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January 2020

A G D I Working Paper

WP/20/084

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Forthcoming: Renewable Energy

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2020 African Governance and Development Institute WP/20/084

Research Department

Inequality, Finance and Renewable Energy Consumption in Sub-Saharan Africa

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Abstract

The study investigates linkages between financial development, income inequality and renewable energy consumption from 39 countries in Sub-Saharan Africa. The empirical evidence is based on data for the period 2004-2014, Generalized Method of Moments (GMM) and Quantile Regressions (QR). The GMM results show that financial development unconditionally promotes renewable energy consumption while income inequality counteracts the underlying positive effect. The QR results reveal that the GMM findings only withstand empirical validity in bottom quantiles of the renewable energy consumption distribution. In order to increase room for policy implications for the promotion of renewable energy consumption, critical masses of income inequality that should not be exceeded are computed for bottom quantiles of the renewable energy consumption distribution while income inequality thresholds that should be exceeded are computed for top quantiles of the renewable energy consumption distribution. The study reconciles two strands of the literature. Theoretical, practical and policy implications are discussed.

JEL Codes: H10;Q20; Q30; O11; O55

Keywords: Renewable energy; Inequality; Finance; Sub-Saharan Africa; Sustainable development

1. Introduction

This research is premised on four fundamental elements from scholarly and policy-making circles. These four main grounds include: (i) the troubling concern of environmental pollution across the world in general and sub-Saharan Africa (SSA) in particular; (ii) debates in the extant literature on the nexus between financial development and environmental degradation[1]; (iii) contribution of the study to the attendant literature and (iv) relevance of the study to the sustainable development agenda in terms of sustainable development goals (SDGs). The four critical elements surrounding the positioning of the study are elicited in the same order as highlighted.

Concerns of environmental degradation and shortage of energy are most apparent in developing countries, especially countries located south of the Saharan desert (i.e. SSA countries) because of *inter alia*, the sub-region is characterized by energy grid systems that are some of the worst in the world (Jarrett, 2017; Asongu, Iheonu & Odo, 2019). Moreover, the attendant literature has also documented that the sub-region would be worst hit by the consequences of climate change (Asongu & Odhiambo, 2020a, 2020b). In essence, given that the electricity produced in the whole of SSA is equivalent to that produced in the State of New York of the United States of America (USA), contemporary literature is consistent with the position that apart from the absence of inclusive development which represents a major development challenge in the region, issues relevant to environmental degradation, climate change, low usage of renewable energy and exclusive growth are largely traceable to, *inter alia*, lack of funding and poor financial development (Nathaniel & Iheonu, 2019; Asongu & Odhiambo, 2019a, 2019b Akinyemi, Efobi, Asongu & Osabuohien, 2019; Nathaniel & Bekun, 2020; Joshua & Alola, 2020; Asongu, Agboola, Alola & Bekun, 2020; Joshua, Bekun & Sakordie, 2020). However, despite the documented importance of funding and financial development in promoting environmental sustainability and a green economy, there is no consensus in the literature on how finance affects various dimensions of the green economy.

There are two main strands in the literature on the nexus between finance and environmental degradation in terms of carbon dioxide (CO_2) emissions. The first strand posits that financial development contributes towards promoting the green economy by mitigating CO_2 emissions. Some studies in this strand encompass, *inter alia*: Tamazian, Chousa and Vadlamannati (2009); Dogan and Seker (2016); Shahbaz, Tiwari and Nasir (2013); Jalil and Feridun (2011); Xiong and Qi (2018); Omri, Daly, Rault and Chaibi. (2015); Xing et al.

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[1] Hence, finance, financial development and financial access are used interchangeably throughout the study.

(2017); Saidi and Mbarek (2017); Tamazian and Rao (2010); Zaidi, Zafar, Shahbaz and Hou. (2019) and Zafar, Saud and Hou (2019). The second strand of studies entails research that has found that financial development can reduce environmental sustainability by increasing carbon emissions: Al-Mulali, Ozturk and Lean. (2015); Boutabba (2014); Zhang (2011); Shahbaz, Shahzad, Ahmad and Alam (2016); Bekhet, Matar and Yasmin. (2017); Cetin, Ecevit and Yucel (2018); Ali et al. (2018) and Lu (2018). The present study contributes to the extant literature by assessing how income inequality moderates the effects of financial development on renewable energy consumption in SSA.

There is one main shortcoming that is apparent from the engaged literature in the previous paragraph: a policy dimension is missing the investigated nexuses. This study argues that simply establishing whether financial development influences environmental degradation or not, is not enough because policy makers need to be provided with some policy tools on how to influence the nexuses. By assessing the nexuses among finance, inequality and renewable energy consumption, the present study also improves the policy relevance of the associated findings by establishing income inequality thresholds at which financial development increases or decreases renewable energy consumption. Accordingly, the dimension of inequality is particularly relevant for the sub-region in the light of challenges to SDGs in SSA.

The closest paper to this study in the literature is Odhiambo (2020) which has investigated linkages between CO_2 emissions, inequality and financial development in SSA using the Generalized Method of Moments (GMM). This study extends Odhiambo (2020) in at least two ways. (i) It focuses on renewable energy consumption instead of CO_2 emissions in order to assess whether the findings of the underlying study withstand empirical scrutiny when another dependent variable on environmental sustainability is taken on board. It is important to clarify that CO_2 emissions is an environmental sustainability variable with a negative signal whereas renewable energy consumption is an environmental sustainability variable with a positive signal. (ii) The findings based on GMM provide blanket policy implications because the attendant estimations are based on mean values of the outcome variable. Accordingly, assessing the underlying linkages without accounting for initial levels of the outcome variable may provide ineffective policy implications unless the estimations are contingent on the initial levels of the environmental sustainability variable and tailored differently across countries with low, intermediate and high levels in the environmental sustainability variable. Hence, contrary to Odhiambo (2020), the study examines the underlying nexuses throughout the conditional distribution of renewable energy consumption.

The concern of inequality is particularly relevant in the post-2015 development agenda because most countries in the sub-region (i.e. approximately 45%) did not achieve inclusive development target of reducing extreme poverty by half by 2015 despite over two decades of renewed in economic growth (Tchamyou, 2019a, 2019b). Moreover, current projects suggest that unless income inequality levels are reduced by means of the equitable distribution of the fruits of economic prosperity, the 2030 sustainable development extreme poverty target would still not be achieved in the sub-region (Bicaba, Brixiova & Ncube, 2017). Moreover, environmental sustainability is also fundamental in the post-2015 development agenda in the light of the universal objective of promoting (limiting) renewable energy consumption (CO_2 emissions) in economic and households activities (Mbah & Nzeadibe, 2016; Asongu, El Montasser & Toumi, 2016; Asongu, le Roux & Biekpe, 2017).

