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Abstract

Despite growing attention on the role of renewable energy in promoting economic growth and environmental sustainability, its adoption rate remains uncomfortably low, especially in developing countries. This study attempts to explore the ways to extend the installed capacity of renewable energy in 16 sub-Saharan African (SSA) countries over the period 1980-2017. The results from panel cointegration econometric techniques suggest that policies to enhance financial integration should increase the installed capacity of renewable energy in SSA, though the beneficial effect is only statistically significant in the long run. This effect holds, although disproportionately when the financial integration index is disaggregated into its *de facto* and *de jure* aspects. Moreover, the quantile regression analysis reveals that the effect of financial integration on renewable energy capacity is positive but heterogeneous across the conditional distribution of renewable energy capacity. However, the positive effect of financial integration is not enough to ensure the diversification of the energy mix, measured as the share of renewable installed capacity in the total installed capacity. The results show that economic growth is positively linked to renewable energy generation capacity while financial development is negatively associated with renewable energy production. Overall, these findings suggest that policies to increase the openness to foreign capitals are welcomed as far as renewable energy generation is concerned.

Key words: Financial integration, Renewable energy, Sub-Saharan Africa, Cointegration

1. Introduction

The point of departure of this paper from the extant literature is built from two strands of debate that are entwined. This study builds on Sustainable Development Goals (SDGs) 7 and 13 which respectively aim to broaden access to affordable, reliable, and modern clean energy for all, and take urgent actions to combat climate change. In this debate, continues climate change has been attributed to a persistent increase in greenhouse gas emissions, and this, in turn, has been a result of continued use of non-renewable sources of energy such as fossil fuels as the main source of energy (Gu et al., 2019). This is attributed on one hand to the energy poverty that characterizes most countries especially developing countries (Zubi et al., 2019) and the economic and social advantages obtain from energy despite its source. Energy enhances economic growth and development (Wang et al., 2022), reduces income inequality (Igawa and Managi, 2022), and improves educational quality (Banerjee et al., 2021). These advantages offered by energy have been at the origin of a continuous increase in energy consumption. In fact, World's electricity consumption has more than tripled from the 1980 level (World Bank, 2020). For instance, the energy consumption level moved from 7.323 billion kilowatt-hours in 1980 up to 23.398 in 2018 (IRENA, 2021). However, the choice of the form of energy has been a problem on its own altogether. Energy used by households and firms has been the major cause of greenhouse gas emissions in the modern era. This has been the worry of both national governments and international organizations. As an attempt to give a solution to this, the reduction of greenhouse gas emissions was considered as a priority in the post-2015 sustainable development agenda. Despite this recognition and concerted efforts by policy makers to achieve Agenda 2050 of zero net carbon emissions, greenhouse gas emissions continue to increase with fossil CO_2 emissions dominating the total greenhouse gas emissions mostly due to the use of fossil fuels as the main source of energy (Nchofoung and Asongu, 2021).

Recent empirical studies have emphasized the necessity of investment in renewable energy (RE) as one of the key pathways for slowing down the rate of greenhouse gas emissions (Mazzucato and Semieniuk, 2018; Shahnazi and Shabani, 2021; Mehmood, 2021; Yu et al., 2022). The same recommendation has emerged from international organizations, this was the case of the international climate agreements that aim to reduce dependence on fossil fuels by ensuring a smooth transition to renewable energy (IRENA, 2021). One of the main sources of renewable energy that is far from being exhausted identified is solar energy. Despite its vast renewable potential, only 5% of the solar energy potential is exploited. Moreover, less than 13% of energy investments are directed towards RE. Country or regional initiatives have been undertaken to strengthen renewable energy production. RE does not cause the local damage that some of the currently widespread alternatives, like traditional biomass and coal, cause, contributing to the goal of ensuring healthy lives via the reduction in indoor air pollution (Schwerhoff and Sy, 2017).

In Africa, energy demand moved from 91 terawatt-hours in 2010 to 163 in 2020 and is projected to reach 463 terawatt-hours by 2040 (IRENA, 2021). The concern with this projection is that the Africa's contribution to greenhouse gas emissions is likely to rise considering the fact that the usage of unclean fuel is widespread across continent (United Nations, 2021). One of the strategies policymakers in Africa can employ to address this situation is the adoption of RE sources that most often on its part necessitate huge investments for its proper functioning. Successful financing of innovation in RE requires a better understanding of the relationship between different types of finance and their willingness to invest in RE (Mazzucato and Semieniuk, 2018). In this respect, global renewable energy investment reached USD 322 billion in 2018 and is expected to reach USD 800 billion by 2050. Between 2013 and 2018, public sector financing represented only 14% of the total financing while the private sector took the responsibility of the highest chunk of the finance. On the global investment in renewable energy, while on average, countries in East Asia and Pacific attracted on average 32% of renewable energy investments between 2013-2018, those in Central Asia, Eastern Europe, Latin America and the Caribbean, Middle East and North Africa, South Asia, and Sub-Saharan Africa attracted only 15% (i.e., USD 45 billion)in the same period (IRENA, 2020).

These disparities across differences in finance in renewable energy have been mainly due to the sources of finance of each country. Schumpeter (1939) placed finance at the centre of his theory of innovation–a theory that limits itself to banks as the only source of finance. Recent literature, has, however, emphasised the role of other sources of financing (Mazzucato and Semieniuk, 2018). These could be through the public sector (Mazzucato, 2013), the private sector, or other innovation agencies (Mazzucato and Penna, 2016). Besides, one of the sources of finance that developing countries have continued to benefit from is external financing. External financing comes through aid, foreign direct investments, or remittances. These sources of finance are regrouped under the well-known concept of financial globalization. Globalization has been argued to be a motor of RE diffusion (Kim, 2018; Koengkan et al., 2020 a). According to these authors, globalization spurs economic growth, through knowledge diffusion, innovation, global value chain participation, and infrastructural development (Asongu et al., 2022). Globalization is thus, for the most partly linked to increasing industrial productivity as a result, and increase in energy demand. This in consequence will increase investments in RE sources to meet up with the extra energy demand. In recent years, economic growth in Africa has mostly been driven by the presence of high foreign capital in the form of foreign direct investments (Adusah-Poku, 2016).

