Towards Inclusive Green Growth in Africa: Critical energy efficiency synergies and governance thresholds

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26 June 2022

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Abstract

This study contributes to the scholarly literature on the drive towards sustainable development in light of the UN's Agenda 2030 and the African Union's Agenda 2063 by examining pathways through which energy efficiency (EE) promotes inclusive green growth (IGG) in Africa. Our contribution is novel from both the conceptual and empirical perspectives. With regard to the former, we develop a framework on how EE and governance feed into IGG, and on the latter, our contribution is based on country-level data for 23 African countries for the period 1996 – 2020. First, evidence from the generalised method of moments (GMM) estimator shows that EE is not unconditionally effective for spurring IGG. Second, we find that governance is both directly, and indirectly effective for repackaging EE to foster IGG. In particular, the evidence suggests that governance mechanisms for controlling corruption while ensuring regulatory quality and government effectiveness are keys for forming relevant synergies with EE to foster IGG. Third, regarding the socioeconomic sustainability (SES) and environmental sustainability (EVS) dichotomy of IGG, we find that the EE-governance pathway is more effective for driving the latter compared to the former. We also make some policy recommendations.

Keywords: Africa, Inclusive Growth; Inclusive Green Growth; Greenhouse Gases; Environmental Sustainability; Carbon Intensity; Sustainable Development

***JEL Codes**: I3; O11; O43; O44; O55; Q01; Q43; Q56*

1. Introduction

As a result of increasing pressure on global resources, mounting environmental problems, and non-inclusive economic growth, there is a growing focus on growth that is both greener and more inclusive (Gu et al., 2021; Halkos et al., 2021; Fay, 2012). Inclusive green growth (hereafter "IGG") denotes achieving a growth trajectory that is (1) socially progressive and (2) environmentally sustainable such that natural assets continue to provide the resources and environmental services on which life depends (OECD, 2017; UNFCCC, 2015; GGKP 2013; Elkington, 1998; Brundtland, 1987; Meadows et al., 1972). In other words, IGG emphasises the total harmonisation of three spheres: economy, environment, and society (Sun et al., 2020; World Bank, 2012). For developing countries like those in Africa, achieving social progress alone is a daunting task considering the seeming lack of progress toward income inequality in response to recent growth strides (Ofori et al., 2022; Obeng et al. 2022; AUC/OECD, 2021; IMF 2020; World Bank, 2020). Further, with the onset of the coronavirus pandemic and its deleterious effects on people's welfare, cracks in Africa's recent growth momentum have been made clear. The pandemic has cast doubts on achieving the UN's Agenda 2030 and the African Union's Agenda 2063, and the World Bank (2020) has noted that 87 percent of the world's extreme poor will reside in Africa if current socioeconomic conditions continue. Additionally, the continent is facing numerous environmental issues, and hence the importance of IGG in Africa.

It is in this regard that this study examines the effects on IGG of two crucial channels that are consistent with the UN's and African Union's sustainable development agendas: (i) energy efficiency and (ii) good governance. Specifically, the aim of this study is to investigate the pathways through which energy efficiency (hereafter "EE") promotes IGG in Africa. Indeed, the SDG 7 stresses the essence of EE for both socioeconomic and environmental sustainability. The relevance of EE for socioeconomic sustainability (hereafter "SES"), especially in Africa, is implicitly anchored in the new endogenous growth and catch-up theories of sustained shared growth. EE fosters SES by promoting and sustaining industrialisation, innovation, economic growth, and durable employment creation (Razzaq et al., 2021; Adom et al., 2021; Ohene-Asare et al., 2020; Lakhera, 2016; Lipsey et al., 2005). Energy efficiency can also play a crucial role in bridging income gaps by increasing energy-related cost savings for low-income households, thereby freeing up resources for other productive activities in the process (Njiru & Letema, 2018).

With respect to environmental sustainability (hereafter "EVS"), EE could play a role in protecting human life and biodiversity by reducing energy intensity and the stress on natural asset bases (Arouri et al., 2021; Akram et al., 2020; Lin & Abudu, 2020). Beyond its much-emphasised role in addressing climate change through reductions in carbon emissions and the achievement of net-zero emissions in the broader perspective by 2050 (UNFCCC, 2015), EE can also support environmentally-friendly practices and innovations which have been found to be relevant pathways for promoting the environmental quality of life (IEA, 2021; WEF, 2021; OECD, 2017; GGKP, 2013).[1] Particularly in African countries where resources for mitigating climate change concerns and for building resilience to withstand environmental shocks are limited, EE presents a pathway that can be leveraged to address the Environmental Kuznets Hypothesis (EKC).

Notwithstanding the aforementioned EE-IGG linkages, concerns on the viability of EE in delivering sustainable development dividends have also been raised. First, based on the growth-impeding effect of EE, scholars have argued that strict adherence to environmentally-friendly policies (e.g., improvements in EE) presents more risks than opportunities, since a large amount of energy production and consumption is needed to spur and sustain growth in developing countries (Esen & Bayrak, 2017; Dercon, 2012; Khazzoom, 1980). The rebound effect of EE also raises the concern that improvements in EE may not necessarily translate into environmental sustainability (Khazzoom, 1980). This is because EE may not necessarily be cost-effective, as though it frees up resources through reductions in the implicit cost of energy consumption on the one hand, it can also trigger higher energy demand and pollution on the other (Adom et al., 2021; Ohene-Asare et al., 2020; Khazzoom, 1980). For instance, cost savings arising out of EE could be invested in energy-intensive productive industries like print media, food, and basic organic and inorganic chemical production, potentially triggering EVS setbacks (Adom et al., 2021; Gillingham et al., 2020; Fayiya et al., 2018; Conti et al., 2016). This situation is exacerbated because the use of "non-clean" cooking fuels in Africa is high (Pye et al., 2020; Lindgren, 2020; Bekun et al., 2019; Behera & Ali, 2017; Puzzolo et al., 2016).

It is with this in mind that we contend that the effectiveness of EE in fostering IGG could be contingent on quality governance, and we argue that good political, economic, and institutional governance have roles to play in ensuring that EE contributes towards achieving multi-dimensional sustainability. From the SES perspective, sound political governance is

[1] A few interesting examples are those of Norway, Singapore, Sweden, and the Netherlands, which are producing energy-efficient and environmentally-sustainable cars (WEF, 2021).

imperative for social cohesion and the protection of domestic and foreign investors (Adegboye et al., 2020; Asongu & Nwachukwu, 2016; Khan, 2012), which could go a long way toward alleviating poverty and income inequality. Prudent economic governance that reduces investment risks and the cost of doing business is also imperative for addressing the wastage of human resources and ensuring that the private sector takes advantage of incentives such as EE to improve upon process or product innovation and engage in durable employment creation (Asongu & Kodila-Tedika, 2016; De Haan, 2015; Pritchett & Werker, 2012). Additionally, strong institutional governance is important not only for sharing the gains from growth but also for spearheading accountability, social inclusion, and levelling of the playing fields in order for all to have a chance at decent living and to contribute to national development (Ivanyna & Salerno, 2021; OECD, 2017; World Bank, 2012).

Despite these EE-governance-IGG linkages, there is a research gap regarding the relevance of EE for IGG in Africa. Although studies have examined the unconditional effects of EE or governance on inclusive growth or environmental sustainability (see e.g., Adom et al., 2021; Dauda et al., 2021; Akram et al., 2020; Ohene-Asare et al., 2020; Opoku & Boachie, 2020; Lin & Abudu, 2020), the question of whether good governance can engender positive synergy with EE to foster IGG remains unanswered. Finally, despite Africa's weak institutions (see Figure A.1), comprehensive empirical studies examining the IGG gains from improving governance quality from the short-term through to the long-term are missing in the literature. Our study therefore seeks to fill these gaps in the scholarly literature, and is driven by three objectives. First, we investigate whether unconditionally both EE and governance foster IGG in Africa. Second, we examine whether good governance develops relevant synergies with EE to promote IGG in Africa. Third, we explore whether there are favourable sustainable development gains of EE at various governance thresholds.

Our study which is based on the dynamic GMM estimator and macrodata for 23 African countries generated the following results. First, unconditionally, EE is not effective for spurring IGG in Africa. The coefficient of EE is negative, suggesting that the rebound effect of EE outweighs possible cost-saving and growth-inducing gains of EE. On the second objective, we find that governance matters for repackaging EE to foster IGG. Notably, institutions which deal with issues such as corruption, regulatory quality, and government effectiveness are crucial for propelling EE to foster IGG. Third, the evidence from our threshold analysis shows that higher IGG gains are apparent from the short-term through to the long-term if resources are channelled into EE promotion and the strengthening of Africa's institutional fabric.

The rest of the paper is organised as follows: the next section provides a theoretical and conceptual framework linking EE and governance to IGG, while Section 3 sheds light on the methodology. Section 4 presents and discusses the results, and Section 5 provides concluding remarks and policy implications.

2. Theoretical background and literature review

2.1 Relationship between EE and IGG: theoretical and empirical perspectives

Regarding SES, the Porter and van der Linde hypothesis positions EE as a key driver of durable growth. Porter and van der Linde (1995) suggest that EE can contribute to firm productivity directly through energy savings and indirectly through energy efficient-technological adoption and innovations. This is echoed by Goulder and Mathai (2000), who argue that strict adherence to energy conservation policies such as EE, foster economic growth. Although more of an implicit relationship, the catch-up and new endogenous growth theories consider EE as a major shared growth input in several dimensions (see Adom et al. 2021; Ayres et al., 2007). Deichmann and Zhang (2013) argue that EE can spur growth through innovations and technological development, which could in turn improve firm performance and cost-competitiveness. Also, Rajbhandari and Zhang (2017) point out that compared to non-renewable energy-induced innovations, EE-related innovations generate more new demand and new markets, spurring durable growth and jobs in the process. Crucially, Deichmann and Zhang (2013) posit that EE investments reduce energy-related expenditure, especially for energy-importing countries, providing resources to spend in other priority areas such as health, education and transport. From the EVS perspective, the ecological modernisation theory stresses that EE can reduce environmental shocks associated with high energy-intensive growth, through green innovation and practices (Razzaq et al., 2021; Gouldson & Murphy, 1997; Murphy & Gouldson, 2000).[2] On the basis of these theories, we formulate our first hypothesis:

Hypothesis 1a: Energy efficiency induces inclusive green growth in Africa.

On the empirical front, there is a growing body of research highlighting the crucial role of EE for both environmental and social progress. For instance, recent studies based on instrumental variable regression, and which focused on Africa showed that EE promotes economic growth

[2] The energy variable, *EE,* was incorporated in the aggregate production function to examine the conditions for balanced growth in Eriksson (2013).

and poverty alleviation (Agradi et al. 2022; Adom et al. 2021). Similarly, Bataille and Melton (2017) use a recursive CGE model to estimate the impact of EE improvements on GDP, employment, economic structure, and welfare in Canada. The study, which covers the period 2002 – 2012, reveals that EE improvement enhances economic growth. Aside from their robust findings on the crucial role of EE for income growth, Cantore et al. (2016) provide strong evidence to show that EE promotes the total factor productivity of manufacturing firms in 29 developing countries. Interrogating the EE-SES relationship by way of cointegration and Granger causality analysis, Bayar and Gavriletea (2019) find evidence for the economic growth-inducing effect of EE in the long-run. Additional evidence from the causality analysis also shows a short-run unidirectional causality from EE to economic growth. Additionally, Go et al. (2020) examine the relationship between EE, CO_2 emissions, foreign direct investment, exports, and real GDP at both the aggregated and disaggregated levels in Malaysia from 1971 to 2013. Based on the autoregressive distributed lag (ARDL) approach, their results indicate that EE Granger causes economic growth but only at the aggregate level.

Studies on the effect of EE in EVS are emerging. For instance, Akram et al. (2020) report a negative relationship between EE and CO_2 emissions in developing countries, suggesting that EE investments could mitigate climate change. In a similar vein, Rajbhandaria and Zhang (2018), show that EE is crucial for promoting equitable income growth and distribution as well as reducing carbon footprint. Moreover, a study which focused on 36 countries for the period 1971-2009, found evidence, based on the common correlated effects estimator, that EE reduces CO_2 emissions in the long-run (Özbuğday and Erbas 2015). Across the OECD and the top 5 greenhouse gas– emitting countries (China, USA, India, Germany, and Japan) researcher find that energy-saving technologies are key modules for addressing the EVS concerns of high-energy-intensive growth (Tajudeen and Banerjee 2018; Javid and Khan 2019).

Nonetheless, some studies report no significant or harmful impacts of EE on sustainable development. For example, Ponce and Khan (2021) in their study which covered the period 1995 to 2019, report that EE is not potent enough for reducing CO_2 emissions in 9 advanced countries. Their finding was corroborated by Lei et al. (2021) who applied the non-linear ARDL to estimate the effects of EE on CO_2 emission in China for the period 1991 to 2019. Marques et al. (2019), however, find strong evidence in the case of 36 middle-income and high-income countries to show that EE increases carbon emissions in the long-run.

2.2 Relationship between governance and IGG: theoretical and empirical perspectives

The institutional and environmental governance theories explain the relationship between governance and IGG. The former stresses the role of better frameworks and structures for inclusive growth (see North, 1990; Acemoglu, Johnson & Robinson, 2010, 2008; Sharma, 2007). This is clearly articulated by North (1990. p.3), who argues that the role of institutions for shared growth is hardly controversial. Additionally, the theoretical relationship between institutions and the environment is anchored in the efficiency-effect hypothesis of quality governance. This hypothesis highlights the relevance of governance for investments decisions and the shaping of eco-friendly interactions, production and consumption behaviours (North, 1990). Accordingly, poor environmental quality is closely associated with poor institutional quality.

Also, the theory of environmental governance points to a direct relationship between government effectiveness and environmental preservation (Ahmed et al., 2021). The theory emphasises that institutions have been entrusted with the responsibility of setting environmental standards and empowering economic agents to act in a manner that is environmentally sustainable (OECD, 2017, 2011; GGKP, 2013; World Bank, 2012). The government's role is therefore to correct prices and provide regulatory frameworks to influence producers to be more eco-efficient, and to offer consumers choices for 'green' and 'ethical' products. For example, where low building energy efficiency contributes to high energy imports, enacting regulations or developing new mechanisms to encourage homeowners to invest in insulation and energy-efficient appliances could pay off in two ways: strengthening the economy and also preserving the environment (IIED, 2016; Fay, 2012). Taking cues from these theoretical perspectives, we argue that the success of EE in promoting IGG from both sides of the EVS and SES divide may be contingent on good governance. In line with the foregoing arguments on the possible direct and moderating effects of governance in the EE-IGG relationship, the following hypotheses are introduced:

Hypothesis 1b: Good governance promotes inclusive green growth.

Hypothesis 2: Good governance interacts with energy efficiency to induce inclusive green growth.

On the empirical angle, Rodriguez-Martinez et al. (2019) examine the relationship between e-governance, e-participation, and level of control of corruption and environmental performance in 116 countries. Their results suggest that in countries where corruption is low, incomes are high and e-participation is promoted, the environmental quality of life is enhanced. Dluhopolyskyi et al. (2019) also report that government effectiveness, democratic institutions, and administration are vital preconditions for improving environmental performance. Using a balanced panel comprising 19 Arab countries over the period 1995 to 2014, Abdelbary and Benhin (2019) also find that good governance (proxied by regulatory quality) has a significant positive effect on growth. Another study which focused on 14 Asian countries for the period 1990 to 2011 and used four institutional quality indicators (government effectiveness, regulatory quality, corruption control, and political stability and absence of violence) found that institutions cause significant reduction in CO_2 emissions (Apergis and Ozturk 2015). Baloch and Wang (2019) analyse the role of governance in CO_2 mitigation among BRICS economies for the years 1996 to 2017. According to their findings, better governance quality mitigates CO_2 emissions and by extension, environmental quality (Baloch and Wang 2019).

In a related study, Hussain and Dogain (2021) used data from 1992 to 2016 to determine the short-and long-term relationship between institutional quality (IQ), environment-related technologies (ERT), energy consumption, and the ecological footprint in BRICS economies. Evidence from the augmented ARDL estimation technique suggests that IQ and ERT promotes EVS by accelerating reduction in ecological footprint. Wawrzyniak & Doryń (2020) also provide evidence that high level of government effectiveness mitigates the CO_2 emission associated with high energy-intensive growth of 93 emerging and developing countries from 1995 to 2014. Along similar lines, Sulaiman et al. (2017) show that corruption control and government effectiveness promote environmental progress in 45 SSA countries between the period 2005 and 2013. A study of 47 developing countries demonstrates that better institutional quality enhances environmental progress by reducing carbon dioxide emissions (Ali et al. 2019). A disaggregated study examined the impact of governance on CO_2 emissions in 25 sub-Saharan Africa and found that while political stability, government effectiveness, and corruption control contribute to pollution reduction, the weak regulatory quality and rule of law hinder environmental progress (Abid 2016). Similarly, Bokpin (2017) shows that strong institutions are crucial in nullifying the adverse impact of FDI on EVS in Africa – a result that has been confirmed by Sarkodie et al. (2018). According to these authors, governance (proxied by political stability) slows down climate change in 47 sub-Saharan African countries (Sarkodie et al. 2018).

A study exploring the impact of corruption control on carbon emissions in 61 developing and developed countries between 2003 and 2016, find that while corruption control reduces carbon emissions in developing countries, the favourable effect eludes advanced countries (Akhbari and Nejati 2019). The authors attribute these opposing findings to the fact that corruption control in developed countries has reached a saturation point compared to their developing counterpart extensive margins for improvements are glaring (Akhbari and Nejati 2019). Azam et al. (2020) also constructed an institutional quality index (IQI) that captures political stability, administrative capacity, and democratic accountability to evaluate its effects on environmental indicators in 66 developing countries examined from 1991 to 2017. Results from the system GMM estimator reveal that IQI increases energy consumption and environmental pollution in developing countries, attributing the harmful effect to policymakers favouring industrial advancement and a high number of constituencies (Azam et al. 2020).

Clearly, although prior studies have examined the role of EE and governance across the EVS and SES dimensions of IGG, there is an empirical research gap with respect to whether EE and governance matter for IGG. A few studies have examined the moderating role of governance for inclusive growth or environmental degradation (see e.g., Ofori et al., 2022a; Wawrzyniak & Doryń, 2020; Sarkodie et al., 2020), but have not addressed this pertinent issue. Additionally, there is a lacuna in the extant scholarship regarding which investments in governance could possibly payoff for IGG in the long run. This study fills these gaps in the empirical literature on IGG and sustainable development in Africa.

2.3 Inclusive Green Growth (IGG): A conceptual framework

Our theoretical exposition brings us to a key contribution of this study, which has to do with the development of a conceptual framework for IGG, as shown in Figure 1. The conceptual framework links sustainable development to (i) socioeconomic sustainability (SES) and (ii) environmental sustainability (EVS). The framework points to the interrelationship between social progress (which is achieved by improving social inclusion and protections for health, education, water, and sanitation, as well as equitable distributions of income and wealth), environmental sustainability (achieved by protecting natural asset bases, improving the environmental quality of life, creating environmentally-friendly economic opportunities, and devising efficient resource production strategies), and inclusive green growth (IGG).