It is worthwhile to also emphasize that, in addition to departing from the mainstream literature on the finance-"environmental sustainability" nexus as discussed above, the focus of this study also steers clear of the two main strands of environmental sustainability literature, notably on, nexuses between economic development, energy consumption and energy pollution. The first group has focused on linkages between environmental degradation and economic growth (Layachi, 2019; Bah, Abdulwakil & Azam, 2019; Bah, Abdulwakil & Azam, 2020; Magazzino, Bekun, Etokakpan & Uzuner, 2020) while the second is concerned with nexuses between energy consumption and pollution of the environment (Wang & Dong, 2019; Adams & Nsiah, 2019; Nathaniel & Iheonu, 2019; Akinyemi, Efobi, Osabuohien & Alege, 2019; Acheampong, Adams &Boateng, 2019; Kuada & Mensah, 2020).

The remainder of the paper is structured as follows. The theoretical underpinnings linking finance, inequality and energy consumption on the one hand and, the conditional nature of the attendant linkages, on the other hand, are discussed in Section 2. Section 3 covers the data and methodology while Section 4 presents and discusses the empirical results. The study concludes in Section 5 with implications and future research directions.

2. Theoretical underpinnings on nexuses between finance, inequality and energy consumption

2.1 Nexuses between finance, inequality and energy consumption

This study posits that financial development promotes renewable energy consumption (*Hypothesis* 1) and the attendant nexus is dampened by income inequality because, with higher levels of inequality, few individuals in society have the financial means to recourse to renewable energy consumption (*Hypothesis* 2). Hence, in this section, the intuition surrounding the relationships among financial development, income inequality and sustainable development in terms of renewable energy consumption are discussed. According to Tchamyou, Erreygers and Cassimon (2019a), two theoretical views are apparent on the nexus between financial development and other economic development outcomes.

In the light of the first theoretical perspective, financial development promotes economic development (i.e. entailing renewable energy consumption) by reducing income inequality while, the second theoretical perspective maintains that financial development does not engender positive economic development outcomes (i.e. including renewable energy consumption) because of apparent concerns of information asymmetry that limit access to the much needed finance for economic development (Kusi, Agbloyor, Ansah-Adu & Gyeke-Dako, 2017; Kusi & Opoku- Mensah, 2018; Kusi, Agbloyor, Gyeke-Dako & Asongu, 2020). Of the two strands, the hypotheses underlying this study are more in accordance with the former strand given that financial development is considered as a means of promoting renewable energy consumption and income inequality can potentially mitigate the favorable role of financial development in outcomes of environmental sustainability such as renewable energy consumption. The counteracting role of inequality in the underlying nexus is based on the established theoretical evidence that income inequality severely limits the relevance of financial development in development outcomes (Galor & Zeira, 1993; Galor & Moav, 2004; Aghion & Bolton, 2005). Intuitively, renewable energy consumption is connected with financial development, as clarified in Section 2.2.

The contending strand of literature maintains that financial development is more beneficial to the wealthy in society, compared to the poor and hence, the poor are obliged to recourse to the non-formal financial sector owing to constraints of information asymmetry between banks and clients in the formal financial sector (Asongu, Nwachukwu & Tchamyou, 2016). It follows that due to constraints surrounding financial access in the formal banking sector, the poor mostly rely on remittances and the non-formal financial sector (Beck, Demirgüç-Kunt & Levine, 2007; Ssozi & Asongu, 2016). The above insights motivate the following testable hypotheses.

Hypothesis 1: Financial development promotes renewable energy consumption

Hypothesis 2: Income inequality dampens the favourable incidence of financial development on renewable energy consumption

The highlighted hypotheses also align with a third theoretical strand of the debate which reconciles the first and second strands by positing that a non-linear relationship is apparent between financial development and development outcomes (Greenwood & Jovanovic, 1990; Asongu & Tchamyou, 2014). The non-linear aspect of the debate is captured by *Hypothesis* 2 because it is based on interactive regressions, since the purpose of the study is to assess income inequality thresholds that influence *Hypothesis* 1 or how financial development promotes renewable energy consumption. Moreover, the non-linear nexuses covered so far are related to independent variables of interest. However, in the light of the motivation of the study, the non-monotonic element of the study is also articulated in the dependent variable because the investigated relationships are emphasized throughout the conditional distribution of the dependent variable in order to highlight countries with a low, intermediate and high initial level of the outcome variable.

2.2 The conditional relationship

Consistent with the motivation in the introduction, in order to increase the policy relevance of this study, the paper departs from the extant literature by assuming that countries with high initial levels of renewable energy consumption respond differently to *Hypotheses* 1-2, compared to their counterparts with low initial levels of renewable energy consumption (i.e. *Hypothesis* 3). The underlying assumption, therefore, attempts to reconcile the mainstream debate on the relationship between financial development and environmental sustainability because both strands of the debate can be validated when renewable energy consumption is assessed throughout the conditional distribution of renewable energy consumption. In what follows, the two main strands of the debate are briefly expanded before a statement of the attendant hypothesis which aims to reconcile both strands of the debate in the same specification or modelling exercise.

The first stand of the debate maintains that financial systems that are developed provide financial assistance to domestic economic activities for the purposes of *inter alia*, the acquisition of clean and environmentally-friendly technology, which could ultimately contribute towards promoting a green economy especially by means of renewable energy consumption (Yuxiang & Chen, 2011). In essence, in a financial system that is developed, it is expected the funds are sufficiently available to fund environmentally sustainable initiatives from existing businesses and new ventures (Frankel & Rose, 2002). Moreover, according to the narrative, a developed financial system improves conditions for the attraction of foreign investors which are susceptible to attracting investments in research and development (R&D) schemes and clean energy. It is also worthwhile to articulate that, a technology that promotes environmentally-friendly schemes are associated with renewable energy consumption and it has been documented that foreign investment can be tailored to assisting host/domestic economies especially developing countries in funding renewable energy schemes (Paramati, Apergi & Ummalla, 2017; Paramati, Mo & Gupta, 2017; Kutan, Paramati, Ummalla & Zakari, 2017). In essence, financial development within the spectrum of stock market development has the potential of punishing businesses that are not environmentally friendly (Salinger, 1992) and rewarding businesses that are friendly to the environment (Klassen & McLaughlin, 1996).

