Does Economic Complexity Promote Inclusive Green Growth?

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Abstract

Despite the growing scholarly attention concerning the effect of economic complexity (ECI) on inclusive growth and the environment, there remain some pertinent gaps in the literature. First, previous studies have not explored the effect of ECI on inclusive green growth (IGG). Second, prior contributions have not assessed the role of energy consumption (disaggregated into renewable and non-renewable) in the relationship between ECI and IGG. This study addresses these gaps by using macro data for 22 selected African countries. Robust evidence based on the dynamic system GMM and the Driscoll-Kraay standard errors estimators reveal that economic complexity promotes IGG. Additionally, the contingency analysis reveals that non-renewable energy diminishes the IGG-enhancing effect of ECI, whereas renewable energy amplifies it. Finally, when we decompose IGG into environmental and socioeconomic sustainability, we find that the ECI-energy consumption interaction has a greater effect on the latter rather than the former. We conclude that investments for boosting Africa's productive knowledge and renewable energy capacities are crucial for IGG.

Keywords: Africa; Economic Complexity; Renewable Energy Consumption; Inclusive Green Growth

JEL Codes: O44; O55; Q01; Q43; Q56

1. Introduction

Global attention on inclusive green growth (hereafter: IGG) has grown in the economic development literature over the last two decades. African countries, like those in other regions, are striving for resilient, inclusive, and greener growth (Intergovernmental Panel on Climate Change [IPCC], 2022; Sachs et al., 2021). One variable that has received little attention in the emerging green growth scholarship is economic complexity. Economic complexity (hereafter: ECI) is defined as a country's accumulation of productive knowledge and capabilities as expressed in the goods and services it produces (Hildalgo & Hausmann, 2009). The impact of ECI on IGG is worth exploring considering its role on growth, income inequality, and the environment (see e.g., Hartmann et al. 2017; Can & Gozgor, 2017; Pugliese et al., 2017; Lee & Vu, 2019).

Indeed, whereas some studies suggest that ECI can promote greener more inclusive growth, others report contrary findings. Regarding the latter, studies have shown that transitioning from a less complex and agrarian economy to a highly diversified and knowledge-driven modern industrial system can intensify high energy consumption and ozone precursor gas emissions (Shahzad et al., 2021). Additionally, ECI can trigger environmental setbacks by intensifying the depletion of natural capital (e.g., water bodies, forest, and land) (Khan et al., 2017). For instance, the substitution of synthetic fertilisers for traditional fertilisers in farming can result in environmental degradation. This is due to the presence of substances such as cadmium, chromium, and radionuclides in inorganic fertilisers, which can contaminate air, soil, water, and biodiversity. Moreover, in Africa where informality is high and human capital is generally low, the drive towards a highly industrialised and service-driven economies can exacerbate income inequality (Chu & Hoang, 2020; Hartmann et al., 2017).

A strand of the literature also documents that ECI can promote share growth and environmental sustainability through increased economic connectedness, diversification, and ubiquity (see e.g., Bhorat et al., 2019; Hausmann & Hidalgo, 2011, 2014). Crucially, in Africa, where there is extensive margin for greater economic sophistication, ECI can accelerate private sector growth by deepening forward and backward linkages, innovation, global value chain participation and competitiveness in the global market. In this way, ECI can promote shared economic growth by promoting upskilling, industrialization, job creation, and poverty alleviation (Hartman et al., 2017; Lee & Vu, 2020). Because of the strong sectoral interconnectedness inherent in the economic fabric of complex societies, ECI can foster shared prosperity in Africa by improving access to healthcare, education, potable water, communication, and other critical social overheads (Hidalgo & Hausmann, 2009). Besides, ECI can contribute to environmental sustainability deepening innovation, recycling, and reuse, which can reduce the strain on natural capital for growth. Also, ECI can improve environmental quality of life by lowering energy intensity and ecological footprints (Romero & Gramkow, 2021). Further, ECI can enhance environmental progress through eco-innovation as well as the development and dissemination of green technologies, in various domains, including wastewater treatment and sustainable food processing and packaging (Gramkow & Anger-Kraavi, 2018).

The ECI-IGG perspective above suggests that energy consumption also deserves attention. We contend that the analyses of the ECI-IGG relationship will be incomplete if we do not consider mediating role of energy consumption. We argue that it is impossible to transition from a predominantly primary-sector-led economy to highly productive and knowledge-based one without reliable and affordable energy (Hidalgo, 2021). However, the potential contingency effect of energy consumption in the ECI-IGG relationship is not clear, at least in the context of African. First, in Africa, where energy systems are less developed and non-renewable energy consumption is high, ECI can harm the environment and, consequently IGG, through increased carbon intensity and air pollution. Second, given Africa's abundant renewable energy potential and growing investments in green energy, ECI has the potential to promote IGG.

Although previous studies (e.g., Ofori et al., 2023a, b; 2022; Abid et al., 2021) have investigated the effects of energy efficiency, institutional quality, economic globalisation, and digital infrastructure on IGG, there is still a research gap regarding whether economic complexity and energy consumption matter for IGG. Further, whether ECI interacts with energy consumption to promote IGG remain unexplored in the literature. Moreover, prior empirical contributions have examined the effect of ECI on either socioeconomic sustainability (e.g., Hidalgo, 2021; Vu, 2020; Hartmann et al., 2017) or environmental sustainability (e.g., Shahzad et al., 2021; Romero & Gramkow, 2021). This study fills these gaps by using macro data for 22 selected African countries for the period 2008-2020.

By addressing these voids in the extant literature, this study advances our understanding of IGG and contributes to the sustainable development discourse in several ways. First, the study contributes to the policymaking in Africa by estimating the extent to which economic complexity affects inclusive green growth. In this sense, we determine the magnitude to which the accumulation of productive knowledge impacts IGG in Africa. This is particularly important as Africa strives to industrialise and improve wellbeing in line with its Agenda 2063. Also, our empirical contribution provides empirical evidence on how economic complexity, a major component of SDG Targets 8.2 and 9.5, contributes to shared prosperity. This way, our study informs African governments and their development partners as to whether channelling resources to the development of the research, innovation and productive capacity of Africa can promote IGG.

