Delivering double wins: How can Africa's finance deliver economic growth and renewable energy transition?

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Abstract

Countries tend to industrialize using fossil fuels at the expense of the environment as they grow, undermining the progress made in combating climate change. Therefore, how to finance a clean energy transition amidst economic growth remains a crucial policy concern. We examine the effect of financial development on clean energy transition in 20 low-income and middle-income sub-Saharan countries. The study employs fixed-effects and instrumental variable two-stage Least squares (IV-2SLS) models to examine the effect of financial development on the transition to renewable energy. Overall, the results show a positive effect of financial development on renewable energy transition. However, the financial development effect is only significant for financial institutions instead of financial markets – a signal of weak financial markets in the region. More importantly, the results show that this financial development effect on renewable energy transition is significant only in low-income countries, contrary to middle-income economies. This result implies that as Sub-Saharan Africa (SSA) countries grow, their financial sectors tend to spur investments in fossil fuels compared to clean energy sources. We recommend that governments in SSA further develop and promote innovative financial market products such as green bonds and digital financial products that support private sector investments in renewable energy. Regarding trade, it is also critical for governments to subsidize environmentally friendly green energy imports while taxing non-renewable products that promote the use of fossil fuels.

Keywords: Financial development, Renewable energy transition, Economic growth

1. Introduction

The sub-Saharan African Economies (SSA) have grown significantly in recent years. Before the COVID-19 pandemic, SSA was predicted to double in size by 2030, growing by an average of 4.4 percent annually (Amadou, 2014; Baquedano et al., 2021). The region has registered unprecedented demand for energy due to sustained economic activity expansion, increased industrialization, and population rise (Naeem et al., 2023; Mutezo & Mulupo, 2021).

Estimates show that out of 800 million people without access to electricity – about 600 million live in sub-Saharan Africa (IEA, 2021). The region is also home to the 20 countries with the lowest electrification rates that include Burundi, Chad, Malawi, Democratic Republic of Congo, and Niger, among others (World Bank, 2021). Relatedly, biofuels are the primary source of Africa's energy and account for 43 percent of the region's energy compared to oil (23.3 percent) and natural gas (16 percent) (IRENA, 2022). This deficit in access to clean energy translates into a high mortality risk due to household pollution from cooking, environmental degradation, and high business costs among firms (WHO, 2018; Martin et al., 2018). Additionally, limited access to energy infrastructure undermines healthcare and education services to the population (Ahlborg et al., 2016; Okereke et al., 2019).

Consequently, African policymakers face a twin policy challenge— achieving energy security to support their economic growth while mitigating vulnerability to climate change to attain sustainable growth and development. Sustainable Development Goal (SDG) 7 further underscores the urgency to strike this balance, emphasizing the need for access to affordable, reliable, sustainable, and modern energy for all by 2030 (United Nations, 2015). Relatedly, SDG 13 highlights the need for countries to take urgent action to combat climate change and its impact.

However, to address this twin policy challenge, an efficient and robust financial sector is very critical for Africa's clean energy agenda as it determines areas of credit (whom to lend) and investment decisions (where to invest, whether renewable or non-renewable energy). Unfortunately, financial markets in the region are hugely underdeveloped, characterized by inadequate regulation and prohibitive interest rates that undermine credit access by firms and households (Allen et al., 2014; Soumaré et al., 2021). Additionally, capital markets are immature, dominated by short-term government securities and lack diversity in financial instruments. These constraints have culminated in low investment rates in Africa (24 percent) compared to other emerging world economies such as China (40 percent), South Asia (28 percent) and East Asia and Pacific (32 percent) (World Bank, 2020).

Using panel data from 20 low- and middle-income countries in sub-Saharan Africa, our study examines the effect of financial development on the transition to renewable energy. There are multiple channels through which financial development can affect the transition to renewable energy (Lin & Okoye, 2023). Moreover, most studies focusing on sub-Saharan Africa use only two indicators of financial development: the ratio of private sector credit to GDP and broad money (amount of money in circulation) and overlook financial access and efficiency components of financial development.

We adopt the new broad-based index (Svirydzenka, 2016) as a multidimensional measure of financial development that includes financial access, financial depth, and financial efficiency. Thus, we uncover the possible channels through which financial access, depth, and efficiency affect the transition to renewable energy. We further disaggregate the analysis to examine the effect of financial development on renewable energy transition in middle-income countries versus low-income countries. Our study findings provide empirical evidence on how SSA countries can leverage finance to foster a renewable energy transition as they pursue economic growth.

Specifically, the study answers critical research questions that could shape Africa's Agenda on clean energy transition and economic growth and development. First, how does financial development affect renewable energy transition in sub-Saharan Africa? Second, how does the effect of financial development on renewable transition vary across Low-income and middle-income countries in sub-Saharan Africa? This study contributes to the existing literature on financial development in the clean energy transition in two main ways: First, a vast body of literature has examined the nexus between financial development and renewable energy transition (Mukhtarov et al., 2021; Dimnwobi et al., 2021; Saadaoui, 2022; Anton & Nucu, 2020; Cheng et al., 2020; Prempeh; 2023; Obobisa, 2022). However, these studies have examined the nexus between financial development and renewable energy consumption based on aggregate measures of financial development. Hence, they fail to break it down into its different forms.

Consequently, they do not explicitly provide targeted policy interventions, particularly which financial development dimensions should be emphasized to drive renewable energy transition amidst economic growth. The other contribution concerns the identification strategy used in the study. Unlike other studies, we address the potential endogeneity issue, which would otherwise provide inconsistent and biased results. Potential endogeneity could emerge from the time-varying omitted or auxiliary variables correlated to financial development, which the fixed effects model does not capture. Secondly, endogeneity could result from reverse causality, where renewable energy transition translates into increased financial development. For instance, the recent wide adoption of the Pay as You Go home solar systems among households and small and medium enterprises (SMEs) could spur savings and investments and promote financial development (Pazarbasioglu et al., 2020; Dogan et al., 2021).