The second strand is sympathetic to the perspective that, financial systems that are developed might contribute to environmental degradation and pollution through increase in CO_2 emissions and reduction in renewable energy consumption (Minetti, 2011; Aye & Edoja, 2017; Xing et al., 2017). To put this point into perspective, Aye and Edoja (2017) have argued that financial development resulting from financial assistance that is granted to domestic firms could improve enterprising in areas which ultimately engender environmental unsustainability in terms of CO_2 emissions, environmental pollution and land degradation. Xing et al. (2017) posit that by augmenting credit to clients and by extension, development of the financial system, could increase purchases in a plethora of equipment such as automobile and other facilities that consume energy. The above narratives are consistent with some scholarly views maintaining that, compared to other financial institutions; banks are more likely to increase activities that are associated with environmental degradation. This is essential because, as argued in Minettit (2011), the fact that banks are conservative on the technical front induces them to be more averse to funding new, cleaner and riskier technologies.

In the light of the above, it is not intuitive to expect blanket nexuses among inequality, financial development and renewable energy consumption in the sampled countries because countries with high initial levels of renewable energy consumption may respond differently compared to their counterparts with low initial levels of renewable energy consumption.

Hypothesis 3: Countries with low initial levels of renewable energy consumption respond differently to their counterparts with high initial levels of renewable energy consumption in the nexuses among financial development, inequality and renewable energy consumption.

In order to assess the validity of the attendant hypothesis, quantile regressions are used because such an estimation technique is tailored to account for the entire distribution of the outcome variable (Koenker & Bassett, 1978; Koenker, 2005; Hao & Naiman, 2007; Asongu, 2013). Hence, in the corresponding empirical analysis, the estimation technique accounts for low, intermediate and high initial levels of the outcome variable or renewable energy consumption.

3. Data and methodology

3.1 Data

In order to examine if the stated hypotheses in the previous section withstand empirical scrutiny, the present study focuses on a panel of 39 SSA countries with data for the period 2004-2014[2]. The time and geographic dimensions of the sample are informed by constraints in data availability at the time of the study. The data are obtained from four main sources, namely, the: (i) World Development Indicators (WDI) of the World Bank; (ii) Financial Development and Structure Database (FDSD) of the World Bank; (iii) World Governance Indicators (WGI) of the World Bank and (iv) Global Consumption and Income Project (GCIP).

The inequality indicators are obtained from the GCIP, namely: the Gini coefficient, the Atkinson index and the Palma ratio. The choice of these three inequality indicators is informed by the contemporary inclusive development literature which is consistent on the need to complement the Gini coefficient with other inequality indicators that articulate extreme points of the inequality distribution (Tchamyou et al., 2019a; Meniago & Asongu, 2018; Naceur & Zhang, 2016). Hence, the purpose of engaging inequality indicators that capture both the mean (i.e. the Gini coefficient) and the tails (i.e. the Atkinson index and the Palma ratio) of the inequality distribution is to provide findings that are robust to the entire distribution of income inequality dynamics. The corresponding definitions are as follows: (i) the Gini coefficient is understood as the distribution of national wealth across the population. (ii) The Atkinson index shows the percentage of overall income that a given society is prepared to sacrifice in order to enhance equality in income distribution across the population. (iii) The Palma ratio mirrors the share of national income of the top 10% of households against the bottom 40%.

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[2] The 39 sampled countries are: “Angola; Benin; Botswana; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Congo Democratic Republic; Congo Republic; Cote D’Ivoire; Eswatini; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritius; Mozambique; Namibia; Niger; Nigeria; Rwanda; Sao Tome and Principe; Senegal; Seychelles; Sierra Leone; South Africa; Sudan; Tanzania, Togo and Uganda”

The adopted dependent variable from WDI is renewable energy consumption (% of total final energy consumption), in accordance with the extant environmental sustainability literature (Nathaniel & Iheonu, 2019; Asongu et al., 2019; Akinyemi et al., 2019) while financial development from the FDSD is proxied with financial access in terms of "private domestic credit by domestic banks and other financial institutions". This measurement of financial development which is qualified as financial system activity or credit by the FDSD is consistent with the problem statement of this study because the conception and definition of financial system activity encompass both the formal and non-formal financial sectors (which entail the majority of the poor). This is essentially because the poorer elements of society are more associated with non-formal financial sector of the economy (Tchamyou, 2019a, 2020). Hence, improvement of the financial system measurement is consistent withthe emphasis on both the poor and the rich. As documented by Asongu and Acha-Anyi (2017), "other financial institutions" represent institutions that are, for the most part, registered but not licensed as financial institutions by the central bank and the government, namely: (i) microfinance establishments, (ii) credit unions that engender the entrepreneurial poor and (iii) micro-businesses. The conception and definition of the financial system are in accordance with the information provided in Appendix 1, which is sourced from Asongu and Acha-Anyi (2017).

In order to control for the concern of variable omission bias which can potentially reduce the robustness of the estimated models, two control variables are adopted, namely: regulation quality from WGI and mobile phone penetration from WDI of the World Bank. The selection of these variables in the conditioning information set is informed by contemporary environmental sustainability literature (Asongu, 2018a; Asongu & Odhiambo, 2020c). Before engaging the empirical results, it is worthwhile to clarify why only two elements are adopted in the conditioning information set. In essence, as far as GMM regressions are concerned, there is a hard choice between avoiding variable omission bias and avoiding models that are not robust. Hence, in order to avoid estimated models that are not robust owing to, *inter alia*, instrument proliferation, it is typical in extant contemporary GMM-centric literature for fewer control variables to be adopted. This is the case with GMM studies which have used two control variables as in this study (Bruno, De Bonis & Silvestrini, 2012) or used no control variable at all (Osabuohien & Efobi, 2013; Asongu & Nwachukwu, 2017; Asongu & Odhiambo, 2020d), even when the option of collapsing instruments in engaged in the estimation exercise. Appendix 4, Appendix 3 and Appendix 2 respectively, disclose the correlation matrix, the summary statistics and definitions of variables.