According to the World Bank (2020), external financial flows into Africa have been on a steady increase. In fact, in Sub-Saharan Africa (SSA), FDI rose from 6.8578 billion USD in 2000 to US$32.222 billion in 2018. In the same period, workers' remittances witnessed a sharp increase, rising from US$4.801 billion in 2000 right up to US$48.169 Billion in 2018 while official development assistance (ODA) increased from US$13.058 billion to US$50.478 billion. These continued inflows have prompted research on the effect of financial globalization on the economy in Africa. This has been through its ability to enhance financial development (Asongu and De Moor, 2017; Asongu, 2017), promote economic development (Prasad et al., 20003), enhance inclusive development (Asongu and Nwachukwu, 2017), help in economic transformation (Idode and Sanusi, 2019). Besides, Acheampong et al. (2019) have recently argued that renewable energy and FDI reduce CO_2 emissions. On their part, Mahalik et al. (2021) assess the effect of foreign aid and foreign energy aid on CO_2 emission and suggest that these inflows improve environmental quality whereas remittances harm the environment. Studies on renewable energy include renewable energy consumption (Ergun et al., 2019; Olanrewaju et al., 2019; Ibrahiem and Hanafy, 2021), renewable energy production or development (Bayale et al., 2021; da Silva et al., 2018; Nyiwul, 2017), on renewable demand (Ackah and Kizys, 2015; Akintande et al., 2020). However, the literature is lacking on the effect of international financial integration on the renewable energy supply in Sub-Saharan Africa. The objective of the study is therefore to investigate how financial globalization affects renewable energy generation in Sub-Saharan Africa.

The study focuses on SSA for three principal reasons. Firstly, SSA is the least emitter of CO_2 in the World, but the growth rate of emission in this sub-region has been above that of several regions in the world including both East and Central Europe. It is a development that could possibly see the sub-region emerging as the highest emitter in the next decade (Nchofoung and Asongu, 2021). Secondly, countries are adopting renewable energy as a way out of GHG emissions. Thirdly, according to the post-2015 objective of the African Development Bank, among their development priorities include powering Africa, improving the quality of life in Africa, and integrating Africa. By integration, the objective aims at linking Africa through infrastructures and globalization which will increase access to larger markets. Currently, however, the climate funs RE energy project in Africa is mostly through grants (95%), 3% with loans, and less than 1% with private equity. In fact, African governments are at the center of all RE financing and only 14 African countries received other forms of financing and only Botswana, Equatorial Guinea, and South Africa have a share of grants lower than 50% (Afful-Koomson, 2015). Given that grants are mostly used for small-scale projects, the implementation of large scales projects in a poverty streak economy like that of SSA requires external funding either through borrowing, foreign investments, development support funds from international organizations, or through regional development Banks. This study thus seeks to answer the following question: what is the effect of financial globalization on renewable energy development in SSA?

The contribution of this present study is threefold. Firstly, the measure of financial integration adopted is to the best of knowledge the first on the subject. While past studies on this subject have often used FDI, remittances, development aid as individual indicators, this study integrates a composite indicator that takes into account all the possible measures of financial integration. Besides, the measure is further divided into *de jure* and *de facto*, which past studies have neglected. Secondly, the study contributes to the literature on sustainable development which is the main policy focus of every nation and international organization today. In this respect, the study considers the role play by financial globalization in financing renewable energy as a policy towards climate change mitigation. This is particularly of importance to the SSA economy given the high share of foreign capital in its economies and the setback the renewable energy development has experienced in the sub-region. Thirdly, we rely on various economic techniques that control for (i) cross-sectional dependence, (ii) endogeneity, and (iii) distributional heterogeneity of the individual across the sample. Since each of the biases is a concern, applying these techniques may improve the robustness of the results.

The remainder of the paper is structured as follows. Section 2 highlights a selected review of the literature; Section 3 presents the methodology. In Section 4, the findings are reported and discussed. Section 5 presents the conclusion and policy implications.

2. Literature Review

The literature review focuses on prior theoretical and empirical contributions linking financial globalization to economic development. In the Neo-classical framework, financial globalization should lead to the flows of capital from capital-rich economies to capital-poor economies. Besides, financial liberalization facilitates risk-sharing and thereby enhances production specialization, capital allocation, and economic growth (Obstfeld, 1994; Acemoglu and Zilibotti, 1997; Edison et al., 2002). It equally intensifies competition within the domestic economy through its positive outcome on the domestic financial market. In the midst of competition, enterprises turn to innovate, so as to meet up with the competition (Edison et al., 2002). Innovation could come in the form of product upgrading, technological innovation, involving the adoption of new forms of energy for productive and commercial purposes (Bayer et al., 2013). However, in the early stages of economic growth, the consequences of innovation can be slow and difficult to visualize, as the energy innovation process requires a time lag to become fully efficient (Wang et al., 2012, He and Zhang, 2012; Alvarez-Herranz et al., 2017). On the other hand, a recent strand of research has identified three principal drivers of innovation in renewable energy: technology-push, demand-pull, and systemic policy instruments (Pitelis et al., 2020). The proponents of the demand-pull side argue that factors such as taxes on competing new technologies (which could come with globalization) orientate the direction to innovate. Researchers favoring the technology-push also hold the view that it rather influences innovation in RE from the supply side which in this case is from the inventors. This means that local firms need to materialize their adsorptive capacity to cope with new technologies that accompany globalization. The systemic policy instruments come to facilitate the implementation of the former two instruments.

On the empirical front, the literature is divided into two main strands. The first strand of literature examines the effect of financial globalization on the economy while the second strand of literature studies the determinants of renewable energy. In the first strand of debate, financial globalization has a varying effect on the economy. It enhances financial development (Asongu and De Moor, 2017; Asongu, 2017; Aluko and Opoku, 2022). In this regard, financial globalization permits the modification of institutional structure to suiteone that adapts to competition and innovation increasing, as a result, the performance of the financial system. Moreover, financial globalization has been found to favor economic development (Prasad et al., 2003; Edison et al., 2002; Asongu and Nwachukwu, 2017; Osei and Kim, 2020; Kristi et al., 2022). The authors argue that financial globalization greatly affects savings and investment decisions, implicitly pointing to financial development as a key channel through which financial globalization affects economic development. In the same line, Tille (2008), had earlier argue that monetary shocks that come with financial globalization in open economies may destabilize the exchange rate and as a result, increase economic uncertainty thereby negatively impacting development. Additionally, there is also evidence that financial globalization leads to economic transformation (Gui-Diby and Renard, 2015; Idode and Sanusi, 2019; Mamba et al., 2020)and environmental sustainability (Acheampong et al., 2019; Akadiri and Adebayo, 2021; Kihombo et al., 2021; Mahalik et al., 2021; Miao et al., 2022; Shahzad et al., 2022). Mahalik et al. (2021) assess the effect of foreign aid and foreign energy aid on CO_2 emission and posit that these inflows improve environmental quality whereas remittances harm the environment. In this respect, the authors argue that the effect of globalization on renewable energy depends on the form in which financial globalization takes. In the same vein, Kihombo et al. (2021) however argue that the ability of financial globalization to affect environmental sustainability depends on its effect on economic growth and on population density. Besides, if the technological gains that come with financial globalization involve environmental technology, this will improve energy efficiency and low energy intensity (Paramati et al., 2022). This is the subject of the next strand of literature.