The rest of the study is organized as follows: Section 2 reviews the past literature regarding financial development and renewable energy transition in the context of Africa’s development, while Section 3 presents and discusses the study's methodology. Section 4 presents and discusses the results. Section 5 concludes and provides the policy implications and recommendations of the study.

2. Financial Development and Renewable energy transition in Africa's development Agenda

Several theories in the literature attempt to explain the relationship between financial development and [renewable] energy transition, focusing on its drivers and implications (Sadorsky, 2010). Various studies empirically examine the effect of financial development on the transition to renewable energy using several theoretical frameworks and empirical strategies. Studies suggest that a sound financial system could facilitate investments in renewable energy (green energy projects) that are premised on the growing demand for renewable energy products (Saadaoui & Chtourou, 2022).

One strand of empirical literature shows that financial development is positively related to renewable energy transition (Kim & Park, 2016; Best, 2017; Charfeddine & Kahia, 2019; Ji & Zhang, 2019; Eren et al., 2019; Shahbaz et al., 2021; Mukhtarov et al., 2022). It is posited that financial development is a crucial driver of the transition from non-renewable to renewable energy because it boosts demand for (supply of or investments in) renewable energy products. This transition is higher in higher-income countries with more developed financial sectors (Kim & Park, 2016). For instance, Best (2017) finds that financial capital positively influences the shift from fossil fuels (e.g., coal) to renewable energy (e.g., wind energy, solar or biomass), depending on the country's level of development. Relatedly, Kim and Park (2016) show that the level of development of the financial sector (markets) is critical for fast-tracking green energy investments. In other words, the country's level of development is necessary but not sufficient for the transition to renewable energy. Mukhtarov et al. (2022) and Sadorsky (2010) also note that higher levels of financial development are associated with lower financial risk, more transparency, lower borrowing costs, and easier access to funds. Further, Raza et al. (2020) find a positive and significant relationship between financial development and renewable energy transition in a high financial development regime.

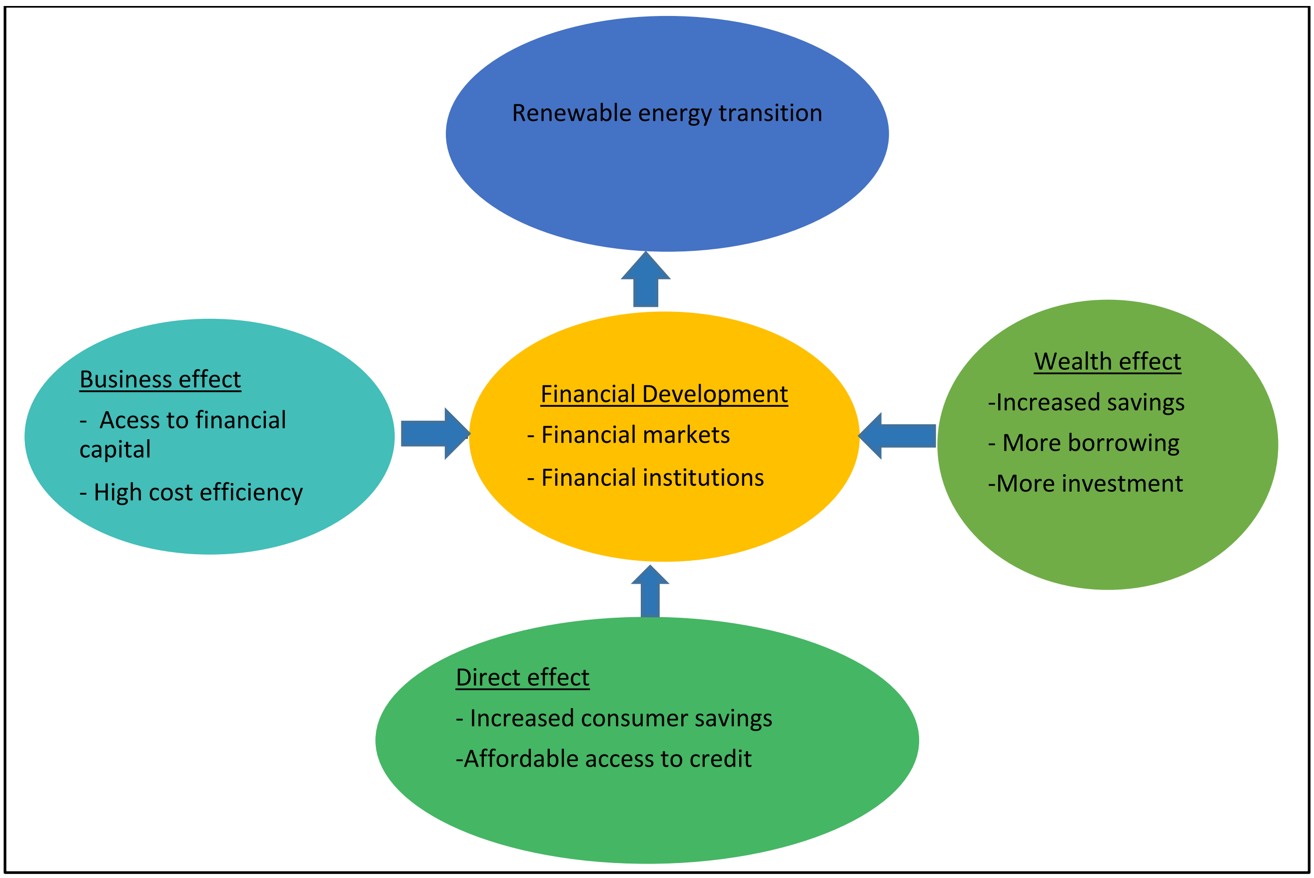
On the other hand, another strand of literature underscores that the development of the financial sector can negatively affect the transition to renewable energy, especially among early-growing economies, through several channels. First, Acheampong (2019) argues that financial development enables firms to access credit to purchase more machinery and equipment that use oils as energy sources. Financial development is also critical in unlocking industrialization that accounts for a substantial release of carbon emissions and pollution (Aye & Edoja, 2017). More evidence also shows that banks are hesitant to fund renewable energy products due to the strict Basel capital rules, which limit lending by financial institutions; hence, most renewable projects are considered hazardous (Iqbal & Mohsin, 2019; Mohsin et al., 2023). Additionally, banks' resources are derived from deposits, which are typically short to medium-term, yet renewable energy projects need long-term, resulting in a maturity mismatch for banks (Mohsin et al., 2023).