3.2 Estimation technique

3.2.1Generalize Method of Moments (GMM) specification

The estimation approach in this study is consistent with empirical literature on the imperative of conforming the technique with the behavior of the data (Kou, Ergu, Chen, Lin, 2016; Kou, Yang, Xiao, Chen & Alsaadi, 2019; Kou, Lu, Peng & Shi, 2012; Kou, Chao, Peng & Alsaadi, 2019; Kou, Peng & Wang, 2014; Vu & Asongu, 2020). One of the estimation techniques adopted by the study is the *two-step* GMM because of three principal motives which are discussed without any chronological order of importance. (i) The first premise informing the choice of the estimation technique is that the number of cross sections (which in the present paper are represented by countries) should be higher than the corresponding number of periods or time intervals within each country (Assefa & Mollick, 2017; Fosu & Abass, 2019). (ii) In the light of the dynamic nature of the technique (i.e. the introduction of a lagged dependent variable into the specification), the observations in level series in the dependent variable have to be considerably correlated with its previous observations. In this case, the correlation coefficient between the level and first difference series should be sufficiently high, notably, above 0.800, owing to the rule of thumb threshold documented in contemporary GMM-centric literature (Tchamyou, 2019a, 2020). (iii) The concern pertaining to endogeneity is addressed in the present study on two fronts, notably: reverse causality or simultaneity is taken on board through the employment of internal instruments and some bite on the unobserved heterogeneity is considered by the involvement of time fixed effects in the specification exercise (Asongu & Odhiambo, 2018a, 2018b; Tchamyou, 2019b; Agyei et al., 2019).

Equation (1) and Equation (2) below respectively, present the standard system GMM specification in levels and first difference, for the assessing how inequality modulates the effect of financial access on renewable energy consumption.

$$REC_{i,t} = \sigma_0 + \sigma_1 REC_{i,t-\tau} + \sigma_2 F_{i,t} + \sigma_3 I_{i,t} + \sigma_4 FI_{i,t} + \sum_{h=1}^{2} \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$\begin{aligned} REC_{i,t} - REC_{i,t-\tau} &= \sigma_1 (REC_{i,t-\tau} - REC_{i,t-2\tau}) + \sigma_2 (F_{i,t} - F_{i,t-\tau}) + \sigma_3 (I_{i,t} - I_{i,t-\tau}) \\ &\quad + \sigma_4 (FI_{i,t} - FI_{i,t-\tau}) + \sum_{h=1}^{2} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} + \varepsilon_{i,t-\tau}) \end{aligned}, \quad (2)$$

where $REC_{i,t}$ denotes an indicator of renewable energy consumption of country i in period t ; I reflects an inequality indicator (encompassing the Gini coefficient, the Atkinson index and the Palma ratio); F is financial access; FI denotes an interaction between an inequality dynamic and the financial access measurement ("Gin coefficient" × "Financial access", "Atkinson index" × "Financial access", "Palma ratio" × "Financial access",); σ_0 is a constant; τ is the degree of auto-regression that is one because such a lag appropriately captures past information; W denotes the set of control variables adopted for the research (*mobile phone penetration and regulation quality)*, η_i is the country-specific effect, ξ_t is the time-specific constant and $\varepsilon_{i,t}$ the error term.

The option of the GMM technique adopted in this study is the difference GMM extension by Roodman (2009) founded on "forward orthogonal variations" which has been established in more contemporary empirical literature to deliver more robust estimated coefficients (Boateng, Asongu, Akamavi & Tchamyou, 2018; Asongu & Odhiambo, 2019c; Tchamyou *et al.*, 2019a, 2019b). It follows that the adopted GMM approach which steers clear of the mainstream approaches is an improvement of the difference GMM technique of Arellano and Bover (1995).

3.2.2 Identification, exclusion restrictions and simultaneity

Three main points are worth emphasizing in order to clarify the robustness of a GMM specification. These points are tailored along the lines of identification, exclusion restrictions and simultaneity. The front of identification consists of defining three main types of variables involved in the specification exercise, namely: (i) the dependent variable, (ii) the suspected endogenous, endogenous explaining or predetermined variable and (iii) the strictly exogenous variable. The dependent or outcome variable is renewable energy consumption; the predetermined variables are independent variables of interest (i.e. inequality dynamics and financial access) and control variables (i.e. mobile phone penetration and regulation quality) while the strictly exogenous variables are years or time fixed effects. The identification process is consistent with recent literature (Tchamyou & Asongu, 2017a) and Roodman (2009) who has argued that the adoption of years as strictly exogenous is because it is unfeasible for years to become endogenous after a first difference.

The exclusion restriction assumption underpinning the identification process presupposes that the identified strictly exogenous variables should influence the outcome variable exclusively via the identified channels pertaining to the endogenous explaining or predetermined variable. Moreover, a criterion used to assess the validity of the attendant exclusion restriction is the Difference in Hansen Test (DHT) which is employed to examine whether the adopted strictly exogenous instruments or factors reflects strict exogeneity. It follows that in the findings reported in Section 4, the null hypothesis of the DHT should not be rejected in order for the assumption of exclusion restriction to hold. This narrative underlying the exclusion restriction assumption is consistent with less contemporary instrumental variable estimation approaches in which the null hypothesis of the Sargan/Hansen test should not be rejected in order for the identified instruments to elicit the outcome variable exclusively through the identified channels or exogenous components of the endogenous explaining variables (Lalountas, Manolas & Vavouras, 2011; Beck, Demirgüç-Kunt & Levine, 2003; Agbloyor, Abor, Adjasi & Yawson, 2013; Amavilah, Asongu & Andrés, 2017).

The concern of simultaneity is addressed by employing forward orthogonal deviations instead of first differences as in the difference GMM technique, in order to enable the parallel or orthogonal conditions that counteract the source of endogeneity. Accordingly, Helmert transformations are employed to purge fixed effects from the specifications and hence, avoid the potential correlation between fixed effects and the lagged dependent variable. The underpinning technical scheme for tackling the relevant concern of endogeneity is consistent with the documented importance of obtaining orthogonal or parallel situations between the lagged dependent variable and fixed effects (Arellano & Bover, 1995; Roodman, 2009).

3.2.3Quantile Regressions

So far, the modeling of the investigated nexuses has been contingent on the mean value of renewable energy consumption. However, in order to assess *Hypothesis* 3 of this study, it is also relevant to investigate the nexuses throughout the conditional distribution of renewable energy consumption. In so doing, low, intermediate and high initial levels of renewable energy consumption are taking into account in the estimation exercise. Hence, contrary to the approach based on mean values of the outcome variable that leads to blanket policies, the estimation based on Quantile regressions provides findings that are contingent on existing levels of renewable energy consumption. This is essentially because blanket policies based on mean values (i.e. as in the GMM estimations) may be ineffective unless they are contingent on initial levels of renewable energy consumption and hence, tailored differently across countries with different levels of renewable energy consumption.