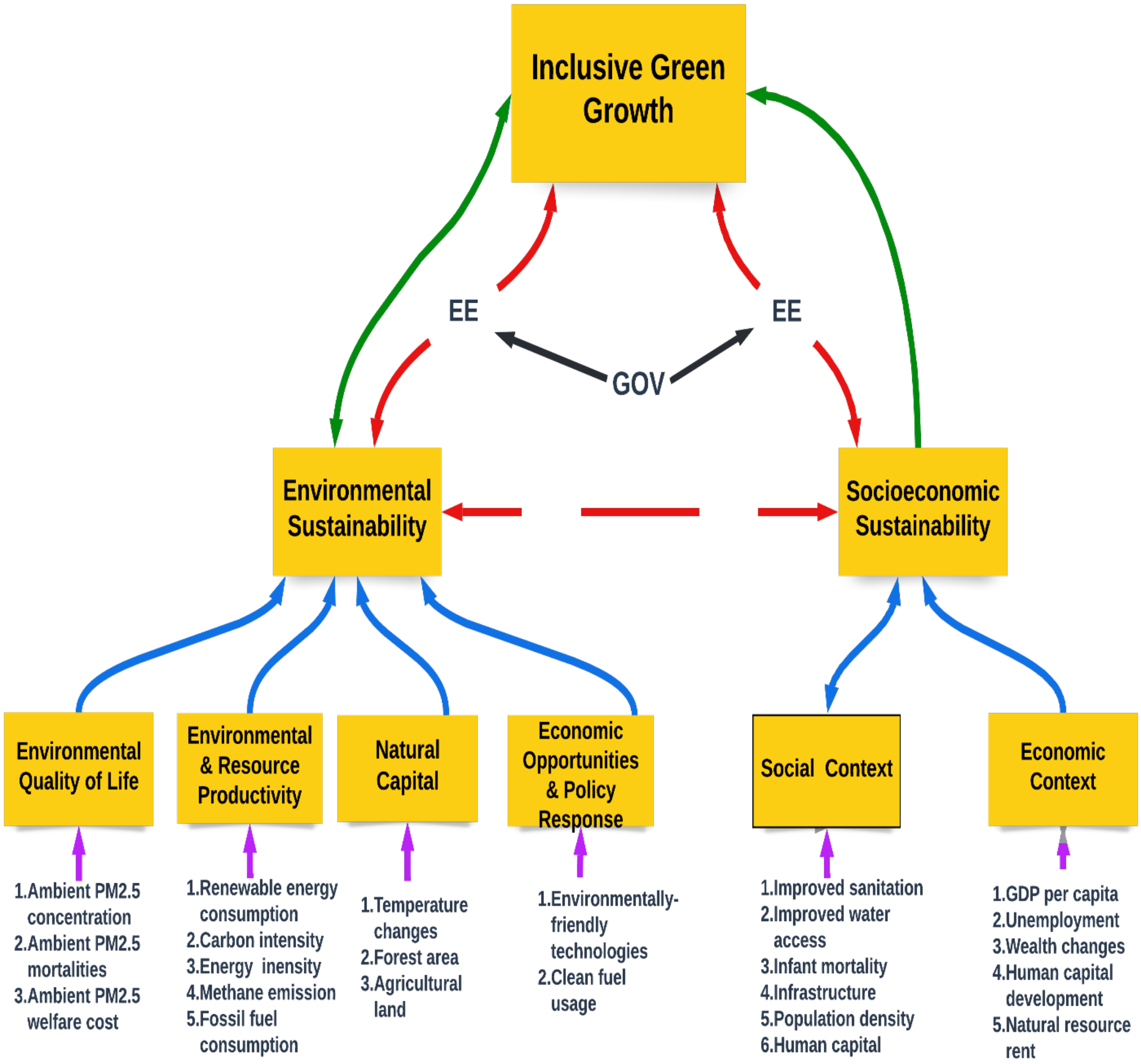

Figure 1: Conceptual Framework for Inclusive Green Growth
Source: Authors' construct

Second, the SES-EVS-IGG linkages indicate that while SES and EVS are pillars for IGG, both SES and EVS can also be enhanced with the achievement of IGG. The flip side holds, however, meaning that growing 'dirty' and 'porous' can hamper sustainable development through the destabilisation of social progress and environmental quality of life. Finally, per our established pathways for fuelling IGG, we incorporate energy-efficient production and consumption practices as well as effective governance in the realisation of sustainable development.

3. Methodology and data

3.1 Data

The study employs a balanced panel dataset spanning 2000 – 2020 over a sample of 23 African countries for the analysis.[3] Our main outcome variable, inclusive green growth (IGG), is not directly accessible in databases, and is therefore generated. In this study, we follow prior empirical studies such as those by Jolliffe (2002), Del Carpio (2017), and Tchamyou et al. (2019) by generating our IGG series using the dimensional reduction technique of principal component analysis (PCA). To inform policy on how the EE-governance linkages matter for SES and EVS, we proxy the former by the Palma ratio and the later by greenhouse gas emissions. The choice of the Palma ratio follows the relative shared growth argument by the IMF (2007) and Ravallion and Chen (2003) that social progress is achieved when the growth in incomes of the bottom 40 percent occurs faster vis-à-vis that of the top 10 percent.

The key regressor in this study is energy efficiency, and this is also generated by following the stochastic frontier approach (SFA) of Kumbhakar et al. (2014). Also, on the basis of the differing dimensions through which governance can affect sustainable development as presented in the preceding sections, we capture our governance moderator by 6 indicators: regulatory quality, government effectiveness, corruption control, political stability, and rule of law and voice and accountability.

It is imperative to point out that some IGG covariates are also controlled for on the grounds of econometric prudence. Specifically, we control for economic integration, development assistance, ICT diffusion, and financial deepening in order to: (i) capture the rise in economic integration of Africa following the implementation of the AfCFTA, (ii) take into account the role of budgetary support in the samples, and (iii) mitigate possible omitted variable bias. The motivation for these control variables in the conditioning information set is discussed in the following.

First, we consider financial deepening due to its power in supporting environmental sustainability through green finance, innovation, and low greenhouse gas emissions while promoting socioeconomic sustainability through the provision of resources to address poverty, inequality, and precarity (Ofori et al. 2022d; Bekhet et al., 2017; Weber, 2014; Shahbaz et al., 2013). Our choice of economic integration strategy follows the implementation of the

[3] The African countries investigated are: Algeria; Angola; Benin; Botswana; Cameroon; Democratic Republic of Congo; Republic of Congo; Cote d'Ivoire; Ethiopia; Gabon; Ghana; Kenya; Mauritius; Mozambique; Namibia; Niger; Nigeria; Senegal; Seychelles; South Africa; Tanzania; Togo; and Tunisia.

AfCFTA, which as Ofori et al. (2022a) and Adeleye *et al*. (2019) reckoned, could prove crucial in addressing Africa's conundrums of poverty, inequality, high informality, and human resource wastage. On the environmental front, while economic integration can trigger innovation and the manufacturing of environmentally-friendly goods to fight climate change (see Opoku & Boachie, 2020), it can also hamper environmental quality of life through pollution/depletion of natural asset bases, especially in the developing world where lapses in environmental regulation are glaring (see Dauda et al., 2021; Nathanael & Iheonu, 2019; Sarkodie & Strezov, 2019).

The inclusion of ICT diffusion also centres on the argument that digital infrastructure can be leveraged to foster social progress and EVS through social inclusion, effective governance, and low-energy-intensive production and consumption practices (Ofori & Asongu, 2021; Ofori et al. 2021a; Asongu et al., 2018). However, there is also the concern that it can contribute to environmental degradation through the rebound effect (Higón et al., 2017). Finally, we keep tabs on development assistance considering global efforts by multilateral organisation such as the World Bank, OECD, and African Development Bank in supporting African countries to build capacity to foster shared growth while supporting climate change adaptability and mitigation through green finance (United Nations, 2015; OECD, 2017; GGKP, 2013). Table 1 shows the descriptions and data sources for the variables.

Table 1: Description of variables and data sources

Variables	Symbol	Descriptions	Sources
Dependent variable			
Inclusive green growth	*igg*	Sustainable development indicator generated using the PCA	Authors
Palma ratio	*palma*	Indicates the ratio of national income shares of the top 10 percent of households to those of the bottom 40 percent	GCIP
Greenhouse gas emissions	*ghgas*	Total greenhouse gas emissions (thousand metric tons of CO_2 equivalent excluding land-use change and forestry)	WDI
Control variables			
Foreign aid	*aid*	Inflow of official development assistance (%GNI)	WDI
ICT infrastructure index	*ictdif*	Composite index for the construction, extension, improvement, operation, and maintenance of communication systems (postal, telephone, telegraph, wireless, and satellite communication systems).	AIKP
Financial deepening	*findep*	Credit to private sector (%GDP)	WDI
Economic globalisation	*trade*	Sum of imports and exports (%GDP)	WDI
Economic growth	*gpc*	GDP per capita (US$' 2017)	WDI
Moderating variables			
Control of corruption	*corrupt*	Captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests (estimate)	WGI
Rule of law	*rol*	Captures perceptions of the extent to which agents have confidence in and abide by the rules of society, in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence	WGI
Government effectiveness	*govef*	Perceptions of the effectiveness of governments in managing and introducing policies aimed at economic growth and development (estimate)	WGI
Regulatory quality	*rol*	Captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	WGI
Political stability	*pol*	Measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism.	WGI
Voice & accountability	*vna*	Captures perceptions of the extent to which a country's citizens participate in selecting their government, as well as freedom of expression, freedom of association, and free media.	WGI

Note: WDI is World Development Indicators; Findex is IMF's Financial Development Index; GCIP is Global Consumption and Income Project; WGI is World Government Indicators; KOF is KOF; Globalisation Index and AIKP is Africa Infrastructure Knowledge Program

3.2 Estimation of energy efficiency

Among the several techniques for generating energy efficiency (EE) scores, the Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) methods stand out (see Agradi et al. 2022; Adom et al., 2021, 2018; Ohene-Asare et al. 2020; Hu et al. 2019; Mutz et al., 2017; Kumbhakar et al. 2014; Filippini & Hunt, 2011). This study opts for the latter on grounds of econometric prudence. First, according to Hu et al. (2019), the SFA accommodates omitted variable bias problems better. Additional caveats for applying the SFA is that it handles data outliers, measurement errors, and data uncertainty better than the DEA (Adom et al., 2021; Mutz et al., 2017). Another key advantage of the SFA over the non-parametric DEA is that it enables one to split EE scores into transient and permanent components. This decomposition, as Adom et al (2021) and Kumbhakar et al. (2014) argue, informs policy action as to whether long-term or short-term energy efficient investments should be pursued.

According to Malghan (2019), measuring EE involves reporting the extent to which the current energy use deviates from the optimal energy use. In this regard, we follow the approach of Adom et al. (2021) and Filippini and Hunt (2011) by specifying a single conditional energy demand frontier function as apparent in Equation 1. In line with Agradi et al. (2022), we proceed by specifying a Cobb-Douglas energy demand function as seen in Equation (2), which is then linearised by way of logarithmic transformation to obtain Equation (3).

$$e_{it}^{ED} = f(p_{it}, h_{it}, K_{it}, \emptyset)e^{v_{it}-u_{it}}, \tag{1}$$

where $\emptyset_p < 0$ and $\emptyset_h > 0$

$$e_{it}^{ED} = f(p_{it}, h_{it}, K_{it}, \emptyset) = Ap_{it}^{\emptyset_p} h_{it}^{\emptyset_h} k_{it}^{\emptyset_k} \tag{2}$$

$$lne_{it}^{ED} = \delta_0 + \emptyset_p lnp_{it} + \emptyset_h lnh_{it} + \emptyset_k lnK_{it} + \varepsilon_{it} \tag{3}$$

where our outcome variable, energy demand, $\boldsymbol{e_{it}^{ED}}$ is a modelled as a function income ($\boldsymbol{h_{it}}$), price of energy ($\boldsymbol{p_{it}}$) and other energy demand drivers ($\boldsymbol{K_{it}}$) as indicated in Equation (3). It follows that $\boldsymbol{f(p_{it}, h_{it}, K_{it},; \emptyset)}e^{v_{it}-u_{it}}$ is the benchmark energy demand frontier, with '$\boldsymbol{e}$' being the Euler's mathematical constant; $\emptyset$ capturing the energy-demand elasticities; A is a constant, ε_{it} is the error term comprising a measure of energy inefficiency, u_{it}, (assumed be half-normally distributed) and 'v_{it}' is the idiosyncratic noise term, with a normal distribution.

To compute technical EE denoted by $\boldsymbol{ef_{it}}$, we follow Greene (2005) by introducing the energy inefficiency term $(-u_{it})$ to Equation (3) to obtain:

$$lne_{it}^{ED} = \delta_0 + \emptyset_p lnp_{it} + \emptyset_h lnh_{it} + \emptyset_k lnK_{it} + \varepsilon_{it} - u_{it} \quad (4),$$

where the price of energy ($\boldsymbol{p_{it}}$) is captured as crude oil price (*lnCrude*) in US$, $\boldsymbol{h_{it}}$ is national income in current US$, $\boldsymbol{i}$ represents individual countries and $\boldsymbol{t}$ is time in years. Following prior contributions in the energy demand literature, we capture the control variables $(\boldsymbol{K_{it}})$ by: industrialisation (***lnind***), trade openness (***lntrade***), and human capital (***hc***) (see Agradi *et al*. 2022; Adom et al., 2021; Adom, 2020a; Adom, 2019a; Adom et al., 2018; Zhang & Adom, 2018; Filippini & Hunt, 2011). Next, we obtain the energy efficiency scores by taking the exponential of $(-u_{it})$.

$$ef_{it} = \exp\,(-u_{it}) \quad (5),$$

where $0 \leq ef_{it} \leq 1$.

Finally, to decompose the inefficiency term $-u_{it}$ into permanent/time invariant (α_i) and transient/time-variant (π_{it}) while accounting for unobserved country-specific heterogeneities $[\boldsymbol{\omega_i}]$ in Equations (6) and (7). we follow the approach of Agradi et al. (2022), Alberini and Filippini (2018), Kumbhakar et al. (2014), and Greene (2005) by specifying Equation (7). This approach as Kumbhakar et al. (2014) reckon, follows four key steps. The first requirement is the estimation of Equation (7) by applying the random effect or fixed effect estimator, decided based on the Hausman test as apparent Table A.1 in the Appendices section[4]. The second requirement involves the estimation of the transient EE $(exp\,(-\pi_{it}))$. The third is the estimation of persistent EE component $(exp\,(-\alpha_i))$, using the stochastic frontier residuals. The final step is the computation of the overall EE scores $(exp\,(\pi_{it} - u_i)$, which is a product of the transient and persistent components of EE.

$$u_{it} = \boldsymbol{\omega_i} + \alpha_i + \pi_{it} \quad (6)$$

$$lne_{it}^{ED} = \delta_0 + \emptyset_p lnp_{it} + \emptyset_h lnh_{it} + \emptyset_k lnK_{it} + \varepsilon_{it} - u_i - \alpha_i - \pi_{it} \quad (7)$$

[4] The results favour the random effect estimation per the Hausman test.

One key concern regarding the estimation of stochastic frontier models is the decision of whether to adopt a cost-type or production-type function. In this regard, Schmidt and Sickles (1984) suggest a skewness test to inform a choice. According to Schmidt and Sickles (1984), a production-type stochastic frontier is preferred if there is negatively skewed OLS residuals whereas a cost-type stochastic frontier is preferred for positively skewed residuals (see Adom & Adams, 2020b). The results as reported in Table 2 show that the former is preferred.

Table 2: Test of Skewness of the energy demand function (Equation 7)

Skewness	Kurtosis	Pr(Skewness)	Pr(Kurtosis)	Joint Chi-square test
-0.6772	2.4490	0.0000	0.0012	33.15 ***

*** *p<0.01,* ** *p<0.05,* * *p<0.1*

3.3 Theoretical and empirical model specifications

The theoretical underpinnings of this study rest on the integration of environmental and socioeconomic dimensions of sustainable development (Howarth, 1997; Cantore et al., 2016; Grossman and Krueger, 1991; Akram et al., 2020). To this end, we follow the functional form specification of Opoku and Boachie (2020) by modelling inclusive green growth as:

$$igg = f(ee, gov, V), \quad (8)$$

where $\boldsymbol{igg}$ is inclusive green growth endogenously determined energy efficiency ($\boldsymbol{ee}$), governance ($\boldsymbol{gov}$) and other determining factors ($\boldsymbol{V}$). We proceed to specify the functional of the environmental sustainability dimension of IGG by adopting the functional form of Akram et al. (2020)[5] where:

$$evs = f(ee, gov, y, y^2, Z), \quad (9)$$

where $\boldsymbol{evs}$ is an environment variable, $\boldsymbol{ee}$ is energy efficiency, $\boldsymbol{gov}$ is included as the moderating variable, $\boldsymbol{y}$ is per capita income, $\boldsymbol{y^2}$ is per capita income squared capturing the EKC, and $\boldsymbol{Z}$ denote other exogenous variables that can affect environment quality. Finally, we take cues from Cantore et al. (2016) and Howarth (1997) by specifying the theoretical connection between socioeconomic sustainability, energy efficiency and governance as apparent in Equation (10)

$$ses = f(ee, gov, y\, y^2, Z), \quad (10)$$

[5] Akram et al (2020) incorporated EE into the general EKC equation to examine the effect of EE in the EKC framework using CO_2 emission as dependent variable.

where $\boldsymbol{ses}$ is the socioeconomic sustainability, $\boldsymbol{y^2}$ is per capita income squared capturing the Kuznets effect, $\boldsymbol{ee}, \boldsymbol{gov}, \boldsymbol{y}$ in respective terms, represent energy efficiency, governance and income, respectively, and $\boldsymbol{K}$ connotes the control variables.