Second, this study provides valuable insights within the context of SDGs 7 and 13. Our analysis thoroughly examines the impact of energy consumption. A key aspect of our study is the disaggregation of energy consumption into renewable and non-renewable sources to gauge their distinct effects on IGG. This decomposition is imperative to put into context the impacts that renewable and non-renewable energy have on IGG. This is also relevant as several African countries still rely on fossils fuels to meet their industrial and household needs. By doing so, we inform prominent organizations such as the African Development Bank, International Energy Agency, the World Bank and the United Nations about the potential of supporting Africa's green transition in achieving IGG. Empirical evidence from this study can also contribute to the policy formulation concerning the integration of energy consumption in line with Agenda 2050 (i.e., the carbon neutrality target) and climate change mitigation.

Third, this study quantifies the contingent effects of renewable and non-renewable energy consumption on the relationship between economic complexity and IGG. Considering the indispensable role of energy in complex systems, it is imperative to do this disaggregation to enable African governments in formulating energy strategies that effectively influence economic complexity and foster IGG.

The remainder of the study is organised as follows. The literature review and methods are presented in Sections 2 and 3, respectively, Section 4 focuses on the results, and Section 5 provides the concluding remarks.

2. Brief review of literature

In this section, we provide some theoretical and empirical perspectives on the link between economic complexity and IGG on the one hand, and energy consumption and IGG on the other. We conclude the section by providing an analytical framework that serves as the foundation for our empirical contribution.

2.1 The theoretical relationship between economic complexity and IGG

The theoretical link between economic complexity and IGG is deeply rooted in structural transformation theories (Lewis, 1954; Rostow, 1959; Kuznets, 1966), endogenous growth theory (Romer, 1994), and innovation theory (Schumpeter, 1934). According to the structural transformation and endogenous growth theories, a shift from low-productivity to high-productivity activities (economic complexity) is associated with the structural transformation process, which involves the acquisition of productive knowledge or technical know-how. This is seen in manufacturing transitions from simpler to more complex products (Hausmann & Hidalgo, 2011; Bhorat et al., 2019). Furthermore, according to Schumpeterian economics, innovation is at the heart of economic transformation through the creation of new products and processes. According to Stojkoski et al. (2023), progress in economic complexity, for example, in green technology, technical know-how, research and trade can promote IGG. This is possible because the integration of knowledge and skills and product diversity and ubiquity in industrial systems and structures can reduce pressures on the natural environment.

More specifically, in terms of IGG's socioeconomic development (SES) dimension, economic complexity can promote shared economic prosperity by promoting inclusive education, better health care, and improved water, and electricity (Neagu & Teodoru 2019; Hidalgo & Hausmann, 2009). For instance, economic complexity can reduce income inequality through improved occupational structures, which enhance job opportunities and poverty alleviation (Hartman et al. 2017; Lee & Vu, 2019). However, according to the skills-biased technological change theory, technological progress may exacerbate income inequality. This arises in that skills-biased technological change puts premium on the skills/capabilities of the skilled compared to the unskilled (Violante, 2008).

Concerning the environmental sustainability (EVS) perspective of IGG, the ecological Kuznets curve (EKC) deserves an attention (Grossman & Kreuger, 1991; 1995). The idea is that transitioning from a predominantly agrarian economy to a highly industrialised, complex and service driven economy cap to promote environmental quality. At the heart of this argument complex economies lead the pace for eco-friendly technologies and research and development that foster environmental sustainability (Romero & Gramkow, 2021; Paramati et al., 2022; Shahzad et al., 2021; Neagu & Teodoru, 2019). based on these theoretical perspectives, we formulate the first hypothesis as:

Hypothesis 1: Economic complexity promotes inclusive green growth.

2.2 Empirical literature on economic complexity and IGG

In recent years, there has been increased interest in the shared growth and environmental implications of economic complexity. A subset of the literature contends that ECI enhances socioeconomic outcomes. Hartmann et al. (2017), for example, show that a high level of economic complexity reduces income inequality. Furthermore, Ferraz et al. (2018) argue that ECI improves human development, whereas Pugliese et al. (2017) find that economic complexity reduces poverty. Similarly, Vu (2020) demonstrates that ECI improves population health by creating jobs. From this perspective, scholars argue that economic complexity fosters inclusiveness by facilitating strong interdependence between political and economic freedom, human capital, R&D, and innovation (Hartmann et al., 2022; Ferraz et al., 2021). These studies therefore advocate for policymakers to strive for economic complexity as a tool for improving living conditions. However, other researchers argue that economic complexity may harm inclusive growth by exacerbating inequalities (Baek, 2017). For instance, Chu and Hoang (2020) find evidence that economic complexity widens income disparity gap in 88 countries. Additionally, Lee and Vu (2020) use instrumental variable regression to show that increasing economic complexity fuel income inequality in 113 countries.

Discussions about the environmental impact of economic complexity have sparked similar interests among scholars. For example, Can and Gozgor (2017) employ the dynamic ordinary least squares estimator to show that economic complexity reduces CO_2 emissions in France. Similarly, Romero and Grankow (2020) apply the fixed effect and the dynamic system GMM estimator to a dataset comprising 67 countries to suggest that economic complexity reduces greenhouse gas emissions. We sight a contribution in Dogan and Inglesi-Lotz (2020), who find that economic complexity reduces environmental degradation in 28 OECD countries.

Another school of thought holds that economic complexity is harmful to environmental sustainability. The crux of these scholars' argument is that the natural resource, fossil fuel, and energy needs of complex economic systems can degrade the environment. For example, Khan et al. (2022) use the fully-modified least squares and dynamic least squares estimation techniques to demonstrate that economic complexity intensifies ecological footprints in the G-7 countries. Furthermore, Shahzad et al. (2021) provided evidence from the quantile autoregressive distributed lags that economic complexity increases ecological footprint in the United States. In a parallel development, Laverde-Rojas et al. (2021) find evidence in the case of Columbia that economic complexity impedes environmental quality.