Borrowing from both contemporary and non-contemporary literature on the subject (Koenker & Bassett, 1978; Tchamyou & Asongu, 2017b), the adopted quantile regression approach is relevant in articulating initial levels of outcome variables. Accordingly, the quantile regression is being increasingly employed to complement estimation techniques that are characterized by blanket policy implications because the corresponding estimation is based on mean values of the outcome variable (Koenker, 2005; Hao & Naiman, 2007; Okada & Samreth, 2012; Asongu & Odhiambo, 2019d).

The θ^{th} quantile estimator of renewable energy consumption is obtained by solving for the optimization problem which is disclosed Equation (3) in the absence subscripts for simplicity in order to enhance readability.

$$\min_{\beta\in R^k}\left[\sum_{i\in\{i:y_i\geq x_i'\beta\}}\theta\left|y_i-x_i'\beta\right|+\sum_{i\in\{i:y_i<x_i'\beta\}}(1-\theta)\left|y_i-x_i'\beta\right|\right], \quad (3)$$

where $\theta\in(0,1)$. As opposed to Ordinary Least Squares (OLS) that is based on minimizing the sum of squared residuals, Quantile regressions are based on minimizing the weighted sum of absolute deviations. For instance, the 75th or 90th quantiles (with θ=0.75 or 0.90 respectively) are estimated by approximately weighing the residuals. The conditional quantile of renewable energy consumption or y_i given x_i is:

$$Q_y(\theta / x_i) = x_i'\beta_\theta, \quad (4)$$

where, parameters that are characterized by a unique slope are estimated for each θ^{th} specific quantile. Equation (4) is analogous to $E(y/x) = x_i'\beta$ in the OLS slope where the estimated parameters are modeled contingent on the conditional distribution of renewable energy consumption. Moreover, in the attendant equation, the outcome variable y_i is renewable energy consumption while x_i contains: a constant term, financial access, inequality dynamics (the Gini coefficient, the Atkinson index and the Palma ratio),mobile phone penetration and regulation quality.

4. Empirical results

4.1 Presentation of results

This section presents the empirical findings in Tables 1-2. Table 1 shows the GMM results while Table 2 discloses the corresponding Quantile regression results. The presentation of the findings is divided into three main categories, notably, regressions pertaining to the Gini coefficient, the Atkinson index and the Palma ratio. To examine if the findings in Table 1 are valid, four principal criteria of information are employed to assess the validity of estimated models[3].In the light of these criteria, estimated models without the conditioning information

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[3] *"First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second, the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections*

set (or control variables) are not valid because the corresponding Arellano and Bond autocorrelation test in difference is significant.

It is apparent from Table 1 that financial development promotes renewable energy consumption (validation of *Hypothesis* 1) and inequality counteracts the positive effect of financial development on renewable energy consumption (validation of *Hypothesis* 2). This is essentially because the unconditional effect of financial development on renewable consumption is positive whereas the interactive effect (i.e. between financial development and inequality) on renewable energy consumption is negative. The validation of *Hypotheses* 1-2 is therefore robust to the Gini coefficient and Palma ratio specifications. The control variables are largely significant.

Table 1: Finance, inequality and renewable energy consumption in SSA (GMM)

	Dependent variable: Renewable energy consumption (Renenc)					
	Gini Coefficient		**Atkinson Index**		**Palma Ratio**	
Renewable energy (-1)	**0.986*****	**0.974*****	**1.000*****	**0.974*****	**1.011*****	**0.997*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
Financial Access (Finance)	0.313	**0.203****	**0.280****	0.159	**0.088*****	**0.076*****
	(0.002)	**(0.032)**	**(0.017)**	(0.179)	**(0.001)**	**(0.003)**
Gini Coefficient (Gini)	**16.373*****	**11.832*****	---	---	---	---
	(0.000)	**(0.000)**				
Atkinson Index (Atkinson)	---	---	**13.159****	**6.787***	---	---
			(0.011)	**(0.085)**		
Palma Ratio (Palma)	---	---	---	---	**0.472*****	**0.432*****
					(0.006)	**(0.002)**
Finance × Gini	-0.556	**-0.369****	---	---	---	---
	(0.003)	**(0.032)**				
Finance × Atkinson	---	---	**-0.421****	-0.251	---	---
			(0.022)	(0.190)		
Finance × Palma	---	---	---	---	**-0.014*****	**-0.013*****
					(0.004)	**(0.006)**
Mobile Phones	---	**0.009****	---	**0.016****	---	**0.016*****
		(0.022)		**(0.024)**		**(0.000)**
Regulation Quality	---	**-0.929***	---	**-1.653*****	---	**-1.174****
		(0.099)		**(0.001)**		**(0.012)**
Thresholds	nsa	0.550	nsa	na	nsa	5.846
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
AR(1)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)
AR(2)	(0.091)	**(0.107)**	(0.094)	**(0.111)**	(0.098)	**(0.115)**
Sargan OIR	**(0.692)**	**(0.840)**	**(0.686)**	**(0.894)**	**(0.731)**	**(0.898)**
Hansen OIR	**(0.103)**	**(0.338)**	**(0.152)**	**(0.378)**	**(0.260)**	**(0.560)**
DHT for instruments						
(a)Instruments in levels						
H excluding group	(0.060)	**(0.303)**	**(0.239)**	**(0.266)**	(0.099)	**(0.299)**
Dif(null, H=exogenous)	**(0.205)**	**(0.366)**	**(0.158)**	**(0.439)**	**(0.393)**	**(0.631)**
(b) IV (years, eq(diff))						
H excluding group	---	**(0.560)**	---	**(0.582)**	---	**(0.605)**
Dif(null, H=exogenous)	---	**(0.232)**	---	**(0.260)**	---	**(0.442)**
Fisher	**194344.09*****	**205589.80*****	**91442.55*****	**104441.06*****	**1544.54*****	**8592.86*****
Instruments	24	32	24	32	24	32
Countries	37	37	37	37	37	37
Observations	352	349	352	349	352	349

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. Constants are included in all regressions.

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in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fisher test for the joint validity of estimated coefficients is also provided" (Asongu& De Moor, 2017, p.200).

It is relevant to emphasize that the results which are opposite to those of Odhiambo (2020), nonetheless, validate the findings of Odhiambo (2020) because the underlying study has used a negative environmental sustainability signal (i.e. CO_2 emissions) while the present study has used a positive environmental sustainability signal (i.e. renewable energy consumption).