We now turn attention to the specification of our empirical models. We begin by paying attention to specify our baseline models for inclusive green growth (IGG), environmental sustainability[6] (EVS), and socioeconomic sustainability (SES) as presented in Equations (11), (12) and (13), respectively:

$$igg_{it} = \alpha_0 + \delta_1 igg_{it-1} + \delta_2 trade_{it} + \delta_3 ictdif_{it} + \delta_4 aid_{it} + \delta_5 findep_{it} + \mu_i + \mu_t + \epsilon_{it} \quad (11)$$

Next, to capture the conditional and unconditional effects of EE and governance on IGG in Africa, we modify Equation (11) into a standard panel specification[7] as:

$$igg_{it} = \alpha_0 + \delta_1 igg_{it-1} + \delta_2 trade_{it} + \delta_3 ictdif_{it} + \delta_4 aid_{it} + \delta_5 findep_{it} + \delta_6 ee_{it} + \delta_7 gov_{it} + \delta_8 (ee_{it} \times gov_{it}) + \mu_i + \mu_t + \epsilon_{it} \quad (14)$$

Following Stock and Watson (1993), the dynamic least squares method can be applied to Equations 8 – 14, but the estimates will not be efficient due to some cross-sectional dependence and endogeneity concerns, which if unresolved can bias our estimates and render the attendant inferences flawed. For instance, endogeneity is apparent due to: (i) the introduction of the lag of IGG and (ii) the simultaneity between IGG and EE (Adom et al., 2021). Regarding the latter particularly, the endogeneity concern arises since $\boldsymbol{igg_{it-1}}$ depends on $\boldsymbol{\epsilon_{it-1}}$, which also depends on the country-specific impact $\boldsymbol{\mu_i}$. In the presence of the aforementioned estimation concerns, competing techniques such as the fixed random effect and the first-difference GMM estimator are also not appropriate. In light of these issues, this study applies the Blundell and Bond (1998) two-stem GMM estimator Additional caveats for applying the system GMM estimator are that: (i) the number of sample countries (i.e., N) used in the study are greater than the number of time periods in each cross-section (i.e., T) (see Ofori et al. 2022b, 2022c), and

---

[6] $ghgas_{it} = \alpha_0 + \omega_1 ghgas_{it-1} + \omega_2 trade_{it} + \omega_3 ictdif_{it} + \omega_4 aid_{it} + \omega_5 findep_{it} + \omega_6 gpc_{it} + gpc_{it}^2 + \mu_i + \mu_t + \epsilon_{it} \quad (12)$

$palma_{it} = \alpha_0 + \beta_1 palma_{it-1} + \beta_2 trade_{it} + \beta_3 ictdif_{it} + \beta_4 aid_{it} + \beta_5 findep_{it} + \beta_6 gpc_{it} + \beta_7 gpc_{it}^2 + \mu_i + \mu_t + \epsilon_{it} \quad (13)$

[7] $ghgas_{it} = \alpha_0 + \omega_1 ghgas_{it-1} + \omega_2 trade_{it} + \omega_3 ictdif_{it} + \omega_4 aid_{it} + \omega_5 gpc_{it} + \omega_6 gpc_{it}^2 + \omega_7 ee_{it} + \omega_8 gov_{it} + \omega_9 (ee_{it} \times gov_{it}) + \mu_i + \mu_t + \epsilon_{it} \quad (15)$

$palma_{it} = \alpha_0 + \beta_1 palma_{it-1} + \beta_2 trade_{it} + \beta_3 ictdif_{it} + \beta_4 aid_{it} + \beta_5 gpc_{it}^2 + \beta_7 ee_{it} + \beta_8 gov_{it} + \beta_9 (ee_{it} \times gov_{it}) + \mu_i + \mu_t + \epsilon_{it} \quad (16)$

(ii) corrects possible reverse causality between IGG and governance. In this regard, we follow the Blundell and bond (1998) approach by instrumenting the level equation with the lagged first-differenced covariates and that of the first-differenced estimation with the lagged level variables. This approach for addressing the endogeneity concerns have been found to be robust. In particular, Windmeijer (2005) argues that using the aforementioned instrumentation procedure yields asymptotically consistent and reliable estimates (i.e., lower bias and standard errors) compared to the first-difference GMM. More crucially, we follow the advice in Roodman (2009) by collapsing the instruments to take of a possible overfitting of the endogenous variables, which if unresolved can result in wrong coefficients and confidence intervals. As re-echoed in Mehrhoff, (2009), doing so addresses instrument proliferation[8], which can be a source of overfitting.

Accordingly, we follow Ofori et al. (2022b) transform Equation (14) into Equations (17) and (18) to capture the level and first-difference specifications, which encapsulate the dynamic system estimation method[9]:

$$igg_{it} = \lambda_0 + \delta_1 igg_{it-1} + \beta_1 ee_{it} + \beta_2 gov_{it} + \sum_1^5 \theta_k V_{kit-\tau} + \mathcal{J}_i + \mu_t + \varepsilon_{it} \quad (17)$$

$$igg_{it} - igg_{it-\tau} = \delta_1(igg_{it-\tau} - gg_{it-2\tau}) + \beta_1(ee_{it} - ee_{it-\tau}) + \beta_2(gov_{it} - gov_{it-\tau}) + \sum_1^5 \theta_k(V_{kit-\tau} + V_{kit-2\tau}) + (\mu_t - \mu_{it-\tau}) + (\varepsilon_{it} - \varepsilon_{it-\tau}) \quad (18)$$

Next, to capture the hypothesised joint effect of EE and governance dynamics on inclusive growth, Equation (18) is modified to obtain Equation (19):

$$igg_{it} - igg_{it-\tau} = \delta_1(igg_{it-\tau} - igg_{it-2\tau}) + \beta_1(ee_{it} - ee_{it-\tau}) + \beta_2(gov_{it} - gov_{it-\tau}) + \beta_3(ee_{it} \times gov_{it} - ee_{it-\tau} \times gov_{it-\tau}) + \sum_1^4 \theta_k(V_{kit-\tau} + V_{kit-2\tau}) + (\mu_t - \mu_{it-\tau}) + (\varepsilon_{it} - \varepsilon_{it-\tau}) \quad (19)$$

For brevity, we point out that we follow similar specifications to present the GMM models for the EVS and SES in respective terms as seen in Equations 20 and 21.

[8] A case where a single instrument is created for each time period and lagged variables, and the number of instruments exceeds the sample size.

[9] Note that for brevity, V_k is used to denote our control variables.

$$ghgas_{it} - ghgas_{it-\tau} = \delta_1(ghgas_{it-\tau} - ghgas_{it-2\tau}) + \beta_1(ee_{it} - ee_{it-\tau}) + \beta_2(gov_{it} - gov_{it-\tau}) + \beta_3(ee_{it} \times gov_{it} - ee_{it-\tau} \times gov_{it-\tau}) + \sum_1^5 \theta_k(V_{kit-\tau} + V_{kit-2\tau}) + (\mu_t - \mu_{it-\tau}) + (\varepsilon_{it} - \varepsilon_{it-\tau}) \quad (20)$$

$$palma_{it} - palma_{it-\tau} = \delta_1(palma_{it-\tau} - palma_{it-2\tau}) + \beta_1(ee_{it} - ee_{it-\tau}) + \beta_2(gov_{it} - gov_{it-\tau}) + \beta_3(ee_{it} \times gov_{it} - ee_{it-\tau} \times gov_{it-\tau}) + \sum_1^5 \theta_k(V_{kit-\tau} + V_{kit-2\tau}) + (\mu_t - \mu_{it-\tau}) + (\varepsilon_{it} - \varepsilon_{it-\tau}) \quad (21)$$

Following Ofori et al (2021b, 2022d), we compute the attendant net effects from the interactions between our governance dynamics and EE in Equation 19 (IGG model), Equation 20 (GHGAS model) and Equation 21 (PALMA model) are expressed respectively as:

$$\frac{\partial(igg_{it})}{\partial(ee_{it})} = \beta_1 + \beta_3\overline{(gov_{it})} \quad (22)$$

$$\frac{\partial(ghgas_{it})}{\partial(ee_{it})} = \beta_1 + \beta_3\overline{(gov_{it})} \quad (23)$$

$$\frac{\partial(palma_{it})}{\partial(ee_{it})} = \beta_1 + \beta_3\overline{(gov_{it})} \quad (24)$$

where $\overline{\boldsymbol{gov_{it}}}$ is the average of each of the 6 aforementioned governance indicators; $\boldsymbol{igg_{it} - igg_{it-\tau}}$ is the initial inclusive green growth in country $\boldsymbol{i}$ at time $\boldsymbol{t}$; $\boldsymbol{trade_{it}}$ is trade openness; $\boldsymbol{ictdif_{it}}$ is ICT diffusion; $\boldsymbol{aid_{it}}$ is foreign aid; and $\boldsymbol{findep_{it}}$ is financial deepening. Also, $\boldsymbol{ee_{it}}$ is energy efficiency; $\boldsymbol{gov_{it}}$ is our governance indicator comprising *corruption control, political stability, rule of law, government effectiveness, regulatory quality, and voice and accountability*; $(\boldsymbol{ee_{it} \times gov_{it}})$ are the interaction terms for energy efficiency and governance[10]; $\boldsymbol{\mu_i}$ represents the country-specific effects; and $\boldsymbol{\epsilon_{it}}$ is the idiosyncratic error term.[11] It is worth noting that the significance of the interaction terms in Equations 19 – 21 gives impetus for the computation of the short-term to long-term IGG-gains of improving the various governance dynamics.

It is imperative to point out that the effectiveness of the GMM estimator in yielding robust estimates depends on some post-estimation tests which we take into account. First, we evaluate the validity of the instruments based on Hansen's test of over-identification, which is

[10] The interactions are 6 and are introduce stepwisely in the model.
[11] But for greenhouse gas emissions, economic growth, trade openness and financial deepening which were logged (i.e., natural logarithm), all other covariates entered our models at levels.

evaluated against the null hypothesis that the set of identified instruments and the residuals are uncorrelated (Alagidede & Ibrahim, 2017). Additional post-estimation tests regarding whether: (i) there is evidence of second-order serial correlation in the residuals or not; (ii) the interaction terms are significant; and (iii) the estimated models are jointly significant, are evaluated. Finally, we check the sensitivity of the estimates on two counts. We obtain the first sub-sample by excluding the first 5 years from the dataset (i.e., dataset is for 2005 – 2020) while the second sample is also obtained by excluding the last 5 years (i.e., dataset is for 2000 – 2015).

4. Results and discussion

4.1. Summary statistics

We begin the presentation of our main findings by paying attention to the summary statistics of the variables employed for the empirical analysis (see Table 3). The pairwise correlations between these variables are reported in Table A.2 in the Appendices section.

Table 3: Summary statistics, 1996 – 2020

Variables	Obs	Mean	Std. Dev.	Minimum	Maximum
Dependent variables					
Inclusive green growth *(igg)*	180	0.000	1.000	-1.424	1.783
Greenhouse gas emissions *(ghgg)*	437	118.853	184.514	-85.277	828.87
Palma ratio *(palma)*	361	6.332	1.725	3.016	14.435
Main independent variable					
Energy efficiency *(EE)*	483	0.550	0.213	0.124	0.984
Moderating variables					
Rule of law *(rol)*	437	-0.510	0.625	-1.791	1.077
Regulatory quality *(regu)*	437	-0.462	0.582	-1.684	1.127
Corruption control *(corrupt)*	437	-0.529	0.593	-1.572	1.217
Voce and accountability *(vna)*	437	-0.407	0.686	-1.697	.941
Government effectiveness *(govef)*	437	-0.497	0.617	-1.746	1.057
Political stability *(pol)*	437	-0.488	0.870	-2.388	1.200
Control variables					
Trade openness *(ecoglob)*	467	71.919	27.245	20.723	156.862
Development assistance *(aid)*	460	4.666	5.750	-0.251	62.187
ICT diffusion *(ictdif)*	414	8.315	12.664	0.000	71.813
Credit to private sector *(cps)*	422	29.208	33.019	0.491	160.125
GDP per capita (US$) *(gpc)*	483	5996.05	4955.11	630.70	22870.29
GDP per capita square (US$) *(gpcsqr)*	483	6.05e+07	8.86e+07	397784.5	5.23e+08

Note: Obs = Observations; Std. Dev is Standard Deviation

For our socioeconomic sustainability indicator of Palma ratio, the data reveal an average value of 6.332, meaning that the income share of the richest 10 per cent people in Africa is at least 6 times that of the poorest 40 per cent. Also, we observe an average GDP per capita value of US$5996.05. With respect to our moderating variables, the data show that Africa's institutional fabric is weak given the negative mean values of all the governance indicators.

Perusing the data further, we observe that SES and EVS require more attention. For instance, Figure 2 (Column 2) shows that Africa is a continent with huge fossil fuel consumption, though renewable energy consumption is also on the rise.

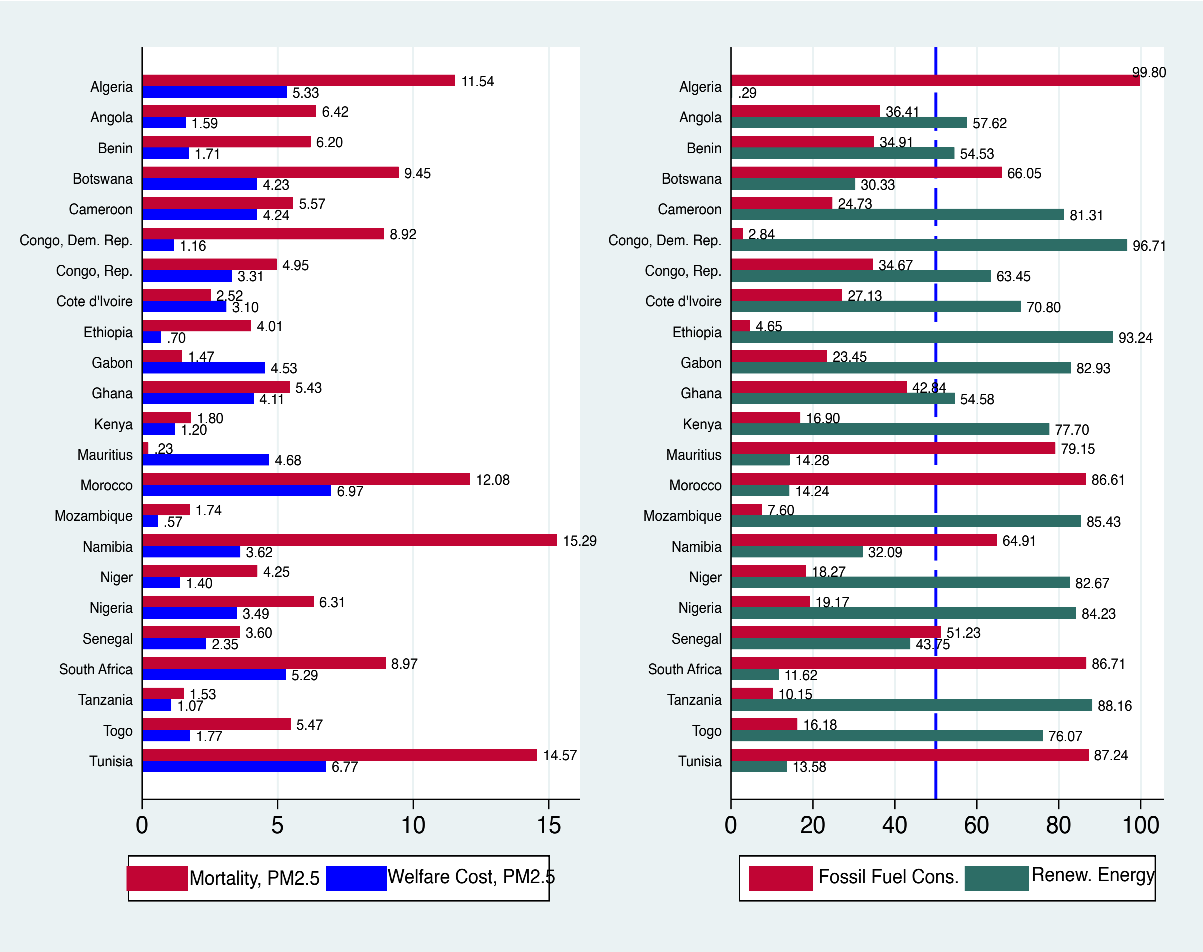

Figure 2: In-country Average Environmental Sustainability Indicators, 2000 – 2020.

However, in a setting where growth is non-inclusive, infant mortality is high (52.179), and the adoption of green technologies and clean fuels is low, as apparent in Figure A.2, investing in EE and institutions could yield IGG. For instance, effective governance could enable EE to promote environmental quality of life, which could go a long way toward reducing deaths from exposure to ambient PM2.5, governance expenditure on environmental degradation (see Figure 2), and improving life expectancy (see Figure A.2). This is more so considering the high fossil fuel consumption, welfare costs, and mortality resulting from ambient PM2.5 concentrations in countries such as Tunisia, Morocco, Algeria, Botswana, South Africa, and Namibia.

4.2 Energy efficiency: estimation of persistent, transient and total scores

In this section, we present our results on the drivers of EE and its attendant estimates dichotomised into persistent and transient efficiencies. First, the results, as reported in Table 4, show that while covariates such as trade openness, human capital, urbanization, and industrialisation are significant drivers of energy demand, crude oil price proved otherwise. Our results corroborate prior studies (see Adom et al., 2018; Adom et al., 2021; Fillippini & Zang, 2016).

Table 4: Determinants of energy demand frontier (Equation 3)

Variable	Coefficient	Standard error	t-value
Trade openness	-0.0343	0.0244	-1.40
Urbanization	-0.439***	0.0973	-4.52
Economic growth	0.0641	0.0411	1.56
Crude oil price	-0.0273**	0.0112	-2.45
Industrialisation	0.0713**	0.0328	2.17
Human capital	0.654***	0.159	4.11
t	-0.0051**	0.0020	-2.51
t^2	0.0001	0.0001	0.16
Constant	13.116***	3.287	-0.15
Observations	451	–	–
Countries	23	–	–
F-stats[P-value]	205.9***[0.000]	–	–

Note: (Dependent variable: energy consumptions (all sectors), OECD data

With all that said, we proceed with the presentation of the summaries on EE (overall) as well as its persistent and transient components (see Table 5).

Table 5: Energy efficiency estimates

Energy efficiency (EE)	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Transient EE ($-\tau_{it}$)	483	0.963	0.040	0.797	0.992
Persistent EE ($-\mathcal{U}_i$)	483	0.570	0.215	0.125	0.997
Overall EE ($-\tau_{it} - \mathcal{U}_i$)	483	0.550	0.213	0.124	0.984

Note: All EE estimates are generated following the stochastic frontier approach by Kumbhakar et al. (2014) (see Section 3.2).

Our EE results, as displayed in Table 5, reveal an average persistent EE of 0.570 compared to 0.963 for that of transient EE. Overall, the level of EE for Africa over the study period is 0.550. While our result is glaringly higher than that of Adom et al. (2021), it similar to that of Ohene-Asare et al. (2020) which was obtained using the DEA approach. The sharp difference in our estimates vis-à-vis those of Adom et al. (2021) is plausibly due to our study period, which coincided with efforts by African countries to improve efficiency. Finally, the results show that EE in Africa is more transient than persistent, requiring efforts aimed at streamlining structural inefficiencies.

4.3 Construction of inclusive green growth index (outcome variable)

In this section, we shed light on how our inclusive green growth index was generated. We do this following the socioeconomic and environmental sustainability perspectives of sustainable development. Following the UNDP (2017), OECD (2017), and GGKP (2013), we identify 24 covariates that cut across the 2 thematic areas of sustainable development: socioeconomic sustainability (composed of economic growth and social equity) and environmental sustainability (natural asset bases, environmental quality of life, environmental and resource productivity, economic opportunities, and policy responses). These variables, employed in our IGG calculations, are presented in Table 6. As Tchamyou (2017) amnd mavilah et al. (2017) point out, the PCA is a powerful dimensional reduction technique that helps to keep the multi-dimensionality of the 24 socially progressive and environmentally sustainable variables while addressing the problem of collinearity among these indicators in order to obtain a smaller set of indices, known as principal components. In this regard, the approach helps to obtain a unique measure of sustainable development out of the 24 covariates. It is imperative to point out that the appropriateness of our dimension reduction (i.e., PCA) in generating the IGG index depends on the overall correlations/interrelations among the variables as well as the adequacy of our sample.