Another strand of literature also suggests that the effect of economic complexity on the environmental depends on how the latter is measured and the level of economic development of countries being examined. For example, focusing on a sample of 88 developed and developing countries from 2002-2012, Boleti et al. (2021) uncover that economic complexity improves environmental performance index, it worsens particulate matter of diameter 2.5 microns, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions. Adedoyin et al. (2021) showed in a similar study that economic complexity harms environmental quality in low-income countries while improving environmental sustainability in upper-middle- and high-income countries. Martins et al. (2021) also confirmed that ECI degrades environmental quality in low- and middle-income countries, while Neagu and Teodoru (2019) used the FMOLS and DOLS techniques for a panel of 25 EU countries to show that, while economic complexity reduced GHG emissions for all the panels, EU countries with lower levels of ECI experience slower pollution reduction than EU countries with higher ECI.

2.3 Theoretical relationship between energy consumption and IGG

The theoretical link between energy consumption and IGG is anchored in the energy-growth theory, an extension of Solow's (1956) neoclassical growth theory. The energy-growth theory postulates that energy consumption can foster shared growth by improving technical efficiency (Solow, 1997; Stiglitz, 1998; Brown & Wolk, 2000). Furthermore, the theoretical link between energy and economic development can be assessed from the perspectives of four notable hypotheses, namely, (1) the growth hypothesis, which contends that energy consumption causes economic growth; (2) the conservation hypothesis, which contends that economic growth drives energy consumption; (3) the feedback hypothesis, which contends that energy consumption and economic growth are interdependent; and (4) the neutrality hypothesis, which contends that energy consumption and economic growth are neutral (see Payne, 2009). Indeed, the role of energy in accelerating sustainable development outcomes cannot be overstated, as it drives innovation, productivity, and economic growth (IEA, 2020). Furthermore, improved energy access is critical for reducing poverty and multidimensional inequalities. This position stems from the argument that increased private sector productivity and job creation can influence income distribution (IRENA, 2018).

From the environmental sustainability angle, the environmental Kuznet curve (EKC) hypothesis also suggests that energy consumption initially increases with income, causing pollution to rise. However, in later stages of economic development, the increase in income can promote environmental quality (Grossman & Krueger, 1991). The EKC hypothesis, by extension, divides the impact of economic expansion on environmental pollution into three distinct effects: (i) scale effect, (ii) composition effect, and (iii) technique effect (Copeland & Taylor, 2004). According to the scale effect, a growing economy requires more energy, which can raise emission levels, whereas the composition effect reflects a shift in energy share as a result of changes in production/industrial structures (Keho, 2016). Lastly, the technique effect occurs when new, advanced technologies are introduced into manufacturing, resulting in a reduction in energy intensity (Copeland & Taylor, 2004).

Given these theoretical and empirical arguments regarding the effects of ECI on both SES and EVS, we contend that energy consumption could play a significant role in conditioning ECI to promote IGG. Accordingly, we formulate the second and third hypothesis as follows:

Hypothesis 2: Energy consumption enhances inclusive green growth.

Hypothesis 3: Energy consumption moderates economic complexity to enhance inclusive green growth.

2.4 Empirical literature on energy consumption and sustainable development

On the empirical front, a growing body of literature on the SES effects of energy consumption has produced conflicting findings. For instance, Shahbaz et al. (2018) find evidence in the top ten energy-consuming countries that energy consumption enhances economic growth. Similarly, Rahman and Velayutham's (2020) study reveals a positive effect of renewable and non-renewable energy consumption on economic growth in five South Asian countries for the period1990- 2014. Salahuddin and Gow (2014) also examine the relationship between economic growth, energy consumption, and CO_2 emissions in the Gulf Cooperation Council (GCC) countries from 1980-2012. The authors confirm a unidirectional causal link between economic growth and energy consumption. Similarly, Inglesi-Lotz (2016) find that high levels of renewable energy consumption promote economic development in 34 OECD countries between 1990-2010.

Also, regarding the effect of energy consumption on the environment, Alola et al. (2019), for example, apply the pool mean group autoregressive distributed lag estimator to a panel of 16 EU countries to show that renewable energy reduces environmental degradation, while non-renewable energy hampers it. Khan et al. (2022) add to the discourse by revealing that renewable energy reduces ecological footprint in G-7 economies. In a corroborative study by Balsalobre-Lorente et al. (2018), the authors find that renewable electricity consumption enhances environmental quality in five EU countries (Germany, France, Italy, Spain, and the United Kingdom) from 1985-2016. Likewise, Bilgili et al. (2016) utilised the dynamic least squares estimator to show that renewable energy consumption mitigates CO_2 emissions in 17 OECD countries within the period 1977-2010

However, several studies also contend that renewable energy consumption can degrade the environment. For instance, Al-Mulali et al. (2016) used the dynamic ordinary least squares to indicate that renewable energy consumption reduce pollution in the

Americas, Central and Eastern Europe, Western Europe, East Asia, South Asia, and the Pacific regions. This effect, however, is not significant in the Middle East region. Also, Zoundi (2017) report that renewable energy consumption has a negative impact on CO_2 emissions in 25 African countries.

2.5. Analytical framework

In this section, we introduce an analytical framework to situate the relationship between economic complexity and energy consumption in the context of IGG (see Figure 1). This analytical framework draws on the pioneering work of Ofori et al. (2022), which underscores the need to promote socioeconomic and environmental sustainability. Regarding environmental sustainability, our framework highlights the importance of (i) reducing air pollution and greenhouse gas emissions, (ii) preserving natural capital (achieved by conserving forest cover, arable land, aquatic life, and so on), (iii) improving environmental and resource productivity and (iv) putting in place mechanisms and structures to promote economic opportunities.