In the second strand of research, several studies have documented the determinants of RE. These include that of Aguirre and Ibikunle (2014) who on a global scale argue that public energy policies are shown to impede RE investments, equally, environmental concerns drive renewable energy investment and that countries under pressure to meet energy supply will reduce commitments towards RE. In a similar study, Omri and Nguyen (2014) find evidence that CO_2 emission and trade openness are the principal drivers of RE. Also, the extant literature on RE financing identifies financial development and financial openness necessary for this financing in the European Union (EU) and Latin America (Shahbaz et al. 2021; Koengkan et al. 2020b). Besides, Paramati et al. (2017) argue that the financing of RE in the EU, G20, and OECD countries depends highly on stock market development and foreign direct investments. In the same vein, for EU countries, Papież (2018) shows that RE in the EU is relatively mixed. Whereas the energy mix is a potential determinant of renewable energy, while countries with the lowest shares of RE are the ones with relatively high energy self-sufficiency. Besides countries with high fossil fuel deposits turn to develop RE better and it is further stimulated by the increase in economic growth, concentration of energy supply, and the increase in the cost of consumption of fossil fuels. Recently, Zhao et al. (2022) through a multi-criteria decision analysis argue that the development of wind energy projects will be a great step towards local energy requirements and minimize fossil energy usage. Moreover, Villanthenkodath and Velan (2022) argue that education and economic growth enhance RE consumption while foreign direct investment and financial development have negative effects. Given this variation on the determinants of RE on a global scale and out of Africa, studies on Africa have their own specificities.

In the context of Africa, several empirical works exist on renewable energy though it is still in the early stages of development. For instance, Ergun et al. (2019) argue that countries with higher human capital and higher economic growth have lower shares of renewable energy in their national grid, whereas, FDI inflows increase renewable energy. Akintande et al. (2020) also modeled the determinants of RE consumption in Africa through the Bayesian Model Averaging (BMA) method and put into evidence that urban population and economic growth explain RE consumption. da Silva et al. (2018) had earlier found similar results for SSA, they had further argued that despite the availability of resources, and potentials in generating RE in this sub-region, these resources have been under-utilized. Olanrewaju et al. (2019) also assessed RE within the remit of consumption and recommended that countries should charge high taxes for fossil fuel consumption and subsidies the use and consumption of RE. However, Nyiwul (2017) rather contends that an increase in oil prices reduces RE consumption and that it is the size of the population and industrial expansion that encourages RE consumption. Ankrah and Lin (2020) surmise that foreign direct investment and trade openness drive RE while economic growth rather has consequential results. Focusing on North African countries, Ibrahiem and Hanafy (2021) suggest that for policymakers to effectively improve upon RE generation, policies towards enhancing economic growth, trade openness, and foreign direct investments should be put in place. Besides, the cost of CO_2 emission should not be neglected. Also, Asongu and Odhiambo (2021) argue that financial development unconditionally enhances RE consumption in SSA while inequality offsets this effect. In this regard, there is an inequality threshold required to maintain the positive effect. Bayeet al. (2021) distinguishing carbon-efficient from least carbon-efficient countries argue that there are varying degrees of RE consumption in SSA countries. For instance, technological innovation, governance, economic growth, and climatic conditions influence renewable energy consumption. As a result, economic, environmental, and socio-economic factors promote renewable energy consumption in the region. Adedoyin et al. (2021) on their part suggests an urgent need for the implementation of sound macroeconomic and energy policies in SSA to safeguard the energy sector from interferences and to lessen its negative effect on the environment in the region. Recently, Chapel (2022) posits that Chinese and World Bank development assistance for renewable energy increases household and community access to electricity in SSA and that this effect is more enhancing than that of non-renewable energy projects.

The highlighted literature is lacking on renewable energy financing. Besides, the role of globalization in financing is a great gap in the literature. This study, therefore, fills these research gaps. Section 3 proposes the methodology to this effect.

3. Econometric Methodology

3.1. Model specification

This paper attempts to investigate the effect of financial integration in renewable energy generation capacity in SSA countries. In accordance with empirical literature (Koengkan et al., 2019; 2020a), we employ the following model:

$$renewable_{it} = \tau_0 + \tau_1 \, finglob_{it} + \beta_i \, X_{it} + \varepsilon_{it} \,, \qquad (1)$$

where renewable is the installed capacity of renewable energy; finglob is the financial integration index, X is a vector of control variables including income per capita, oil price and financial development. The subscripts *i* and t stand for the N cross-sections and the T periods, respectively. ε is the error-term. Given that all the variables are in the log-form, τ and β are interpreted as elasticities.

Dependent variable

The renewable energy installed capacity is measured as renewable energy generation per capita (in kilowatt-hour per capita). Renewable energy includes the energy retrieved from non-fossil sources including hydro, wind, solar, geothermal, waste, and biomass. This variable has been widely used to investigate the effect of renewable energy on growth (Vural, 2020) and environmental quality (Acheampong et al., 2020). Also, Koengkan et al. (2019) use this variable to proxy the investments for renewable energy extension in Latin America.

Variable of interest

Financial integration represents the degree to which countries do not restrict cross-border financial transactions (Edison et al., 2002; Calderón and Kubota, 2009). Our variable of interest is the overall financial integration index. This variable is built as a combination of de facto and de jure financial integration. The de facto index refers to the actual flows of international capital, the stocks of foreign assets and liabilities, while the de jure financial globalization index measure government policies and rules that enable the international flow of capital. These policies and rules include the number of international investment agreements, restrictions on investment and capital account openness (Gygli et al., 2019). The overall, de facto and de jure financial globalization are used in this study.

Control variables

To reduce the bias of omitted variables, we use some variables that can potentially explain the changes in the renewable energy generation capacity in a country. These variables are selected from the relevant literature.

The first control variable is the income per capita as a proxy to economic growth. Ideally, as a country becomes richer, governments can increase their investment in the production of durable goods, particularly in the energy sector. Furthermore, as income increases, individuals may increase their demand for more environmentally friendly goods, especially clean energy. However, a contradictory result would not be unexpected. Indeed, renewable energy as other environmentally friendly goods can be considered a luxury good (Beckerman, 1992), i.e. a good for which the demand increases when countries reach a high-income level. Indeed, Chen et al. (2021) find that economic growth decreases renewable energy production in developing countries while an opposite relationship holds for developed countries. Similarly, Shahbaz et al. (2021) find a negative effect of economic growth on renewable energy consumption in a sample of middle-income developing countries. Unlike the previous, Koengkan et al. (2019) report an enhancing effect of economic growth on the installed capacity of renewable energy in Latin American countries. We measure economic growth with per capita GDP. Thus, we expect a positive effect of economic growth on the generation capacity of renewable energy.