In order to provide more policy implications, thresholds of inequality that should not be exceeded are computed. It follows from this computation that the Gini coefficient should be kept below 0.550 (0.203/0.369) and the Palma ratio should not exceed 5.846 (0.076/0.013) in order for the unconditional favorable effect of financial development on renewable energy consumption not to change to negative from positive.

In order to examine the relevance of *Hypothesis* 3 which is contingent with assessing whether the established nexuses withstand empirical scrutiny/validity throughout the conditional distribution of renewable energy consumption, Quantile regressions are taken on board as apparent in Table 2.

Hypothesis 3 mainly consists of examining whether the *Hypotheses* 1-2 are valid throughout the conditional distribution of renewable energy consumption. Accordingly, it consists of examining whether countries with low initial levels of renewable energy consumption respond differently from their counterparts with high initial levels of renewable energy consumption in the nexuses among financial development, inequality and renewable energy consumption. From the findings, *Hypothesis* 3 is valid because, while *Hypotheses* 1-2 are consistently valid in bottom quantiles of the renewable energy distribution, they are not valid for the top quantiles of the renewable energy consumption distribution. It follows that *Hypotheses* 1-2 are only relevant in countries in which, renewable energy consumption is relatively low. Hence, countries already benefiting from comparatively higher levels of renewable energy consumption cannot effectively leverage on financial development to further enhance renewable energy consumption unless inequality levels exceed certain thresholds. This is why for bottom quantiles of the renewable energy consumption, negative thresholds are established because of the negative marginal effects while for top quantiles of the renewable energy consumption distribution, positive thresholds are established in the light of the attendant positive marginal effects.

Table 2: Finance, inequality and renewable energy consumption in SSA (Quantile regressions)

	Dependent variable: Renewable energy consumption																	
	Gini Coefficient						**Atkinson Index**						**Palma Ratio**					
	OLS	Q.10	Q.25	Q.50	Q.75	Q.90	OLS	Q.10	Q.25	Q.50	Q.75	Q.90	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Finance	0.721	**6.993****	**6.778*****	-1.036	**-2.136***	-0.411	1.496	**6.254*****	**5.143*****	**4.544*****	**-1.768****	**-0.918***	-0.033	**2.320*****	**1.380*****	-0.117	-0.791	-0.147
	(0.685)	**(0.029)**	**(0.000)**	(0.639)	**(0.059)**	(0.509)	(0.208)	**(0.009)**	**(0.000)**	**(0.002)**	**(0.010)**	**(0.057)**	(0.932)	**(0.001)**	**(0.000)**	(0.812)	(0.001)	(0.374)
Gini	12.211	**312.535****	**198.153*****	-29.502	**-76.967***	-3.676	---	---	---	---	---	---	---	---	---	---	---	---
	(0.782)	**(0.013)**	**(0.006)**	(0.733)	**(0.081)**	(0.880)												
Atkinson	---	---	---	---	---	---	17.885	**160.490***	**148.303*****	60.377	**-84.443*****	**-48.897*****	---	---	---	---	---	---
							(0.571)	**(0.066)**	**(0.000)**	(0.257)	**(0.001)**	**(0.005)**						
Palma	---	---	---	---	---	---	---	---	---	---	---	---	0.429	**8.553*****	**6.139*****	0.225	**-2.687*****	-0.210
													(0.708)	**(0.003)**	**(0.000)**	(0.913)	**(0.007)**	(0.761)
Finance × Gini	-1.991	**-12.854****	**-12.744*****	0.909	**3.273***	0.646	---	---	---	---	---	---	---	---	---	---	---	---
	(0.526)	**(0.023)**	**(0.000)**	(0.815)	**(0.098)**	(0.553)												
Finance ×Atkinson	---	---	---	---	---	---	-2.924	**-10.133*****	**-8.606*****	**-7.764*****	**2.231****	**1.231***	---	---	---	---	---	---
							(0.109)	**(0.006)**	**(0.000)**	**(0.001)**	**(0.031)**	**(0.092)**						
Finance × Palma	---	---	---	---	---	---	---	---	---	---	---	---	-0.069	**-0.491*****	**-0.339*****	-0.079	**0.091****	0.017
													(0.343)	**(0.000)**	**(0.000)**	(0.364)	**(0.030)**	(0.540)
Mobile Phones	**-0.106*****	0.066	-0.096	**-0.134****	**-0.116*****	**-0.104*****	**-0.105*****	0.100	**-0.097****	**-0.144****	**-0.104*****	**-0.085*****	**-0.105*****	0.103	**-0.072***	**-0.133****	**-0.103*****	**-0.095*****
	(0.003)	(0.446)	(0.056)	**(0.026)**	**(0.000)**	**(0.000)**	**(0.004)**	(0.310)	**(0.023)**	**(0.018)**	**(0.000)**	**(0.000)**	**(0.004)**	(0.218)	**(0.076)**	**(0.026)**	**(0.000)**	**(0.000)**
Regulation Quality	**8.544*****	-1.396	5.214	**12.668*****	**8.634*****	-1.994	**9.821*****	8.915	**8.367*****	**12.395*****	**7.513*****	0.477	**9.023*****	8.934	**4.820***	**12.655*****	**8.516*****	-2.061
	(0.002)	(0.823)	(0.148)	**(0.004)**	**(0.000)**	(0.101)	**(0.000)**	(0.203)	**(0.006)**	**(0.004)**	**(0.000)**	(0.734)	**(0.001)**	(0.138)	**(0.077)**	**(0.003)**	**(0.000)**	(0.152)
Thresholds	na	0.544(-)	0.531(-)	na	0.652(+)	na	na	0.617(-)	0.597(-)	0.585(-)	0.792(+)	0.745(+)	na	4.725(-)	4.070(-)	na	na	na
Fisher	**21.34*****						**19.56*****						**21.52*****					
Pseudo R²	0.160	0.138	0.153	0.095	0.057	0.061	0.175	0.153	0.165	0.103	0.069	0.061	0.164	0.145	0.162	0.097	0.063	0.061
Observations	386	386	386	386	386	386	366	386	386	386	386	386	386	386	386	386	386	386

*,**,***: significance levels of 10%, 5% and 1% respectively.Finance: Financial Access. Gini: Gini Coefficient. Atkinson: Atkinson Index. Palma: Palma Ratio. OLS: Ordinary Least Squares. R² for OLS and Pseudo R² for quantile regression. Lower quantiles (e.g., Q 0.1) signify nations where renewable energy consumption is least. na: not applicable because at least one estimated coefficient needed for the computation of thresholds is not significant. Thresholds with (-) correspond to negative thresholds whereas thresholds with (+) correspond to positive thresholds. Constants are included in all regressions.

