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Toyo A. M. Dossou, Dossou K. Pascal, Emmanuelle N. Kambaye, Simplice A. Asongu, and Alastaire S. Alinsato

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Toyo A. M. Dossou
Laboratory of Public Economics, University of Abomey-Calavi in Benin
Abomey-Calavi 02BP 2163, Gbégamey-Cotonou, Benin.
&
Université de Bourgogne, UFR Droit, sciences économique et politique, Site de Dijon
E-mail: dossoumarcel863@yahoo.fr

Dossou K. Pascal
Faculty of Economics and Management of the University of Abomey-Calavi in Benin
Abomey-Calavi 02BP 2163, Gbégamey-Cotonou, Benin
E-mail: pascalkouessidossou@gmail.com

Emmanuelle N. Kambaye
School of International Business, Southwestern University of
Finance and Economics, No. 555 Liutai
Ave, Wenjiang District, Chengdu,
Sichuan 611130, China.
E-mail: nemmanuelle@yahoo.fr

Simplice A. Asongu
School of Economics, University of Johannesburg,
Johannesburg, South Africa
E-mails: asongusimplice@yahoo.com, asongus@afridev.org

Alastaire S. Alinsato
Faculty of Economics and Management of the University of Abomey-Calavi in Benin
Abomey-Calavi 02BP 2163, Gbégamey-Cotonou, Benin
E-mail: alastaires@yahoo.fr

**Abstract**

Although the impact of financial development on renewable energy consumption has been extensively examined in recent years, the study regarding the moderation of governance quality on the financial development on renewable energy consumption nexus is sparse. By filling the gap in the energy economics literature, this study investigates the moderating effect of governance quality on the relationship between financial development on renewable energy consumption for a panel of 33 African countries over the period 2000-2020. The fully modified ordinary least square (FMOLS) estimation techniques has been used to account for the cointegration and cross-sectional dependence, respectively. The results unveil that the impact of governance quality and financial development on renewable energy consumption is negative and statistically significant. Moreover, the results reveal that the FD-governance quality interactions are significant and negative. Governance quality thresholds at which the negative incidence

of financial development on renewable energy consumption is completely nullified are 0.825; 2.15; 2.86; 3.52;3.36; and 0,1, respectively.

**Keywords:** Financial development, renewable energy consumption, governance quality, Africa

*Corresponding author. Laboratory of Public Economics, University of Abomey-Calavi. Address: Abomey-Calavi 02BP 2163, Gbégamey-Cotonou, Benin. Email: dossoumarcel863@yahoo.fr

## 1.Introduction

Environmental pollution has been documented as a major threat to the world economy in recent years (Acheampong, Dzator, Amponsah, & Dzator, 2022; Caglar, 2022; Yang, Usman, & jahanger, 2021; You, Zhang, & Lee, 2022). In recent years, financial development seems to boost renewable energy development through diversifying energy mix and increasing energy security. In recent years, many recommendations have emerged from international organizations, namely International Monetary Fund, World Bank, and United Nations Development Programme to invest in the renewable energy sector as it has power to curb $CO_2$ emissions and thereby promoting environmental quality (Dimnwobi et al., 2022). As argued by Iheonu et al. (2020), a well-functioning financial sector could contribute to facilitate domestic firms through increasing their access to local funds. As such, it can contribute to promote innovation in the renewable energy sector. In the same vein, as financial development occurs from globalization, Fotio et al. (2022) documented that financial globalization is expected to positively affect domestic economy by promoting innovation. This has been corroborated by Asongu et al. (2022) who argued that financial globalization could positively affect economic growth through promoting knowledge diffusion and innovation, increasing global value chain participation and enhancing infrastructural development. According to the authors, these channels can be identified as a significant factor that could contribute to promote energy renewable development. Theoretically, these arguments stem from the theory of Schumpeter (1939) which pointed out finance as a driver of innovation. As financial development could play a significant role in the renewable energy sector, (Dimnwobi et al., 2022)recommended that the Nigeria's central bank should provide a preferential lending rate for the renewable energy businessman as it can help them to strengthen innovation in the renewable energy sector. Unfortunately, renewable energy projects have subjected to many obstacles, namely high information cost, capital costs and high specificity of assets which explain its current underdevelopment in many economies(Kim & Park, 2016). This supports the argument of Dimnwobi et al. (2022) who pointed out the underinvestment in the renewable energy sector in developing countries in recent years. As these factors impede renewable energy development, the authors argued that enhancing renewable energy technologies (RETs) requires a well-functioning financial market. Despite these arguments regarding the effect of financial development on the renewable energy sector, the study on the impact of financial development on renewable energy consumption in Africa is quite inexistent.

Meanwhile, we argue that the positive effect of financial development on the renewable energy sector depends on the quality of governance. One the one hand, poor governance

can negatively affect financial development, which in turn, can impede renewable energy development. For instance, Sharma and Paramati (2021) documented that the growth of corruption could undermine the efficiency of the bank system or financial development, which by extension could negatively affect renewable energy development. Atanga Ondoa and Seabrook (2022) came up with similar view that the growth of corruption can undermine government capacity toward making an important reform in the financial sector. As such, it can negatively affect renewable energy development. Similarly, due to the growth of corruption, politician may use their power to influence banks' officials to divert the flow of fund, which may impede the renewable energy sector(Ben Ali et al., 2020). It has been noticed that corruption may contribute to declining bank lending, which further can hurt renewable energy development (Ekşi & Doğan, 2020). Moreover, increasing corruption has been found to delay financial development and renewable energy development (Pan, Dossou, Berhe, & Kambaye, 2022). In the same vein, Jha (2019)documented that the growth of corruption may lead to financial underdevelopment. As such it may contribute to undermining the renewable energy sector. As poor governance can be explained by the increase of political instability, Roe and Siegel (2011) documented that its increase could undermine financial development (innovation), which by extension could impede renewable energy development. This has been corroborated by Mlachila and Ouedraogo (2020) who found that the odds of a banking crisis are 2.5 times greater when a country is affected by a conflict[1]. As such, it will negatively undermine renewable energy development. However, good governance has been documented to promote financial development (Sayılır et al., 2018), which in turn, is expected to enhance renewable energy development. Based on these arguments, it is important to investigate the moderation of governance quality on the financial development-renewable energy consumption linkage.

This study makes three contributions. First, unlike Dimnwobi et al. (2022) who investigated the influence of financial development on renewable energy consumption in Nigeria, the present study examines the relationship between financial development and renewable energy consumption for a panel 33 African economies over the period 2000-2020. This study innovates by considering a panel data as it contains several advantages compared to time series data. (i) According to Topcu and Tugcu (2019), the Panel data possesses information related to time and cross-section dimension. (ii)as the panel data contains high degree of freedom, it could provide a robust result. (iii) the individual heterogeneities could be considered in the panel data while it could be ignored in other data types. Second, this study is the first to assess the moderation of governance quality on the relationship between financial development and renewable energy consumption. Literature on the impact of financial development on renewable energy consumption to the knowledge of the authors has ignored the potential role of governance quality in altering the financial development-renewable energy consumption linkage. Moreover, the present study contributes to previous studies that examine the impact of governance quality on renewable energy consumption by using six governance quality indicators. Although Africa is blessed with natural resources, there is lack of fund and governance in the renewable energy sector (Pan et al., 2022) which lagged Africa behind other continent. Therefore, looking at the moderation of governance on the finance-renewable energy development nexus can guide African

[1]https://www.imf.org/en/Blogs/Articles/2020/07/29/impact-of-conflict-and-political-instability-on-banking-crises-in-developing-economies

leaders to structure their plan to attract more funds in the sector. Third, investigating whether governance quality moderates the relationship between financial development and renewable energy consumption will provide relevant knowledge to authorities that will aid the development of renewable energy in the continent.

The rest of the study structured as follows. Section 2 discusses the stylized facts and literature while the data and methodology are covered in Section 3. The empirical results are disclosed and discussed in Section 4 and Section 5 while Section 6 concludes.