Some studies highlight the moderating effects of institutional quality in boosting the effects of financial development on renewable energy consumption (Wu & Broadstock, 2015; Nguyen et al., 2022; Mesagan & Olunkwa, 2022). Other studies show that the effect of financial development on renewable energy consumption or demand is moderated by economic growth (Saadaoui & Chtourou, 2022). Therefore, efforts to enhance financial sector development should be undertaken with institutional quality reforms and measures to boost economic growth (Sadorsky, 2010). The brief literature review shows mixed evidence on the effect of financial development on renewable energy consumption. The studies show that this effect can also vary depending on the country's development level or the financial system. Besides, it is also sensitive to the data type used, empirical model, time period, and proxy for financial development. Also, several country-specific factors (such as institutional quality) mediate the relationship between financial development and renewable energy consumption. This study builds on the previous studies to identify the empirical relationship between financial development and renewable energy transition in a panel of Sub-Saharan African countries.

2.1 Conceptual framework

The study's conceptual framework draws from Sadorsky (2010), who examines the effect of financial development on renewable transition in the context of economic growth in three ways (Figure 1). First, through the direct effect, consumers can borrow easier and cheaper and buy durable, renewable energy products. Second is the business effect through which businesses can access venture capital to invest in renewable energy. Financial development also incentivizes firms and governments to invest in environmentally friendly technology by providing access to low-cost capital, further reducing carbon emissions (Dasgupta et al., 2001; Tamazian et al., 2009). Notably, it improved financial access to the stock markets, venture capital, and credit for industries and businesses to increase renewable energy consumption and investment (Lahiani, 2021; Chang, 2015). Third, through the wealth effect, increasing transactions in the stock exchange affect the trust of consumers and businesses in the market by creating a wealth effect. Consequently, increased economic confidence boosts the economy and increases renewable energy demand. On the contrary, there is also a possibility that these developments in the financial sector can instead increase investments in fossil fuels to foster economic growth and undermine renewable energy transition, a hypothesis that this study seeks to explore.

Figure 1: The pathways of financial development effect on renewable energy transition



Source: Authors' construct based on Sadorsky (2010)

3. Methodology

3.1 Data

Our analysis in this study utilizes yearly balanced panel data from 20 countries in sub-Saharan Africa from 2000-2019. These are Angola, Burkina Faso, Benin, Chad, Equatorial Guinea, Mozambique, Mali, Uganda, Zimbabwe, Zambia, Cameroon, Democratic Republic of Congo, Ethiopia, Gabon, Togo, Senegal, Nigeria, Namibia and South Africa. We select 20 countries out of a total of 46 SSA countries because of data gaps on renewable energy transition and financial development. Notably, various SSA countries had incomplete data over the study period (2000-2019) however this was accounted for in the sample's regional, geographical, and economic representation.

The data are obtained from different sources. Data on financial development indicators were obtained from the International Monetary Fund (IMF) database. Control variables data on population, inflation rate, foreign direct investment, level of corruption, and gross domestic product (GDP) per capita were extracted from the Development Indicators Database (WDI) of the World Bank. Relatedly, we extract data on regulatory quality from the World Bank Governance indicator database of the World Bank. We further categorize the countries into middle-income and low-income SSA countries based on the World Bank Atlas classification using GDP per-capita figures[3.] Middle-income countries include Kenya, Cameroon, South Africa, Senegal, Namibia, Botswana, Zimbabwe, Gabon, Senegal, Angola, Nigeria and Equatorial Guinea. In contrast, Low-income economies include Uganda, DRC, Togo, Ethiopia, Benin, Mali, Chad, and Burkina Faso. More precisely, countries are classified as Middle-income countries if their GDP per capita is between USD 1,085 and USD 13,205, while Low-income countries have a GDP per capita below USD 1,085.

3.2 Renewable Energy Transition

The dependent variable of the study is the transition to renewable energy. However, since there is no direct measure of renewable energy transition, we use renewable energy consumption as a proxy measure for renewable energy transition based on past studies (Irfan et al., 2022; Saadaoui et al., 2022). Renewable energy consumption is measured as the share of renewable energy consumption of the total energy consumption in different countries.