Table 6: Definition of Variables in Inclusive Green Growth (IGG) Index

Variable	Symbol	Variable description	Data source
A. Socioeconomic sustainability			
(i) Social context			
Sanitation	*sanit*	Population with access to improved sanitation, % total population	GGKP Data
Population density	*pop*	Population density, inhabitants per km2	OECD Statistics
Potable water	*powat*	Population with access to improved drinking water sources, % total population	GGKP Data
Infant mortality	*infmort*	Mortality rate, infant (per 1,000 live births)	WDI Data
Life expectancy	*lifexp*	Life expectancy at birth, total (years)	OECD Statistics
Transport infrastructure	*trans*	Composite index for road, air, maritime, and railway transport infrastructure	AIKP
(ii) Economic context			
Changes in wealth	*cwea*	Changes in wealth per capita (US$)	GGKP Data
Income growth	*incgro*	GDP per capita, PPP (constant 2017 international $)	GGKP Data
Income inequality	*ineq*	Gini index (0=Lowest; 1=Highest)	GGKP Data
Human capital index	*hci*	Human capital index, based on years of schooling and returns to education	PWT
Unemployment	*unemp*	Unemployment, total (% of total labor force)	GGKP Data
B. Environmental sustainability			
(i) Natural asset base			
Agricultural land	*agric*	Agricultural land (% of land area)	GGKP Data
Forest cover	*forest*	Forest area (% of land area)	OECD Statistics
Temperature changes	*temp*	Annual surface temperature, change since 1951-1980	OECD Statistics
(ii) Environmental quality of life			
Exposure to Ambient PM.2.5	*amb*	Mean population exposure to PM2.5	OECD Statistics
Ambient PM.2.5 mortalities	*ambmort*	Mortality from exposure to ambient PM2.5	OECD Statistics
Ambient PM.2.5 welfare cost	*ambcost*	Welfare costs of premature mortalities from exposure to ambient PM2.5, GDP equivalent	OECD Statistics
(ii) Environmental & resource productivity			
Methane emission	*metha*	Agricultural methane emissions (thousand metric tons of CO_2 equivalent)	GGKP Data
Natural resources rent	*natres*	Total natural resources rents (% of GDP)	GGKP Data
Renewable energy	*renener*	Renewable energy consumption (% of total final energy consumption)	WDI Data
Carbon intensity	*carint*	CO_2 intensity level, primary energy	WDI Data
Fossil fuel consumption	*fosful*	Fossil fuel energy consumption (% of total)	OECD Statistics
(iv) Economic opportunities & policy response			
Clean fuel usage	*cleanfuel*	Access to clean fuels and technologies for cooking (% of population)	WDI Data
Environmentally friendly technologies	*envtech*	Development of environment-related technologies, % all technologies	OECD Statistics

Note: Source: Authors' construct, 2022

In addressing these requirements, we employ: the (1) KMO measure of sampling adequacy, (2) the Bartlett test of variable intercorrelations, and (3) pairwise correlation test among the variables. First, as reported in Table A.3, there is evidence of strong correlations between all the IGG covariates. Second, per the Bartlett Chi-square (X^2) statistic of 6891.67 and a p-value significant at 1 percent ($p = 0.000$), there is sufficient evidence of strong interrelationships among all the IGG covariates. Lastly, given the overall KMO statistic of 0.7435, we conclude that our IGG sample (i.e., 24 covariates) is adequate and sufficient for empirical analysis. Given that these IGG variables are captured in different scales, we first normalised all the variables before generating the indices for each country. The results are presented in the following. First, the scree plot of the PCA, as apparent in Figure 3, indicates the total number of IGG components and the Kaiser threshold of 1 for selecting components for generating our IGG.

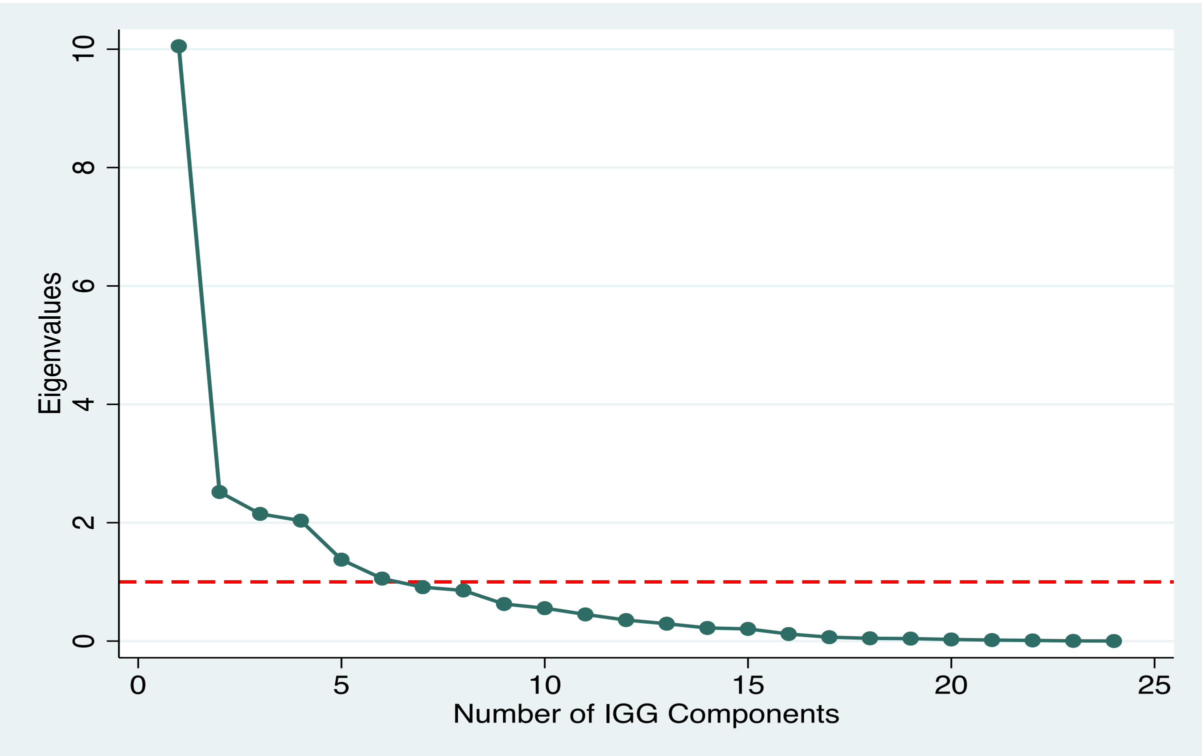

Figure 3: Scree plot of IGG Components

Based on the Kaiser rule of retaining components with eigenvalues of at least 1, we follow prior contributions such as from Tchamyou et al. (2019), Del Carpio (2017), and Jolliffe (2002) by generating our inclusive growth index based on the first 6 components[12]. Information gleaned from Table 7 indicates that these components are appropriate, as they cumulatively account for a 79.9 percent variation in the dataset.

[12] The eigenvectors of these variables (components) are provided in Table A.4 in the Appendices section.

Table 7: Principal components and eigenvalues for inclusive green growth

Component	Eigenvalue	Difference	Proportion	Cumulative	KMO Statistic
Comp 1	**10.051**	**7.532**	**0.419**	**0.419**	**0.826**
Comp 2	**2.519**	**0.370**	**0.105**	**0.524**	**0.363**
Comp 3	**2.149**	**0.113**	**0.089**	**0.613**	**0.744**
Comp 4	**2.036**	**0.659**	**0.085**	**0.698**	**0.579**
Comp 5	**1.376**	**0.320**	**0.057**	**0.755**	**0.800**
Comp 6	**1.057**	**0.146**	**0.044**	**0.799**	**0.831**
Comp 7	0.911	0.055	0.038	0.837	0.776
Comp 8	0.855	0.228	0.036	0.873	0.684
Comp 9	0.627	0.071	0.026	0.899	0.844
Comp 10	0.556	0.105	0.023	0.922	0.742
Comp 11	0.451	0.096	0.019	0.941	0.876
Comp 12	0.355	0.062	0.015	0.956	0.610
Comp 13	0.293	0.071	0.012	0.968	0.850
Comp 14	0.222	0.016	0.009	0.977	0.296
Comp 15	0.206	0.086	0.009	0.986	0.708
Comp 16	0.120	0.054	0.005	0.991	0.758
Comp 17	0.066	0.019	0.003	0.994	0.821
Comp 18	0.047	0.005	0.002	0.996	0.655
Comp 19	0.042	0.015	0.002	0.997	0.391
Comp 20	0.028	0.010	0.001	0.999	0.746
Comp 21	0.017	0.006	0.001	0.999	0.669
Comp 22	0.011	0.008	0.001	1.000	0.558
Comp 23	0.004	0.002	0.000	1.000	0.569
Comp 24	0.002	0.000	0.000	1.000	0.749
Overall	**–**	**–**	**–**	**–**	**0.720**

Note: KMO is Kaiser-Meyer-Olkin; Comp is Principal Component
Source: Authors' construct, 2022

To make clear the overview of our IGG series across the understudied countries, Figure 3 is presented. To allow for cross-country comparison as Kaufmann et al. (2010) point put, we present the standard deviation version of IGG whereby the worst IGG score becomes -2.5 and that of the best is +2.5. The result is presented in Figure 3, which shows that out of the 23 African countries, only 9 have growth trajectories that are inclusive and green. It is however necessary to point out that IGG in this case depends on the strengths of the two dimensions of sustainability, socioeconomic and environmental, and therefore, while a country could be worse off from the socioeconomic perspective (see Figure A.2, inclusive growth graph), it may have strong environmental performance, culminating in an overall positive IGG. A negative IGG, however, holds for the reverse intuition above or a combined poor performance in both the sustainability dimensions. Figure 4 shows that lags in IGG are conspicuous in countries such as the Democratic Republic of Congo, Ethiopia, Kenya, Niger, Nigeria, and Togo.

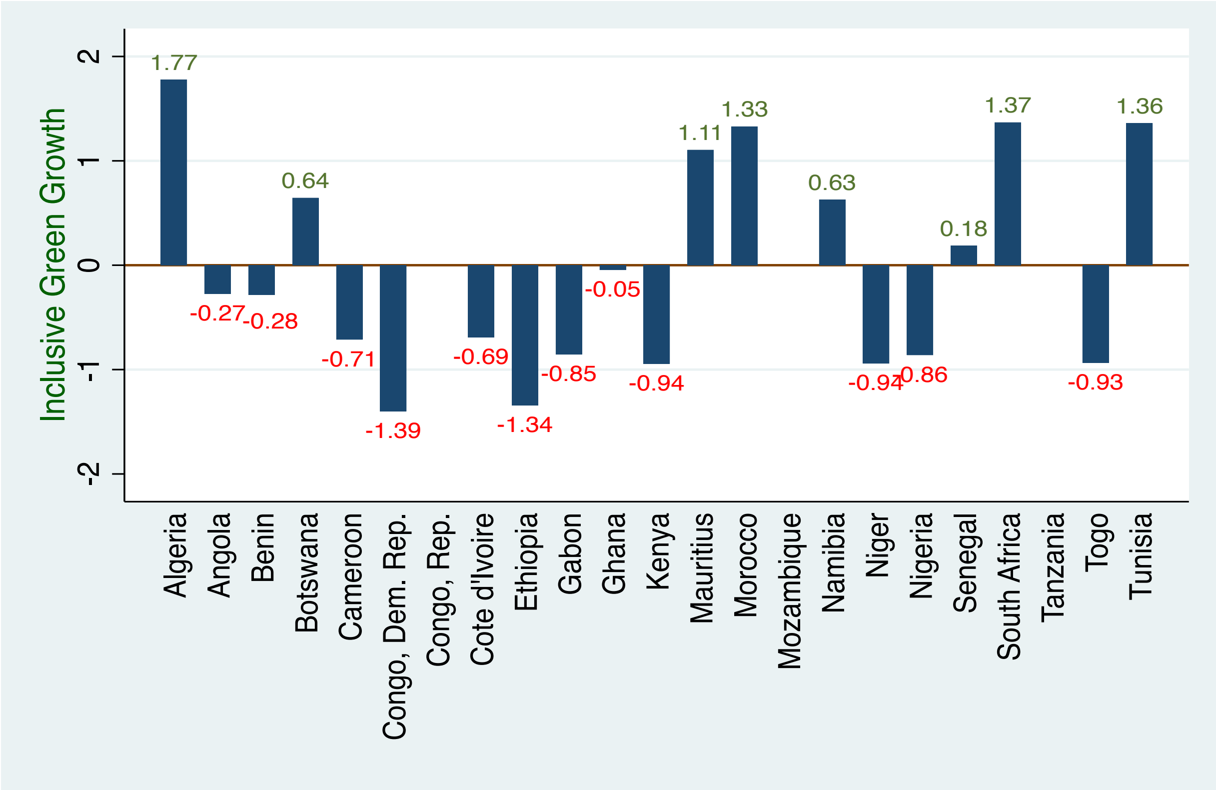

Figure 4: In-country Inclusive Green Growth in Africa, 2000 – 2020

4.4. Results for the effects of energy efficiency and governance effectiveness on inclusive green growth in Africa

Column 1 of Table 8 presents the baseline results from estimating Equation (15). We find that ICT diffusion and financial deepening significantly impact inclusive green growth. First, we find that for every 1 per cent increase in ICT diffusion, IGG is enhanced by a modest 0.0012 per cent. This result is in line with the claim that ICT fosters SES through access to information, opportunities, and inclusive governance, while promoting EVS via reductions in CO_2 emissions (Ofori & Asongu, 2021; Asongu & Odhiambo, 2019; Asongu et al., 2018). This finding means that the rise in the digital economy in Africa is IGG-enhancing and with extensive margins for greater ICT diffusion as Ofori and Asongu (2021) point out, greater gains could be realised in the long term. Second, unlike prior contributions (see Bekhet et al. 2017), we find strong evidence that financial deepening hampers IGG. This evidence is consistent with concerns that financial development can hurt both social progress through a heating-up of the economy (see e.g., Peprah et al., 2019; Law & Singh, 2014) and environmental progress by fuelling investments in energy-intensive ventures (see e.g., Ahmad et al., 2021; Halkos & Polemis, 2017).

Table 8: GMM results for the effects of energy efficiency and governance on sustainable development (Dependent variable: inclusive green growth)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Trade openness	-0.0001	-0.0006	0.0007	0.0007	0.0006	0.0003	0.0006	-0.0002	-0.0008	0.0008	0.0027**	-0.0021*	0.0010	0.0002
	(0.0004)	(0.0006)	(0.0009)	(0.0008)	(0.0006)	(0.0006)	(0.0007)	(0.0004)	(0.0011)	(0.0015)	(0.0011)	(0.0011)	(0.0009)	(0.0011)
Foreign aid	0.0035	0.0099	0.0043	0.0009	-0.0007	0.0057*	0.0045	0.0061	0.0056	0.0058	0.0047	0.0116**	-0.0008	0.0035
	(0.0028)	(0.0066)	(0.0033)	(0.0038)	(0.0040)	(0.0027)	(0.0041)	(0.0057)	(0.0041)	(0.0064)	(0.0044)	(0.0042)	(0.0063)	(0.0055)
ICT diffusion	0.0012**	0.0012*	0.0017**	0.0015	0.0018**	0.0018**	-0.0004	0.0017	-0.0026	-0.0013	0.0002	-0.0012	-0.0000	-0.0011
	(0.0006)	(0.0006)	(0.0008)	(0.0010)	(0.0008)	(0.0007)	(0.0010)	(0.0010)	(0.0021)	(0.0018)	(0.0015)	(0.0011)	(0.0014)	(0.0016)
Financial deepening	-0.0019***	-0.0029**	-0.0018	-0.0013*	-0.0001	-0.0019**	-0.0011	-0.0015	0.0051	0.0003	0.0030**	0.0039***	0.0012	0.0020*
	(0.0004)	(0.0011)	(0.0015)	(0.0007)	(0.0011)	(0.0007)	(0.0009)	(0.0012)	(0.0032)	(0.0020)	(0.0014)	(0.0013)	(0.0017)	(0.0012)
EE		-0.4355							1.8575*	0.9082	2.5075**	1.9549**	2.7723**	1.2348*
		(0.4194)							(0.9692)	(0.5497)	(0.9570)	(0.6903)	(1.1804)	(0.6041)
Corruption control			0.1876***						-0.5734*					
			(0.0578)						(0.3155)					
Voice and accountability				0.0399						-0.0128				
				(0.0335)						(0.2279)				
Government effectiveness					0.1044***						-0.0155			
					(0.0344)						(0.2275)			
Regulatory quality						0.0989**						0.6519***		
						(0.0395)						(0.2081)		
Political stability							0.0211						0.2222	
							(0.0374)						(0.2360)	
Rule of law								0.1092*						-0.2250
								(0.0525)						(0.2935)
EE × Corruption control									1.2481**					
									(0.5541)					
EE × Voice and accountability										0.2750				
										(0.4002)				
EE × Government effectiveness											0.7221**			
											(0.2756)			
EE × Regulatory quality												1.3087***		
												(0.3076)		
EE × Political stability													0.0357	
													(0.3431)	
EE × Rule of law														0.5795
														(0.3373)
Inclusive green growth (-1)	1.0776***	1.0665***	0.9623***	1.0065***	0.9229***	1.0254***	1.0450***	1.0130***	1.0549***	1.0893***	1.0545***	1.1685***	1.3300***	1.0724***
	(0.0230)	(0.0251)	(0.0372)	(0.0371)	(0.0623)	(0.0423)	(0.0381)	(0.0598)	(0.0571)	(0.1171)	(0.0823)	(0.0991)	(0.1778)	(0.0404)
Constant	0.0663**	0.3267	0.0839*	0.0099	0.0201	0.0570	0.0003	0.1017**	-0.9097*	-0.4626	-1.3540**	-0.8581**	-1.3813**	-0.6162*
	(0.0256)	(0.2519)	(0.0428)	(0.0489)	(0.0396)	(0.0349)	(0.0672)	(0.0410)	(0.5034)	(0.2751)	(0.5284)	(0.3411)	(0.5972)	(0.3414)
Time effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	129	129	129	129	129	129	129	129	129	129	129	129	129	129
Countries	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Instruments	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Net effect	na	na	na	na	na	na	na	na	1.1972**	–	2.1486**	1.3503***	–	–
Joint Significant Stats. (P-value)	na	na	na	na	na	na	na	na	5.07(0.038)	–	6.87(0.018)	18.10(0.001)	–	–
Wald Statistic	21584***	18360***	5552***	6956***	7720***	18559***	8070***	29813***	11591***	2837***	2538***	507.8***	7277***	2930***
Wald P-value	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
Hansen P-Value	0.749	0.751	0.712	0.659	0.201	0.717	0.861	0.541	0.741	0.636	0.407	0.726	0.616	0.699
AR(1)	0.014	0.013	0.018	0.014	0.015	0.013	0.014	0.016	0.031	0.018	0.029	0.007	0.011	0.018
AR(2)	0.480	0.480	0.499	0.578	0.731	0.412	0.582	0.508	0.758	0.670	0.767	0.552	0.913	0.574

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

Under the remit of Hypothesis 1 of this study, we turn our attention to the results for the direct effects of EE and governance on IGG (see Columns 2 – 8). First, we find that EE alone does not have a statistically significant influence on IGG (see Column 2), and the negative sign suggests the possibility of a 'rebound effect' of EE improvements. This evidence supports the claim by Adom et al. (2021) and Herring and Sorrell (2009) that in settings like Africa where precarity is widespread and lags in EE are apparent, the potential SES-gains from EE may fall short of EVS setbacks imposed implicitly by the rebound effect of EE. Additionally, the EVS and SES setbacks associated with EE, as reflected in the rebound and growth-impeding effects, may cancel out some possible IGG gains from EE, putting economies and economic agents at a disadvantage.