## 2.Stylized facts and literature review

### 2.1 Stylized facts

Four reasons have been given to explain the choice of Africa as a case study to examine the moderating effect of governance quality on the financial development-renewable energy development nexus. First, according to Tchamyou et al. (2019), financial development in Africa is low compared to Asia and Latin America. Second, although Africa emits less emissions, the consequences of environmental degradation is the continent are huge(Huang et al., 2022). For example, in recent years, Africa has been widely hit by climate change. According to Ujunwa et al. (2021), climate change appears to have an increasing impact on income inequality in Africa. This has been corroborated by the recent report, which documented that almost 100 million people in Africa are expected to be pushed into extreme poverty due to climate change[2]. Moreover, nearly half of the population lives without electricity (Pan et al., 2022). Additionally, although Africa has huge potential in terms of renewable energy, its share in the continent is less (Adedoyin, et al., 2022; Pan et al., 2022). This has been corroborated by Figure1. Based on these arguments, there is a need to develop renewable energy. Third, while good governance appears to promote economic growth and development, the quality of institutions or governance is relatively poor in Africa (Dossou et al., 2022; Ofori et al., 2021; Pan et al., 2022). This has been shown by Figure 2. Moreover, this argument has been corroborated by Ouedraogo et al. (2021) who said that the average value of all governance indicators in Africa is negative. Fourth, although, a study by Amoah et al. (2022) investigated the linkage between financial development and renewable energy consumption for 48 African countries, the study regarding the moderating effect of governance on the linkage between financial development and renewable energy consumption is rare.

[2]https://www.fpri.org/article/2021/10/the-impact-of-climate-change-on-africas-economies/

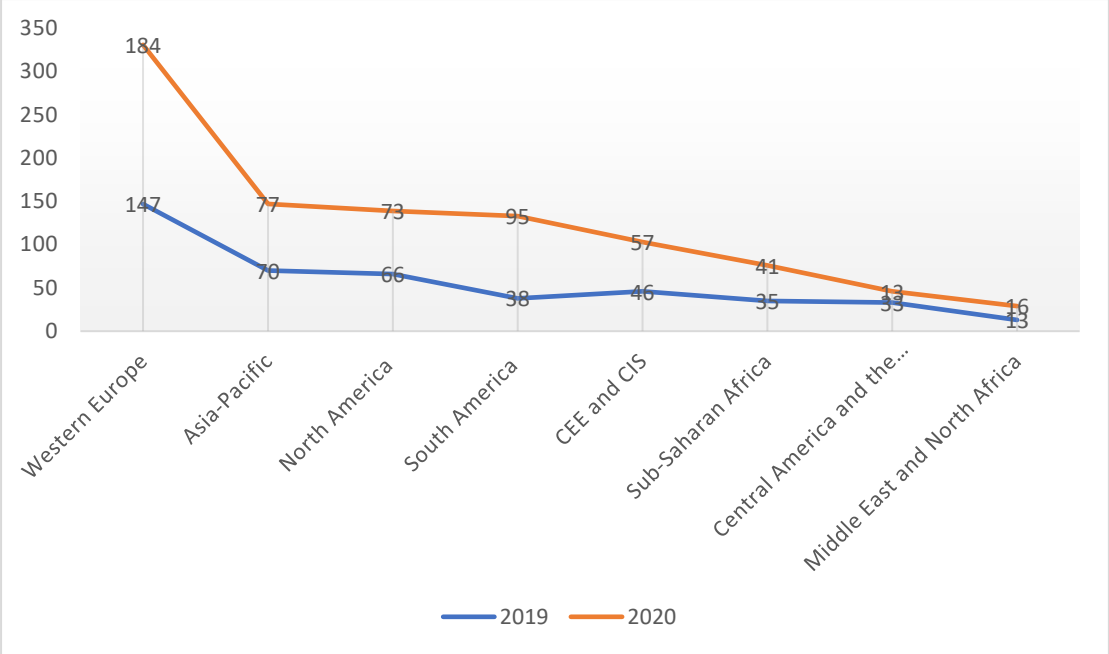


Figure 1. Breakdown of renewable and alternative power FDI projects by destination region.
Source: Global Data's FDI Projects Database
Note: CEE: Central Eastern Europe and CIS: Commewealth Independent States

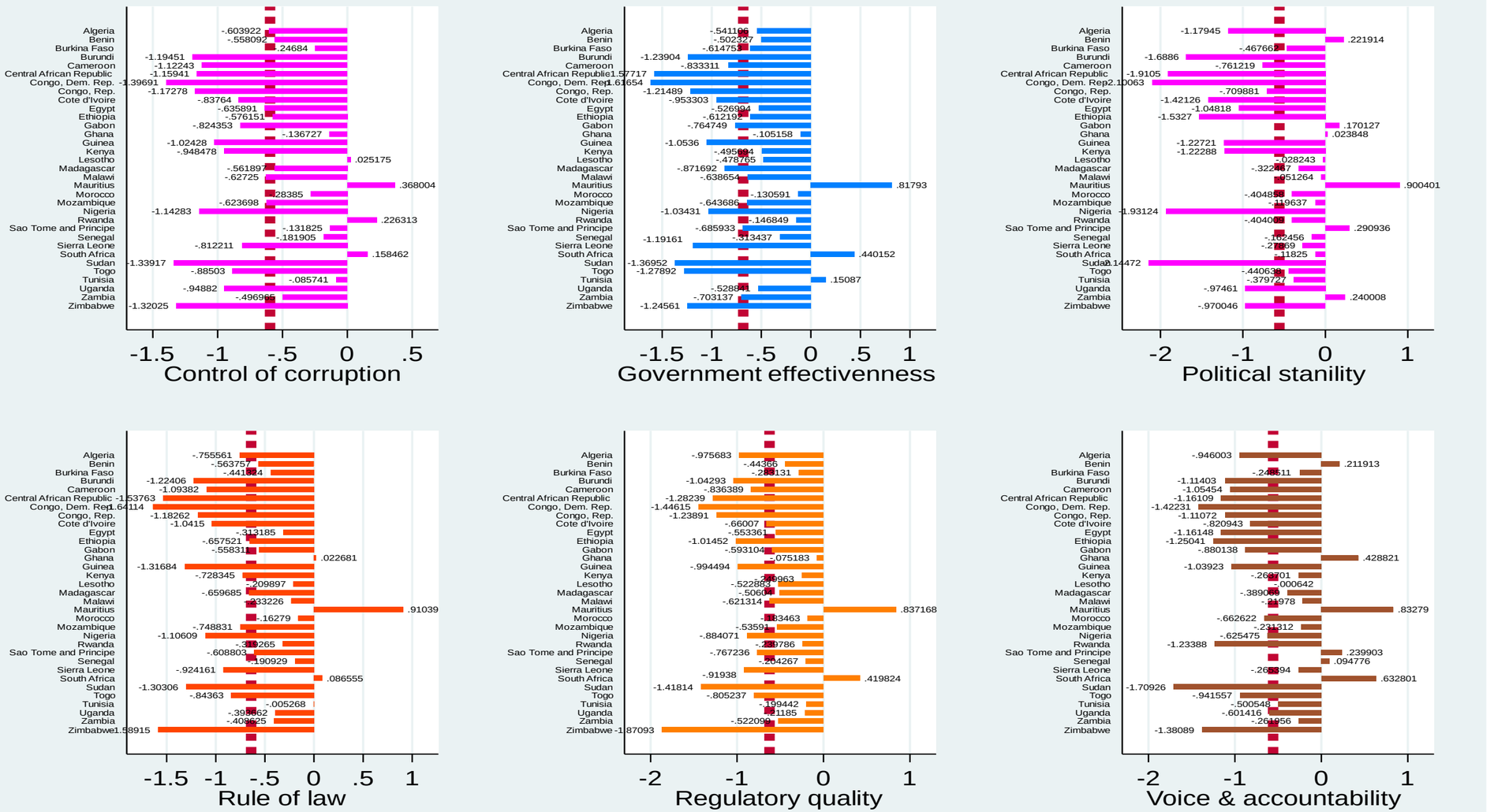


Figure 2. In country governance quality in Africa, 2000-2020

Sources: Authors' computation based on data set from World Governance Indicators.