We have also control for the effect of the price of non-renewable energy using crude oil prices (current dollars). Non-renewable and renewable energy are considered substitutes in the energy mix. According to the demand theory, an increase in the price of non-renewable energy will force governments and consumers to reply on renewable energy, all other factors remaining constant. However, a reverse effect would indicate that non-renewable energy and renewable energy are complementary. Finally, we control for financial development. As advocated by the theorists of financial liberalization like McKinnon (1973) and Shaw (1973), the financial system plays a crucial role in mobilizing and allocating savings to their most productive uses. By doing that, the financial system increases the probability of successful innovation and the speed of technological progress, and ultimately improves economic growth (King and Levine, 1993). Many studies have shown that the financial sector plays a prominent role in spurring economic growth (Levine et al., 2000; Rioja and Valev, 2004; Ibrahim and Alagidede, 2015). In the energy sector, Anton and Nucu (2020) claim that a sound and well-developed financial system is an avenue to support the funding of the renewables industry at lower costs. However, relatively little is known about the effect of financial development on renewable energy since most of the existing studies focused on the effect of financial development on aggregate energy consumption (Sadorsky, 2010). A handful of studies investigate the effect of financial development on renewable energy. Theoretically, Shahbaz et al. (2021) argue that a well-developed financial sector reduces financial risk and credit costs, this can increase the financial capital, investment flow, and advanced technology directed to the energy sector. As pointed out by Schumpeter (1991), a developed financial system can encourage innovation in the energy sector. To control for the financial system, we use the domestic credit provided to the private sector (in % of GDP). This variable has been widely in recent studies (Avom et al., 2020; Njangang et al., 2020).

3.2.Data and descriptive analyses

To investigate the effect of financial integration on the RE installed capacity, we use data on 16 Sub-Saharan African countries over the period 1980-2017. We use renewable energy generation in kilowatt-hour per capita to capture the installed capacity of renewable energy. This variable is retrieved from the US Energy Information Administration. Data on financial integration are collected from the KOF Swiss Economic Institute. The initial globalisation series were generated by Dreher et al. (2006) and improved by Gygli et al. (2018) to account for flow and activities, but also policies, conditions, and rules that enable the international capital flows. Data on crude oil prices measured $2020 (deflated using the Consumer Price Index for the US) are retrieved from the British Petroleum Statistical Review of World Energy. Finally, data on GDP per capita ($ constant 2015) and domestic credit to the private sector (% of GDP) are taken from the World Development Indicators of the World Bank (2021). Table 1 reports the descriptive statistics on the variables.

Table 1: Variable description and descriptive statistics

Variables	Description	Descriptive statistics			
		Mean	Std. Dev.	Min	Max
Renewable	Renewable energy generation per capita in kilowatt-hours	160.22	180.344	0.4566	797.962
Overall finteg	Overall financial globalization	43.859	11.764	13.890	86.737
De facto finteg	De facto financial globalization	45.462	15.924	9.621	99.204
De jure finteg	De jure financial globalization	42.377	13.770	7.389	80.369
Gdpc	Gross domestic product per capita ($ constant 2015	2083.86	2243.486	286.431	80.3699
Oilpr	Crude oil prices	62.428	32.365	20.189	128.008
Findev	Domestic credit to private sector (% of GDP)	22.911	25.886	0.6645	142.422

Source: authors' computation

Table 2: Correlation matrix

Variables	renewable	Overall finteg	De facto finteg	De jure finteg	Gdpc	Oilpr	Findev
Renewable	1.000						
Overall finteg	0.270	1.000					
De facto finteg	0.295	0.832	1.000				
De jure finteg	0.115	0.747	0.243	1.000			
Gdpc	0.680	0.456	0.416	0.2893	1.000		
Oilpr	0.043	0.003	0.016	-0.018	0.049	1.000	
Findev	-0.004	0.296	0.298	0.155	0.499	0.071	1.000

Source: authors' computation

4. Estimation approach

The empirical analyses start through the cross-sectional dependence (CSD) test. The CSD arises from spatial or spillover effects, and unobserved common factors such as global shocks (Baltagi and Pesaran, 2007). Failure to account for CD in the variables could lead to a significant bias in the results (Breusch and Pagan, 1980; Pesaran 2004). The study therefore applies the Pesaran's (2004) CSD test, which is expressed as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \quad \Rightarrow \text{N}(0,1) \qquad (2),$$

where N is the cross-sections, T is the period and $\widehat{\rho_{ij}}$ is the coefficient of pair-wise correlation obtained from specific OLS estimation using equations 2.1 to 2.5. The null hypothesis of the test assumes that the series are cross-sectionally independent. In the second step, we implement the panel unit root test to avoid spurious regressions. In the presence of CSD, the usual panel stationarity tests do not produce reliable results. In this case, the second-generation unit root tests give efficient estimates. To deal with the CSD, we implement the cross-sectionally augmented

Dickey-Fuller (CADF) and the cross-sectionally augmented Im-Pesaran-Shin (CIPS) tests). The CADF and CIPS statistics are computed from the following cross-sectionally augmented model:

$$\Delta y_{it} = \alpha_i + b_i y_{i,t-1} + c\bar{y}_{t-1} + d_i \Delta \bar{y}_t + e_{it} \quad (3)$$

Where Y_{it} and $\Delta \bar{y}_t$ are the cross-sectional averages of lagged levels and first differences of individual series, respectively.

The CADF and CIPS statistics are computed as follows:

$$CADF = t_i(N;T) = \frac{\Delta y_i' \bar{M}_\omega y_{i,-1}}{\hat{\sigma}_i (y_i' \bar{M}_\omega y_{i,-1})^{\frac{1}{2}}} \quad (4)$$

The error-correction-based panel cointegration test of Westerlund is employed in the third step to explore the existence of a long-run relationship between the variables of models 1. This test accounts for slope heterogeneity, unit-specific short-run dynamics, and CSD (Persyn and Westerlund, 2008). The model to be estimated is written as follow:

$$\Delta y_{it} = \delta_i' d_t + \alpha_i (y_{i,t-1} - \beta_i' x_{i,t-1}) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + e_{it} \quad (5)$$

Where the subscripts $t= 1, \ldots, T$ and $i= 1, \ldots, N$ index the time-series and cross-sectional units; d_t is the deterministic trend, Y and X are the dependent and independent variables respectively; α_i is the error-correction term.

The test relies on two group mean statistics (G_τ and G_α) and two a panel statistics (P_τ and P_α) constructed as follows:

$$G_T = \frac{1}{N}\sum_{i=1}^{N} \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad \text{and} \quad G_\alpha = \frac{1}{N}\sum_{i=1}^{N} \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)}$$

$$P_T = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \quad \text{and} \quad P_\alpha = T\hat{\alpha}$$

Where $SE(\hat{\alpha}_i)$is the conventional standard error of$\hat{\alpha}_i$ in each cross-section. The null hypothesis assumes that there is no cointegration for all cross-sections (H_0: α_i= 0 for all *i*). The rejection of the null hypothesis for G_t and G_α indicates the presence of cointegration in minimum one of the cross-sections. Likewise, the rejection of the null hypothesis for P_t and P_α discloses the existence of cointegration in the panel, as a whole. In the last step, we estimate eq. 1 using various methods to ensure the robustness of the results. We start using conventional OLS, Fixed-effects and Random-effect model. These models assume that the errors are not serially correlated and homoscedastic. However, these techniques do not account for endogeneity and CSD. Also, they do not allow distinguishing between the sort and the long-run dynamics. To account for these issues, The following representative ARDL (p, q, q, q) model is derived from equation (1):

$$\Delta Y_{it} = \lambda_i Y_{i,t-j} + \alpha_i^{'} X_{i,t-j} + \sum_{j=1}^{P-1} \lambda_{ij} \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \alpha_{ij}^{'} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (6)$$

Where Y_{it} stands for the dependent variable (renewable energy generation per capita), X_{it} is a (4x1) vector of explanatory variables (financial integration, income per capita, crude oil prices, financial development), (p, q, q, q) is the optimal lag length selected by minimizing the Akaike information criterion; $\mu_i$is the fixed effects; α_i' and λ_i are the long-run parameters whereas α_{ij}' and λ_{ij} are the short-run coefficients.