With respect to our governance dynamics, we find strong evidence in support of SDG 16 and Aspirations 3 and 4 of the African Union's Agenda 2063, that strong structures, frameworks, and polices matter for sustainable development. Specifically, improvements in government effectiveness, corruption control, and regulatory quality are directly linked with a 0.2 per cent, 0.1 per cent, and 0.1 per cent increase in IGG respectively. The result suggests that a well-defined and stable regulatory structure that is clear regarding sustainability development concerns could promote IGG by attracting 'green' investors while aiding the private sector in adopting sustainable production and consumption practices. The results also suggest that by addressing loopholes in resource generation and allocation, public financing could spur IGG by reducing precarity and pressures on the environment while supporting private sector growth and innovation. Despite being statistically insignificant, voice and accountability and political stability carried the *a priori* signs. This suggests that a stable political system is crucial for sustainable development. In addition, the more room there is for public opinion to influence and control the actions of resource-seeking, efficiency-seeking, and market-seeking by local and international companies, as well as the actions of policymakers, the higher the possibility of adherence to EVS laws and practices.

We now turn attention to our second hypothesis, where we examine the contingency effects of EE on IGG (Columns 9-14). But for political governance, we find strong evidence that economic governance (i.e., government effectiveness and quality of regulation) and institutional governance (i.e., corruption control) engender positive synergies with EE to foster IGG. This clearly means that the apparent lags in the effectiveness of civil society organisations and the media as well as the geopolitical fragilities in the continent neither promotes social progress nor environmental sustainability. We proceed, therefore, to compute the net effects for the significant pathways. First, based on Equation (20), we find a net effect of 1.1972 for the EE-corruption control interaction (Column 9). This is calculated as:

$$\frac{\partial(igg_{it})}{\partial(gov_{it})} = 1.8575 + [(1.2481) \times (-0.529)] = 1.1972,$$

where the direct effect of EE is 1.8575, the indirect effect is 1.2481, and -0.529 is the mean value of control of corruption, as apparent from Table 2. Following similar calculations, we report a net effect of 2.1486 for the EE-government effectiveness pathway. We compute this as:

$$\frac{\partial(igg_{it})}{\partial(gov_{it})} = 2.5075 + [(0.7221) \times -(0.497)] = 2.1486,$$

where 2.5075 is the unconditional effect of EE and 0.7221 is the unconditional effect of EE, while the average government effectiveness score is -0.497. Likewise, we calculate the net effect from the EE-regulatory quality as:

$$\frac{\partial(igg_{it})}{\partial(gov_{it})} = 1.9549 + [(1.3087) \times (-0.462)] = 1.3503,$$

where the direct effect of EE on IGG is 1.9549, 1.3087 is the coefficient of the EE-regulatory quality interaction term, and -0.462 is the mean regulatory quality score.

Our results are quite compelling. While in the remit of Hypothesis 1, EE on its own is not enough to spur IGG, we find evidence in Hypothesis 2 to show that it interacts with some governance modules to foster IGG. In particular, we find that among the three significant governance modules, it is government effectiveness that has the strongest IGG net effect (2.15%). This is in line with the OECD (2016), Abid et al. (2021), and Asongu and Odhiambo (2021), in that government effectiveness is key for delivering SES and EVS in the developing world. For instance, sound economic management is not only essential for addressing the wastage of human resource, but it also ensures that the private sector takes advantage of environmentally-friendly measures like EE to improve upon productivity, innovation, and EVS. In this regard, we contribute to the resolve on the part of the United Nations to identify and strengthen, where they exist, positive synergies among SDGs.

The reliability of our results is backed by their robustness to several diagnostic tests such as the absence of instrument proliferation, as revealed by the Hansen p-values. Also, the absence of second-order serial correlation in the residuals, as apparent in the AR (2) statistics and the significance of the Wald statistics, reaffirms the robustness of our findings. Additionally, our results remain largely the same under sensitivity analysis with respect to time (see supplementary results: Table SM1 – 6)

4.5 Effects of energy efficiency and governance on socioeconomic sustainability (SES)

In this section, we extend the analyses by examining the conditional and unconditional effects of EE by disaggregating IGG into environmental sustainability (EVS) and socioeconomic sustainability (SES). We begin by presenting the results of the latter in Table 9, and proceed with the former in Table 10.

Table 9 presents the results of the effects of EE and governance on socioeconomic sustainability (SES). We find significant evidence, in contrast to the Kuznets (1955) proposition, considering the negative coefficient for GDP per capita and a positive-sign GDP per capita squared (Column 1). This means that economic development could contribute to reductions in inequality within and between households, even at the initial stages of development. As Ofori et al. (2022a) argue, this could be attributed to the fact that the study period coincided with the same time African leaders intensified efforts in the form of social protection coverage towards the achievement of SDG 10.[13] Further, the results show that trade openness and foreign aid are not statistically significant for reducing inequalities among rich and poor households.

Shifting focus to our first hypothesis, we find that EE is not potent enough to induce SES (Column 2). Additionally, we find that of the 6 governance modules, only corruption control (Column 3), regulatory quality (Column 6), and political stability (Column 7) are potent for promoting SES. Among these 3 statistically significant governance dynamics, control of corruption is the most important for promoting fairer income growth and distribution in Africa. Specifically, while institutions for controlling corruption reduce within- and between-household inequalities by 0.16 percent, those for ensuring regulatory quality and political stability provide dampening effects of 0.09 percent and 0.11 percent, respectively. Our results provide empirical evidence for the assertion by the UNDP (2017), United Nations (2015), and African Union (2015) that stronger institutions will prove crucial in achieving the rest of the SDGs and Africa's Agenda 2063.

[13] Encouraging developments can be found in countries such as Ghana, Uganda, South Africa, Tunisia, and Namibia, where social redistribution programmes such as free/subsidized education, including technical and vocational, as well as digital infrastructure, which are effective modules for reducing income inequalities between and within-households, have been rolled out or constructed.

Table 9: GMM results for the effects of energy efficiency and governance on socioeconomic sustainability (Dependent variable: Palma ratio)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Trade openness	-0.0008	-0.0021	-0.0006	-0.0004	-0.0007	-0.0015**	-0.0019**	-0.0004	-0.0007	-0.0003	-0.0010	-0.0032**	-0.0030*	-0.0023
	(0.0008)	(0.0017)	(0.0004)	(0.0009)	(0.0008)	(0.0006)	(0.0007)	(0.0010)	(0.0021)	(0.0013)	(0.0011)	(0.0014)	(0.0015)	(0.0016)
Foreign aid	0.0003	0.0043*	-0.0003	-0.0003	-0.0000	-0.0009	0.0019**	0.0025	0.0006	-0.0003	0.0017	0.0027	0.0033	0.0017
	(0.0010)	(0.0025)	(0.0009)	(0.0010)	(0.0014)	(0.0010)	(0.0008)	(0.0015)	(0.0021)	(0.0028)	(0.0019)	(0.0019)	(0.0021)	(0.0023)
ICT diffusion	0.0017***	-0.0001	0.0023***	-0.0006	-0.0006	0.0017**	0.0027***	-0.0007	0.0029	-0.0020	-0.0002	0.0003	-0.0013	0.0014
	(0.0005)	(0.0012)	(0.0006)	(0.0013)	(0.0008)	(0.0007)	(0.0005)	(0.0009)	(0.0050)	(0.0016)	(0.0012)	(0.0012)	(0.0023)	(0.0012)
GDP per capita	-0.0229***	-0.0155	-0.0035	-0.0119*	-0.0128	-0.0132**	-0.0050	-0.0158*	-0.0111	0.0060	0.0025	-0.0101	0.0036	-0.0038
	(0.0073)	(0.0091)	(0.0079)	(0.0063)	(0.0075)	(0.0050)	(0.0053)	(0.0089)	(0.0078)	(0.0108)	(0.0099)	(0.0092)	(0.0182)	(0.0129)
GDP per capita squared	0.0086***	0.0071**	0.0023	0.0045*	0.0059***	0.0042**	0.0035***	0.0056*	0.0080***	0.0000	0.0022	0.0049	0.0031	0.0047
	(0.0018)	(0.0033)	(0.0019)	(0.0022)	0.0019)	(0.0016)	(0.0011)	(0.0029)	(0.0024)	(0.0035)	(0.0029)	(0.0035)	(0.0046)	(0.0030)
EE		-0.3581							-0.2713	-0.1257	-0.5041***	0.2064*	-0.4423**	-0.2079
		(0.2466)							(0.3216)	(0.2907)	(0.0897)	(0.3084)	(0.1834)	(0.4017)
Corruption control			-0.1644***						-0.2697					
			(0.0455)						(0.2105)					
Voice and accountability				0.0163						-0.3930				
				(0.0615)						(0.2595)				
Government effectiveness					0.0191						-0.1255			
					(0.0630)						(0.1144)			
Regulatory quality						-0.0912**						-0.5688**		
						(0.0367)						(0.2534)		
Political stability							-0.1173***						-0.8362***	
							(0.0291)						(0.1871)	
Rule of law								0.0544						-0.4922*
								(0.0693)						(0.2554)
EE × Corruption control									0.2970					
									(0.5649)					
EE × Voice and accountability										0.7065				
										(0.4300)				
EE × Government effectiveness											-0.0159			
											(0.2119)			
EE × Regulatory quality												1.2427***		
												(0.3961)		
EE × Political stability													1.0352***	
													(0.3495)	
EE × Rule of law														0.6726
														(0.4255)
Palma ratio (-1)	0.9941***	0.9627***	1.0392***	1.0010***	0.9944***	1.0225***	1.0095***	0.9803***	0.9974***	0.9786***	0.9770***	0.9693***	0.9472***	0.9904***
	(0.0074)	(0.0198)	(0.0115)	(0.0129)	(0.0138)	(0.0084)	(0.0091)	(0.0122)	(0.0679)	(0.0196)	(0.0229)	(0.0205)	(0.0386)	(0.0246)
Constant	-0.0182	0.4495	-0.3523***	-0.0206	0.0238	-0.1301	-0.0558	0.0857	0.0594	0.2541	0.3425	0.3466	0.6767	0.2345
	(0.0857)	(0.3693)	(0.1142)	(0.1434)	(0.1531)	(0.0995)	(0.1018)	(0.1673)	(0.7712)	(0.3080)	(0.2455)	(0.2954)	(0.4482)	(0.4011)
Time effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	284	284	284	284	284	284	284	284	284	284	284	284	284	284
Countries	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Instruments	21	22	21	21	21	21	21	21	21	21	21	21	21	21
Net effect	na	na	na	na	na	na	na	na	–	–	–	-0.3676***	-0.9474***	–
Joint Significant T Stats (P value)	na	na	na	na	na	na	na	na	–	–	–	9.84(0.005)	8.78(0.007)	–
Wald Statistic	720923***	149030***	281213***	364482***	390856***	315540***	502996***	1.132e+06***	174395***	109818***	90972***	117095***	110959***	332428***
Wald P-value	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
Hansen P-Value	0.219	0.222	0.106	0.180	0.145	0.186	0.161	0.177	0.243	0.169	0.132	0.271	0.172	0.216
AR(1)	0.064	0.075	0.088	0.084	0.077	0.084	0.088	0.079	0.074	0.099	0.096	0.084	0.087	0.088
AR(2)	0.451	0.403	0.276	0.352	0.377	0.342	0.299	0.395	0.351	0.307	0.300	0.320	0.243	0.295

*Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.*

Consistent with our second hypothesis, the synergistic effect of EE and governance is apparent. The results indicate that only regulatory quality and political stability are crucial for propelling EE to foster social progress. The calculated net effects are reported in Columns 12 and 13 of Table 9. From the results, we can deduce that improvements in two dimensions of governance, namely regulatory quality and political stability, can amplify the inequality-reducing effect of EE in Africa. This result indicates that regulatory quality complements EE to yield a net effect of -0. 37 percent on income inequality (Column 12). This net effect is computed by adjusting Equation (20) as:

$$\frac{\partial(palma_{it})}{\partial(gov_{it})} = 0.20648 + (1.2427 \times -0.462) = -0.3676,$$

where -0.2064 indicates the direct effect of EE on income inequality, 1.2427 is the conditional effect of EE, and -0.462 is the average level of regulatory quality. Similarly, the joint effect of the EE-political stability pathway is -0.95 percent (Column 13). We calculate this as:

$$\frac{\partial(palma_{it})}{\partial(gov_{it})} = -0.4423 + (1.0352 \times -0.488) = -0.9474,$$

where the unconditional effect of EE is -0.4423 and 1.0352 is the coefficient of the interaction term for EE and political stability, while -0.488 is the mean value of political stability. The negative net effect of the interaction between EE and political stability on income inequality means that by addressing Africa's lingering geopolitical frailties, EE could contribute to SES. The results suggests that without frameworks for ensuring effective regulation that protect and support the private sector while addressing the recurrent reconstruction of Africa, EE could go a long way toward inducing equitable income growth and distribution.

4.6 Effects of energy efficiency and governance on environmental sustainability (EVS)

The results from our baseline estimation, as reported in Table 10, show a statistically significant and positive effect of trade openness on greenhouse gas emissions (GHGs). This result provides evidence in support of the pollution haven hypothesis and is consistent with prior contributions from researchers such as Dauda et al. (2021), Sarkodie and Strezov (2019), Shahbaz et al. (2019), and Yu et al. (2011), that in societies where environmental laws are lax, freer trade regimes can trigger environmental degradation.

Table 10: GMM results for the effects of energy efficiency and governance on environmental sustainability (Dependent variable: Greenhouse gas emissions)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Trade openness	0.0007**	0.0007**	0.0002	0.0008**	0.0007**	0.0006***	0.0005***	0.0006***	0.0012*	0.0019***	0.0003	0.0011***	0.0010	0.0002
	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0006)	(0.0006)	(0.0004)	(0.0003)	(0.0006)	(0.0004)
Foreign aid	0.0007*	0.0007	0.0010***	-0.0001	0.0005	0.0007	0.0008*	-0.0001	0.0014	0.0017**	0.0006	0.0004	0.0018	0.0004
	(0.0004)	(0.0004)	(0.0003)	(0.0003)	(0.0004)	(0.0005)	(0.0004)	(0.0005)	(0.0012)	(0.0007)	(0.0005)	(0.0011)	(0.0015)	(0.0005)
ICT diffusion	-0.0002	-0.0002	-0.0002*	0.0003	0.0001	0.0000	-0.0001	-0.0001	-0.0001	0.0005	-0.0002	-0.0001	0.0009	0.0001
	(0.0002)	(0.0002)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0009)	(0.0005)	(0.0003)	(0.0006)	(0.0007)	(0.0003)
GDP per capita	0.0038***	0.0042***	0.0060***	0.0069***	0.0045***	0.0051***	0.0045***	0.0061***	0.0047***	0.0030**	0.0047***	0.0031**	0.0046***	0.0049***
	(0.0009)	(0.0009)	(0.0007)	(0.0009)	(0.0009)	(0.0007)	(0.0007)	(0.0008)	(0.0016)	(0.0014)	(0.0010)	(0.0011)	(0.0010)	(0.0015)
GDP per capita squared	-0.0002	-0.0003	-0.0003**	-0.0007***	-0.0002	-0.0002	-0.0003**	-0.0005***	-0.0004	-0.0007	-0.0001	-0.0005	0.0001	-0.0002
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0004)	(0.0008)	(0.0003)	(0.0004)	(0.0008)	(0.0004)
EE		0.0132							-0.5248**	-0.2654	-0.1533	-0.3275**	-0.0468	-0.2261
		(0.0316)							(0.2307)	(0.1683)	(0.0902)	(0.1362)	(0.1425)	(0.1562)
Corruption control			-0.0095*						0.2606					
			(0.0051)						(0.2987)					
Voice and accountability				-0.0595***						0.3082***				
				(0.0097)						(0.0867)				
Government effectiveness					-0.0172*						0.0594			
					(0.0091)						(0.1068)			
Regulatory quality						-0.0237**						0.0775		
						(0.0100)						(0.1536)		
Political stability							-0.0114						0.2248*	
							(0.0069)						(0.1229)	
Rule of law								-0.0279***						0.1485
								(0.0055)						(0.1174)
EE × Corruption control									-0.6289					
									(0.4123)					
EE × Voice and accountability										-0.6725***				
										(0.1554)				
EE × Government effectiveness											-0.1839			
											(0.1902)			
EE × Regulatory quality												-0.4025		
												(0.2505)		
EE × Political stability													-0.3457*	
													(0.1750)	
EE × Rule of law														-0.3850*
														(0.2151)
GHG emissions (-1)	0.9875***	0.9879***	0.9915***	0.9816***	0.9888***	0.9826***	0.9872***	0.9896***	0.9954***	0.9547***	0.9873***	0.9466***	0.9566***	0.9819***
	(0.0109)	(0.0111)	(0.0090)	(0.0144)	(0.0121)	(0.0079)	(0.0076)	(0.0097)	(0.0510)	(0.0280)	(0.0218)	(0.0214)	(0.0359)	(0.0198)
Constant	0.1132	0.1010	0.0838	0.1392	0.0806	0.1466*	0.1153	0.0772	0.2136	0.4573**	0.1804	0.5972**	0.4050	0.2527
	(0.1021)	(0.1041)	(0.0866)	(0.1374)	(0.1167)	(0.0762)	(0.0743)	(0.0934)	(0.4496)	(0.1939)	(0.2200)	(0.2201)	(0.2932)	(0.2020)
Time effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	360	360	360	360	360	360	360	360	360	360	360	360	360	360
Countries	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Instruments	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Net effect	na	na	na	na	na	na	na	na	–	–	–	–	–	–
Joint Significant T Stats (P value)	na	na	na	na	na	na	na	na	–	–	–	–	–	–
Wald Statistic	1.122e+06***	888826***	1.690e+07***	2.007e+06***	689844***	1.392e+06***	3.347e+06***	1.275e+06***	155839***	92670***	1.242e+06***	275882***	212958***	653761***
Wald P-value	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
Hansen P-Value	0.684	0.683	0.695	0.691	0.685	0.678	0.695	0.693	0.698	0.699	0.680	0.663	0.699	0.689
AR(1)	0.173	0.170	0.163	0.154	0.170	0.168	0.169	0.160	0.167	0.170	0.168	0.169	0.173	0.166
AR(2)	0.393	0.385	0.356	0.335	0.393	0.384	0.379	0.350	0.405	0.393	0.378	0.403	0.442	0.360

*Note: EE is energy efficiency; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.001*

Likewise, increases in foreign aid have a deleterious effect on environmental sustainability via increased GHGs. However, we find ICT diffusion to contribute positively towards environmental sustainability despite not being statistically significant. This result aligns with the findings of Asongu and Odhimabo (2019), Asongu et al. (2018), and Higón et al. (2017), that ICT can potentially reduce CO_2 emissions from households and corporations. Furthermore, we find evidence of the EKC predictions per the positive coefficient of income (proxied by GDP per capita) on greenhouse gas emissions, which is significant across all specifications, and the negative sign of its squared term. This is in line with the findings of Opoku and Boachie (2020), Aboagye (2017), and Xu and Lin (2015).