## 2.2Empirical studies: financial development and renewable energy consumption

It has been documented that the renewable energy sector is a capital-intensive sector as it has a direct linkage with the infrastructure, innovation and certain costs related to the renewable energy projects(Wang et al., 2021). In recent years, the financial sector has been pointed out as an important ingredient in the renewable energy sector. For instance, it has been noticed that the financial system could accelerate renewable energy development. According to Shahbaz et al. (2021), it has been argued that developing a country's financial system seems to reduce the investment costs related to the renewable energy sector. According to Wang et al. (2021), equity and bank financing are expected to provide new technology projects and large-scale projects, which seems to be more appropriate for increasing the demand of renewable energy. Moreover, Shahbaz et al. (2021) have pointed out three channels, direct effect, business effect and wealth effect in which financial development can improve energy security in both developed and developing nations. According to the authors, consumers are expected to easily borrow and cheaply buy goods thanks to the development of financial system, which thereby could lead to the improvement of the renewable energy sector. Further, business effect, as explained by the authors, is a channel in which the enhancement of financial system improves business environment through increasing financial capital which plays a significant role in increasing renewable energy consumption. In the same vein, additional financial funding can be generated through developing stock exchange which can improve the renewable energy sector. Based on this channel, the authors concluded that developing financial system has the power to increase the potential of business and energy demand. Moreover, wealth effect has been documented as a trust created among consumers and businesses through increasing stock exchange in the market (Shahbaz et al., 2021).

Recently, the study regarding the relationship between financial development and renewable energy consumption using a panel data is less documented. For instance, Shahbaz et al. (2021) for 34 developing nations, used the FMOLS estimation technique to explore the influence of financial development on renewable energy demand over the period 1994-2015. They found that financial development improves renewable energy development. Their study further implies that the government of these nations could increase an investment in the renewable energy sector and also reduce tax related to the renewable energy projects. In the same vein, using 30 countries over the period 2000-2013, Kim and Park (2016) found that financial development improves the renewable energy sector. Similarly, using a GMM estimation technique as well as 103 countries, Sun et al. (2023) examined the impact of financial development on renewable energy consumption and found that an increase in financial development lead to the rise in renewable energy consumption. In the same account, Mukhtaro et al. (2022) used Turkey as a case study and found that a one percent increase in financial development increases renewable energy development by 0.21%. However, Saadaoui et al. (2023) found that financial development has a negative impact on renewable energy development in Tunisia. Although a few studies have investigated the relationship between financial development and renewable energy consumption, unfortunately, the study regarding the case of Africa is quite inexistent.

## 2.3 Empirical studies: governance quality and renewable energy consumption

It has been argued that governance quality plays a significant role in promoting renewable energy development in both developed and developing countries (Pan et al.,

2022). Acknowledging the crucial role of governance quality, many scholars have argued that policies must be implemented to attract more flows of foreign direct investment in the renewable energy sector (Mahbub, Ahammad, Tarba, & Mallick, 2022). According to Wall et al. (2018), several policies (international, national and local) have been introduced to reduce $CO_2$ emissions and promote environmental sustainability through increasing investment in the renewable energy sector. Confirming this fact, four policy implements, namely renewable portfolio standard (RPS), feed-in tariff (FIT), fiscal measure (FM) or tax incentives, and emission trading schemes (ETS) have been identified by Ali et al. (2022) to explain the linkage between quality of institutions or governance and renewable energy consumption. For instance, the regulation and stabilization of the price in the market can be done through implementing feed-in tariff (FIT). According to Wall et al. (2018), FIT has been documented as an appropriate policy that is able to attract green foreign direct investment in the renewable energy sector, namely biomass, solar and wind. This has been corroborated by Ali et al. (2022) who argued that some patent activities seem to be positively affected by FIT as it has the capacity to promote renewable energy development through attracting green foreign direct investment. Based on this policy, the openness for foreign capital can be increased and promote renewable energy development.

Concerning fiscal measure (FM) or tax incentives, it has been pointed out several types of tax incentives, namely sales taxes, energy tax, VAT reduction, and tax credits that can help to attract foreign direct investment in the renewable energy sector in order to avoid climate change and promote environmental quality[3]. As documented by Ali et al. (2022), some investment costs should be covered by governments in order to promote investment in the renewable energy sector. The authors continue by arguing that this can be done through providing financial, political and legislative commitments that can help to overcome the gap in thermal power generation. Further, such policy can be implemented via carbon tax and emission trading which have been considered as an appropriate instrument to promote renewable energy development (Khan et al., 2020). In corroborating this fact, the authors pointed out the positive impact of FM on solar projects. Unfortunately, such policy is not implemented in developing countries, especially in Africa.

Similarly, it has been documented that a policy like renewable portfolio standard (RPS) can contribute to attract green foreign direct investment in the renewable energy sector (S. Ali et al., 2022). According to the authors, RPS has been pointed out as an appropriate instrument to reduce investment risk. As such, it can constribute to increasing return for foreign investors. Moreover, the authors have emphasized the effectiveness of such policy in the renewable energy sector in the developed countries. For example, Dong and Shi (2019) has found the positive effect of RSP on the renewable energy sector in China. In the same vein, Bolkesjø et al. (2014) has confirmed the effectiveness of RSP on the renewable energy sector in Europe. However, RSP has not yet been implemented in developing countries, especially in Africa.

Considering, emission trading schemes (ETS), Ali et al. (2022) argued that it can help to control and lessen pollution and CO2 emissions costs-effectivelly. Moreover, it has been documented that foreign direct investment cannot be attracted through emission

[3]https://www.un-ilibrary.org/content/journals/2076099x/20/2/2/read

trading schemes (ETS) at a comprehensive level. However, it appears to have a positive impact on solar energy development.

The literature review section has two main objectives: (i) expand the corresponding stylized fact and corresponding strands in the literature which were highlighted in the introduction and (ii) engage more literature that justify the choice of the control variables. It is relevant to note that, the elements of style adopted in the introduction are tailored to provide responses to four main questions: (i) What is the problem statement? (ii) What has been done in the extant literature to address the problem statement. (ii) What are gaps in the extant literature? (iii) How does the proposed study contribute to the extant literature in the light attendant gaps? It follows that the adopted elements of scholarly communication in the introduction are already tailored to identify the gap in the extant literature and discuss contribution of the present exposition in the light of the attendant gap.

## 3.Model specification, data and methodology

### 3.1Model specification

Following Awijen et al. (2022) and Pan et al. (2022), the baseline can be expressed as:
$REC_{it} = \alpha_0 + \alpha_1 TOP_{it} + \alpha_2 FDI_{it} + \alpha_3 ICT_{it} + \alpha_4 GDPpc_{it} + \varepsilon_{it}$ (1)

Where: REC=renewable energy consumption which is Renewable energy consumption and Renewable electricity output; TOP=trade openness which is trade freedom index; FDI= Foreign direct investment which is foreign direct investment as percentage of GDP; ICT=information and communication technology which is internet penetration; GDPpc =economic growth which is gross domestic product per capita; i=44; t=2000…..2020; $\varepsilon$=error term.
Considering the first hypothesis of this study, the baseline (equation 1) can be extended as:
$REC_{it} = \alpha_0 + \alpha_1 TOP_{it} + \alpha_2 FDI_{it} + \alpha_3 ICT_{it} + \alpha_4 GDPpc_{it} + \alpha_5 FD_{it} + \alpha_6 Gov_{it} + \varepsilon_{it}$ (2)

Where: FD=financial development which is Domestic credit to private sector (% of GDP); Gov= Governance quality which is rule of law, government effectiveness, regulatory quality, control of corruption, political stability and voice & accountability.
We now turn to our second hypothesis which consists to investigate the moderation of governance quality on the financial development-renewable energy consumption linkage. Hence, Equation 2 can be extended as:
$REC_{it} = \alpha_0 + \alpha_1 TOP_{it} + \alpha_2 FDI_{it} + \alpha_3 ICT_{it} + \alpha_4 GDPpc_{it} + \alpha_5 FD_{it} + \alpha_6 Gov_{it} + \alpha_7 (FD \times Gov)_{it} + \varepsilon_{it}$ (3)

Where: $FD \times Gov$=the interaction between financial development and governance quality.
Considering the Equation 3, the marginal effect can be computed as:
$\frac{\partial REC_{it}}{\partial FD_{it}} = \alpha_5 + \alpha_7 Gov_{it}$ (4)

### 3.2Control variables

### 3.2.1Economic growth

Economic growth has been documented to promote renewable energy development(Wang et al., 2021). According to the authors, an increase in economic growth could result in innovation in the renewable energy sector through technology spillover. Therefore, the increase in economic growth could increase the demand in the renewable energy.

