternative hypothesis: individual AR coefs. (between-dimension)			
	Statistic	Prob.			Statistic	Prob.		
Group rho-Statistic	3.536330	0.9998			4.491160	1.0000		
Group PP-Statistic	−7.406308	0.0000			−0.029868	0.4881		
Group ADF-Statistic	−6.652623	0.0000			−2.977685	0.0015		
				SSA-MI				
Alternative hypothesis: common AR coefs. (within-dimension)					Alternative hypothesis: common AR coefs. (within-dimension)			
	Statistic	Prob.	Weighted statistic	Prob.	Statistic	Prob.	Weighted statistic	Prob.
Panel v-Statistic	−1.256064	0.8955	9.305872	0.0000	−1.552427	0.9397	−3.246730	0.9994
Panel rho-Statistic	4.693222	1.0000	2.924493	0.9983	2.978023	0.9985	3.108239	0.9991
Panel PP-Statistic	1.372479	0.9150	−4.977415	0.0000	−1.406625	0.0798	−3.414968	0.0003
Panel ADF-Statistic	−8.341169	0.0000	−2.782839	0.0027	1.361048	0.9133	−1.155727	0.1239
Alternative hypothesis: individual AR coefs. (between-dimension)					Alternative hypothesis: individual AR coefs. (between-dimension)			
	Statistic	Prob.			Statistic	Prob.		
Group rho-Statistic	4.322859	1.0000			4.634383	1.0000		
Group PP-Statistic	−3.840256	0.0001			−3.284842	0.0005		
Group ADF-Statistic	1.086577	0.8614			0.956709	0.8306		

Source: Author's construct (2021).

grouping the sample into low and middle income countries, four out of the six statistics are significant at 1% with only two being insignificant on the CE as the dependent variable while three out of the six indicators are also significant with CO2 in low-income countries in SSA. The situation is not much different in the middle income countries. With the CE being the dependent variable, three of the indicators are significant with the remaining three being insignificant. On the same category with CO2 being the dependent variable, two of the six variables are significant with the other four being insignificant. In conclusion, the Pedroni test confirms that there exist cointegration among the variables in all the categories of the study.

4.4. Panel PMG-ARDL results

After confirming cointegration among the variables using the Pedroni test, this paper examined further the long-run relationship that exist between financial development and foreign direct investment on one hand and clean energy and carbon dioxide emission on the other hand using Pool Mean Group (PMG) estimator. Apart from its ability to control for endogeneity, PMG is able to also account for any cross-sectional dependence among countries (Shahbaz et al., 2018; Wang et al., 2021). The results are shown in Table 7.

For the sample on the entire region, financial development and carbon dioxide emission are found to be significantly positive with clean energy consumption. This means that any increase in the financial sector development in SSA will lead to an increase in clean energy consumption. On the contrary, economic growth is found to be negatively significant with clean energy consumption indicating that an increase in the growth of economy in SSA leads to decrease in the consumption of clean energy in the region. FDI is found to be insignificant with the consumption of clean energy in the region. In the same category, when carbon dioxide emission is made the dependent variable, all the independent variables are found to be significant at 1% significant level. Only FDI is positively correlated with carbon dioxide emission showing that an increase in FDI inflows into the region will lead to an increase in carbon dioxide emission in the region. Financial development, economic growth and clean energy are all found to have an inverse relationship with carbon dioxide emission in SSA.

In the case of low-income countries in SSA alone, financial sector development, FDI and economic growth are all found to have significant positive impact on clean energy consumption in the long run. Carbon dioxide emission is noted to have no significant impact on clean energy consumption in the long-run. With carbon dioxide

Table 7. Results of long run PMG-ARDL estimation.

	SSA		SSA-LI		SSA-MI	
Variable	CE	CO2	CE	CO2	CE	CO2
FSD	0.218***	−0.001***	0.055***	0.0042***	0.6767***	−0.0019**
FDI	0.229	0.003***	0.0721***	0.0023***	−0.4236***	−0.0095***
GDPG	−0.034***	0.011***	0.0309***	0.043***	−0.8189***	0.0012
CO2/CE	3.536***	−0.003***	0.1990	0.0013**	5.642***	−0.0023**

Note: ***, ** denote significance level of 1% and 5% respectively.
Source: Author's construct (2021).

being the dependent variable, all the four independent variables (FSD, FDI, GDPG and CE) are found to be significantly positive with carbon dioxide emission in these countries. This simply shows that while FDI, FSD and GDPG enhance clean energy consumption in low-income countries in SSA, these same variables contribute largely to the pollution of the environment through carbon dioxide emission.