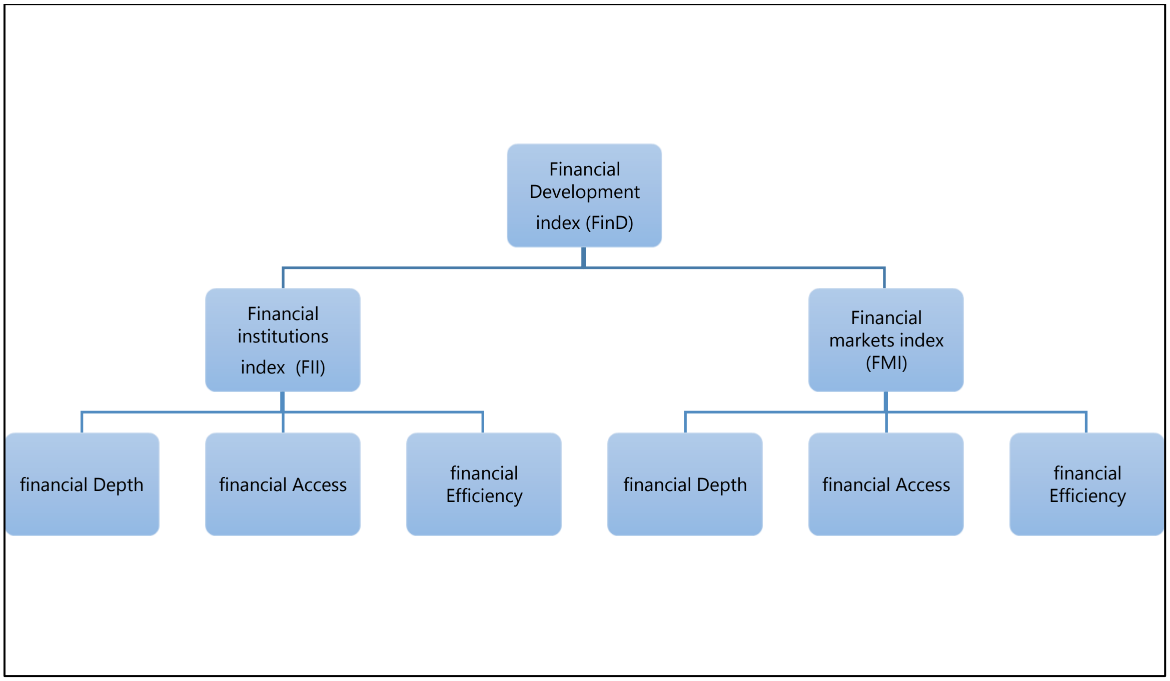
3.3 Financial development measures

[3] The World Bank uses the *Atlas* conversion factor instead of simple exchange rates to determine the economic status classification of countries worldwide. The purpose of the *Atlas* conversion factor is to reduce the impact of exchange rate fluctuations in the cross-country comparison of national incomes.

The study adopts financial development (FinD) as the independent variable of interest. Drawing on the IMF methodology by Svirydzenka (2016), financial development is measured by two components of the financial system. These are financial institutions and financial markets. Financial institutions include banks, insurance companies, mutual funds, pension funds, and other non-bank financial institutions. Financial markets entail stock markets and bonds. The performance of the financial institutions and markets is measured along three indicators of the financial system: financial depth, financial access and financial efficiency (Figure 2). Precisely, financial depth measures the size and liquidity of markets, while financial access denotes the ability of individuals and businesses to access financial services. Financial efficiency assesses the ability of financial institutions to provide financial services at a low cost. This procedure follows the OECD approach of constructing other multi-dimensional indices such as the financial inclusion index, financial stress index, Gender-inequality index, and multi-dimensional poverty index (OECD, 2008).

The sub-indices and final indices are constructed for 183 countries annually between 1980 and 2020, covering financial institutions such as banks, insurance companies, mutual funds, pension funds and other non-financial institutions, stock markets and bonds. To address the shortcomings of using single indicators as proxies for financial development, we develop several sub-indices for each of the three dimensions of FD based on the weights of different financial and institution market variables. The sub-indices are further translated into a final composite index, normalized in the range of 0 and 1, denoting the lowest and highest levels of financial development, respectively. For this study, we use three indices: 2 sub-indices (financial institutions index and financial markets index) and the composite financial development index.

Figure 2: Construction of the financial development index



Source: Svirydzenka (2016)

3.4 Control variables

Additionally, we control for other country-specific variables that may affect renewable energy consumption in the SSA region. Specifically, we include GDP per capita because it determines households' disposable incomes and, consequently, the standard of living and renewable energy use (Tudor & Sova, 2020; Ahlborg et al., 2015). Additionally, we consider regulatory quality to recognize the role of effective government regulations in formulating sound policies to promote the private sector in renewable energy investments (Khan et al., 2022; Haldar & Sethi, 2023). We also include the variable on Foreign Direct Investment (FDI) as this stimulates the investments in the production and consumption of renewable energy in the region (Adjei-Mantey, 2023; Doytch & Narayan, 2016). Evidence shows that energy prices are critical for renewable energy consumption through income and substitution effects (Anton & Nucu, 2019; Dimnwobi et al., 2022). The population variable is critical because the population stimulates demand for renewable energy (Vo, 2021). On the other hand, population also affects the use of renewable energy and exerts pressure on the environment (Mujtaba et al., 2022; Alam et al., 2016). We introduce a control variable on the colony origin to reflect the commercial laws of countries. Notably, legal systems differ markedly in their capacity to increase property rights with the common law (Beck et al., 2008). A summary of these variables and their measurement is presented in Table 1.

Table 1: Variables used in the study

Variable	Definition	Measure
Renewable energy transition	The share of total energy consumption from renewable energy	Percent
Financial development (FinD)	The composite measure of financial development in a country	Index
Foreign Direct Investment	The Foreign Direct Investments amount reported annually	US Dollars
Population	The annual population size of the country	Millions
GDP per capita	The annual Gross Domestic per capita of a country	US Dollars
Inflation (CPI)	The annual rate of inflation in a country	Percent
Trade openness	The sum of a country's exports and imports as a share of the country's GDP	Percent
British colony	A dummy variable that takes 1 if a country is a British colony	N/A
French colony	A dummy variable that takes 1 if a country is a French colony	N/A
Germany colony	A dummy variable that takes 1 if a country is a German colony	N/A
Debt (%)	The ratio of Government debt to the GDP reported annually	Percent
Regulatory quality index	An index that measures the ability of the government to formulate and implement sound policies and regulations that permit and promote private-sector development	Index
Rule of law index	An index that measures the adherence to the rule of law in a country	Index

Source: Own authors' construct

3.3 Estimation Strategy

We estimate the effect of financial development on renewable energy transition in sub-Saharan African countries using the following regression model;

$$Y_{it} = \delta_i FD_{it} + \beta_i X_{it} + \alpha_i + \varepsilon_{it} \quad (1)$$