The null hypothesis (H_0) assumes that there is no cointegration. If the null hypothesis of no cointegration is rejected, the following error correction model is estimated to highlight the short run dynamics:

$$\Delta Y_{it} = \delta_i ecm_{i,t-1} + \sum_{j=1}^{P-1} \lambda_{ij}^{*} \Delta Y_{2it-j} + \sum_{j=0}^{q-1} \theta_{ij}^{*'} \Delta X_{it-j} + \mu_i + \varepsilon_{it} \quad (7)$$

Where: $\delta_i = -(1 - \sum_{m=j+1}^{P} \lambda_{ij})$ $\quad \alpha_i^{*} = \sum_{j=0}^{q} \theta_{ij} \Big/ (1 - \sum_{k} \lambda_{ik})$; $\lambda_{it}^{*} = -\sum_{m=j+1}^{P} \lambda_{im}$, $\theta_{ij}^{*} = -\sum_{m=j+1}^{q} \theta_{im}$

With $i = 1,2,...,q-1$ and $j=1,2,..., p-1$.

The convergence coefficient δ_i captures the speed of adjustment toward equilibrium. It should be negative and statistically significant to allow for the existence of a long-run relationship between RE and it driving forces.

4. Empirical results

This section reports and discusses the findings. It begins with the pre-estimation analyses and ends with the discussion of the main findings.

4.1. Pre-estimation and principal results

Before estimating the effect of financial integration on renewable energy production, we test for the CSD in the variables. The results of the CSD in Table 3 do not allow accepting the null hypothesis of cross-sectional independence since all the statistics are statistically significant at the 1% level. Subsequent to finding the CSD, we have implemented the second generation unit root test. The results in Table 3 indicate that all the variables are not stationary at the level with the CADF test. However, all the variables are stationary in the first difference and this satisfies the condition to implement a cointegration test.

Table 3: Tests for CSD and unit root

Variable	CSD test			Unit root test	
	Pesaran test	P-value		CADF level	CADF first dif
Renewable	3.685***	0.000		-1.985	-4.741***
Overall finteg	16.787***	0.000		-2.480	-4.370***
De facto finteg	18.088***	0.000		-2.423	-4.263***
De jure finteg	6.483***	0.000		-1.826	-2.800**
Gdppc	4.418***	0.000		-2.106	-3.779***
Oilpr	67.52***	0.000		-1.985	-2.728**
Findev	9.197***	0.000		-2.448	-4.354***

Notes:*** and ** are statistical significance at the 1% and 5% levels, respectively. The critical values of the unit root test at 10%, 5% and 1% significance levels are -2.630, -2.630, and -2.850, respectively
Source: authors' computation

To account for the CSD in our variables, we implement the Westerlund cointegration test. Three models are estimated, respectively for the overall financial integration index, the de facto integration index and the de jure financial integration index. Findings in Table 4 provide strong evidence to support evidence for a long-run relationship between renewable energy generation capacity, financial integration, economic growth, oil price and financial development. This suggests that previous variables move together and a long-rung relationship can be investigated.

Table 4: cointegration result

Model	Gt	Ga	Pt	Pa
With overall finteg	-2.903***(0.ooo)	-9.201***(0.000)	-8.891***(0.000)	-7.670***(0.000)
With de facto finteg	-2.907***(0.ooo)	-9.302***(0.000)	-8.970***(0.000)	-5.642(0.333)
With the jure finteg	-2.598***(0.ooo)	-8.775***(0.000)	-7.967***(0.000)	-7.081***(0.000)

Notes: Robust P-values in parentheses, *** is statistical significance at the 1% level
Source: authors' computation

The presentation of the results starts with the homogenous panel estimates. Findings in Table 5 suggest that overall financial integration significantly contributes to the extension of the installed capacity of renewable energy in SSA regardless the estimation technique. The results show that a 1% increase in the financial integration index increases renewable generation capacity by about 0.359% to 0.620%. A similar effect is found for the de facto aspect of integration albeit different in the magnitude. Also, the de jure financial integration significantly improves the installed capacity of renewable energy in SSA. Moreover, findings show that economic growth encourages investments in renewable energy, while the financial development has a negative and statistically significant effect on the extension of the renewable energy generation capacity. The effect of crude oil prices is however, not statistically significant.

Table 5: Baseline results from homogenous panel estimates

	OLS	FE	RE	OLS	FE	RE	OLS	FE	RE
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Overall finteg	0.359***	0.622***	0.620***						
	(0.135)	(0.0899)	(0.0897)						
De jure finteg				-0.0291	0.199***	0.199***			
				(0.0939)	(0.0707)	(0.0704)			
De facto finteg							0.417***	0.526***	0.523***
							(0.109)	(0.0667)	(0.0665)
Gdppc	1.010***	0.697***	0.718***	1.050***	0.793***	0.808***	1.000***	0.645***	0.671***
	(0.0466)	(0.0917)	(0.0864)	(0.0454)	(0.0935)	(0.0876)	(0.0459)	(0.0916)	(0.0864)
Oilpr	0.0324	-0.0156	-0.0156	0.0177	-0.0402	-0.0395	0.0379	-0.0173	-0.0176
	(0.0710)	(0.0356)	(0.0356)	(0.0713)	(0.0366)	(0.0366)	(0.0706)	(0.0351)	(0.0351)
findev	-0.482***	-0.0670	-0.0765*	-0.458***	-0.0164	-0.0268	-0.498***	-0.0405	-0.0508
	(0.0489)	(0.0415)	(0.0412)	(0.0484)	(0.0426)	(0.0423)	(0.0489)	(0.0400)	(0.0397)
Constant	-3.016***	-2.690***	-2.806***	-1.860***	-1.823***	-1.906***	-3.138***	-2.031***	-2.180***
	(0.564)	(0.647)	(0.653)	(0.494)	(0.668)	(0.665)	(0.501)	(0.613)	(0.620)
Obs	608	608	608	608	608	608	608	608	608
R-squared	0.484	0.195		0.478	0.141		0.490	0.213	

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Source: authors' computation

We have further estimated our models using the panel ARDL model to account for heterogeneity and cross-sectional dependence. The Hausman specification test is employed to differentiate between the PMG and the MG models. The P-values associated with the Hausman statistics are statistically insignificant, suggesting the estimates from the PMG group are efficient. Thus, the discussions will focus on the estimates in columns 1, 3, and 5 in Table 6. Still in Table 6, the convergence coefficients are negative and statistically significant for all the estimated models with the PMG. This result suggests the existence of an error-correction mechanism between the installed capacity of renewable energy and its determinants. More specifically, a 1% deviation in the long-run equilibrium path the renewable energy generation capacity will be cancelled by 28%, 29%, and 27% in the following year, respectively for the model with the overall financial integration, de facto overall financial integration, and de jure overall financial integration measures.