Out framework also emphasises the need to enhance socioeconomic sustainability by promoting (i) equitable income growth (achieved by promoting economic growth, reducing unemployment, and increasing income equality), and (ii) fairer access to social amenities such as potable water, sanitation, and healthcare while addressing issues of malnutrition.

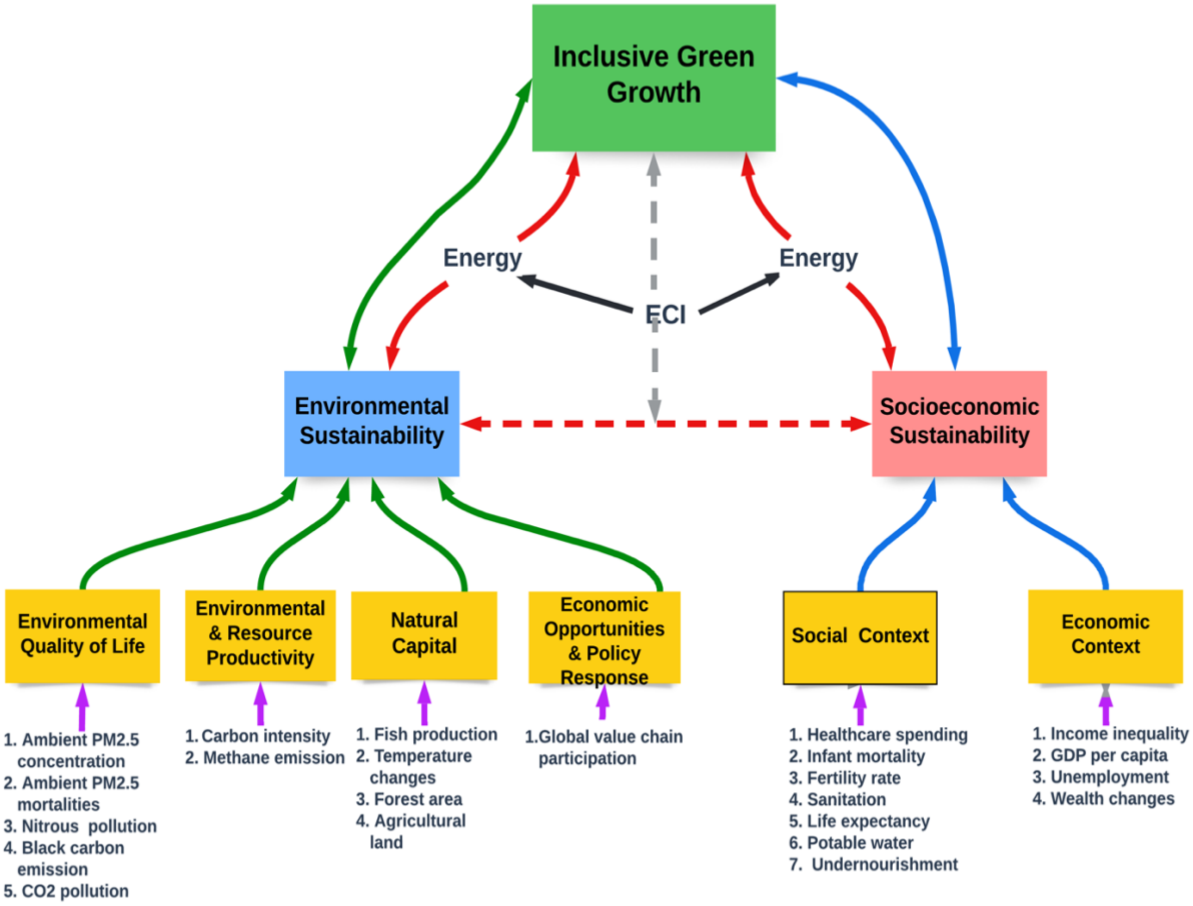

Figure 1: Analytical Framework for the Relationship between ECI, Energy, and IGG.
Source: Adapted from Ofori, Gbolonyo, and Ojong (2022)

Figure 1 also shows how ECI and energy consumption are inextricably linked to socioeconomic sustainability, environmental progress, and IGG in the broader context. Furthermore, the framework suggests that energy consumption can mediate the relationship between ECI and IGG. The graphical relationships between ECI and IGG on the one hand, and energy consumption and IGG on the other, as shown in Figure 2, are worth investigating. Figure 2 shows that while ECI and renewable energy have positive relationships with IGG, fossil fuel consumption has a negative relationship.

3. Methods and data

3.1 Data and justification for the inclusion of variables

For the analysis, the study examines a balanced macro-panel for 22 countries over the years 2008-2020. The dependent variable in this study is inclusive green growth (IGG), a multidimensional sustainable development indicator generated using principal component analysis (PCA). According to Ofori et al. (2023a, b) and Ofori et al. (2022), the IGG index is comprehensive because it captures drivers of both socioeconomic and environmental sustainability. Next, we disaggregate IGG into socioeconomic sustainability (proxied by the Palma ratio) and environmental sustainability (proxied by greenhouse emissions). The essence of this disaggregation is to inform policy about which dimension of IGG responds more to the ECI-energy consumption interaction. According to Ofori et al (2022), proxying environmental sustainability by greenhouse gas emissions is appropriate because it captures (i) ozone precursor gases (e.g., hydrofluorocarbons and nitrous oxides), (ii) acidifying gases (e.g., ammonia and sulphur oxides). Furthermore, using the Palma ratio to capture inclusive growth is appropriate because social progress can be achieved when the income of the poor grows faster than that of the rich (Ravallion & Chen (2003). Data on greenhouse gas emissions and Palma ratio are taken from the World Development Indicators [WDI] (World Bank, 2023) and the World Income Inequality Database (UNU-WIDER, 2022)

The main predictor variable in this study is economic complexity (ECI). It captures the accumulation of productive knowledge for diversity and ubiquity. The ECI series developed by Hidalgo and Hausmann (2009) are accessed from the Observatory of Economic Complexity (OEC) database[1]. The moderating variable in this study is primary energy consumption, which we further decomposed into renewable and non-renewable energy consumption. This disaggregation is critical as it enables us to inform policy whether it is socially and environmentally viable to invest in Africa's renewable energy production. Data on all the energy variables are taken from the WDI (World Bank, 2023).