Where Y_{it} is the renewable energy transition share of select SSA country i for the year t, FD financial development, which is the variable of interest, δ is the intercept and β, is the effect of control variables, X_{it}, α_i is the effect of the unobserved time-invariant country-specific variables while ε_{it} is the error term. Estimating equation (1) using ordinary least squares provides inefficient and biased results due to failure to account for unobserved heterogeneity across countries (Allison, 2009; Millimet & Bellemare, 2023). Put differently, these are variations across countries arising from omitted variables correlated with the outcome variable (renewable energy transition). To address this challenge, we estimate equation (1) using two comparable panel data estimation techniques: random-effects (RE) and fixed-effects (FE) models. The choice between the RE and FE models depends on this assumption. The RE estimates are appropriate if the specific country component α_i is uncorrelated to the regressors X_{it} (Tipayalai, 2020). On the contrary, the fixed effects model assumes that α_i is correlated to the regressors (country characteristics). As such, the OLS estimator would be inconsistent with RE model estimates;

hence, we adopt the third model, the fixed effects model, that takes the form of equation (1). Consequently, we choose between the fixed and random effect models based on the Hausman test criteria (Hausman, 1978). The Hausman test investigates whether the individual country errors α_i in equation (1) are correlated with regressors based on equation (2).

$$H = \left(\hat{\beta}_{RE} - \hat{\beta}_{FE}\right)' \left[Var\left(\hat{\beta}_{RE}\right) - Var\left(\hat{\beta}_{FE}\right)\right] \left(\hat{\beta}_{RE} - \hat{\beta}_{FE}\right) \quad (2)$$

Where $\hat{\beta}_{RE}$ and $\hat{\beta}_{FE}$ are the vectors of random and fixed model estimates. The Hausman tests follows a Chi-squared distribution with the number of degrees of freedom equal to the number of regressors in the model. When the Hausman statistic is greater than critical values at a 5 percent level of significance, then we conclude that there is a significant difference between random and fixed effects models. As such, we reject the null hypothesis in favour of the alternative, which implies that the fixed effects model is appropriate.

4. Results

4.1 Summary statistics

Table 2 presents descriptive statistics on the variables used in the study. The results show that renewable energy transition in SSA countries averagely grew from 9.2 percent in 2000 to 12.4 percent in 2019. Financial development rose by 0.03 index points from 0.13 to 0.16 in the same period. Financial development growth in the review period is driven by financial institutional growth (0.07 index points) compared to financial markets (0.01). This is explained by the expansion in financial innovations and financial services, such as mobile banking, targeting low-income populations and traditionally under-served territories in the region (Mlachila et al., 2016). Specifically, countries such as Kenya, Angola, Somalia, Uganda, and Tanzania have registered tremendous growth in mobile banking strategies that increased credit access to firms and people. On the contrary, financial markets reflected in the Financial Markets Index (FMI) in SSA countries have remained weak from 0.005 in 2000 to 0.006 in 2019. Additionally, the average GDP per capita of the selected countries over the two decades increased from USD 882 to USD 2,682. The results further suggest that, of the selected countries, 35 percent had French colonial history, 30 percent had British colony history, and 35 percent had German colony history.

Table 2: Summary statistics of the variables used in the study

	2000					2019			
Variable	N	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Renewable energy transition	400	9.16	8.14	0.20	23.2	12.35	13.93	0.90	63.1
Population ('Millions')	400	2.13	2.88	0.61	122.2	3.53	4.67	1.33	201.5
GDP per capita (USD)	400	882	1112	124	4136	2682	2736	507	8381
Financial Development (FinD)	400	0.13	0.10	0.05	0.49	0.16	0.14	0.04	0.64
Financial Markets Index (FMI)	400	0.05	0.005	0.000	0.043	0.06	0.11	0.005	0.43
Financial Institutions Index (FII)	400	0.20	0.13	0.08	0.55	0.27	0.17	0.13	0.72
FDI (USD million)	400	174.4	134.1	7.0	396.0	153.2	109.4	8.0	377.0
British colony	400	0.30	0.47	0.00	1.00	0.30	0.47	0.00	1.00
French colony	400	0.35	0.49	0.00	1.00	0.35	0.49	0.00	1.00
Germany colony	400	0.35	0.49	0.00	1.00	0.35	0.49	0.00	1.00
Trade openness (%)	400	4.03	0.48	3.18	5.03	4.06	0.35	3.36	4.72
Debt (%)	400	57.8	24.4	26.4	113	73.9	55.5	20.8	260.9
Inflation (%)	400	1.72	1.96	-0.68	6.24	1.67	1.39	-0.38	5.54
Rule of law index	400	-0.64	0.61	-1.70	0.31	-0.66	0.45	-1.42	0.31
Regulatory quality index	400	-0.54	0.70	-2.30	0.33	-0.66	0.44	-1.52	0.16

Source: Authors' construct based on the study data

4.1.1 Correlation matrix of the variables in the study

Table A1 presents the correlation between the variables in the study. The results show a weak but positive relationship between the two variables. Also, the degree of association between any two variables is less than 0.8 in absolute terms, which requires no multicollinearity (Studemund, 2001). Consequently, we take all the variables for multivariate analysis.

4.2 Empirical results

The section presents the results on the effect of financial development on renewable energy transition in the sampled low-income and middle-income SSA countries. Specifically, we estimate the relationship between financial development and renewable transition for the sample in section 4.2.1 based on the fixed and random effects regression estimates. To take into account heterogeneity across the Low-income and middle-income countries while controlling for potential endogeneity, we estimate the equation (1) based on the two-stage Least Squares instrumental variable technique in subsection 4.2.2

4.2.1 Random and Fixed Effects Estimates

Table 3 reports regression results that examine the relationship between financial development and renewable energy transition using a total sample of SSA countries. First, we estimate Equation 1 using random and fixed effects in models (1) and (2), respectively. We measure financial development using the financial development composite index in both models. We then evaluate the two model results using the Hausman specification test with the null hypothesis that the difference in coefficients in the two models is not systematic. Based on the Hausman statistic (13.04), we reject the null and conclude that the regression results are statistically significant. Consequently, we reject the null and draw our results on the fixed effects approach in model 2.