The results in Table 6 also provide robust evidence regarding the effect of financial integration on the installed capacity of renewable energy in SSA, albeit the effect of financial integration and its aspects not being statistically significant in the short run. This effect could be explained by the fact that uncertainty, high exploration, and exploitation costs lead investors to fall back on conventional energy, which is cheaper. In addition, the lack of incentives may discourage investors from taking an interest in renewable energy in the short term. In the long run, however, a 1% increase in the coefficient of financial integration enhances the installed capacity of renewable energy by up to 0.725%. When considering the aspects of financial integration, the findings suggest that both the de jure and the facto financial integration increase the size of renewable energy generation in SSA.

However, their effects are quite disproportionate since a 1% increase in de facto financial integration enhances the installed capacity by 0.302% while the coefficient of the de facto financial integration stood at 0.267%. This result can be justified by the channel of capital accumulation and technology transfer in renewable energy production. The capital accumulation channel suggests that financial integration increases investment in renewable through foreign direct investment and debt. The technology channel is explained by the fact that given Sub-Saharan Africa's high endowment in renewable resources, investors will tend to direct their investments into renewable technologies. This result is in line with that of Koengkan et al. (2019) who pointed evidence on the positive effect of financial openness on the installed capacity of renewable energy in Latin American countries. However, it is important to distinguish between the flow of activities (de facto integration) and government policies to promote financial integration (de jure integration). The results show that policies to promote international financial openness have a greater impact than actual financial flows. Thus, foreign investors and financial institutions are more motivated to invest in countries for which the host governments offer non-economic incentives including low or no investment restrictions on investment, opening-up of capital account and the participation in international investment agreements, more specifically for renewable energy provision. This finding is new in the literature since to the best of knowledge, no study has distinguished between the effects of de facto and de jure aspects of financial integration when investigating the effect of financial openness on renewable energy generation capacity.

Looking at the control variables, findings suggest that economic growth has a positive and statistically significant effect on renewable energy both in the long and the short run. The effect of a 1% increase in GDP per capita increases investments in renewable energy capacity by 0.698 and 1.103% in the short run while its effect varies between 0.5421% and 1.086% in the long run. A plausible explanation of that result is that economic growth increases energy demand. In order to respond to the additional demand for energy, governments invest in the extension of renewable energy capacity (Koengkan et al., 2019; Koengkan, 2018). This finding is in line with that of Koengkan et al. (2019) in a sample of 10 Latin American Countries. Zhao et al. (2020) find that economic growth increases renewable energy demand in China. Also, Paramati et al. (2017) show that economic growth has a positive and statistically significant effect on clean energy in countries from the EU, the G20, and the OECD. However, this finding is in conflict with that of Anton et al. (2019) in a selected sample of 28 countries from the European Union. Shahbaz et al. (2021) pointed out a negative effect of economic growth on renewable energy demand in middle-upper-income developing countries. The contradiction between the findings of Paramati et al. (2017) and Anton &Nucu (2019) might suggest that the effect of economic growth on renewable energy is sensitive to factors such as the period of the study and the estimation method.

Moreover, the findings suggest that changes in the crude oil prices do not a significant effect on renewable energy generation. This is in contradiction with the findings of Nyiwul (2017) who posit a positive impact of oil prices and RE consumption. Finally, financial development does not play a significant role in explaining variations in renewable energy generation, though the coefficient is statistically significant in column 3 (with de facto financial integration). This result indicates that the expansion in financial resources allocated to the private sector does not contribute to the extension of the installed capacity of renewable energy. This is in contradiction with the findings of Eren et al. (2019) for India and Shahbaz et al. (2021) in a sample of 34 upper-middle-income developing countries. Due to the high costs of exploration and storage of renewable, national investors may be less prone to invest in renewable energy projects. Governments should thus provide financial incentives to encourage the private sector to participate in the provision of renewable energy.

Table6: Main findings from panel heterogeneous estimates

	Overall		*De facto*		*De jure*	
	PMG	MG	PMG	MG	PMG	MG
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Long-run						
Finteg	0.725***	-0.0213	0.267***	-0.196	0.302**	0.00914
	(0.172)	(0.285)	(0.0951)	(0.196)	(0.131)	(0.191)
Gdppc	0.841***	0.468	0.541***	0.540	1.086***	0.408
	(0.143)	(0.815)	(0.136)	(0.721)	(0.153)	(0.942)
Oilpr	-0.0159	-0.108	-0.0511	-0.138	-0.0293	-0.120
	(0.0352)	(0.141)	(0.0319)	(0.138)	(0.0403)	(0.159)
Findev	0.0104	0.358	-0.0817*	0.268	0.0940	0.450
	(0.0581)	(0.413)	(0.0457)	(0.332)	(0.0709)	(0.550)
Short-run						
Convergence	-0.280***	-0.555***	-0.291***	-0.547***	-0.270***	-0.552***
	(0.0561)	(0.0654)	(0.0576)	(0.0633)	(0.0529)	(0.0675)
D.Finteg	0.404*	-0.110	-0.212*	-0.172	-0.0734	0.112
	(0.231)	(0.193)	(0.129)	(0.149)	(0.140)	(0.127)
D.Gdppc	0.698*	0.891**	0.740	1.103**	0.909*	0.722**
	(0.395)	(0.377)	(0.493)	(0.503)	(0.541)	(0.328)
D.Oilpr	-0.0152	0.0704	-0.0207	0.0776	0.0124	0.100*
	(0.0718)	(0.0566)	(0.0736)	(0.0542)	(0.0663)	(0.0609)
D.Findev	7.12e-05	-0.0167	0.0115	-0.0430	-0.0334	-0.0353
	(0.0389)	(0.105)	(0.0385)	(0.0946)	(0.0346)	(0.137)
Constant	-1.251***	-1.944	0.0315	-1.776	-1.335***	-2.104
	(0.281)	(4.532)	(0.0751)	(4.276)	(0.301)	(4.972)
Observations	592	592	592	592	592	592
Hausman PMG≠MG	1.45 (0.121)		3.67 (0.3456)		1.68 (0.301)	

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, D is the first difference operator
Source: authors' computation

4.2. Other considerations

4.2.1. Alternative estimation techniques

To check for the robustness of the estimates, this study employs the fully modified OLS and dynamic OLS. In addition to controlling the CSD and heterogeneity, they account for the eventual bias of endogeneity of the variables and serial correlation (Herzer and Donaubauer, 2017; Ngouhouo and Nchofoung, 2021). The estimates reported in Table 7 suggest that overall financial integration and its de jure aspect have statistically positive effects on the installed capacity of renewable energy in the long run. The effect of de facto integration is still positive but statistically significant only with the FMOLS. Also, economic growth plays a crucial in extending the renewable energy generation capacity whereas variations in crude oil prices do play a significant role in explaining changes in renewable energy generation capacity. The effect of financial development remains negative but statistically significant for the model with the DOLS. Overall, these findings probe robust evidence on the positive effect of financial integration on renewable energy generation capacity in SSA.