The study also controls for some variables in line with the scientific standards for robust multiple regression analysis. We do this to mitigate possible omitted variable bias and to account for the role of institutions, capital flows, resource allocation, and digital infrastructures in sustainable development. Specifically, we control for ICT diffusion, foreign direct investment (FDI), government effectiveness, and financial development. First, our attention to ICT diffusion is informed by the growing scholarly evidence that digital infrastructure can accelerate carbon intensity, and by extension, poor environmental quality of life in societies where consumption of fossil fuels is high (Shafiei & Salim, 2014). Also, some scholars have found that due to differential access and skill premiums, ICT diffusion can deepen inequalities in healthcare, job opportunities, and quality education, especially in

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[1] See the Observatory of Economic Complexity; https://oec.world

developing countries (Richmond & Triplett, 2018; Bauer, 2018). Nonetheless, some studies also report a favourable effect of ICT diffusion on social inclusion, wider markets, and low energy intensity (Tchamyou et al., 2019).

Second, the study pays attention to government effectiveness, in line with the argument by Fay (2012) that proactive governance in charting the course for sustainable production and consumption practices can deliver IGG. For example, the role of government in smart mobility (e.g., urban transport, railway development), access to social amenities (e.g., quality healthcare, potable water, sanitation), eco-innovation, and research and development can be instrumental for IGG. Similarly, in societies with poor governance quality, (i) growth may not be shared, (ii) access to social overheads may be polarised, and (iii) economic agents may not commit to environmental standards, hurting IGG in the process (Bokpin, 2017).

Also, our attention to FDI is because it has been identified as a vehicle for economic growth, job creation, poverty alleviation, and income inequality reduction (Xu et al., 2021; Opoku et al., 2019). Also, concerning the environment, several studies document that FDI facilitates access to green technologies (e.g., for carbon abatement and energy conservation) and the spread of sustainable production practices (Immurana, 2021). Contrariwise, some studies also report that FDI accelerates macroeconomic instability and capital flight as well as the emission of greenhouse gasses and air pollutants (Ndikumana & Sarr, 2019; Shahbaz et al., 2018).

Finally, the relevance of financial development for IGG is anchored in the extensive margin theory and the supply-leading hypothesis. These theories suggest that an efficient financial sector innovates to provide financial products and services essential for investment, private sector performance, economic growth, and poverty alleviation (De Haan et al., 2021). Particularly on environmental sustainability, although some studies find that financial development supports green innovation and the diffusion of eco-friendly technologies, dark sides in the form of income inequality, air pollution, and greenhouse gas emissions have also been reported (Jauch & Watzka, 2016). But for the data on financial development and ICT diffusion, which are taken from the International Monetary Fund's Financial Development Database (Svirydzenka, 2016) and the African Infrastructure Knowledge Program (African Development Bank [AfDB], 2018) respectively, all the control variables are taken from the WDI (World Bank, 2023). A summary of the description and sources of the variables is provided in Table 1.

Table 1: Variable description and data sources

Variables	**Symbol**	**Descriptions**	**Sources**
Dependent variable			
Inclusive green growth	*igg*	Multidimensional sustainable development scores generated using the PCA	Authors
Palma ratio	*palma*	The ratio of the share of income held by the richest 10% of the population to that of the poorest 40% of the population.	UNU-WIDER (2022)
Greenhouse gas emissions	*ghg*	Total greenhouse gas emissions (kilotons of CO_2 equivalent)	World Bank (2023)
Main independent variable			
Economic complexity	*eci*	Economic complexity index	OEC
Moderating variables			
Primary energy consumption	*priener*	Total primary energy supply (in million tonnes of oil equivalent)	World Bank (2023)
Renewable energy consumption	*rener*	Renewable energy consumption (% of total final energy consumption)	World Bank (2023)
Non-renewable consumption	*nonrew*	Fossil fuel energy consumption (% of total)	World Bank (2023)
Hydroelectricity consumption	*elechyd*	Electricity production from hydroelectric sources (% of total)	World Bank (2023)
OGC electricity consumption	*elecogc*	Electricity production from oil, gas, and coal sources (% of total)	World Bank (2023)
Control variables			
Foreign direct investment	*fdi*	Net inflow of foreign direct investment (% GDP)	World Bank (2023)
ICT diffusion	*ictdif*	A Composite index in construction, extension, improvement, operation, and maintenance of communication systems (postal, telephone, wireless, and satellite communication systems).	AfDB (2018)
Government effectiveness	*govef*	Captures perceptions of the quality of public services, degree of their independence from political pressures, quality of policy formulation and implementation, and credibility of government commitment to such policies.	World Bank (2023)
Financial development	*fdevt*	Financial development index	Svirydzenka (2016)

Note: OEC is Observatory of Economic Complexity; AfDB is African Development Bank

3.2 Model specifications and empirical strategy

Following Ofori et al. (2022), we specify a functional form, as apparent in Equation (1), in which inclusive green growth is driven chiefly by governance, energy consumption, economic complexity, and capital flows.

$$igg = f(energy, eci, govef, fdi, ictdif, fdevt), \tag{1}$$

where $\boldsymbol{igg}$ is inclusive green growth, $\boldsymbol{eci}$ is economic complexity index, $\boldsymbol{fdi}$ is foreign direct investment, $\boldsymbol{ictdif}$ is ICT diffusion index, $\boldsymbol{fdevt}$ is financial development index, and $\boldsymbol{ener}$ is an energy dynamics indicator comprising primary energy consumption ($\boldsymbol{priener}$), renewable energy ($\boldsymbol{rener}$), non-renewable energy ($\boldsymbol{nonrew}$), hydroelectricity ($\boldsymbol{elechyd}$), and electricity consumption from oil, gas and coal ($\boldsymbol{elecogc}$). Similarly, we specify the functional forms for socioeconomic and environmental sustainability as:

$$palma = f(energy, eci, govef, fdi, ictdif, fdevt) \tag{2}$$

$$ghg = f(energy, eci, govef, fdi, ictdif, fdevt) \tag{3}$$

where $\boldsymbol{palma}$ is the Palma ratio and $\boldsymbol{ghg}$ is greenhouse gas emissions, and all other symbols remain previously indicated. The next step then is to transform our theoretical specifications in Equations 1-3 into econometric models. We first specify baseline models for IGG, socioeconomic sustainability, and environmental sustainability, as shown in Equations 4, 5, and 6, respectively.