For our first hypothesis, the insignificant coefficient for EE implies that energy efficiency improvements alone do not drive environmental sustainability. Also, the positive sign for EE is an indication of a possible rebound effect. This is in line with the claim by Borenstein (2015) that a strong rebound does not necessarily imply that efficiency-enhancing policies are crucial, but rather an indication that such policies operating alone are not sufficient to generate environmental improvements. It is also evident from Table 10 that the dimensions of governance collectively reveal the theorized negative relationship with EVS. However, for political stability, which is not statistically significant, we find that governance matters for reducing greenhouse gas emissions, which could go a long way to improve EVS by sustaining natural capital and environmental quality of life. Our finding reinforces previous contributions by Asongu and Odhiambo (2021), Holley and Lecavalier (2017), Atkinson and Klausen (2011), and Ager et al. (2003), that in unequal and disadvantaged settings like Africa, robust, innovative, and environmentally-friendly mechanisms and structures are imperative for reducing greenhouse gas emissions and stress on the environment.

With regard to the conditional effect of EE on EVS, net effects are not computed, considering the alternating statistical significance of the conditional and unconditional effects of EE. However, the signs for the interaction terms of EE and all the dimensions of governance are negative, indicating possible GHGs-reducing effect of EE (Columns 9-14). This also suggests that significant GHG dividends could be seen in the longer term with investments in political, economic, and institutional governance (Hunjra et al., 2020).

4.7. Further discussion and threshold estimates

So far, it is evident from the empirical analyses that EE does not unconditionally drive IGG, socioeconomic, and environmental sustainability. However, the sign for EE confirms the graphical illustration in Figure A.3 and gives an indication of dirty growth trajectories in

Africa, as EE is positively related to both economic growth and greenhouse gas emissions but inversely related to income inequality. These effects cumulatively feed into the negative coefficient of EE for our IGG estimation, suggesting that the rebound effect outweighs the socioeconomic gains from EE and EE-related savings. This further suggests that good governance is essential to repacking EE for concurrent achievements in socioeconomic and environmental sustainability.

Indeed, in the remit of Hypothesis 2, the results suggest that even in the face of the weak institutional fabric of Africa, EE-induced IGG gains are evident. Overall, the results indicate that governance mechanisms for fighting corruption and delivering social equity policies are significant for fostering IGG. Across the environmental and socioeconomic sustainability dichotomy of IGG, however, we find that while rule of law, voice, and accountability are key, regulatory quality and political stability are more notable for the latter.

In this section, we speak to policies on how improving the various facets of governance, as apparent in Figure A.1, could yield greater IGG dividends. We answer the question of the short-term to long-term gains of IGG if African leaders are to improve the current level of governance, as envisaged in Aspirations 3 and 4 of Agenda 2063. We do this by taking cues from the average values (all negative) of our various governance indicators as reported in Table 3 and the relationships between IGG and governance as presented in Figure A.3. In other words, the study goes beyond the estimation of the net effects of the EE-governance interaction to analyse the sustainable development gains of improving Africa's institutional fabric from the short-term (0.5) through to the long-term (1.5). That said, we proceed to compute the attendant net effects at these governance thresholds. It is worth noting that these thresholds are computed based on Equation (20) and our pathway estimates reported in Columns 9 – 14 of Table 8 (i.e., main inclusive green growth results).

Table 11: Governance thresholds and inclusive green growth net effects

	Net Effects					
Thresholds	**CC**	**VA**	**GE**	**PS**	**RQ**	**RL**
0	1.8575	–	2.5075	–	1.9549	–
0.5	2.4815	–	2.8686	–	2.6092	–
1.0	3.1056	–	3.2296	–	3.2636	–
1.5	3.7296	–	3.5906	–	3.9179	–

Note: CC: Control of corruption; PS: Political stability; RG: Regulatory quality; RL: Rule of law; VA: Voice and Accountability; GE: Government Effectiveness

The threshold results in Table 11 suggests that by improving conditions, structures, and frameworks for corruption control, government effectiveness, and regulatory quality to the World Bank's threshold of zero (0), the nullifying effects are mitigated completely.[14] Additional gains are then apparent as governance levels improve from the short-term (0.5) to the medium- (1.0) and long-term (1.5). Our evidence suggests that (i) easing constraints to private sector innovation and growth and (ii) protecting the public purse while mapping out support packages for social equity in Africa are crucial for IGG.

4.8 Theoretical contribution of the study

Theoretically, we developed a framework which contributes to the post-2015 development discourse on how good governance and EE feed into inclusive green growth. This framework is unique and can be used by researchers as an analytical framework for future research. Our framework can also be used to inform policy on how energy efficient modules and governance matter for both social progress and environmental sustainability. Additionally, our framework can be employed as the theoretical basis for rigorous empirical contributions where the role of institutions, energy efficiency and energy-efficient modules on sustainable development are being evaluated.

5. Conclusion and policy recommendations

Motivated by the need to achieve sustainable development in the light of the UN's Agenda 2030 and African Union's Agenda 2063, we examine the joint effects of EE and governance on inclsive green growth in Africa. We do this by taking cues from the SDG7, which seeks to double the current global EE efforts and renewable energy capacity in order to enable universal access to sustainable, modern, and clean energy by 2030 and improving Africa's institutional fabric. Our contribution is novel both theoretically and empirically. From a theoretical perspective, we developed a framework that illustrates how EE and governance feed into IGG.

Empirically, our study is based on annual macrodata for 23 countries for the period 1996 – 2020 and brings to the fore the following findings. First, the results show that EE is not unconditionally effective for spurring IGG. The coefficient for EE is, however, negative across all sustainability indicators, suggesting that the rebound effect of EE outweighs the possible cost-saving and growth-inducing gains of EE. Second, we find that governance is effective for repackaging EE to foster IGG. Particularly, we find that governance mechanisms for

[14]According to the World Bank Governance Indicators, the average governance score is 0.

controlling corruption while ensuring regulatory quality and government effectiveness are vital for forming relevant synergies with EE to foster IGG. Third, our evidence suggests that relative to the SES divide, the EE-governance pathway is more effective for driving the EVS aspect of IGG. Additionally, we provide evidence by way of threshold analysis to show that higher IGG gains can be achieved from the short term through to the long term.

We here make policy recommendations based on our results. First, African leaders and their development partners such as the African Development Bank and World Bank should channel resources toward EE investment and innovation. Investment in EE contributes to building more vibrant economies, create jobs, and improve livelihoods Job creation is particularly important in the continent, due to its young population. In other words, EE investment and innovation is good both economically and environmentally. Second, attention should be paid to easing private sector growth constraints and fighting corruption while increasing social protection measures in Africa. This will require policymakers to provide systems and institution in the area of infrastructure, for instance, to reduce precarity, which inhibits EE adoption as well as EVS and SES. Third, to realise the clean-growth-inclusivity objectives of the AfCFTA, African leaders should prioritise investments in environmentally-friendly innovations and renewable energies. They could also use trade policy measures within the AfCFTA context to incentivise domestic production in the area of renewable energy, which could reduce cost of production as well as create jobs in the sector.

Declaration: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Abdelbary, I., & Benhin, J. (2019). Governance, capital and economic growth in the Arab Region. *The Quarterly Review of Economics and Finance*, *73*, 184-191.

Abid, M. (2016). Impact of economic, financial, and institutional factors on CO2 emissions: evidence from sub-Saharan Africa economies. *Utilities Policy*, *41*, 85-94.

Abid, N., Ikram, M., Wu, J., & Ferasso, M. (2021). Towards environmental sustainability: exploring the nexus among ISO 14001, governance indicators and green economy in Pakistan. *Sustainable Production and Consumption*, *27*, 653-666.

Acemoglu, D., & Robinson, J. (2008). *The role of institutions in growth and development* (Vol. 10). Washington DC: World Bank.

Adegboye, F. B., Osabohien, R., Olokoyo, F. O., Matthew, O., & Adediran, O. (2020). Institutional quality, foreign direct investment, and economic development in sub-Saharan Africa. *Humanities and Social Sciences Communications*, *7*(1), 1-9.

Adeleye, I., Debrah, Y. A., & Nachum, L. (2019). Management of financial institutions in Africa: Emerging themes and future research agenda. *Africa Journal of Management*, *5*(3), 215-230.

Adom, P. K., Agradi, M., & Vezzulli, A. (2021). Energy efficiency-economic growth nexus: What is the role of income inequality? *Journal of Cleaner Production*, *310*, 127382.

Adom, P. K., Amakye, K., Abrokwa, K. K., & Quaidoo, C. (2018). Estimate of transient and persistent energy efficiency in Africa: A stochastic frontier approach. *Energy Conversion and Management*, *166*, 556-568.

Adger, W. N., Brown, K., Fairbrass, J., Jordan, A., Paavola, J., Rosendo, S., & Seyfang, G. (2003). Governance for sustainability: towards a 'thick'analysis of environmental decision-making. *Environment and Planning A*, *35*(6), 1095-1110.

African Union Commission. (2021). *Africa's Development Dynamics 2021 Digital Transformation for Quality Jobs: Digital Transformation for Quality Jobs*. OECD Publishing.

Agradi, M., Adom, P. K., & Vezzulli, A. (2022). Towards sustainability: Does energy efficiency reduce unemployment in African societies? *Sustainable Cities and Society*, 103683.

Agrawal, A. (2007). Forests, governance, and sustainability: common property theory and its contributions. *International Journal of The Commons*, *1*(1), 111-136.

Ahmed, F., Kousar, S., Pervaiz, A., & Shabbir, A. (2022). Do institutional quality and financial development affect sustainable economic growth? Evidence from South Asian countries. *Borsa Istanbul Review*, *22*(1), 189-196.

Akhbari, R., & Nejati, M. (2019). The effect of corruption on carbon emissions in developed and developing countries: empirical investigation of a claim. *Heliyon*, *5*(9), e02516.

Akram, R., Chen, F., Khalid, F., Ye, Z., & Majeed, M. T. (2020). Heterogeneous effects of energy efficiency and renewable energy on carbon emissions: evidence from developing countries. *Journal of Cleaner Production*, *247*, 119122.

Alagidede, P., & Ibrahim, M. (2017). On the causes and effects of exchange rate volatility on economic growth: Evidence from Ghana. *Journal of African Business*, *18*(2), 169-193.

Ali, H. S., Zeqiraj, V., Lin, W. L., Law, S. H., Yusop, Z., Bare, U. A. A., & Chin, L. (2019). Does quality institutions promote environmental quality? *Environmental Science and Pollution Research*, *26*(11), 10446-10456.

Amavilah, V., Asongu, S. A., & Andrés, A. R. (2017). Effects of globalization on peace and stability: Implications for governance and the knowledge economy of African countries. *Technological Forecasting and Social Change*, 122, 91-103.

Apergis, N., & Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators*, *52*, 16-22.

Arouri, M., El Ghoul, S., & Gomes, M. (2021). Greenwashing and product market competition. *Finance Research Letters*, 101927.

Atkinson, R., & Klausen, J. E. (2011). Understanding sustainability policy: governance, knowledge and the search for integration. *Journal of Environmental Policy & Planning*, *13*(3), 231-251.

Asongu, S., & Kodila-Tedika, O. (2016). Fighting African conflicts and crimes: which governance tools matter? *International Journal of Social Economics*.

Asongu, S. A., Le Roux, S., & Biekpe, N. (2018). Enhancing ICT for environmental sustainability in sub-Saharan Africa. *Technological Forecasting and Social Change*, *127*, 209-216.

Asongu, S. A., & Nwachukwu, J. C. (2016). The role of governance in mobile phones for inclusive human development in Sub-Saharan Africa. *Technovation*, *55*, 1-13.

Asongu, S. A., & Odhiambo, N. M. (2019). How enhancing information and communication technology has affected inequality in Africa for sustainable development: An empirical investigation. *Sustainable Development*, *27*(4), 647-656.

Asongu, S. A., & Odhiambo, N. M. (2021). Enhancing governance for environmental sustainability in sub-Saharan Africa. *Energy Exploration & Exploitation*, *39*(1), 444-463.

AUC/OECD - African Union Commission, 2021. Africa's Development Dynamics 2021: Digital Transformation for Quality Jobs: Digital Transformation for Quality Jobs. OECD Publishing. https://doi.org/10.1787/0a5c9314-en.

Ayres, R. U., Turton, H., & Casten, T. (2007). Energy efficiency, sustainability and economic growth. *Energy*, *32*(5), 634-648.

Azam, M., Liu, L., & Ahmad, N. (2021). Impact of institutional quality on environment and energy consumption: evidence from developing world. *Environment, Development and Sustainability*, *23*(2), 1646-1667.

Baloch, M. A., & Wang, B. (2019). Analyzing the role of governance in CO2 emissions mitigation: the BRICS experience. *Structural Change and Economic Dynamics*, *51*, 119-125.

Bataille, C., & Melton, N. (2017). Energy efficiency and economic growth: A retrospective CGE analysis for Canada from 2002 to 2012. *Energy Economics*, *64*, 118-130.

Bayar, Y., & Gavriletea, M. D. (2019). Energy efficiency, renewable energy, economic growth: evidence from emerging market economies. *Quality & Quantity*, *53*(4), 2221-2234.

Behera, B., & Ali, A. (2017). Factors determining household use of clean and renewable energy sources for lighting in Sub-Saharan Africa. *Renewable and Sustainable Energy Reviews*, *72*, 661-672.

Bekhet, H. A., Matar, A., & Yasmin, T. (2017). CO2 emissions, energy consumption, economic growth, and financial development in GCC countries: Dynamic simultaneous equation models. *Renewable and Sustainable Energy Reviews*, *70*, 117-132.

Bekun, F. V., Emir, F., & Sarkodie, S. A. (2019). Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa. *Science of the Total Environment*, *655*, 759-765.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics*, *87*(1), 115-143

Bokpin, G. A. (2017). Foreign direct investment and environmental sustainability in Africa: The role of institutions and governance. *Research in International Business and Finance*, *39*, 239-247.

Borenstein, S. (2015). A microeconomic framework for evaluating energy efficiency rebound and some implications. *The Energy Journal*, *36*(1).

Bovenberg, A. L., & Smulders, S. (1995). Environmental quality and pollution-augmenting technological change in a two-sector endogenous growth model. *Journal of Public Economics*, *57*(3), 369-391.

Bhattarai, M., & Hammig, M. (2001). Institutions and the environmental Kuznets curve for deforestation: a cross-country analysis for Latin America, Africa and Asia. *World Development*, *29*(6), 995-1010.

Brundtland, G. H. (1987). *Towards sustainable development. In Our Common Future* (pp. 43–66). Oxford, UK: Oxford University Press.

Cantore, N., Calì, M., & te Velde, D. W. (2016). Does energy efficiency improve technological change and economic growth in developing countries? *Energy Policy*, *92*, 279-285.

Conti, J., Holtberg, P., Diefenderfer, J., LaRose, A., Turnure, J. T., & Westfall, L. (2016). *International Energy Outlook 2016 with projections to 2040* (No. DOE/EIA-0484 (2016)). USDOE Energy Information Administration (EIA), Washington, DC (United States). Office of Energy Analysis. https://doi.org/10.2172/ 1296780

Dauda, L., Long, X., Mensah, C. N., Salman, M., Boamah, K. B., Ampon-Wireko, S., & Dogbe, C. S. K. (2021). Innovation, trade openness and CO2 emissions in selected countries in Africa. *Journal of Cleaner Production*, *281*, 125143.

Deichmann, U., & Zhang, F. (2013). *Growing green: the economic benefits of climate action*. World Bank Publications.

Dercon, S. (2012). Is Green Growth Good for the Poor? *Policy Research Working Paper 6231, the World Bank.*

Dluhopolskyi, O., Koziuk, V., Ivashuk, Y., & Klapkiv, Y. (2019). Environmental welfare: quality of policy vs. society's values. *Problemy Ekorozwoju*, *14*(1).

Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, *8*(1), 37-51.

Eriksson, C. (2013). *Economic growth and the environment: An Introduction to the Theory*. Oxford University Press.

Esen, Ö., & Bayrak, M. (2017). Does more energy consumption support economic growth in net energy-importing countries? *Journal of Economics, Finance and Administrative Science*.

Fay, M. (2012). *Inclusive green growth: The pathway to sustainable development*. World Bank Publications.

Fayiga, A. O., Ipinmoroti, M. O., & Chirenje, T. (2018). Environmental pollution in Africa. *Environment, Development and Sustainability*, *20*(1), 41-73. https://doi.org/10.1007/s10668-016-9894-4

Filippini, M., & Zhang, L. (2016). Estimation of the energy efficiency in Chinese provinces. *Energy Efficiency*, *9*(6), 1315-1328.

Fosu, A. K., & Abass, A. F. (2019). Domestic credit and export diversification: Africa from a global perspective. *Journal of African Business*, *20*(2), 160-179.

Gillingham, K., Rapson, D., & Wagner, G. (2016). The rebound effect and energy efficiency policy. *Review of Environmental Economics and Policy*, 10, 68–88. http://www.jstor.org/stable/resre p01115.

Gillingham, K., Rapson, D., & Wagner, G. (2020). The rebound effect and energy efficiency policy. *Review of Environmental Economics and Policy*.

Go, Y. H., Lau, L. S., Yii, K. J., & Lau, W. Y. (2020). Does energy efficiency affect economic growth? Evidence from aggregate and disaggregate levels. *Energy & Environment*, *31*(6), 983-1006.

Goulder, L. H., & Mathai, K. (2000). Optimal CO2 abatement in the presence of induced technological change. *Journal of Environmental Economics and Management*, *39*(1), 1-38.

Gouldson, A., & Murphy, J. (1997). Ecological modernisation: restructuring industrial economies. *Political Quarterly*, *68*(B), 74-86. https://eprints.gla.ac.uk/71082/.

Green Growth Knowledge Platform. (2013). Moving towards a Common Approach on Green Growth Indicators. *Global Green Growth Institute*, OECD, UNEP and The World Bank.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American Free Trade Agreement. *National Bureau of Economic Research Working Paper* 3914, NBER, Cambridge MA.

Gu, K., Dong, F., Sun, H., & Zhou, Y. (2021). How economic policy uncertainty processes impact on inclusive green growth in emerging industrialized countries: A case study of China. *Journal of Cleaner Production*, *322*, 128963.

Halkos, G., de Alba, J. M., & Todorov, V. (2021). Economies' inclusive and green industrial performance: An evidence based proposed index. *Journal of Cleaner Production*, *279*, 123516.

Halkos, G. E., & Polemis, M. L. (2017). Does financial development affect environmental degradation? Evidence from the OECD countries. *Business Strategy and the Environment*, *26*(8), 1162-1180.

Herring, H., & Sorrell, S. (2009). Energy efficiency and sustainable consumption. *The Rebound Effect, Hampshire*.

Higón, D. A., Gholami, R., & Shirazi, F. (2017). ICT and environmental sustainability: A global perspective. *Telematics and Informatics*, *34*(4), 85-95.

Holley, C., & Lecavalier, E. (2017). Energy governance, energy security and environmental sustainability: A case study from Hong Kong. *Energy Policy*, *108*, 379-389.

Howarth, R. B. (1997). Energy efficiency and economic growth. *Contemporary Economic Policy*, *15*(4), 1-9.

Hunjra, A. I., Tayachi, T., Chani, M. I., Verhoeven, P., & Mehmood, A. (2020). The moderating effect of institutional quality on the financial development and environmental quality nexus. *Sustainability*, *12*(9), 3805.

Hussain, M., & Dogan, E. (2021). The role of institutional quality and environment-related technologies in environmental degradation for BRICS. *Journal of Cleaner Production*, *304*, 127059.