Table 7: Results from alternative estimation techniques

	FMOLS			DOLS		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Overall Finteg	0.622***			0.630***		
	(0.192)			(0.131)		
De jure Finteg		0.201***			0.404***	
		(0.020)			(0.102)	
De facto Finteg			0.496***			0.145
			(0.018)			(0.113)
Gdppc	0.705***	0.804***	0.655***	0.612***	0.547***	0.737***
	(0.006)	(0.006)	(0.006)	(0.119)	(0.131)	(0.118)
Oilpr	0.029	-0.014	-0.021	0.029	0.016	0.013
	(0.021)	(0.021)	(0.0215)	(0.031)	(0.035)	(0.037)
Findev	-0.058***	-0.027*	-0.006	-0.044	0.060	-0.041
	(0.016)	(0.016)	(0.016)	(0.048)	(0.054)	(0.055)
R^2	0.887	0.881	0.890	0.937	0.938	0.936
Adjusted R^2	0.883	0.877	0.886	0.900	0.901	0.897

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' computation

4.2.2. Accounting for distributional heterogeneity

Finally, this study employs the fixed-effect quantile regression analysis to investigate the effect of financial integration on the conditional distribution of renewable energy generation capacity in SSA. One feature of panel data is that most series commonly exhibit outliers and are non-normally distributed (Lin and Xu, 2020). As a result, usual econometric techniques might provide non-robust estimators. To account for the distributional heterogeneity, we rely on the Method of Moments Quantile Regression (MMQR) with fixed effects.

The findings of the quantile regression analysis are reported in Tables 8 – 10, respectively, for the models with overall, de facto, and de jure financial integration indexes. Also, we have specified three ranges of quantiles, which are low renewable energy generation capacity (10th – 30th quantile), middle renewable energy generation capacity (30th – 60th quantile), and high renewable energy generation capacity (70th – 90th quantile). Contrary to past evidence, the findings in Table 8 suggest that financial integration is positively related to renewable energy production, albeit the marginal positive effect decreases with the high level of the installed capacity. To put in perspective, a 1% increase in the overall financial integration index improve the installed capacity by about 0.745% to 0.958% in countries with the lowest installed capacity, by about 0.519% to 0.664% in countries with the middle-installed capacity, and by 0.380% to 0.449% in countries with the highest installed capacity. A similar trend is observed when the overall index of financial integration is segregated into its de facto (Table 9) and de jure (Table 10) aspects. Overall, these findings show that financial integration is positively associated with renewable energy production in SSA though the marginal effect is reduced when the national installed capacity becomes sufficiently high. This finding is similar to that of Edison et al. (2002) in their study on the financial integration – growth nexus. They report that international financial integration promotes economic growth in poor countries while the reverse effect is found for rich countries.

Turning our attention to the control variables, the findings suggest that higher economic growth enables governments to invest in renewable energy generation, though the magnitude of the effect varies across all the conditional distribution. Finally, the results suggest that renewable energy production is inelastic with respect to crude oil price and financial development regardless of the quantile level.

Table 8: Overall financial integration and installed capacity of renewable energy

	Quantile levels								
	Low installed capacity			Middle installed capacity			High installed capacity		
	10^{th}	20^{th}	30^{th}	40^{th}	50^{th}	60^{th}	70^{th}	80^{th}	90^{th}
Overall finteg	0.958***	0.838**	0.745***	0.664***	0.558***	0.519**	0.449***	0.380**	0.290
	(0.247)	(0.191)	(0.153)	(0.130)	(0.122)	(0.128)	(0.145)	(0.171)	(0.211)
Gdppc	0.315	0.415***	0.556***	0.649***	0.734**	0.813***	0.892***	0.971***	1.073***
	(0.224)	(0.173)	(0.139)	(0.119)	(0.111)	(0.128)	(0.132)	(0.154)	(0.192)
Oilpr	-0.012	-0.013	-0.014	-0.015	-0.015	-0.016	-0.017	-0.018	-0.019
	(0.078)	(0.060)	(0.048)	(0.040)	(0.038)	(0.040)	(0.046)	(0.054)	(0.066)
Findev	-0.083	-0.077	-0.072	-0.069	-0.065	-0.061	-0.058	-0.055	-0.050
	(0.107)	(0.082)	(0.065)	(0.055)	(0.052)	(0.055)	(0.062)	(0.073)	(0.091)
Observations	608	608	608	608	608	608	608	608	608

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Source: authors' computation

Table 9: De facto financial integration and installed capacity of renewable energy

	Quantile levels								
	Low installed capacity			Middle installed capacity			High installed capacity		
	10th	20th	30th	40th	50th	60th	70th	80th	90th
De facto finteg	0.768***	0.678***	0.611***	0.550***	0.509***	0.466***	0.429***	0.385***	0.324***
	(0.194)	(0.144)	(0.112)	(0.089)	(0.081)	(0.081)	(0.087)	(0.102)	(0.103)
Gdppc	0.174	0.349*	0.748***	0.597***	0.678***	0.760***	0.832***	0.917***	1.036***
	(0.258)	(0.193)	(0.151)	(0.120)	(0.109)	(0.108)	(0.117)	(0.137)	(0.173)
Oilpr	-0.024	-0.021	-0.019	-0.018	-0.016	-0.015	-0.014	-0.013	-0.011
	(0.091)	(0.067)	(0.052)	(0.041)	(0.037)	(0.037)	(0.041)	(0.048)	(0.061)
Findev	-0.027	-0.032	-0.036	-0.039	-0.041	-0.043	-0.045	-0.047	-0.051
	(0.122)	(0.091)	(0.070)	(0.056)	(0.051)	(0.051)	(0.055)	(0.064)	(0.082)
Observations	608	608	608	608	608	608	608	608	608

Notes: Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: authors' computation

Table 10: De jure financial integration and installed capacity of renewable energy

	Quantile levels								
	Low installed capacity			Middle installed capacity			High installed capacity		
	10th	20th	30th	40th	50th	60th	70th	80th	90th
De jure finteg	0.312*	0.275**	0.244**	0.216**	0.191**	0.160*	0.138	0.113**	0.078
	(0.165)	(0.131)	(0.107)	(0.091)	(0.085)	(0.089)	(0.117)	(0.117)	(0.146)
Gdppc	0.494**	0.519***	0.672***	0.746***	0.812***	0.891***	0.949***	1.015***	1.106***
	(0.210)	(0.167)	(0.137)	(0.117)	(0.109)	(0.114)	(0.127)	(0.149)	(0.186)
Oilpr	-0.072	-0.062	-0.053	-0.045	-0.038	-0.029	-0.023	-0.015	-0.005
	(0.071)	(0.056)	(0.046)	(0.039)	(0.036)	(0.038)	(0.043)	(0.050)	(0.063)
Findev	-0.011	-0.013	-0.014	-0.015	-0.016	-0.018	-0.019	-0.020	-0.021
	(0.193)	(0.074)	(0.060)	(0.051)	(0.048)	(0.050)	(0.056)	(0.066)	(0.083)
Observation	608	608	608	608	608	608	608	608	608