$$igg_{it} = \omega_0 + \beta_1 fdevt_{it} + \beta_2 ictdif_{it} + \beta_3 fdi_{it} + \beta_4 govef_{it} + \mu_i + \rho_t + \varepsilon_{it} \tag{4}$$

$$palma_{it} = \delta_0 + \varphi_1 fdevt_{it} + \varphi_2 ictdif_{it} + \varphi_3 fdi_{it} + \varphi_4 govef_{it} + \mu_i + \rho_t + \varepsilon_{it} \tag{5}$$

$$ghg_{it} = \alpha_0 + \gamma_1 fdevt_{it} + \gamma_2 ictdif_{it} + \gamma_3 fdi_{it} + \gamma_4 govef_{it} + \mu_i + \rho_t + \varepsilon_{it} \tag{6}$$

Next, to respond to Hypotheses 1 and 2, we modify Equations 4-6 by incorporating the direct effects of economic complexity and energy consumption. The resultant equations are specified respectively as:

$$igg_{it} = \omega_0 + \beta_1 fdevt_{it} + \beta_2 ictdif_{it} + \beta_3 fdi_{it} + \beta_4 govef_{it} + \beta_5 eci_{it} + \beta_6 ener_{it} + \mu_i + \rho_t + \varepsilon_{it} \tag{7}$$

$$palma_{it} = \delta_0 + \varphi_1 fdevt_{it} + \varphi_2 ictdif_{it} + \varphi_3 fdi_{it} + \varphi_4 govef_{it} + \varphi_5 eci_{it} + \varphi_6 ener_{it} + \mu_i + \rho_t + \varepsilon_{it} \quad (8)$$

$$ghg_{it} = \alpha_0 + \gamma_1 fdevt_{it} + \gamma_2 ictdif_{it} + \gamma_3 fdi_{it} + \gamma_4 govef_{it} + \gamma_5 eci_{it} + \gamma_6 ener_{it} + \mu_i + \rho_t + \varepsilon_{it} \quad (9)$$

Finally, in line with Hypothesis 3, we incorporate an interactive term for economic complexity and energy consumption in Equations 7- 9 as follows:

$$igg_{it} = \omega_0 + \beta_1 fdevt_{it} + \beta_2 ictdif_{it} + \beta_3 fdi_{it} + \beta_4 govef_{it} + \beta_5 eci_{it} + \beta_6 ener_{it} + \beta_7 (eci_{it} \times ener_{it}) + \mu_i + \epsilon_t + \varepsilon_{it} \quad (10)$$

$$palma_{it} = \delta_0 + \varphi_1 fdevt_{it} + \varphi_2 ictdif_{it} + \varphi_3 fdi_{it} + \varphi_4 govef_{it} + \varphi_5 eci_{it} + \varphi_6 ener_{it} + \varphi_7 (eci_{it} \times ener_{it}) + \mu_i + \epsilon_t + \varepsilon_{it} \quad (11)$$

$$ghg_{it} = \alpha_0 + \gamma_1 fdevt_{it} + \gamma_2 ictdif_{it} + \gamma_3 fdi_{it} + \gamma_4 govef_{it} + \gamma_5 eci_{it} + \gamma_6 ener_{it} + \gamma_7 (eci_{it} \times ener_{it}) + \mu_i + \epsilon_t + \varepsilon_{it} \quad (12)$$

The corresponding total effects from Equations 10-12 are specified respectively as:

$$\frac{\partial(igg_{it})}{\partial(eci_{it})} = \beta_5 + \beta_7 \overline{(ener_{it})}, \quad (13)$$

$$\frac{\partial(palma_{it})}{\partial(eci_{it})} = \varphi_5 + \varphi_7 \overline{(ener_{it})}, \quad (14)$$

$$\frac{\partial(ghg_{it})}{\partial(eci_{it})} = \gamma_5 + \gamma_7 \overline{(ener_{it})}, \quad (15)$$

where $\boldsymbol{eci}$ is economic complexity, $\boldsymbol{i}$ is country, $\boldsymbol{t}$ is time in years, and $(\boldsymbol{eci_{it}} \times \boldsymbol{ener_{it}})$ is the interaction term for economic complexity and energy consumption. All the variables enter the models at levels except greenhouse gas emissions (GHG), which is logged.

Before estimating the models, we first subject the dataset to some rigorous preliminary tests. Specifically, to ensure that our estimates are not spurious, we ascertain the stationarity properties of the variables. We do so by applying the Pesaran's (2007) cross-sectionally augmented Im-Pesaran-Shin unit root test (see the results in Table A.1). Second, the study assesses the presence or otherwise of autocorrelation and cross-sectional dependence in the dataset. The corresponding findings in Table A.2 indicates that autocorrelation and cross-sectional dependence should be accounted for in the estimation.[2] Accordingly, we apply the Blundell and Bond (1998) instrumental variable (IV) regression and the Discroll-Kraay (1998) pooled least square estimators for the analysis. The choice of these estimators over other standard panel estimation techniques such as the random effect and fixed effect, are discussed in the following. First, the Blundell and Bond IV estimator addresses endogeneity. In this study, endogeneity is apparent, for example, in Equation (10) because of the possible reverse causality between financial development and IGG on the one hand (Ofori et al., 2023a), and foreign direct investment and IGG on the other hand (Ofori et al., 2023b). Second, the number of sampled countries (N=22) is higher than the study period (T=13).