Finally the paper examined these variables long-run relationship in middle-income countries in SSA. For CE being the dependent variable, all the independent variables are found to have significant impact on clean energy consumption with varied signs. FSD and CO2 are noted to have got positive impact on clean energy consumption while FDI and GDPG on the contrary impacts negatively on clean energy consumption. The result show that in middle income countries in SSA, advancement in financial sector development enhances clean energy consumption while the inflows of FDI reduces clean energy consumption in these countries. With CO2 being the independent variable in the middle income countries, three of the variables including FSD, FDI and CE are found to be significantly negative on CO2. This means any increase in financial development and FDI inflows in these countries reduce carbon dioxide emission in the long-run.

4.5. Panel causality test results

After investigating the existence of long-run impact of FDI and FSD on clean energy consumption and carbon dioxide emission in SSA, the paper employed Dumitrescu and Hurlin (2012) techniques to determine the panel heterogeneous causality among all the variables. This method as indicated earlier has the power to account for heterogeneity in the data series while estimating the pairwise causality between all the variables. This method thus provides more reliable and robust results as compared with the traditional Granger causality test (Paramati et al., 2016). The results for the short-run heterogeneous panel non-causality test are shown in Table 8. In the case of SSA, the study established a bi-directional relationship between CE and CO2; FDI and CO2; FDI and CE; and FSD and CE. There are however unidirectional causality among some of the variables. The study noted that while carbon dioxide emission causes GDPG, GDPG on the other hand does not cause CO2. There is also a unidirectional causality moving from FSD to CO2. Again GDPG and CE have unidirectional causality moving from GDPG. Finally, there is also an evidence of unidirectional causality moving from GDPG to FSD in SSA.

For low-income countries in SSA, FDI and CO2; GDPG and CO2 have both got evidence of bidirectional causality relationships which shows that occurrence of any of them will lead to the other an end. On the unidirectional causalities, there is an evidence of causality moving from CE to CO2 and FSD to CO2. Besides, there is unidirectional causality moving from CE to FDI and GDPG to FSD as established in the study in respect of low-income countries in SSA. In the case of the middle income countries in SSA, bidirectional relationships have been established between these variables: CE and CO2; GDPG and CO2; FDI and CE, GDPG and CE. The study again discovered unidirectional causalities among some of the variables. There is a unidirectional relationship moving from FDI to CO2 and another unidirectional relationship

Table 8. Heterogeneous panel causality analysis.

Null hypothesis:	SSA Zbar-Stat.	SSA-LI Zbar-Stat.	SSA-MI Zbar-Stat.
CE does not homogeneously cause CO2	3.03836***	4.38150***	3.03836***
CO2_1 does not homogeneously cause CE	2.74312***	0.74481	2.74312***
FDI does not homogeneously cause CO2	1.95317*	2.67321***	2.25981**
CO2 does not homogeneously cause FDI	3.06171***	2.29566**	1.12159
GDPG does not homogeneously cause CO2	1.05235	2.91882***	1.95317*
CO2 does not homogeneously cause GDPG	1.77799*	4.04131***	3.06171**
FSD does not homogeneously cause CO2_	2.25981**	1.71809***	1.05235
CO2 does not homogeneously cause FSD	1.12159	0.79281	1.77799*
FDI does not homogeneously cause CE	3.15004***	0.08475	13.1474***
CE does not homogeneously cause FDI	5.86862***	5.67115***	7.14080***
GDPG does not homogeneously cause CE	1.14901	−0.63420	3.15004***
CE does not homogeneously cause GDPG	3.53800***	−0.33742	5.86862***
FSD does not homogeneously cause CE	13.1474***	−1.22733	1.14901
CE does not homogeneously cause FSD	7.14080***	0.99183	3.53800***
GDPG does not homogeneously cause FDI	0.51170	2.70445***	1.20205
FDI does not homogeneously cause GDPG	2.25460**	1.13184	0.25730
FSD does not homogeneously cause FDI	0.25730	1.53670	3.16675***
FDI does not homogeneously cause FSD	1.20205	2.09527**	1.55394
FSD does not homogeneously cause GDPG	1.55394	−0.96265	0.51170
GDPG does not homogeneously cause FSD	3.16675***	2.26655**	2.25460**

Note: ***, **, * denote significance level of 1%, 5% and 10% respectively.
Source: Author's construct (2021).

moving from CO2 to FSD. The study again noted another unidirectional relationship moving from CE to FSD and also moving from FSD to FDI. Finally, while GDPG causes FSD, FSD does not cause GDPG in the middle income countries in SSA.