4.2 Nexus with the literature and contributions to practice and theory

On the nexus of this study with the attendant literature, two points are worth putting into perspective, notably: (i) confirmation of the findings of Odhiambo (2020) on CO_2 emissions (i.e. negative environmental sustainability signal) from the perspective of renewable energy consumption (i.e. positive environmental sustainability signal). (ii) A reconciliation of two strands of the literature given that the empirical validity of the findings of Odhiambo (2020) is no longer relevant when the underlying nexuses are assessed throughout the conditional distribution of the outcome variable. Hence, as discussed below, findings in the bottom quantiles of the renewable energy consumption distribution are consistent with the strand of literature on the positive role of financial development in promoting the green economy while results in the top quantiles of the renewable energy consumption distribution are on the contrary, in accordance with the strand of literature positing that financial development can be detrimental to the promotion of environmental sustainability by means of renewable consumption.

The literature on various strands of the debate has already been covered in Section 2. Accordingly, the strand of literature supporting the findings in the bottom quantiles include, *inter alia*: Salinger (1992), Klassen and McLaughlin (1996), Yuxiang and Chen (2011), Frankel and Rose (2002), Paramati, Apergi and Ummalla (2017), Paramati, Moand Gupta (2017), Kutan, Paramati, Ummallaand Zakari (2017) and Odhiambo (2020). On the contrary, findings in the top quantiles that are consistent with the corresponding literature supporting the fact that financial systems (especially those that are more developed) could contribute more towards environmental pollution, include, *inter alia*: Minettit (2011), Aye and Edoja (2017) and Xing et al.(2017). The reconciliation dimension of the present study is therefore premised on the fact that two strands of the "financial development"-"environmental sustainability" debate can be captured in the same modeling exercise when all the conditional distribution of the environmental sustainability proxy is taken on board.

The practical importance of this study builds on the computed thresholds of inequality for the relevance of financial development in renewable energy consumption. Hence, contrary to the underlying studies motivating the present study which are based on blanket nexuses between independent variables and the outcome variable, this study has combined a policy variable (i.e. financial development) with a policy syndrome (i.e. inequality) in view of providing critical masses of the policy syndromes that are either favorable or detrimental to the promotion of the green economy, through the policy variable, contingent on initial levels of renewable energy consumption. In so doing, the study has provided a practical argument on the importance of providing policy makers with specific critical masses they can act upon to achieve expected or favorable desired outcomes.

The above importance of departing from previous studies (based on providing simple nexuses on among macroeconomic factors) and documenting thresholds is consistent with a growing body of contemporary development literature, notably: critical masses for the effectiveness of development assistance (Asongu, 2014); turning points in U shaped and Kuznets curves (Ashraf & Galor, 2013; Batuo, 2015) and critically points of insurance penetration for economic prosperity (Asongu & Odhiambo, 2020e).

The theoretical contribution front mainly borders on the extension of theoretical underpinning surrounding the finance-inequality literature, to the environmental sustainability literature. Accordingly, the conception and measurement of financial development are tailored to emphasize both the intensive and extensive margin theories which focus on the importance of financial access in reducing inequality and promoting other macroeconomic outcomes. In other words, the conception of financial access is consistent with both the intensive margin theory (i.e. existing clients of the financial system) and extensive margin theory (i.e. previously unbanked fractions of the population), as discussed above because it involves both formal and non-formal financial sectors of the economy. This conception of financial development which is discussed in the data section and summarized in Appendix 1 is important in environmental sustainability studies because efforts from both the poor (i.e. those excluded from the formal financial system and consistent with the extensive margin theory) and the rich (i.e. those included in the formal financial system and consistent with intensive margin theory), are worthwhile in consuming renewable energy that is relevant for environmental sustainability.

The above theoretical contribution should be understood in the light of the fact that the intensive margin theory broadly focuses on improving financial access and services to existing holders of bank accounts and users of bank services (which mostly consists of the rich fraction of the population) while the extensive margin theory is understood as an extension of the attendant bank services to poorer elements of society who do not have formal bank accounts (Evans & Jovanovic, 1989; Holtz-Eakin, Joulfaian & Rosen, 1994; Black & Lynch, 1996; Bae, Han & Sohn, 2012; Chipote, Mgxekwa & Godza, 2014; Odhiambo, 2014; Orji, Aguegboh & Anthony-Orji, 2015; Batabyal & Chowdhury, 2015; Chiwira, Bakwena, Mupimpila & Tlhalefang, 2016). Moreover, consistent with contemporary literature, both theoretical insights can be taken on board in an empirical exercise within the framework of interactive regressions (Tchamyou et al., 2019a; Asongu, Nnanna & Acha-Anyi, 2020).

4.3 Policy implications

Theoretical and practical implications have also been discussed. In what follows, policy implications are discussed with particular emphasis on sustainable development goals (SDGs) on three main fronts, namely: financial access, inequality and renewable energy consumption.

On the front of financial development, increasing financial access in the formal and non-formal financial sectors will go a long way to boosting renewable energy consumption. This is essentially because on average (i.e. based on GMM findings), financial access unconditionally contributes towards the promotion of environmental sustainability within the framework of decreasing CO_2 emissions by means of renewable consumption. However, the policy of enhancing financial access should not be blanket but contingent on initial levels of renewable energy consumption, given that countries already enjoying comparatively higher levels of renewable energy consumption respond differently to financial development. Hence, policies designed to promote financial development should unconditionally target the promotion of a green economy and for countries better performing in green technologies, *inter alia*, the financial development policies should be complemented with other policies in order to have the desired effects on renewable energy consumption.

Inequality in SSA is a fundamental policy syndrome in the post-2015 development agenda because most countries in the sub-region failed to reach the Millennium Development Goal (MDG) extreme poverty target, despite a collective experience of over 20 years of a resurgence in economic prosperity (Asongu & Kodila-Tedika, 2017; Tchamyou et al., 2019b). The attendant exclusive growth is largely traceable to inequality in the light of the fruits from the underlying economic prosperity not being equitably distributed across the population. In this study, we found that income inequality counteracts the positive relevance of financial development on renewable energy consumption. Hence, appropriate measures should be put in place to fight inequality in order to enable measurements designed to enhance financial development to have the expected effects on promoting the green economy. However, it is also worthwhile to articulate that the policies towards reducing income inequality should not be blanket because of the asymmetric response of sampled countries in terms of initial levels of renewable energy consumption. In essence, the counteracting role of inequality reduces with the increasing importance of renewable energy consumption. Hence, it is worthwhile for policy makers to first understand why inequality is an essential but not a sufficient policy concern for countries at the top distribution of renewable energy consumption before implementing the relevant policies. Inequality thresholds at which such complementary policies can be taken on board have been computed and discussed.