It is imperative to point out that this study follows the approach of Blundell and Bond (1998) by using the lag of the predictors as the instruments. This means that Equations 10-12 are estimated as a system in level and at the first difference. Several influential works, including that of Roodman (2009), confirm that the Blundell and Bond estimator produces efficient estimates. This is because the Blundell and Bond technique addresses instruments proliferation even in the presence of persistence. In line with the scientific procedure for assessing the reliability of estimates obtained from IV regression, we subject the results to post estimation tests. The study evaluates if the estimation satisfies the overidentification restriction requirement. In this assessment, the study employs the Hansen (1982) test of overidentification. This test is based on the null hypothesis of no correlation between the identified instruments and the residuals. Additionally, we test the significance of the economic complexity-energy consumption total effects by invoking the *'margins'* command in Stata. Moreover, we evaluate whether all the models are jointly significant. Further, we examine the sensitivity of the estimates by excluding the influence of South Africa in the sample. Finally, we examine the robustness of the estimates by applying the Driscoll-Kraay (1998) pooled least square estimator.

3.3 Computation of inclusive green growth index

In this section, we show how our main outcome variable, IGG, is generated. As illustrated in Figure 1, our IGG index is obtained by considering variables that matter for

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[2] The cross-sectional dependence tests are based on the Friedman (2007) and Frees (2004) cross-sectional dependence tests.

environmental and socioeconomic sustainability. First, regarding the socioeconomic sustainability dimension of IGG, we follow Ofori et al. (2022) and Acosta et al. (2020) by paying attention to variables that drive wealth creation and social inclusion. With this in mind, we collect data on income growth, income inequality, infant mortality, unemployment, undernourishment, healthcare expenditure, and access to potable water and sanitation. Concerning the environmental sustainability aspect of IGG, we focus on variables that are critical for environmental quality of life, environmental and resource productivity, natural capital, and economic opportunities and policy response.

Following the extant scholarship on environmental sustainability, we pay particular attention to air pollution, black carbon, carbon intensity, temperature changes, forest area, fish production, methane emissions, and global value chain participation (Ofori et al., 2022, OECD, 2017; Fay, 2012). Overall, we collected data on 23 variables for the computation. The definitions and summary statistics of these variables are reported in Table 2 and Table A.3, respectively. Cognisance of the dimensionality of these variables, the study employs the PCA for generating the IGG series. According to Jolliffe (2002), the PCA is a powerful technique that keeps the dimensionality of several correlated variables while addressing the problem of collinearity in order to obtain a smaller set of indices, known as principal components. In line with the standard procedure for PCA, we first investigate whether the 23 variables form an adequate sample. Second, we assess the correlation between the 23 variables and the overall sample by using the pairwise correlation and Bartlett tests, respectively.

The findings from these preliminary tests indicate that the PCA is appropriate for generating the IGG series. To begin with, the Kaiser-Meyer-Olkin test statistic of 0.771 suggests that the 23 variables form an adequate sample. Second, the evidence in Table A.4 shows that the correlation between the 23 variables is strong enough for PCA. This is reinforced by the Bartlett statistics of 12428.4, which is statistically significant at 1%. With the requirements met, we proceed to generate our IGG index. The IGG index is generated based on the first five components, since their attendant eigenvalues satisfied the Kaiser rule of at least 1. The resultant eigenvalues and eigenvectors for our IGG index are reported in Table A.5 and Table A.6, respectively. The scree plot for the principal components is also displayed in Figure A.1

Table 2: 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	WDI
Fertility rate	*fertility*	Fertility rate, total (births per woman)	WDI
Healthcare spending	*health*	Current health expenditure (% of GDP)	WDI
Potable water	*water*	Population with access to improved drinking water sources, % total population	WDI
Infant mortality	*infantmort*	Mortality rate, infant (per 1,000 live births)	WDI
Life expectancy	*lifeexp*	Life expectancy at birth, total (years)	WDI
Undernourishment	*undernourish*	Prevalence of undernourishment (% of population)	WDI
(ii) Economic context			
Changes in wealth	*weathchg*	Changes in wealth per capita (US$)	GGKP
Income growth	*gpc*	GDP per capita, PPP (constant 2017 international $)	WDI
Income inequality	*gini*	Gini index (0=Lowest; 1=Highest)	WIID
Unemployment	*unemp*	Unemployment, total (% of total labour force)	WDI
B. Environmental sustainability			
(i) Natural capital			
Fish production	*fish*	Total fisheries production (metric tons)	WDI
Agricultural land	*araland*	Arable land (% of land area)	WDI
Forest area	*forest*	Forest area (% of land area)	WDI
Temperature changes	*temp*	Annual surface temperature, change from 1951-1980	WDI
(ii) Environmental quality of life			
Air pollution	*pm25fossil*	Mean population exposure to PM2.5	OECD Statistics
Ozone mortalities	*ozonemort*	Mortality from exposure to ozone	OECD Statistics
Nitrous emission	*n2ofossil*	Nitrous emissions from fossil sources	EDGAR
Black carbon emission	*bcfossil*	Black carbon emissions from fossil sources	EDGAR
CO_2 pollution	*Co2fossil*	Carbon emissions from fossil sources	EDGAR
(ii) Environmental & resource productivity			
Methane emission	*methane*	Methane emissions (kt of CO_2 equivalent)	WDI
Carbon intensity	*co2fossil*	CO_2 emissions (metric tons per capita)	WDI
(iv) Economic opportunities & policy response			
Global value chain	*gvc*	Gross value added at basic prices (GVA) (constant 2015 US$)	WDI

Note: WDI is World Development Indicators; GGKP is Green Growth Knowledge Program; WIID is World Income Inequality Database; and EDGAR is Emissions Database for Global Atmospheric Research
Source: Authors' construct, 2023

4. Results and discussion

4.1 Summary statistics

Table 3 presents the summary statistics of the variables. The data show a mean greenhouse gas emissions value of 77235.6 Kilotons. Similarly, the mean of socioeconomic sustainability, which we proxy by the Palma ratio, is 4.69, suggesting that the proportion of income held by the top 10% is at least four times higher than that of the bottom 40%.