4.6. Discussions of findings

From the long run results obtained from the ARDL-PMG, financial development is found to have positive impact on clean energy consumption in SSA. Thus any increase in the development of the financial sector in SSA leads to an increase in the consumption of clean energy in the region. This outcome is in support of the work of Paramati et al. (2016). This means that advancement of system in the financial system in SSA makes it possible for households and firms to be in a position to acquire and use energy that is clean in nature. This can to be attributable to easy access and cheaper access to finance which encourage the use of clean energy products. The result is consistent for both low-income countries and middle-income countries in the region. These results are further supported by the link between FSD and CO2. An increase, in financial development leads to a reduction in the carbon dioxide emission in SSA in general and low-income countries in SSA. These findings are in line with the findings of Shahbaz et al. (2013) and Zaidi et al. (2019) but contradict the works of Musah et al. (2021); Nasir et al. (2019) and Shahbaz et al. (2018). It is only in the low-income countries of SSA that the nexus between FSD and CO2 is positive. This can possibly means lack of policies or low enforcement of policies on environmental compliance in low-income countries in SSA as corporate bodies and individuals who have access to funds with the financial sector development.

The link between FDI and clean energy consumption is noted to be insignificant in SSA. This goes to support the findings of Shahbaz et al. (2018) but contradict the findings of Paramati et al. (2016) which show that FDI enhances the consumption of clean energy. After decomposing our sample into low-income and middle income countries, it is observed that FDI has significant impact on clean energy consumption in the sub-divisions. While a significant positive impact is recorded in the low-income countries, an inverse relationship is established in the middle-income countries in the region. Again, the positive link between FDI and CO2 in low-income countries can be attributed to the lack of strict policies or lack of policy enforcement in these countries as against better policies and higher enforcement of environmental lows in middle-income countries.

Economic growth is one of the elements that determine the quality of an environment. For that matter this paper explored the link between economic growth and both carbon emission and the consumption of clean energy in SSA. From the results, economic growth is found to be inversely related to clean energy consumption in SSA in the long-run. This is consistent even in middle-income countries in SSA. It is however found to have positive impact on clean energy consumption in low-income countries in SSA. It shows that as the economic expands in SSA, many activities are undertaken especially industrialisation which leads to the consumption of unclean energy. This could be as a result of search for cheaper means of production as the economic expands thus leading to the use of unclean energy. With the positive link between economic growth and clean energy consumption in low-income countries, it possibly could be attributable to less industrialisation in the expansion in economic activities thus there is heavy reliance on rudimentary techniques which encourages clean energy use as compared with middle income countries where industrialisation is cardinal in their economic growth. Expectedly the link between economic growth and carbon emission in SSA and also across its two income divisions have been positive implying that an increase in the economic expansion certainly comes with expansion in activities which exert negative impacts on the environment by way of carbon emission.

From The causality results, there is a bidirectional relationship between foreign direct investment and carbon dioxide emission in SSA and in the low-income countries in SSA in the short-run. This is in support of the findings of Gökmenoğlu and Taspinar (2016) and Paramati et al. (2016). It does reinforce the assertion that FDI inflows causes increase in CO2 emission through FDI contribution to economic expansion (Joshua et al., 2020). The reverse causality moving from CO2 to FDI shows that more CO2 emission in the short-run signals more FDI as expansion in activities becomes complementary activities that attract MNCs. For instance, infrastructural development and industrialisation are key determinants of FDI. While this bidirectional relationship persists between FDI and CO2 in the low-income countries, it is however a unidirectional relationship in the middle-income countries moving from

FDI to CO2. There is a unidirectional relationship between financial development and CO2 throughout all the categories of the models. This goes to support the work of Musah et al. (2021). This positive unidirectional relationship is moving from FSD to CO2 in SSA in general and low-income countries in SSA. In middle-income countries in SSA, the direction is reversed in direction as it moves from CO2 to FSD only. The positive link between FSD and CO2 indicates that as access to credit increases, it makes households and corporate bodies acquire more automobiles and electrical gadgets which all contribute to CO2 emission in the economy. It does show that FSD policies are not environmentally friendly in the short-term as they destroy the environment with carbon emission. Again there is a reverse causality between FDI and CE in the total sample and in the middle-income countries in SSA. This is also in direct support of the findings of Paramati et al. (2016). In low-income countries however, there is one way causality moving from CE to FDI. On the link between FSD and CE, a bidirectional link exist in SSA with no causality in low-income countries and uni-directional causality in middle-income countries moving from CE to FSD in the short-run.