### 3.2.2Foreign direct investment

The positive relationship between foreign direct investment and economic growth could be translated in the development of renewable energy sector(Sarkodie et al., 2020).Theoretically, foreign direct investment could contribute to lower carbon emissions and promote renewable energy development through Pollution Halo Effect (PHE)(Qin et al., 2021). Therefore, an increase in foreign direct investment could induce the development of renewable energy sector.

### 3.2.3Information and communication technology

Technological improvements in recent years can be seen as an opportunity in every sector, especially the renewable energy sector. As documented by Awijen et al. (2022), the promotion of technology has a significant impact on the renewable energy sector through reducing substantial cost, increasing competitiveness, and reducing ecological footprint. Hence, an increase in information and communication technology could result in the development of the renewable energy sector.

### 3.2.4Trade openness

As it stems from globalization, Pan et al. (2022) documented that trade liberalization is expected to enhance the development of the renewable energy sector through transferring technology. Thus, an increase in trade liberalization could lead to the increase of renewable energy development.

## 3.3 Data

Although African continent contains 54 countries, this study considers 33 African countries during the period 2000-2020 due to the data availability. The data on renewable energy consumption and renewable electricity output, gross domestic product per capita, financial development and internet penetration were collected from the World Development Indicators of the World Bank. While the data on governance quality (rule of law, government effectiveness, political stability, voice & accountability, regulatory quality, and control of corruption) were obtained from the World Governance Indicators of the World Bank, the data on trade freedom index were gleaned from Heritage Foundation.

## 3.4 Econometric procedure

As efficient and unbiased results remain an important for econometric model, it is crucial to test cross-sectional dependence (CD) in this study. In accordance with the argument of Adeola and Evans (2020) and Dossou et al. (2021), CD is always present in panel regression. As argued by the authors, ignoring CD test in panel regression can provide serious consequence such as unaccounted for residential dependence which could lead to estimator efficiency loss and invalid test statistics. Based on these

arguments, following Dossou et al.(2023), Ehigiamusoe (2020) and Bulut et al. (2019), we therefore perform CD test of Pesaran(2004). Further, we use cross-sectionally augmented ADF (CADF) test developed by Pesaran (2007) to examine the integration properties. This test is robust to the presence of CD. Moreover, through the cointegration approach developed by Kao (1999), we investigated the cointegration relationship between variable in empirical model. As argued by Ehigiamusoe (2020), the fully modified ordinary least square (FMOLS) estimation technique is suitable in the cointegrated panels. Moreover, the FMOLS estimation technique possesses more econometric advantages compared to other traditional estimation technique, namely OLS, RE and FE as they are capable to produce a spurious result. First, according to Pedroni (2000), FMOLS estimator accounts for serial correlation. Second, it accounts for endogeneity problems. Furthermore, the panel corrected standard errors (PCSE) estimation technique developed by Jönsson (2005) has been used to account for cross-sectional dependence.

## 4.Empirical results and discussion

### 4.1 Descriptive statistics and correlation matrix

Table 1 shows the descriptive statistics. From Table 1, the mean value for renewable energy consumption and renewable energy output was 52.842% and 52.842%, respectively. This can be corroborated by Figure 3. This supports the arguments of Pan et al. (2022) who argued that renewable energy development is low compared to other continents, namely Asia and Latin America. Moreover, financial development had a mean of 23.575% which is low compared to Asia and Latin America (Tchamyou et al., 2019).

Table 1. Descriptive statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Renewable energy Consumption | 660 | 52.842 | 35.911 | 0 | 100 |
| Renewable energy output | 660 | 64.195 | 29.460 | .06 | 98.34 |
| Financial development | 660 | 23.575 | 26.827 | 0.491 | 142.422 |
| Control of corruption | 660 | -0.639 | 0.509 | -1.572 | 0.762 |
| Government effectiveness | 660 | -0.681 | 0.563 | -1.849 | 1.056 |
| Political stability | 660 | -0.671 | 0.832 | -2.699 | 1.1184 |
| Rule of law | 660 | -0.658 | 0.573 | -1.853 | 1.077 |
| Regulatory quality | 660 | -0.631 | 0.558 | -2.236 | 1.127 |
| Voice & accountability | 660 | -0.577 | 0.657 | -1.850 | 0.940 |
| Economic growth | 692 | 5148.599 | 5504.174 | 630.701 | 32642.85 |
| Information and communication technology | 676 | 12.590 | 16.276 | 0.006 | 84.120 |
| Foreign direct investment | 692 | 3.661 | 5.394 | -4.840 | 42.093 |
| Trade openness | 570 | 63.744 | 11.363 | 0 | 88.7 |

Further, governance quality (control of corruption, government effectiveness, political stability, rule of law, regulatory quality and voice & accountability) has a mean of -0.639, -0.681, -0.671, 0.658, -0.631 and -0.577, respectively. It suggests that the quality of governance is very poor in Africa (Dossou, Toyo Amègnonna, 2023; Dossou et al., 2023).