For robustness, we use the fixed effects in models 3 and 4 to estimate the impact on renewable energy consumption. However, instead of using the composite Financial Development Index (FinD), we use the proxy measures of the Financial Markets Index (FMI) and Financial Institutions Index (FII), respectively.

Overall, the results suggest that financial development positively and significantly affects the transition to renewable energy. On average, a 10 percent increase in financial development (through financial institutions) is associated with 0.1 percent growth in the renewable energy transition, holding other factors constant. This implies that the pathway for the financial development effect on renewable energy transition is only through financial institutions such as banks, SACCOs and fin-techs as opposed to financial market instruments such as bonds, treasury bills and equities. These findings are consistent with previous studies (Anton & Nucu, 2019; Dimnwobi et al., 2022; Dumrul, 2018). Indeed, financial development promotes new savings, private credit and financial innovations that foster investments and consumption of renewable energy products (Mukhtarov et al., 2020). In line with Saadaoui and Chtourou (2022), we find that such investments in the renewable energy sector is accelerated and sustained by the growing demand for renewable energy products. Therefore, efforts to create a sound financial institutions environment must go hand in hand with stimulating or incentivizing demand for renewable energy products and services. Whereas financial markets in Africa are fairly developed to significantly impact the development and consumption of renewable energy, our findings suggest that the continent can, especially with the AfCFTA in place, facilitate this transition. Succinctly, efforts to bolster the development of the financial system (institutions and markets) is critical for fast-tracking green energy investments and demand as Kim and Park (2016) show.

As for the control variables, our results also suggest that debt is positively associated with the transition to renewable energy. This is especially the case where green financing (debts) is increasingly allocated to renewable energy investments to sustainable growth. Indeed, several countries in SSA have received loans to support their efforts to meet SDGs and promote green investments. Our finding is consistent with the fact that non-concession debt is the primary source of financing for renewable energy, such as leasing or bonds and non-recourse loans (UNEP, 2016; IRENA, 2020). It is also corroborated by Streimikiene and Kaftan (2021) and Zhou et al. (2020) who find that green finance could promote environmental sustainability. Indeed, efforts to accelerate the transition to clean energy and low-carbon economic investments could be financed through green bonds along side other innovative financing models.

As expected, the results also suggest a positive impact of foreign direct investments (FDI) on the transition to renewable energy, which encourages high capital flows to facilitate energy investments in solar considering the high start-up cost requirements in renewable energy. This finding is consistent with previous studies which show that an increase in FDI accelerated the adoption of renewable energy (Doytch & Narayan, 2016; Ergun et al., 2019; Dossou, 2023). The effect of FDI is positive but conditional on directing FDI inflows toward renewable energy investments, and the onus is upon countries to incentive clean energy investments. More so, the high initial costs are rarely manageable by a few local firms. However, this finding is inconsistent with Khan et al. (2021) who find that that FDI had a negative impact renewable energy.

Since trade openness comprises imports and exports, where most SSA countries are net importers, more countries have higher import bills that substitute investments and consumption in renewable energy sources. These findings agree with studies by Khan et al. (2022) and Yu et al. (2019), who find that import growth increases carbon emissions and reduces renewable energy transition. Specifically, net importing countries suffer higher expenditures on oil imports, a substitute for renewable energy sources. However, as their exports increase and their income level grows, their investments in renewable energy increase. This, therefore, justifies why the effect of trade openness with middle-income countries is positive, though insignificant.

Table 3: Regression analysis on the drivers of renewable energy transition

	Dependent variable: Renewable energy transition			
	FinD (Random effect)	FinD – (Fixed effects)	FMI – (Fixed effects)	FII- (Fixed effects)
Variables	(1)	(2)	(3)	(4)
Log FinD	0.608***	0.872***	-0.016	0.918***
	(0.220)	(0.251)	(0.086)	(0.239)
Log Population	0.001	0.003	0.046	-0.004
	(0.033)	(0.034)	(0.042)	(0.034)
Log GDP percapita	0.122	0.119	0.302***	0.071
	(0.082)	(0.085)	(0.081)	(0.088)
Log Inflation	0.043	0.042	0.060*	0.042
	(0.033)	(0.033)	(0.033)	(0.033)
British*Log FinD	-0.451	-0.812**	-0.025	-0.609
	(0.304)	(0.369)	(0.102)	(0.441)
French*Log FinD	0.008	-0.506	0.033	-0.821*
	(0.285)	(0.429)	(0.087)	(0.437)
Log FDI	0.058*	0.061*	0.055*	0.055*
	(0.031)	(0.032)	(0.031)	(0.031)
Log Debt	0.205***	0.208***	0.234***	0.199***
	(0.053)	(0.054)	(0.055)	(0.055)
Regulatory quality index	-0.080	-0.128	-0.071	-0.198
	(0.155)	(0.160)	(0.157)	(0.159)
Log Trade openness	-0.277**	-0.255*	-0.195	-0.191
	(0.130)	(0.136)	(0.131)	(0.137)
Constant	1.950	1.777	-0.987	1.589
	(1.239)	(1.213)	(1.012)	(1.245)
Observations	390	390	392	392
R-squared	0.170	0.146	0.103	0.150
Number of Countries	20	20	20	20
Hausman test p-value	13.04 (0.004)			

Note: (i) Standard errors are reported in the parentheses. (ii) *, **, *** indicate significance at the 90%, 95% and 99% level, respectively. (ii)Germany colony**X**FD is the reference category.

4.2.2 Robustness checks

In this section, we examine the robustness of our results in section 4.2.1 from several perspectives. While the results in Table 3 are suggestive, they do not prove a causal relationship running from financial development to renewable energy transition. First, the relationship between financial development and renewable energy transition may be endogenous owing to omitted variables, reverse causality and measurement errors. For instance, the consumption of renewable energy, such as solar energy, by households and firms could lead firms and households to save on energy costs but also use fin-tech and mobile money saving and increase financial development, just as is the case for many African countries, such as Kenya (Rom, 2018; Wagner et al., 2021; Grimm et al., 2017).