5. Conclusion and policy implications

Foreign direct investment and financial development are heavily touted as catalysts for development in general. This has made it very imperative for developing countries to yean for FDI and FSD so as to boost their economic growth. Saddled with deep developmental challenges, countries in sub-Saharan Africa continue to make frantic efforts so as to attract FDI and also enhance their financial development. This however should not be done at the expense of quality the environment. To understand the effect of FDI inflows and development of financial sector on clean energy consumption and carbon dioxide emission, this study employed panel data on 44 SSA countries ranging from 1998 to 2017 as the main sample. Besides, the study further decomposed the sample into low-income countries and middle-income countries so as to determine whether income level matter in these links. In investigating the long-run impact of FDI and FSD on CO2 and CE, ARDL-PMG estimator was used after establishing stationarity at levels or first difference using CIS and CADF which are robust to existence of cross-sectional inter-dependence. Besides, a causality test developed by Dumitrescu and Hurlin (2012) was used to establish the pairwise link between all the variables.

From the long-run results, FSD is found to have positive impact on clean energy consumption in SSA. This was found to be consistent in both low-income and middle-income countries in SSA. FSD is however found to be significantly negative with CO2 in SSA and middle-income countries. Its relationship is only positive in the low-income countries. FDI does not have any significant impact on clean energy consumption in SSA. A significant impact is noted after the decomposition of the sample into low-income and high-income countries. In low-income countries, FDI inflows impacts positively on clean energy consumption. This relationship is however negative with middle-income countries. The link between FDI and CO2 is significantly positive in the whole sample and also in low-income countries. These long-run relationships have been confirmed by the short links established between the variables in the causality test. Bidirectional relationships are found between FDI and CO2 and FDI and CE while unidirectional relationships are found between FSD and CE, and FSD and CO2.

From these findings, the study recommends that policy makers should give priority to the development and deepening of the financial systems in SSA. When the financial system is well-developed, access to finance will not only be easy but cost of borrowing will be low. The impact of easy access and cheaper source of financing will be an enhancement in capital for both households and corporate bodies. This will lead to increase in consumption of clean energy thus improving the quality of environment in the region. This relationship is more reinforced with the adverse relationship between FSD and CO2. Besides, financial institutions in low-income countries should be encouraged to pursue investment in green projects with their credit facilities. The banks can enforce this by giving credit facilities to firms and individuals who have demonstrated ability to comply with environmental laws and policies. This can also be done by giving credits at lower rates to individuals and firms whose activities are reducing carbon dioxide emission and enhancing environmental quality. Government should also create tax incentive packages for financial institutions that provide credit facilities to green projects and borrowers who have higher environmental compliance levels in their activities.

On the inflow of FDI, this paper recommends that the attraction of FDI should be selective as general inflows of FDI increases CO2 emission in SSA. Policies should be geared towards attracting FDI from destinations where environmental laws and enforcement are very high so as to experience a transfer of such compliance. This is however not automatic as multinational corporation operating in home countries may be environmentally friendly, but when same firms move into other countries where environmental laws are not stringent, they become even worst as they have the resources to be able bribe their way to circumvent the laws. This is because most of them move into other countries especially developing countries with the main aim of reducing their cost of operations in order to maximise profits. One of the ways to achieve this is to operate without compliance to environmental rule and laws of the host nation. This attitudes support the Pollution Heaven Hypothesis (Musah et al., 2021; Nyeadi et al., 2022) which believes that most multinational corporations see developing countries as damping grounds where they can make their moneys at the expense of the host environmental sustainability. In such cases, host countries must be strict in the application of their environmental laws against such corporations. Besides, FDI should be attracted into sectors which activities are not hazardous to the environment. Apart from these, comprehensive environmental laws and policies should be developed and enforced strictly against firms including multinational corporations moving into the region. Tax incentives should also be given to multinational corporations that invest in green projects and also have strict environmental levels in host countries.

Due to the scope of the work, this study was not able to examine the interactive effective of FDI and FSD on the consumption of clean energy and carbon emission. There is a greater possibility that the inflows of FDI into countries which are well developed financially in SSA will have more impact on clean energy consumption and carbon dioxide emission and thus having consequences on the environment. The study thus recommends that further studies should delve into exploring this link and possibly decomposing the data into country specifics since most of the countries have some peculiarities that can make findings different and thus leading to different policy recommendations.

Disclosure statement

No potential conflict of interest was reported by the authors.

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