The study has leveraged on two main factors (i.e. financial development and inequality) to articulate how the green economy can be promoted in SSA by means of renewable energy consumption. The promotion of renewable sources of energy is particularly relevant in the common global agenda of fighting climate change and environmental pollution. Moreover, the favorable externalities of the green economy on human health are worthwhile. Hence, it will be imperative to take on board the suggested policy orientations (particularly in relation to financial access and inequality) because of specificity of SSA in the underlying global concerns, *inter alia*: (i) the sub-region appears comparatively to be the most affected by the energy crisis and (ii) the consequences of global warming have also been documented to be potentially most detrimental to the sub-region compared to other regions of the world. To put the attendant literature articulating the underlying policy syndromes in more perspective, it is relevant to emphasize that about 600 million inhabitants of the sub-region (representing approximately half of the population) currently lack access to "*affordable, reliable, sustainable and modern electricity*" (IRENA, 2010; Shurig, 2015; Jarrett, 2017; The Economist, 2017; Asongu, le Roux, Biekpe, 2018; Adesola & Brennan, 2019).

5. Conclusion and future research directions

The study investigates linkages between financial development, income inequality and renewable energy consumption from 39 countries in Sub-Saharan Africa. The empirical evidence is based on data for the period 2004-2014, Generalized Method of Moments (GMM) and Quantile Regressions (QR). Three main inequality indicators are used, namely: the Gini coefficient, the Atkinson index and the Palma ratio. The financial development indicator is tailored to capture both the formal and non-formal sectors of the financial system in order to better inform the connection with the dynamics of inequality, given that the non-formal financial sector is more associated with the poorer fraction of society.

The GMM results show that financial development unconditionally promotes renewable energy consumption while income inequality counteracts the underlying positive effect. The QR findings show that the GMM results only withstand empirical validity in bottom quantiles of the renewable energy consumption distribution. In order to increase room for policy implications for the promotion of renewable energy consumption, critical masses of income inequality that should not be exceeded are computed for bottom quantiles of the renewable energy consumption distribution while income inequality thresholds that should be exceeded are computed for top quantiles of the renewable energy consumption distribution. The study has reconciled two strands of the literature.

Further studies can extend the present study by assessing how varying levels of financial development affect the established nexuses. This is essentially because varying levels of inequality (i.e. Gini coefficient versus the Palma ratio and Atkinson index) and renewable energy consumption (i.e. assessing the nexuses throughout the conditional distribution of renewable energy consumption) have already been considered in this study. Moreover, it is worthwhile for future studies to examine if the findings of the present study withstand empirical validity in other developing countries.

Appendices

Appendix 1: Segments of the financial system by degree of formality in Paper's context

Paper's context			Tiers	Definitions	Institutions	Principal Clients
Formal financial system	IMF Definition of Financial System from International Financial Statistics (IFS)	Formal Financial sector (Deposit Banks)	Formal banks	Licensed by central bank	Commercial and development banks	Large businesses, Government
Semi-formal and informal financial systems		Semi-formal financial sector (Other Financial Institutions)	Specialized non-bank financial institutions		Rural banks, Post banks, Saving and Loan Companies, Deposit taking Micro Finance banks	Large rural enterprises, Salaried Workers, Small and medium enterprises
			Other non-bank financial institutions	Legally registered but not licensed as financial institution by central bank and government	Credit Unions, Micro Finance NGOs	Microenterprises, Entrepreneurial poor
	Missing component in IFS definition	Informal financial sector	Informal banks	Not legally registered at national level (though may be linked to a registered association)	Savings collectors, Savings and credit associations, Money lenders	Self-employed poor

Source: Asongu and Acha-Anyi (2017)

Appendix 2: Definitions of Variables

Variables	Signs	Definitions of variables (Measurements)	Sources
Income Inequality	Gini Coefficient	"*The Gini coefficient is a measurement of the income distribution of a country's residents*".	GCIP
	Atkinson Index	"*The Atkinson index measures inequality bydetermining which end of the distribution contributed most to the observed inequality*".	GCIP
	Palma Ratio	"*The Palma ratio is defined as the ratio of the richest 10% of the population's share of gross national income divided by the poorest 40%'s share*".	GCIP
Renewable energy	Renenc	Renewable energy consumption (% of total final energy consumption)	WDI
Financial Access	Pcrdof	Private domestic credit from deposit banks and other financial institutions (% of GDP)	FDSD
Mobile Phones	Mobile	Mobile cellular subscriptions (per 100 people)	WDI
Regulation quality	RQ	"Regulation quality (estimate): measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development"	WGI

WDI: World Bank Development Indicators of the World Bank. FDSD: Financial Development and Structure Database of the World Bank. GCIP: Global Consumption and Income Project. WGI: World Governance Indicators of the World Bank.

Appendix 3: Summary statistics (2004-2014)

	Mean	SD	Minimum	Maximum	Observations
Gini Coefficient	0.586	0.034	0.488	0.851	428
Atkinson Index	0.704	0.057	0.509	0.834	428
Palma Ratio	6.454	1.477	3.015	14.434	428
Renewable energy	66.216	25.810	0.354	97.882	406
Financial Access	21.055	25.319	0.873	150.209	414
Mobile Phones	47.148	37.672	1.272	171.375	425
Regulation quality	-0.601	0.544	-1.879	1.123	429

S.D: Standard Deviation.

Appendix 4: Correlation matrix (uniform sample: 386)

	Renenc	Gini	Atkinson	Palma	Finance	Mobile	RQ
Renenc	1.000						
Gini	0.046	1.000					
Atkinson	0.012	0.789	1.000				
Palma	0.036	0.927	0.915	1.000			
Finance	-0.362	-0.102	-0.197	-0.129	1.000		
Mobile	-0.152	0.109	0.040	0.125	0.214	1.000	
RQ	-0.026	0.282	0.104	0.275	0.329	0.470	1.000

Renenc: Renewable Energy Consumption. Gini :the Gini Coefficient. Atkinson:the Atkinson Index. Palma: the Palma Ratio. Finance: Financial Access. Mobile: Mobile Phones Penetration. RQ: Regulation Quality.

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