To address this challenge, we re-estimate the effect of financial development on renewable energy transition using the two Stage Least Squares (2SLS) instrumental technique with a set of instruments as proxies for financial development. Specifically, we use two types of instruments. The first set includes the lagged values of the endogenous variables – Financial development. Here, we use the second lags and higher levels of financial development to avoid autocorrelation with the current error term (Zhang & Naceur, 2019; Wang & Bellemare, 2019). The second instrumental variable is the rule of law in different countries, which reflects the different countries (Becker & Levine, 2004; Zhang & Naceur, 2019). Specifically, we use the rule of law index as one of six dimension measures of governance indicators by the World Bank.

The instruments isolate the causal effect of financial development on the transition to renewable energy. In the second estimation (model 2), we still use the 2SLS technique, but instead of using the total sample of countries, we sub-divide the sample into two categories based on economic classification: the low-income countries and middle-income countries to explore the heterogeneity between the two groups as earlier classified. For the last models (4) and (5), we re-estimate the impact of renewable energy transition in the low-income and middle-income SSA countries using sub-indices, the Financial institutions index and the Financial markets index, respectively, as alternative measures of financial development. To test the suitability of the instruments, we adopt the Hansen test of the over-identifying restrictions. The test assesses whether the instrumental variables are associated with the dependent variable beyond their ability to explain cross-country variation in financial development. The joint null hypothesis is that the excluded instruments (i.e., those not included in the second stage regression) are valid and uncorrelated with the error term.

The emerging results in Table 4 are interesting. Overall, the results confirm a positive association between financial development and renewable energy transition. However, a disaggregated analysis of the SSA countries based on their economic classification reveals that financial development is not associated with growth in renewable energy transition in middle-income countries. On the contrary, the effect is significantly positive for low-income countries.

Specifically, a 10 percent growth in financial development is associated with a 0.2 percent growth in the renewable energy transition in low-income countries. These findings allude to previous studies by Anton et al. (2020), Acheampong et al. (2019), and Uzar (2020), which argue that economic growth promotes unprecedented energy demand for economic and industrial activities. This demand is easily met by low-cost fossil fuels rather than renewable energy projects, which suffer high upfront costs in the region. Indeed, evidence suggests that renewables are still more expensive than fossil fuels in the SSA region due to long-term subsidies for fossil fuels (Adedoyin et al., 2021; Asongu et al., 2019; Wesseh & Lin, 2016). For instance, fossil fuels such as coal, oil and gas are still widely used for power generation and industrial processes in industrious SSA countries such as South Africa and Nigeria because of their affordability (Mkhize, 2022; IRENA, 2021a).

Relatedly in some oil-rich countries, a permanent move from using fossil fuels would be a considerable reduction in the value of their national and natural wealth- for example, Nigeria earns 67 percent of her national revenue from the oil and gas industry (Cust et al., 2017; Okutoyi, 2019). Consequently, efforts by financial sector actors such as banks and insurance companies are geared towards more fossil fuel production and consumption, contrary to facilitating renewable energy investments (Gençsü et al., 2022). For example, Nigeria subsidizes fossil fuel production up to USD 2.5 billion yearly. Conversely, other middle-income countries, Angola, Côte d'Ivoire, Tanzania, Zambia, and Zimbabwe, each subsidized fossil fuel production by more than USD1 billion in 2015 (Okutoyi, 2019).

Specifically, these findings suggest that middle-income countries are still hesitant to embrace the transition of renewable energy from fossil fuels for industrial and foreign exchange purposes (for oil production countries). On the contrary, the positive and significant sign in the low-income countries signals the recent growth of renewable energy investments by developing countries, especially solar energy, to close the energy deficit. Findings from the 2015 global trends in renewable energy investment report show that for the first time, investment in renewable energy, excluding large hydro in developing countries, outweighed that of developed economies due to dropping costs in installation of solar energies (UNEP, 2016). Further, the recent financial innovation models in renewable energy, such as the 'Pay as you go' business models, have enabled poor households in Uganda, Kenya and Rwanda to access affordable solar energy regularly through credit-enabled mobile payment technologies (Mukisa et al., 2022, IRENA, 2020)

The transition to renewable energy is also associated with growth and public debts in the SSA middle-income countries. This alludes to the improved effectiveness of these countries in utilizing borrowed funding in renewable energy investments compared to their low-income counterparts. The failure in low-income countries could result from poor institutional quality and corruption that impede the delivery of services in these countries. The results also show that trade openness is associated with a low transition to renewable energy because most exports are driven by high import bills on non-renewable energy products in African countries.

Table 4: Regression analysis on the drivers of renewable energy transition based on the 2SLS technique

	(1)	(2)	(3)	(4)	(5)
	Full country samples	Middle-income countries	Low-income countries	Middle-income countries	Low-income countries
Variables					
Log FinD	1.210**	-0.049	1.289***	-0.436	1.730***
	(0.659)	(0.590)	(0.380)	(3.284)	(0.427)
Log Population	0.004	0.003	0.010	0.005	0.012
	(0.034)	(0.066)	(0.030)	(0.068)	(0.031)
Log GDP percapita	0.032	0.146	-0.130	0.164	-0.346***
	(0.105)	(0.177)	(0.094)	(0.222)	(0.130)
Log Inflation	0.026	-0.000	0.006	-0.005	0.001
	(0.034)	(0.080)	(0.024)	(0.089)	(0.025)
British*Log FD	-0.837	0.456	-0.342	0.138	-0.267
	(0.656)	(0.6753)	(0.374)	(1.530)	(0.347)
French*Log FD	-0.728	1.836*	-1.354***	2.180	-1.546***
	(0.750)	(0.962)	(0.459)	(3.076)	(0.460)
Log FDI	0.064**	0.151**	0.047**	0.149*	0.037*
	(0.032)	(0.080)	(0.022)	(0.081)	(0.023)
Log Debt	0.219***	0.372***	-0.031	0.381***	-0.052
	(0.056)	(0.102)	(0.052)	(0.120)	(0.056)
Regulatory quality index	-0.063	0.061	-0.066	0.073	-0.194
	(0.182)	(0.412)	(0.130)	(0.423)	(0.148)
Log Trade	-0.209*	0.202	-0.294***	0.224	-0.221**
	(0.143)	(0.452)	(0.094)	(0.481)	(0.104)
Constant	2.302	-0.188	5.358***	-0.465	6.472***
	(1.487)	(3.033)	(1.236)	(3.686)	(1.366)
Observations	400	240	160	240	160
Hansen J statistic	0.1328	0.199	0.3159	0.567	0.4562
Number of Country	20	12	8	12	8