Murphy, J., & Gouldson, A. (2000). Environmental policy and industrial innovation: integrating environment and economy through ecological modernisation. *Geoforum*, *31*(1), 33-44.

IEA (2016) Conti, J., Holtberg, P., Diefenderfer, J., LaRose, A., Turnure, J. T., & Westfall, L. (2016). *International Energy Outlook 2016 with projections to 2040* (No. DOE/EIA-0484 (2016)). USDOE Energy Information Administration (EIA), Washington, DC (United States). Office of Energy Analysis.

IIED (2016). *Informality and inclusive green growth: Evidence from 'The biggest private sector' event.* IIED. http://www.greengrowthknowledge.org/sites/default/files/downloads/resource/IIED_informality_inclusive_green_growth.pdf.

IMF (International Monetary Fund) (2020a*). World Economic Outlook: A Long and Difficult Ascent.* October. Washington, DC, International Monetary Fund.
Ivanyna, M., & Salerno, A. (2021). Governance for Inclusive growth. *IMF Working Papers*, *2021*(098).
Javid, M., & Khan, M. (2020). Energy efficiency and underlying carbon emission trends. *Environmental Science and Pollution Research*, *27*(3), 3224-3236.
Jolliffe, I. T. (2002). Principal components in regression analysis. *Principal component analysis*, 167-198.
Khan, M. (2012). Governance and growth challenges for Africa. *Good growth and governance in Africa: Rethinking development strategies*, 114-39.
Khazzoom, J. D. (1980). Economic implications of mandated efficiency in standards for household appliances. *The Energy Journal*, *1*(4).
Kumbhakar, S. C., Lien, G., & Hardaker, J. B. (2014). Technical efficiency in competing panel data models: a study of Norwegian grain farming. *Journal of Productivity Analysis*, *41*(2), 321-337.
Kuznets, S. (1955). Economic growth and income inequality. *The American Economic Review*, *45*(1), 1-28.
Lakhera, M. L. (2016). *Economic growth in developing countries: Structural transformation, manufacturing and transport infrastructure*. Springer.
Law, S. H., & Singh, N. (2014). Does too much finance harm economic growth? *Journal of Banking & Finance*, *41*, 36-44.
Lei, W., Xie, Y., Hafeez, M., & Ullah, S. (2021). Assessing the dynamic linkage between energy efficiency, renewable energy consumption, and CO2 emissions in China. *Environmental Science and Pollution Research*, 1-13.
Lin, B., & Abudu, H. (2020). Can energy conservation and substitution mitigate CO2 emissions in electricity generation? Evidence from Middle East and North Africa. *Journal of Environmental Management*, *275*, 111222.
Lindgren, S. A. (2020). Clean cooking for all? A critical review of behaviour, stakeholder engagement, and adoption for the global diffusion of improved cookstoves. *Energy Research & Social Science*, *68*, 101539.
Lipsey, R. G., Carlaw, K. I., & Bekar, C. T. (2005). *Economic transformations: general purpose technologies and long-term economic growth*. OUP Oxford.
Marques, A. C., Fuinhas, J. A., & Tomás, C. (2019). Energy efficiency and sustainable growth in industrial sectors in European Union countries: A nonlinear ARDL approach. *Journal of Cleaner Production*, *239*, 118045.
Meadows, D.H., Meadows, D.L., Randers, J., Behrens_III, W.W. (1972). The Limits to Growth. New York: Universe Books.
Mehrhoff, J. (2009). A solution to the problem of too many instruments in dynamic panel data GMM. https://www.econstor.eu/bitstream/10419/28620/1/612354555.pdf
Nathaniel, S. P., & Iheonu, C. O. (2019). Carbon dioxide abatement in Africa: the role of renewable and non-renewable energy consumption. *Science of the Total Environment*, 679, 337-345.
Njiru, C. W., & Letema, S. C. (2018). Energy poverty and its implication on standard of living in Kirinyaga, Kenya. *Journal of Energy*, *2018*.
North, D. (1990). *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Pres
Obeng, C. K., Mwinlaaru, P. Y., & Ofori, I. K. (2022). Global value chain participation and inclusive growth in Sub-Saharan Africa. In *The Palgrave Handbook of Africa's Economic Sectors* (pp. 815-840). Palgrave Macmillan, Cham.

OECD (2017). Green Growth Indicators 2017. OECD Green Growth Studies, OECD Publishing, Paris, https://doi.org/10.1787/9789264268586-en.
OECD. (2011). Towards Green Growth: Monitoring Progress: OECD Indicators. OECD Green Growth Studies. OECD Publishing. Paris
Ofori, I. K., & Asongu, S. A. (2021). ICT diffusion, FDI and inclusive growth in Sub-Saharan Africa. *Telematics and Informatics*, *65*, 101718.
Ofori, I. K., Armah, M. K., Taale, F., & Ofori, P. E. (2021a). Addressing the severity and intensity of poverty in Sub-Saharan Africa: how relevant is the ICT and financial development pathway?. *Heliyon*, *7*(10), e08156.
Ofori, I. K., Dossou, T., Asongu, S., & Armah, M. K. (2021b). Bridging Africa's Income Inequality Gap: How Relevant Is China's Outward FDI to Africa?. *European Xtramile Centre of African Studies WP/21/098*.
Ofori, I. K., Gbolonyo, E. Y., Dossou, T. A. M., & Nkrumah, R. K. (2022). Remittances and income inequality in Africa: Financial development thresholds for economic policy. *Research in Globalization*, 4, 100084.
Ofori, I. K. Cantah, W. G., Afful Jr., B, & Hossain, S. (2022a). Towards Shared Prosperity in Sub-Saharan Africa: How Does the Effect of Economic Integration Compare to Social Equity Policies? *African Development Review*, 1-17.
Ofori, I. K., Dossou, T. A. M., & Akadiri, S. S. (2022b). Towards the quest to reduce income inequality in Africa: is there a synergy between tourism development and governance? *Current Issues in Tourism*, 1-21.
Ofori, I. K., Armah, M. K., & Asmah, E. E. (2022c). Towards the reversal of poverty and income inequality setbacks due to COVID-19: The role of globalisation and resource allocation. *International Review of Applied Economics*, 1-28.
Ofori, I. K., Osei, D. B., & Alagidede, I. P. (2022d). Inclusive growth in Sub-Saharan Africa: Exploring the interaction between ICT diffusion, and financial development. *Telecommunications Policy*, *46*(7), 102315.
Ohene-Asare, K., Tetteh, E. N., & Asuah, E. L. (2020). Total factor energy efficiency and economic development in Africa. *Energy Efficiency*, *13*(6), 1177-1194.
Opoku, E. E. O., & Boachie, M. K. (2020). The environmental impact of industrialization and foreign direct investment. *Energy Policy*, *137*, 111178.
Özbuğday, F. C., & Erbas, B. C. (2015). How effective are energy efficiency and renewable energy in curbing CO2 emissions in the long run? A heterogeneous panel data analysis. *Energy*, *82*, 734-745.
Panayotou, T. (1997). Demystifying the environmental Kuznets curve: turning a black box into a policy tool. *Environment and Development Economics*, *2*(4), 465-484.
Peprah, J. A., Ofori, I. K., & Asomani, A. N. (2019). Financial development, remittances and economic growth: A threshold analysis. *Cogent Economics & Finance*, *7*(1), 1625107.
Ponce, P., & Khan, S. A. R. (2021). A causal link between renewable energy, energy efficiency, property rights, and CO2 emissions in developed countries: a road map for environmental sustainability. *Environmental Science and Pollution Research*, *28*(28), 37804-37817.
Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97-118.
Pritchett, L., & Werker, E. (2012). Developing the guts of a GUT (Grand Unified Theory): elite commitment and inclusive growth. *Effective States and Inclusive Development Research Centre (ESID) Working Paper*, (16/12).

Puzzolo, E., Pope, D., Stanistreet, D., Rehfuess, E. A., & Bruce, N. G. (2016). Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. *Environmental Research*, *146*, 218-234.

Pye, A., Ronzi, S., Mbatchou Ngahane, B. H., Puzzolo, E., Ashu, A. H., & Pope, D. (2020). Drivers of the adoption and exclusive use of clean fuel for cooking in sub-Saharan Africa: Learnings and policy considerations from Cameroon. *International Journal of Environmental Research and Public Health*, *17*(16), 58 - 74.

Rajbhandari, A., & Zhang, F. (2018). Does energy efficiency promote economic growth? Evidence from a multicountry and multisectoral panel dataset. *Energy Economics*, *69*, 128-139.

Ravallion, M., & Chen, S. (2003). Measuring pro-poor growth. *Economics Letters, 78*(1), 93-99.

Razzaq, A., Wang, Y., Chupradit, S., Suksatan, W., & Shahzad, F. (2021). Asymmetric inter-linkages between green technology innovation and consumption-based carbon emissions in BRICS countries using quantile-on-quantile framework. *Technology in Society,* 66, 101656.

Rodríguez-Martínez, C. C., García-Sánchez, I. M., Vicente-Galindo, P., & Galindo-Villardón, P. (2019). Exploring Relationships between Environmental Performance, E-Government and Corruption: A Multivariate Perspective. *Sustainability*, *11*(22), 6497.

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal*, *9*(1), 86-136.

Sarkodie, S. A., Adams, S., & Leirvik, T. (2020). Foreign direct investment and renewable energy in climate change mitigation: does governance matter? *Journal of Cleaner Production*, *263*, 121262.

Sarkodie, S. A., & Strezov, V. (2019). Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. *Science of the Total Environment*, *646*, 862-871.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., & Leitão, N. C. (2013). Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. *Renewable and Sustainable Energy Reviews*, *25*, 109-121.

Shahbaz, M., Gozgor, G., Adom, P. K., & Hammoudeh, S. (2019). The technical decomposition of carbon emissions and the concerns about FDI and trade openness effects in the United States. *International Economics*, *159*, 56-73.

Stock, J. H., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica: journal of the Econometric Society*, 783-820.

Sulaiman, C., Abdul-Rahim, A. S., Mohd-Shahwahid, H. O., & Chin, L. (2017). Wood fuel consumption, institutional quality, and forest degradation in sub-Saharan Africa: Evidence from a dynamic panel framework. *Ecological Indicators*, *74*, 414-419.

Sun, Y., Ding, W., Yang, Z., Yang, G., & Du, J. (2020). Measuring China's regional inclusive green growth. *Science of the Total Environment*, *713*, 136367.

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. *Energy policy*, *37*(1), 246-253.

Tajudeen, I. A., Wossink, A., & Banerjee, P. (2018). How significant is energy efficiency to mitigate CO2 emissions? Evidence from OECD countries. *Energy Economics*, *72*, 200-221.

Tchamyou, V. S. (2017). The role of knowledge economy in African business. *Journal of the Knowledge Economy*, 8(4), 1189-1228.

Tchamyou, V. S., Asongu, S. A., & Odhiambo, N. M. (2019). The role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa. *African Development Review*, *31*(3), 261-274.

UNEP. (2011). Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - A Synthesis for Policy Makers. www.unep.org/greeneconomy.

UNFCCC (2015). Press Release: Rising Number of Initiatives by Cities and Better Land Management Show Pathways Towards Carbon Neutral Future. (Bonn. http://www.newsroom.unfccc.int/media/1605/pr20141506_sb40_close.pdf

Wawrzyniak, D., & Doryń, W. (2020). Does the quality of institutions modify the economic growth-carbon dioxide emissions nexus? Evidence from a group of emerging and developing countries. *Economic Research-Ekonomska Istraživanja*, *33*(1), 124-144.

Weber, O. (2014). The financial sector's impact on sustainable development. *Journal of Sustainable Finance & Investment*, *4*(1), 1-8.

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics*, *126*(1), 25-51.

World Bank (2021). World Development Indicators (December Edition). Washington, DC: World Bank

World Bank (2020). *Poverty and shared prosperity 2020: Reversals of fortunes (October).* The World Bank.

World Bank. (2012). *Inclusive Green Growth: The Pathway to Sustainable Development*. Washington, DC. World Bank.

World Economic Forum (2021). Net Zero Carbon Cities: An Integrated Approach. Insight Report.

Xu, B., & Lin, B. (2015). Factors affecting carbon dioxide (CO2) emissions in China's transport sector: a dynamic nonparametric additive regression model. *Journal of Cleaner Production*, *101*, 311-322.

Yu, C., Nataliia, D., Yoo, S. J., & Hwang, Y. S. (2019). Does trade openness convey a positive impact for the environmental quality? Evidence from a panel of CIS countries. *Eurasian Geography and Economics*, *60*(3), 333-356.

Appendices Section

Table A.1: Hausman test on Equation (6)

	Coefficients			
Variables	*Fixed effect (b)*	*Random effect (B)*	*Difference*	*Standard error*
Trade openness	-0.0209	-0.0343	0.0133	0.0000
Urbanisation	-0.312***	-0.439***	0.1273	0.0646
Economic growth	0.0867	0.0641	0.0226	0.0371
Crude oil price	0.0042	-0.0273**	0.0315	0.0126
Industrialisation	0.0494	0.0713**	-0.0218	0.0065
Human capital	0.680***	0.654***	0.0256	0.0476
t	-2.312***	-0.0051**	-2.3064	0.8885
t^2	0.0005***	0.0001	0.0004	0.0001

*Note: **t** is time; $\boldsymbol{t^2}$ is time squared.*
b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic
Chi Statistic: 9.02; Chi(P-value): 0.2512
**** p<0.01, ** p<0.05, * p<0.1*

Table A.2: Pairwise correlation matrix

	igg	*ghgg*	*trade*	*cps*	*aid*	*ictdif*	*gpcg*	*gpcsqr*	*EE*	*pol*	*reg*	*govef*	*rol*	*corrupt*	*vna*
igg	1														
ghgas	0.235^{**}	1													
trade	0.315^{***}	0.162	1												
cps	0.578^{***}	0.00501	0.189^{*}	1											
aid	-0.511^{***}	-0.0529	-0.157	-0.352^{***}	1										
ictdif	0.294^{***}	0.138	0.280^{**}	0.311^{***}	-0.155	1									
gpcg	0.206^{*}	0.202^{*}	0.00941	0.161	-0.0229	0.00236	1								
gpcsqr	0.0755	0.227^{**}	0.205^{*}	0.0442	-0.137	-0.0135	0.231^{**}	1							
EE	-0.690^{***}	-0.28^{**}	-0.455^{***}	-0.433^{***}	0.298^{***}	-0.234^{**}	0.0489	-0.0484	1						
pol	0.370^{***}	0.454^{***}	0.253^{**}	0.226^{**}	-0.161	0.0507	0.0454	0.140	-0.762^{***}	1					
regu	0.553^{***}	0.436^{***}	0.218^{*}	0.561^{***}	-0.414^{***}	0.109	0.211^{*}	0.240^{**}	-0.624^{***}	0.712^{***}	1				
govef	0.733^{***}	0.431^{***}	0.219^{*}	0.561^{***}	-0.424^{***}	0.146	0.271^{**}	0.210^{*}	-0.689^{***}	0.705^{***}	0.908^{***}	1			
rol	0.637^{***}	0.579^{***}	0.323^{***}	0.435^{***}	-0.294^{***}	0.154	0.208^{*}	0.241^{**}	-0.747^{***}	0.823^{***}	0.896^{***}	0.916^{***}	1		
corrupt	0.663^{***}	0.502^{***}	0.322^{***}	0.449^{***}	-0.327^{***}	0.139	0.230^{**}	0.266^{**}	-0.643^{***}	0.727^{***}	0.879^{***}	0.901^{***}	0.941^{***}	1	
vna	0.254^{**}	0.465^{***}	-0.133	0.250^{**}	-0.0826	0.0341	0.192^{*}	0.183^{*}	-0.366^{***}	0.620^{***}	0.757^{***}	0.661^{***}	0.711^{***}	0.726^{***}	1

* *p* < 0.1, ** *p* < 0.05, *** *p* < 0.001

Table A.3: Pairwise correlation matrix for IGG index variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
Cleanfuel (1)	1																					
agric (2)	0.127	1																				
enerint (3)	-0.504***	-0.236**	1																			
forest (4)	-0.151*	-0.439***	0.125	1																		
fosful 51)	0.866***	0.317***	-0.597***	-0.396***	1																	
gpc (6)	0.795***	0.0410	-0.499***	0.0456	0.667***	1																
renener (7)	-0.840***	-0.325***	0.576***	0.398***	-0.991***	-0.657***	1															
amb (8)	-0.290***	-0.0262	0.309***	0.205**	-0.213**	-0.458***	0.235**	1														
unemp (9)	0.631***	0.195**	-0.322***	-0.0673	0.647***	0.732***	-0.624***	-0.242**	1													
sanit (10)	0.630***	0.119	-0.437***	0.130	0.474***	0.717***	-0.482***	-0.376***	0.389***	1												
powat (11)	0.797***	0.227**	-0.726***	0.0297	0.782***	0.842***	-0.781***	-0.300***	0.656***	0.701***	1											
cwea (12)	0.164*	0.263***	-0.188*	-0.475***	0.412***	0.0983	-0.452***	-0.164*	0.230**	0.189*	0.227**	1										
temp (13)	0.143	0.0688	-0.0247	-0.249***	0.155*	-0.197**	-0.126	0.162*	-0.156*	-0.211**	-0.103	-0.0746	1									
pop (14)	0.223**	0.178*	-0.122	-0.115	0.175*	0.285***	-0.200**	-0.467***	-0.165*	0.384***	0.218**	-0.0003	-0.0054	1								
carint (15)	0.512***	0.468***	-0.104	-0.289***	0.647***	0.452***	-0.651***	-0.120	0.678***	0.308***	0.430***	0.177*	0.0286	0.0189	1							
ambmort (16)	0.862***	0.320***	-0.556***	-0.211**	0.820***	0.692***	-0.761***	-0.116	0.644***	0.436***	0.750***	0.102	0.178*	0.157*	0.540***	1						
ambcost (17)	0.852***	0.323***	-0.559***	-0.209**	0.811***	0.662***	-0.749***	-0.0986	0.629***	0.437***	0.741***	0.122	0.183*	0.136	0.523***	0.992***	1					
trans (18)	0.563***	0.141	-0.430***	-0.325***	0.646***	0.732***	-0.669***	-0.523***	0.513***	0.511***	0.648***	0.470***	-0.198**	0.558***	0.325***	0.500***	0.475***	1				
ineq (19)	-0.0129	0.340***	-0.210**	-0.0248	0.166*	0.267***	-0.187*	-0.0500	0.560***	0.253***	0.351***	0.398***	-0.421***	-0.290***	0.382***	0.0683	0.0780	0.303***	1			
hc (20)	0.525***	0.167*	-0.390***	-0.0021	0.515***	0.780***	-0.507***	-0.330***	0.648***	0.461***	0.674***	0.170*	-0.257***	0.233**	0.409***	0.625***	0.598***	0.665***	0.347***	1		
methane (21)	-0.403***	0.0402	0.538***	-0.105	-0.428***	-0.342***	0.442***	0.122	-0.277***	-0.206**	-0.595***	-0.0883	-0.0008	-0.0914	-0.117	-0.439***	-0.428***	-0.365***	-0.180*	-0.378***	1	
natres (22)	-0.0285	-0.453***	0.265***	0.527***	-0.277***	0.0348	0.290***	0.322***	-0.112	0.0344	-0.110	-0.459***	-0.0849	-0.272***	-0.240**	-0.210**	-0.209**	-0.378***	-0.253***	-0.209**	0.252***	1
envtech (23)	0.118	-0.0487	0.0912	-0.0168	0.0656	0.0656	-0.0561	-0.0429	-0.00239	0.0057	-0.0305	-0.009	0.0245	0.142	-0.003	0.0824	0.0809	0.0780	-0.189*	0.0642	0.107	0.00995
infmort (24)	-0.760***	-0.164*	0.441***	0.372***	-0.766***	-0.674***	0.767***	0.507***	-0.578***	-0.353***	-0.628***	-0.337***	-0.0765	-0.283***	-0.425***	-0.695***	-0.680***	-0.675***	0.009	-0.699***	0.366***	0.367***