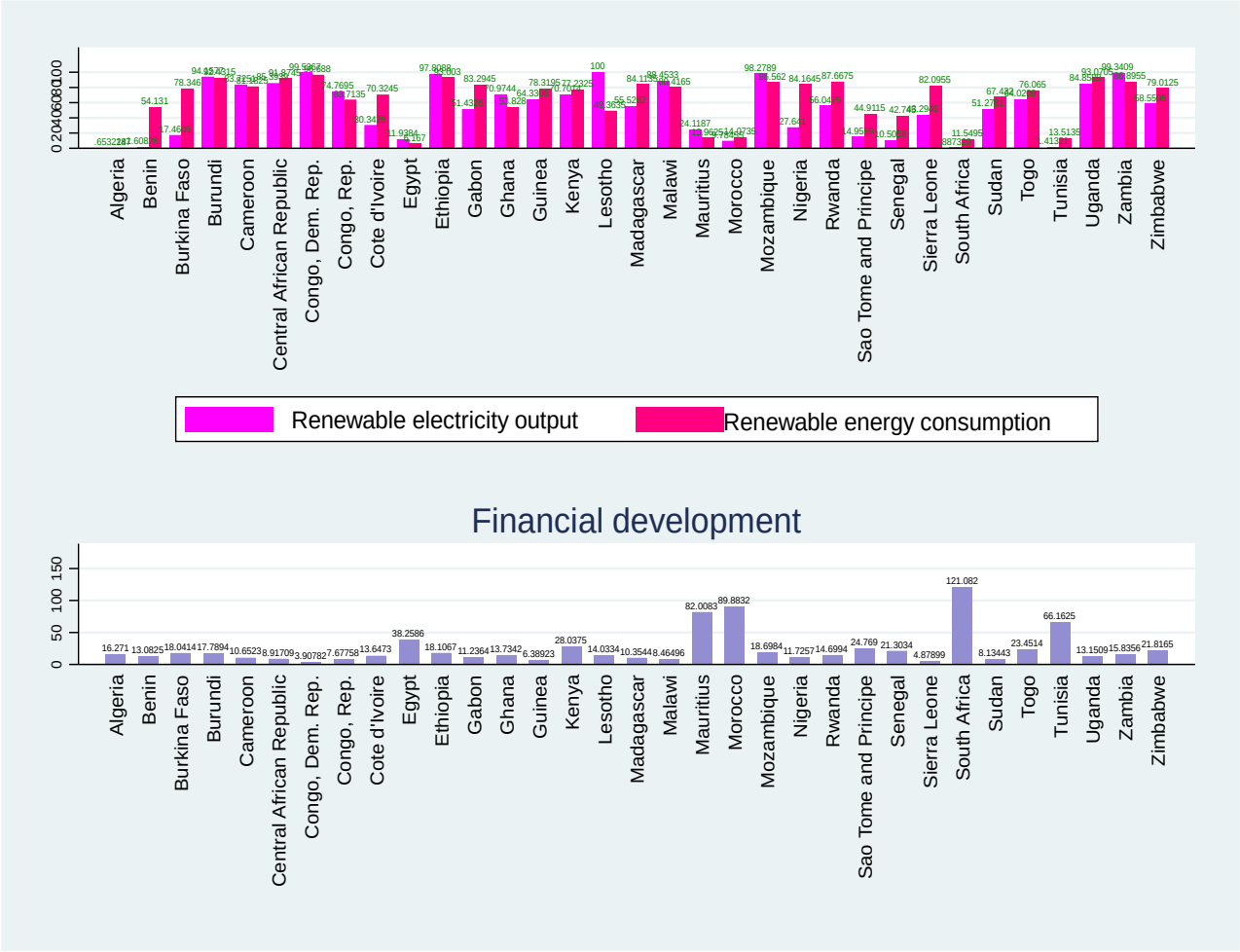


Figure 3. In country renewable energy consumption and financial development in Africa, 2000-2020

Sources: Authors' computation based on data set from World Development Indicators.

The correlation results have been presented in Table 2. As revealed in Table 2, financial development is negatively correlated with renewable energy consumption and renewable energy output. Similarly, the negative correlations are also seen between governance quality and renewable energy development (see Figure A1 in appendix). Multicollinearity is not a concern from two main standpoints: (i) on the front of linear additive models, the governance variables which exhibit multicollinearity are employed in distinct specifications in order to avoid to concern of multicollinearity. Moreover, the correlation between the adopted control variables are and independent variables of interest do not exceed the 0.700 threshold used to established evidence of

multicollinearity (Kennedy, 2008). (ii) With respect to non-linear or interactive regressions, as documented in Brambor et al. (2006) on the pitfalls of interactive regressions, multicollinearity is overlooked in interactive regressions. It is for this reason, that net effects and/or thresholds are computed in order to account for the underlying concern of multicollinearity. Such computation of net effects and/or thresholds entail both the unconditional and the interactive or conditional effect of the main channel (Asongu & Odhiambo, 2020; Asongu & le Roux, 2023; Tchamyou et al., 2023). This clarification has been provided before Table 2 to further boost the narrative on the correlation matrix.

In the light of the above, in interactive regressions, in order to avoid the pitfall of documented in Brambor et al. (2006), the corresponding regressions are not interpreted as in linear additive models in order to avoid the influence of multicollinearity. Hence, the interactive estimated coefficients are not interpreted in isolation because doing so will be interpreting the estimated coefficients as in linear additive models. It is for this reason that net effects and/or thresholds are computed. This has also been clarified just below the narrative on the correlation matrix.

Table 2. Correlation matrix

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1)Renewable energy Consumption | 1 | | | | | | | | | | | | |
| (2)Renewable energy output | 0.542*** | 1 | | | | | | | | | | | |
| (3)Financial development | -0.426*** | -0.751*** | 1 | | | | | | | | | | |
| (4)Control of corruption | -0.334*** | -0.637*** | 0.510*** | 1 | | | | | | | | | |
| (5)Government effectiveness | -0.365*** | -0.709*** | 0.663*** | 0.846*** | 1 | | | | | | | | |
| (6)Political stability | -0.231*** | -0.507*** | 0.298*** | 0.659*** | 0.631*** | 1 | | | | | | | |
| (7)Rule of law | -0.293*** | -0.661*** | 0.537*** | 0.861*** | 0.900*** | 0.755*** | 1 | | | | | | |
| (8)Regulatory quality | -0.397*** | -0.632*** | 0.606*** | 0.794*** | 0.877*** | 0.594*** | 0.884*** | 1 | | | | | |
| (9)Voice& accountability | -0.385*** | -0.740*** | 0.553*** | 0.709*** | 0.781*** | 0.670*** | 0.819*** | 0.782*** | 1 | | | | |
| (10)Economic growth | -0.164** | -0.309*** | 0.432*** | 0.118* | 0.195*** | 0.0343 | 0.170** | 0.228*** | 0.140** | 1 | | | |
| (11)Information and communication technology | -0.381*** | -0.588*** | 0.609*** | 0.377*** | 0.475*** | 0.294*** | 0.446*** | 0.431*** | 0.423*** | 0.414*** | 1 | | |
| (12)Foreign direct investment | 0.204*** | 0.0240 | -0.0723 | -0.0233 | -0.102 | 0.125* | -0.0465 | -0.0688 | 0.0216 | -0.117* | 0.00389 | 1 | |
| (13)Trade openness | -0.140** | -0.274*** | 0.361*** | 0.435*** | 0.408*** | 0.297*** | 0.455*** | 0.510*** | 0.396*** | -0.0621 | 0.355*** | 0.139** | 1 |

*p < 0.05, ** p < 0.01, *** p < 0.001.

### 4.2Cross-sectional dependence test

Table 3 displays the results for the test of cross-sectional dependence test. In accordance with the p-value reported in Table 3, all variable used in this model are significant at the 1% level meaning the existence of cross-sectional dependence. This result might be attributed to the fact that African economies have recently signed the so-called Africa Continental Free Trade Areas (AfCFTA), which seems to promote economic integration.

Table 3. Cross-sectional dependent test.

| Variable | Statistic | p-value |
|---|---|---|
| Renewable energy Consumption | 125.977*** | 0.000 |
| Renewable energy output | 88.582*** | 0.000 |
| Financial development | 62.3350*** | 0.000 |
| Control of corruption | 54.720*** | 0.000 |
| Government effectiveness | 61.080*** | 0.000 |
| Political stability | 23.271*** | 0.000 |
| Voice accountability | 35.798*** | 0.000 |
| Regulatory quality | 75.399*** | 0.000 |
| Rule of law | 59.699*** | 0.000 |
| Trade openness | 60.889*** | 0.000 |
| Foreign direct investment | 79.643*** | 0.000 |
| Information and communication technology | 80.327*** | 0.000 |
| Economic growth | 120.683*** | 0.000 |

*** $p < 0.01$

### 4.3Unit root test

According to the test of unit root which is presented in Table 4, the results show that all variables are stationary after first difference, meaning that this panel contains unit root due to its integration at order one.

Table 4. Pesaran's cross-sectional augmented Dickey–Fuller.

| | Intercept | Intercept and trend |
|---|---|---|
| Variables | t bar | t bar |
| **Level** | | |
| Renewable energy Consumption | -5.347*** | 2.113 |

| | | |
|---|---|---|
| Renewable energy output | -7.195*** | 0.657 |
| Financial development | -5.106*** | -5.106 |
| Control of corruption | -9.095*** | -0.993 |
| Government effectiveness | -10.501*** | -1.647** |
| Political stability | -10.046*** | -1.88** |
| Voice accountability | -9.995*** | -2.351*** |
| Regulatory quality | -8.826*** | -8.826** |
| Rule of law | -9.014*** | -1.692** |
| Trade openness | -13.405*** | -6.18*** |
| Foreign direct investment | -1.692*** | -1.692*** |
| Information and communication technology | 15.341 | 6.891 |
| Economic growth | -4.446*** | 2.032 |
| **First difference** | | |
| Renewable energy Consumption | -17.863*** | -13.734*** |
| Renewable energy output | -16.24*** | -11.47*** |
| Financial development | -16.870*** | -10.892*** |
| Control of corruption | -18.774*** | -14.366*** |
| Government effectiveness | -20.467*** | -18.741*** |
| Political stability | -21.0931*** | -20.105*** |
| Voice accountability | -19.127*** | -15.675*** |
| Regulatory quality | -20.407*** | -17.981*** |
| Rule of law | -19.185*** | -14.742*** |
| Trade openness | -21.687*** | -22.525*** |
| Foreign direct investment | -24.623*** | -25.838*** |
| Information and communication technology | -8.953*** | -4.978*** |

| | | |
|---|---|---|
| Economic growth | -13.021*** | -6.550*** |

*** and ** Indicate 1% level of significance and 5% level of significance.

### 4.4Co-integration test

The test of cointegration has been provided in Table 5 which reveals that all variables are cointegred at 1% level of significance. This means that there is cointegrated relationship among the used variables.