Notes: Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: authors' computation

4.2.3. Alternative measure of the installed capacity of renewable energy

Based on the claim that countries should gradually replace fossil fuels with renewable in the total energy mix to reduce the risk of global warming, we replicate the previous estimates by replacing renewable energy production per capita (eq. 1) with the contribution of renewable energy production to the total energy produced. The new variable is in percentage (%) and indicates the proportion of energy generated from clean sources. This variable is quite interesting as it indicates the efforts of countries toward the diversification of their energy mix. Table 11 reports the findings from the replication analyses. Surprisingly, the effect of financial integration (overall, *de facto* and *de jure*) on the energy mix is negative but statistically insignificant both in the short and the long run. A plausible justification of these findings is that financial integration indirectly increases energy demand through its effect on economic activities. To respond to the increased demand for energy, more investments in the energy sector are required. However, the corresponding increase in renewable energy production seems to be insignificant compared to that of non-renewable energy since fossil fuels remain at the backbone of the energy system in developing countries, including those from SSA. Among the control variables, economic growth plays a significant role in increasing the share of renewable energy in total energy produced. A 1% increase in the per capita GDP increase renewable energy generation capacity by 0.414% and 0.587% in the long run while the corresponding increase stood at 0.516% in the short run. Also, there is an inverse relationship between crude oil price and the installed capacity of renewable energy (as a share of total energy).

Table 11: Financial integration and the energy mix

	Overall		*De facto*		*De jure*	
	PMG	MG	PMG	MG	PMG	MG
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Long-run						
Finteg	-0.157	0.624	0.0584	0.248	-0.406***	0.205
	(0.105)	(0.419)	(0.0783)	(0.170)	(0.0759)	(0.201)
Gdppc	-0.587***	0.101	0.426***	-0.548	0.414***	0.264
	(0.128)	(0.786)	(0.0542)	(1.231)	(0.0916)	(0.715)
Oilpr	-0.104***	-0.145	-0.0161	-0.586	-0.0649*	-0.156
	(0.0299)	(0.125)	(0.0299)	(0.475)	(0.0362)	(0.116)
Findev	-0.0811	0.398	-0.117**	0.921	-0.147**	0.283
	(0.0538)	(0.306)	(0.0546)	(0.675)	(0.0627)	(0.252)
Short-run						
Convergence	-0.219***	-0.533***	-0.244***	-0.521***	-0.247***	-0.532***
	(0.0452)	(0.0617)	(0.0651)	(0.0651)	(0.0642)	(0.0588)
D.Finteg	-0.189	-0.183	0.0251	0.0268	-0.0988	-0.127
	(0.205)	(0.157)	(0.109)	(0.0828)	(0.115)	(0.109)
D.Gdppc	0.843	0.716*	0.765	0.516*	0.916	0.901*
	(0.610)	(0.380)	(0.604)	(0.310)	(0.689)	(0.505)
D.Oilpr	-0.0389	0.0276	-0.0416	0.0586	-0.0342	0.0298
	(0.0713)	(0.0252)	(0.0618)	(0.0360)	(0.0710)	(0.0235)
D.Findev	0.0154	-0.0413	-0.00213	-0.0712	-0.0668	-0.0586
	(0.0334)	(0.106)	(0.0360)	(0.141)	(0.0567)	(0.0941)
Constant	1.935***	-2.252	0.102	-2.446	0.409**	-1.647
	(0.396)	(4.620)	(0.141)	(5.217)	(0.199)	(4.470)
Observations	592	592	592	592	592	592
Hausman PMG≠MG	2.45 (0.451)		4.95 (0.699)		5.07 (0.862)	

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; D is the first difference operator.
Source: authors' computation

5. Conclusion and policy implications

This paper investigated the effect of financial integration on renewable energy capacity in a sample of 16 SSA countries over the period 1980 to 2017. This study deviates from the use of proxies such as FDI or migrant remittances for financial integration. This study employs the KOF index of financial integration which is a composite index to examine the financial integration-renewable energy generation relationship. Another contribution of this paper lies in the fact that it takes into account the importance of the volumes of renewable energies generated and its share in the total energy mix. Based on panel cointegration techniques, the findings show that the positive effect of financial integration (overall) and its key components (de facto and de jure) on the installed capacity of renewable energy is statistically significant only in the long run. All factors remaining constant, a 1% increase in the overall financial index prompts the installed capacity of renewable energy by 0.725%. When considering de facto and de jure aspects of financial integration, we also find positive and statistically significant albeit disproportionate effects of de jure and de facto financial integration on the installed capacity of renewable energy. Additionally, evidence from the quantile regression also reveals that though the effect of financial integration on renewable energy production remains positive across quantile, the marginal effect diminishes as the generation capacity of nation's increases. More specifically, we find that financial integration accelerates renewable energy production with the highest impact in countries with the lowest installed capacity. Furthermore, the findings show that financial integration has a negative but statistically insignificant effect on energy diversification. Looking at the control variables, the findings show that economic growth enhances renewable energy production and its share in the energy mix. Thus, policies to promote economic growth could increase the ability of countries to invest in renewable energy. Additionally, renewable energy production is inelastic with respect to crude oil price while financial development reduces the production capacity of renewable energy, though the effect is statistically insignificant in some models.

To sum up, the results suggest that African countries can increase the installed capacity of renewable energy by developing policies to attract external capital flows. In this regard, African leaders should reinforce the integrity of governments in several aspects including a low level of corruption, improved government effectiveness, ensuring a stable political environment. At the national level, the adverse effect of financial development on the installed capacity reflects the risk aversion of domestic investors to the renewable energy sector. Governments should thus improve the confidence of local investors by encouraging public-private partnerships (PPP). PPP will allow mobilizing private funds while protecting private investors from governance risks (Schwerhof and Sy, 2017). In this scheme, appropriate instruments would be designed depending on the source of energy (wind, solar, geothermal, waste, and biomass) and the type of investment required. Finally, policies to promote economic growth should enable the ability of the governments to invest in renewable energy. However, these policies should be carefully implemented as previous studies have found that economic growth impedes the environmental quality in SSA countries (Nkengfack et al., 2021; Nkengfack and Kaffo, 2019).

Future studies could include additional factors that can have a substantial effect on renewable energy production such as governance (i.e. political, economic and institutional dimensions), education, and ICT development. Moreover, modulating mechanisms could be integrated into future studies.

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