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.001$

Table A.4: Eigenvectors of IGG components

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9	Comp10	Comp11	Comp12	Comp13	Comp14	Comp15	Comp16	Comp17	Comp18
cleanfuel	0.276	0.117	-0.227	0.033	0.080	-0.030	0.179	0.005	-0.014	0.040	-0.067	-0.180	0.109	0.220	0.045	-0.218	0.063	-0.059
agric	0.105	-0.358	0.090	0.136	0.058	0.579	-0.147	0.177	-0.130	-0.141	-0.021	-0.035	-0.407	0.342	0.113	-0.119	-0.080	0.110
enerint	-0.205	-0.034	0.016	0.022	0.471	-0.080	-0.037	-0.177	0.497	0.144	0.113	-0.199	0.052	0.399	-0.035	-0.212	0.267	-0.026
forest	-0.087	0.518	0.069	0.053	-0.085	0.104	-0.145	0.111	0.113	0.237	0.240	-0.312	-0.254	-0.210	0.488	0.064	0.038	-0.139
fosful	0.288	-0.094	-0.135	0.101	0.000	-0.081	0.168	0.077	0.076	0.055	-0.198	0.052	-0.075	-0.212	0.099	-0.026	0.001	-0.186
incgro	0.268	0.260	0.062	-0.076	0.140	0.004	0.054	-0.093	-0.058	-0.059	0.102	0.205	0.020	0.008	-0.024	-0.045	0.273	0.542
renener	-0.285	0.106	0.101	-0.075	0.004	0.088	-0.196	-0.086	-0.124	-0.113	0.229	-0.055	0.197	0.211	-0.060	0.120	-0.054	0.111
amb	-0.130	0.020	-0.139	0.457	-0.046	0.028	-0.039	0.364	0.512	-0.278	0.071	0.124	0.056	-0.241	-0.079	-0.278	-0.162	0.165
unemp	0.237	0.085	0.175	0.260	0.210	-0.146	-0.083	-0.206	-0.119	0.115	0.099	0.090	0.095	0.104	0.368	-0.110	-0.569	0.249
sanit	0.199	0.227	0.114	-0.146	0.056	0.298	0.372	0.233	-0.047	0.139	0.208	-0.297	0.232	-0.036	-0.440	-0.161	-0.302	-0.004
powat	0.282	0.175	0.042	0.036	-0.168	0.084	0.062	0.136	-0.032	0.033	0.010	0.067	-0.161	0.041	0.058	-0.178	0.510	0.178
cwea	0.115	-0.337	0.248	-0.032	-0.054	-0.350	0.362	0.296	0.161	-0.075	0.264	-0.299	-0.151	0.136	0.141	0.400	0.002	0.159
temp	-0.006	-0.203	-0.498	0.103	-0.112	0.028	0.104	-0.124	-0.077	0.339	0.664	0.279	-0.119	0.018	-0.064	0.013	0.003	-0.034
pop	0.091	-0.036	-0.093	-0.551	0.048	0.390	-0.052	0.059	0.361	0.063	-0.005	0.148	0.009	-0.015	0.201	0.084	-0.154	-0.102
carint	0.195	-0.132	0.055	0.269	0.341	0.198	-0.031	-0.185	0.153	0.433	-0.230	-0.043	-0.054	-0.271	-0.180	0.372	0.049	0.066
ambmort	0.271	0.031	-0.225	0.150	0.001	0.083	-0.166	-0.001	0.007	-0.215	0.044	-0.106	0.298	0.123	0.088	0.226	0.079	-0.013
ambcost	0.267	0.025	-0.225	0.162	-0.011	0.082	-0.148	0.028	-0.011	-0.225	0.065	-0.155	0.333	0.141	0.104	0.248	0.086	-0.277
trans	0.246	-0.043	0.155	-0.291	0.029	-0.125	0.034	0.011	0.275	-0.075	0.063	0.442	0.153	0.024	0.177	-0.029	-0.052	-0.080
ineq	0.097	-0.048	0.556	0.259	-0.038	0.030	-0.053	0.105	-0.077	0.157	0.184	0.261	0.141	0.092	-0.060	-0.147	0.167	-0.503
hc	0.236	0.138	0.155	-0.055	0.092	-0.051	-0.359	-0.133	0.129	-0.322	0.306	0.008	-0.298	-0.182	-0.405	0.213	-0.033	-0.048
methane	-0.158	-0.114	0.014	-0.021	0.551	0.156	0.293	-0.033	-0.266	-0.363	0.207	0.009	0.069	-0.413	0.252	-0.066	0.174	-0.108
natres	-0.104	0.442	-0.124	0.148	0.205	-0.013	0.363	0.049	-0.007	-0.163	-0.144	0.321	-0.347	0.358	-0.087	0.285	-0.141	-0.224
envtech	0.016	0.010	-0.172	-0.157	0.411	-0.274	-0.386	0.654	-0.250	0.218	-0.024	0.085	-0.011	0.025	-0.069	0.004	-0.003	0.009
infmort	-0.261	0.070	0.115	0.138	-0.073	0.259	0.089	0.232	0.037	0.148	-0.014	0.255	0.348	0.028	0.062	0.392	0.124	0.248

Variable	Comp19	Comp20	Comp21	Comp22	Comp23	Comp24
cleanfuel	-0.320	0.007	0.652	0.353	-0.103	0.005
agric	-0.199	-0.104	-0.122	0.066	-0.053	0.059
enerint	0.107	-0.240	-0.139	-0.076	-0.003	0.032
forest	-0.233	-0.028	-0.109	0.050	0.012	0.021
fosful	0.026	-0.384	-0.006	-0.256	0.054	0.690
incgro	-0.378	0.100	-0.030	-0.480	-0.069	0.019
renener	0.034	0.352	0.117	0.128	0.074	0.691
amb	-0.022	0.229	0.075	-0.017	-0.004	0.012
unemp	0.329	-0.082	0.077	-0.012	-0.041	-0.045
sanit	0.051	-0.075	-0.247	0.019	0.026	0.016
powat	0.617	0.127	-0.034	0.256	0.016	0.056
cwea	0.009	0.128	0.096	-0.057	0.023	-0.005
temp	-0.011	-0.004	-0.019	0.006	0.002	-0.002
pop	0.231	0.163	0.333	-0.284	0.065	-0.068
carint	-0.050	0.349	-0.022	0.180	0.006	0.039
ambmort	-0.035	-0.082	-0.103	0.011	0.745	-0.124
ambcost	0.095	0.135	-0.200	-0.167	-0.600	-0.030
trans	-0.264	0.028	-0.373	0.496	-0.053	0.086
ineq	-0.076	0.121	0.192	-0.231	0.123	-0.055
hc	0.066	-0.329	0.236	0.128	-0.088	-0.011
methane	0.071	0.005	0.048	0.085	0.019	-0.033
natres	0.053	0.105	-0.045	-0.030	0.062	-0.014
envtech	0.018	0.021	-0.012	0.001	0.006	-0.000
infmort	0.023	-0.494	0.182	0.127	-0.144	-0.032

Note: Comp is principal component;

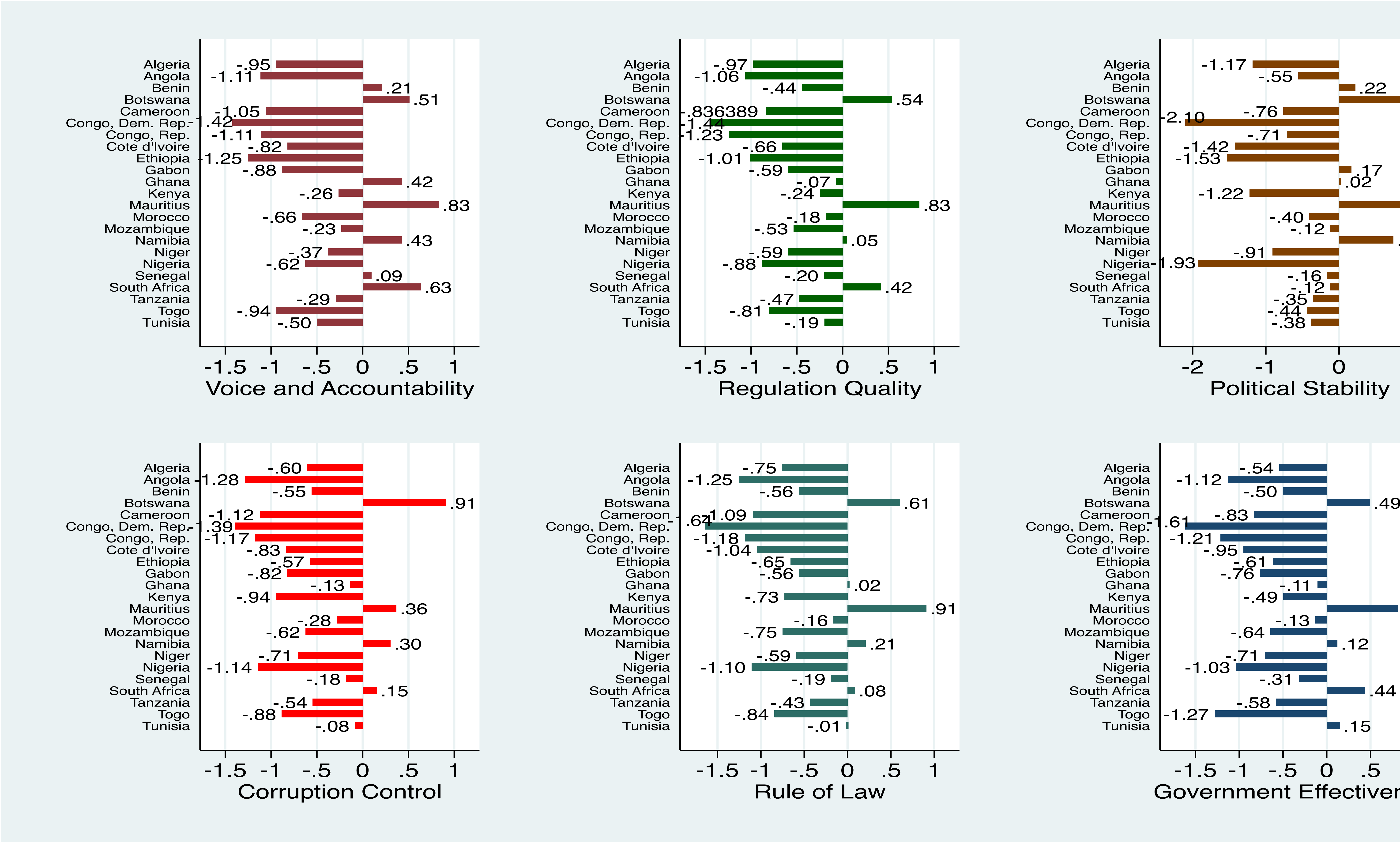

Figure A.1: In-country Governance Performance In Africa, 2000 – 2020

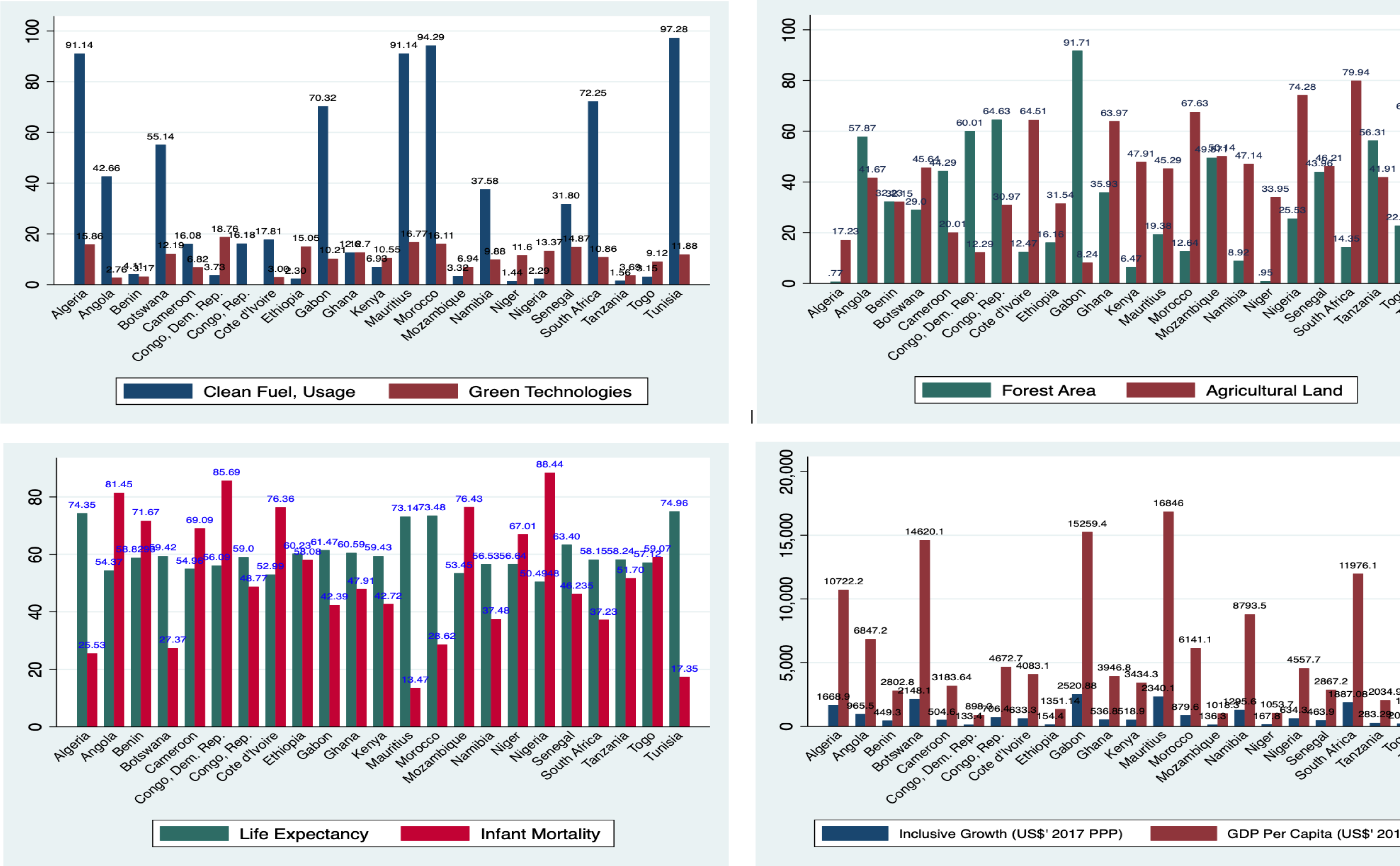

Figure A.2: In-country Average Socioeconomic and Environmental Sustainability Indicators, 2000 – 2020.

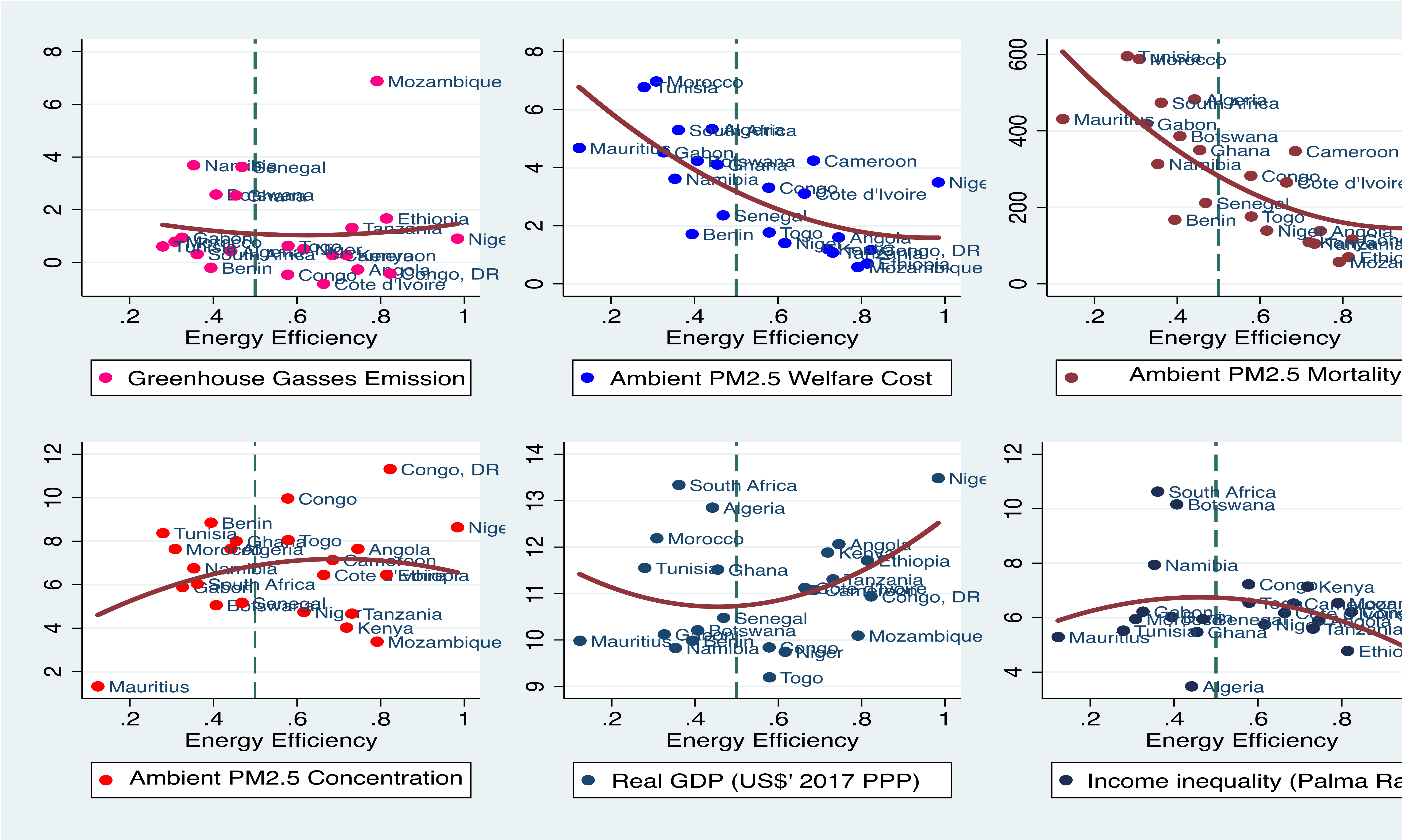

Figure A.3: In-country Sustainability – Energy Efficiency Nexus in Africa, 2000 – 2020