Table 5. co-integration test

| | Statistic | p-value |
|---|---|---|
| Augmented Dickey-Fuller | 4.551*** | 0.000 |

Notes: *** denotes statistical rejection significance at 1% level.

### 4.5 The effects of financial development and governance quality on renewable energy consumption

Table 6 displays the results for the influence of financial development and governance quality on renewable energy consumption in Africa. Considering Column 1 which is the baseline, unlike the empirical evidence of Amoah et al. (2022), the results show that foreign direct investment presents an ineffective impact on renewable energy consumption. We also reveal that a unit increase in information and communication technology leads to a unit increase in renewable energy consumption. This finding can be attributed to the fact that information technology has the power to promote innovation in the renewable energy sector (Khan et al., 2020).Moreover, our finding has been corroborated by the argument of Awijen et al. (2022) who hold that information technology has the power to reduce asymmetric information which plays a significant role in promoting renewable energy development. Similarly, promoting information technology is expected to reduce a substantial cost and increase competition among firms which have the power to promote renewable energy development(Pan et al., 2022).

We also find evidence that economic growth promotes renewable energy development. The magnitude effect shows that a unit increase in economic growth leads to 0.000276-unit increase in renewable energy development. Our finding is consistent with the argument of Murshed (2021) who documented that improving income growth could contribute to developing infrastructure, which further could contribute to enhancing renewable energy development.

Using trade freedom as proxy of trade openness, we reveal that trade liberalization enhance renewable energy development, meaning that a unit increase in trade openness contribute to an increase in renewable energy consumption by 0.832 unit. This finding can be attributed to the fact that the recent signing of Africa Continental Free Trade Areas (AfCFTA) can contribute to reduce tariff and non-tariff barriers, which by extension could play a crucial role in expediting renewable energy development. Our finding has been supported by Murshed (2021) who argue that removing tariff and non-tariff barriers could contribute to the betterment of renewable energy development through exchanging technology among countries.

Considering the first aim of this study, the result show that financial development as a proxy for domestic credit to private sector (% of GDP) has a decreasing effect on renewable energy consumption. The harmful effect of financial system on renewable energy consumption in Africa can be attributed to the fact that the financial development is low in the continent which is not enough to promote renewable energy development as it is more capital intensive (Kim & Park, 2016). According to the authors, renewable energy projects are related to high upfront capital costs. This finding can also be explained by the fact that asymmetric information through an inefficient financial system can impede renewable energy development. Our finding disagreed with the argument of Kim and Park (2016) who posit that moral hazards and adverse selection problem can be overcome through developing financial system which can contribute to reduce firms'cost of raising external funds. This finding can be explained by the immature of financial market which seems to undermine renewable energy development. Moreover, Africa is facing high debt costs which appear to impede renewable energy development(Nelson & Shrimali, 2014). In the same account, this finding has been supported by the argument of Peimani(2018)who posited that developing countries are facing financial barriers which undermined the process of renewable energy. Similarly, our finding opposes the results of Shahbaz et al. (2021)who used the FMOLS estimation and found that financial development increases the demand of renewable energy in 34 developing countries. Our finding also disagreed with the findings of Dimnwobi et al.(2022) who argued that renewable energy development can be promoted through raising external capital as it helps to improve financial system.

The results also unveil the decreasing effect of governance quality on renewable energy consumption. For instance, unit increase in control of corruption, political stability, government effectiveness, rule of law, regulatory quality and voice & accountability leads to 27.41, 13.31, 30.52, 22.88, 31.89 and 25.82-unit decrease in renewable energy consumption, respectively. The finding is not surprising given the fact that the quality of institutions in Africa is poor (Ofori et al., 2021; Pan et al., 2022). As such, it does not have power to implement a good energy strategy. Our findings agreed with Pan et al. (2022) who regressed the influence governance quality on renewable energy consumption for 42 sub-Saharan African countries. A further explanation given by the authors is that renewable energy development can be hampered by several factors, such as institutional, financial, political and legislator barriers. This finding can be attributed to the fact most African institutions still promote non-renewable energy consumption in the continent.

Considering the second aim of this study, the coefficient of the interaction between financial development and governance quality is negative and statistically significant. This finding is not surprising given the fact that the quality of institutions is ineffective to provide a good financial planning which is expected to increase the demand of renewable energy. Moreover, this finding can be corroborated by the fact that African poor institutions have led to an imperfection of financial sector which contributes to impede renewable energy development. Similarly, this finding supports the argument of Acemoglu and Robinson (2010) who have attributed the underdevelopment of Africa to its poor institutions which lead to financial instability, which by extension has negatively impacted the renewable energy sector in the continent. In the same account, this finding can be explained by the fact that poor quality of institutions in Africa has

led to the increase of level of corruption, which has negatively affected financial development and thereby impeded renewable energy development. However, the authors have largely ignored the impact of the moderation of governance quality on the financial development-renewable energy development nexus. Moreover, our finding can be supported by Ekşi and Doğan (2020)who documented that high level of corruption could lead the increase of bank risk, which in turn could contribute to decreasing the demand of renewable energy. In the same spirit, our finding is consistent with the argument of Sharma and Paramati (2021) who posited that a high level of corruption could lead to the misallocation of funds from good projects to bad project in the energy sector. This finding is plausible due to the fact that a high level of corruption and political instability could lead to financial underdevelopment (Jha, 2019), which by extension could decrease the demand of renewable energy. Also, our finding supports the argument of Ben Ali et al. (2020) who noticed that financial underdevelopment can be observed due to high level of corruption which contributes to increase capital outflows, which by extension could contribute to undermining renewable energy development. However, the impact of the interaction of financial development and governance quality on renewable energy development has been overlooked by the authors.

Table 6. Results for the impacts of financial development and governance quality on renewable energy consumption (Dependent variable: Renewable energy consumption).