*Note: (i) Standard errors are reported in the parentheses. (ii) *, **, *** indicate significance at the 90%, 95%, and 99% level, respectively. (ii)Germany colony**X**FD is the reference category*

5. Conclusion

In this study, we examine the effect of financial development using panel data from 20 low-income and middle-income countries in sub-Saharan Africa. Specifically, our analysis employs the panel fixed effects model and 2SLS instrumental variable model to account for unobserved heterogeneity and endogeneity, respectively, in the analysis, which could bias the estimates.

Our results show that financial development marked by expanding savings and private credit provisions to investors accelerates renewable energy consumption in SSA. Specifically, a 10 percent increase in financial development is associated with a 0.1 percent growth in the renewable energy transition in SSA countries. Surprisingly, the results show that the effect of financial development on renewable energy consumption is higher and more significant in low-income countries compared to middle-income countries. Specifically, a 10 percent growth in financial development is associated with a 0.2 percent growth in the renewable energy transition in low-income countries. This alludes to the fact that growth in industrial activity in SSA countries largely depends on fossil fuels rather than renewable energy. Hence, the financial sector is more attracted to invest in fossil fuels than renewable energy.

The results further suggest that financial institutions such as banks, insurance companies, and fin-tech, among others, are the pathway for transitioning to renewable energy instead of financial markets. This is because financial market instruments such as green bonds, carbon pricing, and venture capital still need to be developed in Africa and do not foster investments in green energy. These findings remain robust regardless of the measure of financial development, financial institutions index, or the financial markets and after controlling for potential endogeneity in the estimation.

Our findings also show that public debt is associated with higher levels of renewable energy transition in middle-income countries than in low-income countries. This alludes to the improved effectiveness of middle-income countries in utilizing borrowed concessional funding to promote clean energy investments compared to their low-income counterparts. The results further suggest that trade openness negatively affects renewable energy transition mainly because of most SSA countries' disproportionate share of non-renewable imports.

Our study is without limitations. First, we use a sample of 20 SSA countries for our analysis for a period up to 2019, which was the latest period of data availability. As a result, more sample data from more countries and more recent years might yield more reliable findings. Second, the study uses a limited number of control variables that could have an impact in the estimation of the effect of financial development on renewable energy transition. We had to make trade-offs between the amount of variables included in the analysis and the number of nations taken into account. Consequently, once the data are accessible, future research may consider more control factors and more nations. For instance, variables such as digital financial innovation in financial markets and institutions could be critical for renewable energy transition in future in light of the rising trends of digitalization in Africa (Cao, 2023).

Recommendations and policy implications

The study finds that financial markets, unlike financial institutions, are not associated with renewable energy transition in SSA countries mainly because they are not adequately developed to spur renewable energy transition. Therefore, governments and the private sector need to further develop and promote innovative green financial market products that provide cheap capital and private credit to private investments in clean energy. Well-functioning capital markets increase trust among potential clean energy investors and enhance financial flows among SSA countries and actors. More so, innovative financing instruments in green and sustainable finance such as social bonds, green bonds and loans, carbon pricing, and green digital products need to be developed and popularized among the Micro, Small and Medium (MSME) enterprises to provide access to affordable business capital for clean energy investments. This will facilitate the region's transition from non-renewable to renewable energy sources.

Since public debt is associated with the transition to renewable energy, more concessional clean energy finance targeting clean energy investments in Africa needs to be provided to financial institutions such as banks and microfinance institutions to support and attract private sector investments in renewable energy. Increased green financing de-risks heavy renewable energy investments such as off-grid solar infrastructure, making them competitive and affordable against non-renewable sources. However, for blended financing to work for clean energy transition, especially for Low-income countries, deliberate efforts are imperative to address corruption and mismanagement, delays and bureaucracy. This will increase the overall efficiency of the debt finance and foster the implementation of clean energy initiatives.

To realize the gains in clean energy transitions through trade, SSA countries need to promote the importation of green energy products through subsidy programmes. Subsidies towards the increase of clean manufactured imports such as solar panels and electric cars as opposed to non–renewable products will reduce the use of fossil fuels and promote efforts to achieve a renewable energy transition in Africa. Relatedly, taxing non-renewables that use fossil fuels is also critical.

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Table A1: The correlation between the different variables used in the study

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
(1) Log Renewable Energy	1.000							
(2) log Financial Development	0.163***	1.000						
(3) log Inflation	0.001	0.146***	1.000					
(4) log Trade	-0.138**	-0.448**	0.096**	1.000				
(5) log Debt	0.321**	-0.037	0.150**	-0.055	1.000			
(6) log FDI	0.006	0.087	-0.230**	-0.194***	-0.138***	1.000		
(7) Log GDP	-0.073	0.453***	-0.104*	0.087	-0.420***	-0.018	1.000	
(8) Log Population	0.158***	0.251***	0.346***	-0.172***	0.045	0.023	-0.275	1.000

Source: Authors' computation based on the study data