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foreign direct investment | 0.481 | -0.373 | -0.200 | -0.672 | 0.599 | -0.364 | -0.567 | 0.128 | -0.597 | -0.686 | -0.0906 | -0.697 | -0.778 | -0.211 |
| | (0.783) | (0.561) | (0.634) | (0.638) | (0.657) | (0.687) | (0.632) | (0.503) | (0.423) | (0.481) | (0.433) | (0.453) | (0.480) | (0.355) |
| Information and communication technology | 1.662*** | 0.782*** | 1.128*** | 0.978*** | 1.249*** | 1.145*** | 1.240*** | 0.908*** | 0.511** | 0.597** | 0.498** | 0.453** | 0.640*** | 0.354** |
| | (0.360) | (0.272) | (0.299) | (0.302) | (0.303) | (0.324) | (0.293) | (0.238) | (0.210) | (0.237) | (0.211) | (0.223) | (0.234) | (0.175) |
| Economic growth | 0.000276*** | 0.00134*** | 0.000170*** | 0.000281*** | 0.0000399*** | 0.000377*** | 0.000500*** | 0.000137*** | 0.00123*** | 0.00129*** | 0.00122*** | 0.00135*** | 0.00134*** | 0.00100*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Trade openness | 0.832** | 0.210 | 0.781** | 1.124*** | -0.0334 | 0.974** | 1.475*** | 0.865*** | 1.095*** | 1.076*** | 0.828** | 1.239*** | 1.404*** | 0.965*** |
| | (0.376) | (0.286) | (0.379) | (0.377) | (0.371) | (0.418) | (0.408) | (0.298) | (0.260) | (0.290) | (0.258) | (0.282) | (0.312) | (0.216) |
| Financial development | | -0.775*** | | | | | | | -0.556*** | -0.436*** | -0.658*** | -0.589*** | -0.498*** | -0.183 |
| | | (0.148) | | | | | | | (0.124) | (0.168) | (0.120) | (0.133) | (0.155) | (0.135) |
| Control of corruption | | | -27.41*** | | | | | | -14.76* | | | | | |
| | | | (7.314) | | | | | | (6.868) | | | | | |
| Government effectiveness | | | | -30.52*** | | | | | | -14.99 | | | | |
| | | | | (6.960) | | | | | | (7.770) | | | | |
| Political stability | | | | | -13.31** | | | | | | -7.517 | | | |
| | | | | | (4.486) | | | | | | (4.126) | | | |
| Rule of law | | | -22.88** | | | | | | | | | -14.31* | | |
| | | | (7.391) | | | | | | | | | (6.847) | | |
| Regulatory quality | | | | -31.89*** | | | | | | | | | -18.64* | |
| | | | | (7.209) | | | | | | | | | (7.803) | |
| Voice and accountability | | | | | -25.82*** | | | | | | | | | -12.43** |
| | | | | | (4.612) | | | | | | | | | (4.620) |
| Financial development × Control of corruption | | | | | | -0.447 | | | | | | | | |
| | | | | | | (0.237) | | | | | | | | |
| Financial development × Government effectiveness | | | | | | | -0.235 | | | | | | | |
| | | | | | | | (0.217) | | | | | | | |
| Financial development × Political stability | | | | | | | | -0.264 | | | | | | |
| | | | | | | | | (0.156) | | | | | | |
| Financial development × Rule of law | | | | | | | | | -0.238 | | | | | |
| | | | | | | | | | (0.186) | | | | | |
| Financial development × Regulatory quality | | | | | | | | | | | | | -0.172 | |
| | | | | | | | | | | | | | (0.188) | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Financial development × Voice and accountability | | | | | | | | | | | | | | -0.536** |
| | | | | | | | | | | | | | | (0.169) |
| Constant | 133.5*** | 68.69*** | 14.90 | -10.42 | 73.12** | 4.505 | -27.84 | 12.25 | -2.770 | -1.463 | 19.89 | -10.48 | -19.27 | 5.554 |
| | (23.66) | (18.07) | (26.74) | (26.77) | (24.93) | (29.89) | (28.96) | (20.34) | (18.19) | (20.42) | (17.08) | (19.96) | (22.08) | (14.48) |
| *Observations* | 534 | 494 | 484 | 484 | 484 | 484 | 484 | 484 | 448 | 448 | 448 | 448 | 448 | 448 |
| $R^2$ | 0.750 | 0.721 | 0.777 | 0.727 | 0.708 | 0.667 | 0.731 | 0.197 | 0.717 | 0.718 | 0.768 | 0.753 | 0.715 | 0.741 |

Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p< 0.1.

Moreover, this finding can be corroborated by the argument of Jha (2019) who argued that through poor quality of institutions, financial underdevelopment is expected to increase barriers to cross-country financial transaction, which in turn could limit foreign capital and thereby reducing the demand of renewable energy.

## 5.Robustness check

### 5.1 Robustness check1

In checking the robustness of results, we use an alternative estimation technique, namely the panel corrected standard errors (PCSE) estimation, which has been used to account for cross-sectional dependence. That said, the results displayed in Table 7 unveil that economic growth, information technology, trade openness enhance renewable energy development (see Colunm1).

In the remit of our first aim, the results unconditionally show that financial development has a decreasing effect on the demand of renewable energy. Our results are inconsistent with Pan et al. (2022). Similarly, the impact of governance quality on renewable energy consumption is negative and statistically significant. Our results are in line with (Pan et al., 2022).

### 5.2 Robustness check2

We also check the robustness check of our results by using alternative renewable energy indicator, namely renewable energy output. The results remain unchanged compared to the earlier results reported in Table 6. For brevity, these results have not been reported but are available on request.

Table 7. Robustness check using the panel standard corrected errors (PCSE) estimation.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foreign direct investment | 0.141* | -0.0554 | -0.000846 | -0.160 | 0.329** | -0.0567 | -0.0609 | 0.143 | -0.0830 | -0.149 | 0.142 | -0.129 | -0.135 | 0.0120 |
| | (0.0701) | (0.103) | (0.102) | (0.115) | (0.124) | (0.109) | (0.0977) | (0.102) | (0.0868) | (0.0978) | (0.0962) | (0.0972) | (0.104) | (0.107) |
| Information and communication technology | 0.762*** | 0.418*** | 0.600*** | 0.541*** | 0.679*** | 0.588*** | 4.635*** | 3.737*** | 3.650*** | 3.673*** | 3.401*** | 3.313*** | 3.951*** | 3.508*** |
| | (0.0872) | (0.0777) | (0.101) | (0.0732) | (0.110) | (0.106) | (0.664) | (0.599) | (0.401) | (0.310) | (0.350) | (0.380) | (0.456) | (0.448) |
| Economic growth | 0.000690*** | 0.000262** | 0.000494*** | 0.000391*** | 0.000565*** | 0.000447*** | 5.494*** | 5.369*** | 1.377* | 1.049* | 0.916 | 1.091* | 0.529 | 0.405 |
| | (0.000) | (0.000) | (0.0000) | (0.0000) | (0.000) | (0.000) | (0.482) | (0.562) | (0.543) | (0.416) | (0.478) | (0.518) | (0.488) | (0.583) |
| Trade openness | 0.233* | 0.0938 | 0.118 | 0.129* | -0.0893 | 0.168** | 12.61*** | 9.502** | 14.43*** | 11.35** | 10.66** | 15.56*** | 17.19*** | 16.40*** |
| | (0.102) | (0.0541) | (0.0625) | (0.0578) | (0.0501) | (0.0646) | (3.657) | (2.897) | (3.914) | (3.838) | (3.767) | (4.334) | (4.572) | (4.060) |
| Financial development | | -0.589*** | | | | | | | -0.396*** | -0.314*** | -0.483*** | -0.408*** | -0.393*** | -0.238*** |
| | | (0.0192) | | | | | | | (0.0273) | (0.0335) | (0.0173) | (0.0208) | (0.0229) | (0.0218) |
| Control of corruption | | | -22.41*** | | | | | | -11.58*** | | | | | |
| | | | (1.188) | | | | | | (0.722) | | | | | |
| Government effectiveness | | | | -22.43*** | | | | | | -11.60*** | | | | |
| | | | | (1.003) | | | | | | (0.954) | | | | |
| Political stability | | | | | -11.24*** | | | | | | -5.779*** | | | |
| | | | | | (0.392) | | | | | | (0.638) | | | |
| Rule of law | | | | | | -19.87*** | | | | | | -11.54*** | | |
| | | | | | | (0.736) | | | | | | (0.913) | | |
| Regulatory quality | | | | | | | -19.91*** | | | | | | -9.572*** | |
| | | | | | | | (0.736) | | | | | | (0.869) | |
| Voice and accountability | | | | | | | | -22.01*** | | | | | | -13.06*** |
| | | | | | | | | (0.815) | | | | | | (0.934) |
| Financial development × Control of corruption | | | | | | | | | -0.248*** | | | | | |
| | | | | | | | | | (0.0216) | | | | | |
| Financial development × Government effectiveness | | | | | | | | | | -0.146*** | | | | |
| | | | | | | | | | | (0.0333) | | | | |
| Financial development × Political stability | | | | | | | | | | | -0.169*** | | | |
| | | | | | | | | | | | (0.0222) | | | |
| Financial development × Rule of law | | | | | | | | | | | | -0.116*** | | |
| | | | | | | | | | | | | (0.0210) | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Financial development × Regulatory quality | | | | | | | | | | | | | -0.117*** | |
| | | | | | | | | | | | | | (0.0247) | |
| Financial development × Voice and accountability | | | | | | | | | | | | | | -0.242*** |
| | | | | | | | | | | | | | | (0.0309) |
| Constant | 96.37*** | 79.82*** | 57.77*** | 55.21*** | 78.95*** | 55.57*** | 57.87** | 68.79*** | 26.36 | 35.22* | 43.85* | 19.95 | 11.60 | 8.992 |
| | (7.187) | (3.082) | (4.626) | (4.109) | (3.644) | (4.468) | (17.62) | (15.23) | (19.39) | (17.77) | (18.24) | (20.91) | (21.24) | (20.58) |
| *Observations* | 535 | 495 | 485 | 485 | 485 | 485 | 485 | 485 | 449 | 449 | 449 | 449 | 449 | 449 |
| $R^2$ | 0.317 | 0.593 | 0.531 | 0.552 | 0.477 | 0.513 | 0.523 | 0.665 | 0.712 | 0.680 | 0.699 | 0.695 | 0.659 | 0.773 |
| The net effect | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | -0.21 | -0.37 | -0.33 | -0.32 | -0.1 |
| Threshold | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.825 | 2.15 | 2.86 | 3.36 | 0.1 |

Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p< 0.1.

## 6.**Conclusion and policy implications**

Although the financial development-renewable energy consumption nexus and the governance quality-renewable energy consumption nexus have been investigated in recent years, the study regarding the moderating effect of governance quality on the financial development-renewable energy consumption linkage remains quite inconsistent. Therefore, the present study fills the gap in the energy economics literature by investigating the moderation of governance quality on the financial development-renewable energy consumption linkage for a panel of 33 African countries over the period 2000-2020. The fully modified ordinary least square (FMOLS) and panel standard corrected errors (PCSE) estimation techniques have been used to account for the cointegration and cross-sectional dependence, respectively. The results unveil that the impact of governance quality and financial development on renewable energy consumption is significantly and statistically significant. Moreover, the results reveal that the financial development-governance quality interactions are significant and negative. Governance quality (control of corruption, government effectiveness, political stability, rule of law, regulatory quality, and voice & accountability) thresholds at which the negative incidence of financial development on renewable energy consumption is completely nullified are 0.825; 2.15; 2.86; 3.52; 3.36; and 0,1, respectively.

In accordance to the findings of this study, some policy implications have been provided. African governments need to reform and strengthen policy toward environmental quality by promoting renewable energy development. For example, institutional reform should be made by reducing taxes which is expected to increase capital flows in the renewable energy sector. African institutions should fight corruption which hampers the development in the continent. African institutions should reform the financial sector as it has the power to promote renewable energy development. Furthermore, the governance thresholds at which the unfavourable effect of financial development on renewable energy consumption is completely dampened are actional governance quality thresholds that governments in sampled countries must act upon in order for governance to effectively moderate financial development in view of promoting renewable energy consumption.

The following measures can be taken in order to improve the examined governance levels to reach the targeted thresholds. (i) Political leaders should be elected and replaced within a framework of free and fair elections especially as it pertains to ensuring political stability/no violence as well as boosting voice and accountability (i.e., promotion of political governance). (ii) Economic governance should be promoted through the insurance of governance effectiveness and robust regulatory quality which are worthwhile in making sure that credible policies are formulated and implemented for the delivery of public commodities. (iii) An environment that ensures that both citizens and the government respect institutions that oversee interactions between them should also be consolidated, not least, because doing better controls for corruption and upholds the rule of law.

The findings in this study obviously leave space for further research, especially as it pertains to considering country-specific studies which are not taken into account in the adopted GMM estimation technique. It is worthwhile to note that, theoretically and practically, the GMM technique has the shortcoming of eliminating country fixed

effects that are correlated with the lagged dependent variable and thus, represent a concern of endogeneity. Moreover, further studies should also assess if the established findings withstand empirical scrutiny in other developing regions such as Asia and Latin America.

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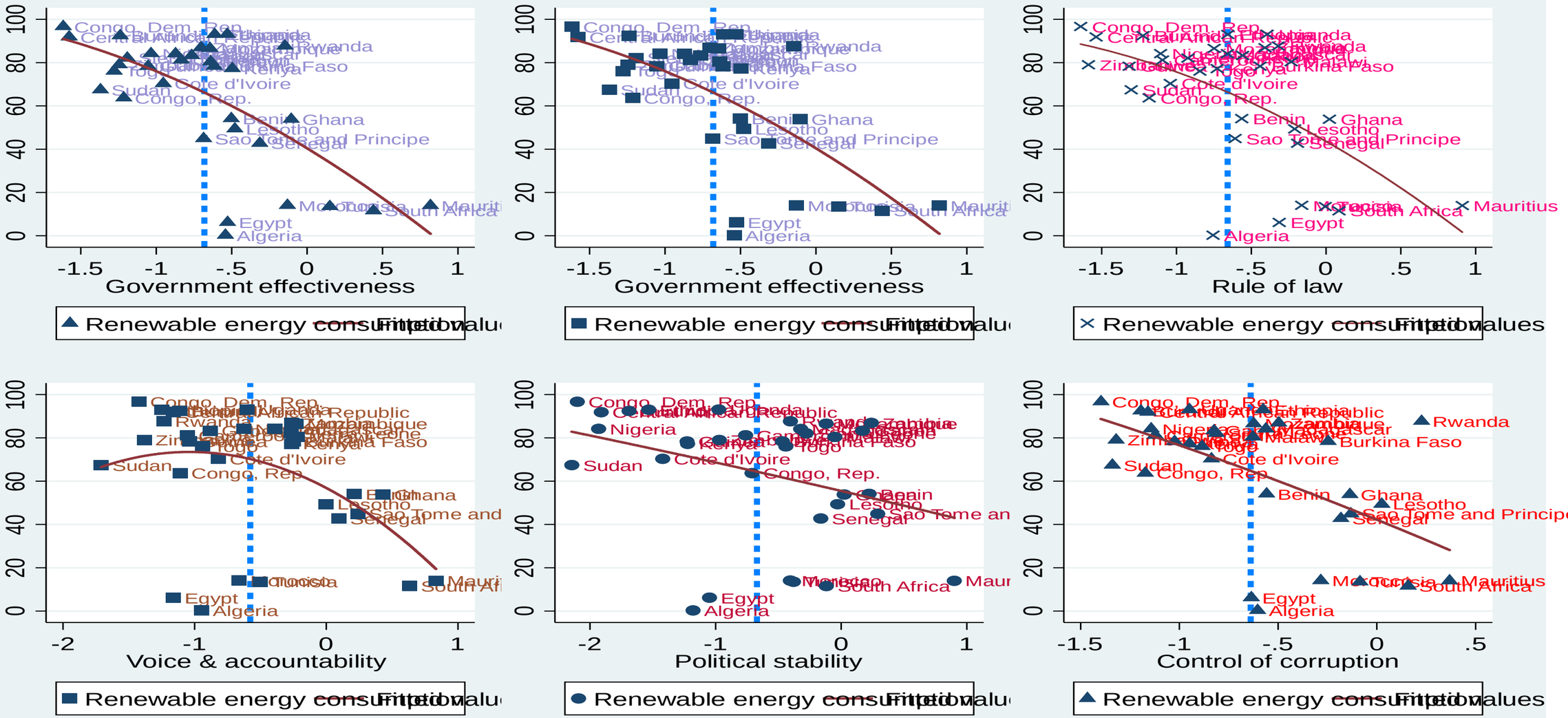


Figure A1. The relationship between governance quality and renewable energy consumption in Africa, 2000-2020

Source: Authors' computation based on data set from World Development Indicators and World Governance Indicators