Also, the mean of financial development (0.19) shows that Africa's financial system is in its nascent stages of development. Also, we report average values of -0.5 and 4.15% for government effectiveness and foreign direct investment, respectively. The former indicates glaring weaknesses in Africa's institutional framework, whereas the latter shows that the inflow of external finance to Africa has been significant over the past two decades. For our main independent variable, economic complexity (ECI), we observe a mean value of -0.8. This indicates that the African countries sampled have a narrow productive capacity/knowledge base. According to Hartmann et al. (2017), this low value means that African countries produce less sophisticated products.

Table 3: Summary statistics, 2008-2020

Variables	Obs	Mean	Std. Dev.	Minimum	Maximum
Outcome variables					
Inclusive green growth	286	0.017	0.999	-1.091	2.736
Greenhouse gas emission	286	77235.62	108625.01	0.000	525050
Palma ratio	286	4.691	2.280	0.000	15.137
Main independent variable					
Economic complexity	286	-0.834	0.586	-2.748	0.513
Moderating variables					
Primary energy consumption	286	23.653	37.419	0.000	157.511
Renewable energy consumption	286	54.670	30.414	0.000	97.940
Hydroelectricity consumption	286	44.654	38.419	0.000	99.950
Fossil fuel consumption	286	39.734	29.687	0.000	99.978
OGC electricity consumption	286	49.864	37.864	0.000	100.000
Control variables					
Financial development	286	0.196	0.145	0.000	0.646
ICT diffusion	286	12.165	13.810	0.003	71.813
Foreign direct investment	286	4.155	6.709	-6.370	39.828
Government effectiveness	286	-0.500	0.605	-1.736	1.057

Note: Obs is observations; Std. Dev is Standard Deviation

Examining the data further, we find some interesting developments regarding ECI in the sampled countries. Indeed, with the exception of South Africa (0.2), we observe that the sampled countries have less sophisticated production base. Particularly, Figure 3 indicates that countries such as Gabon (-1.82), Nigeria (-1.64), Angola (-1.52), Cameroon (-1.35), and the Democratic Republic of Congo (-1.33) are the least diversified countries in Africa. Overall, the overview of the data suggests that African countries have not taken advantage of their huge natural resource deposits to diversify their productive capacities, nor have they significantly invested significantly in the technical capacities of their workforces.

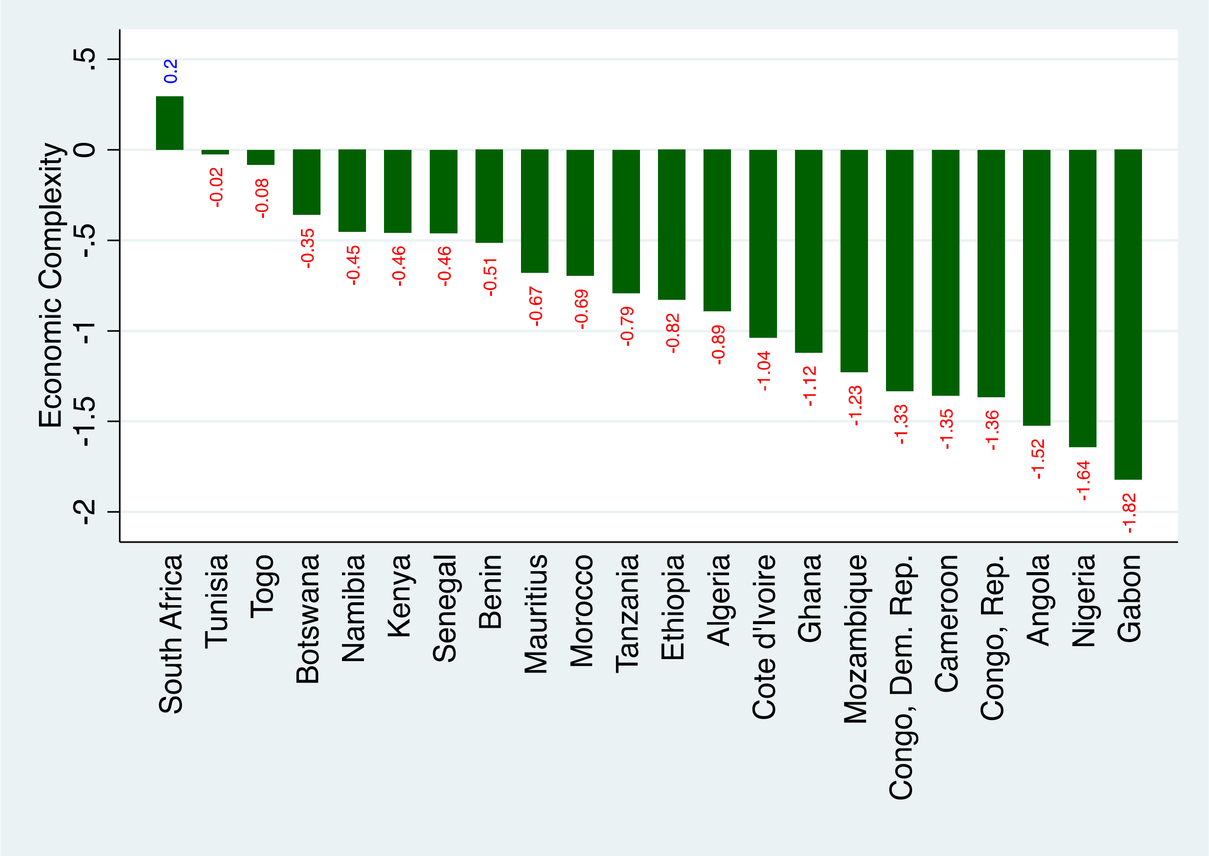

Figure 3: Economic Complexity in African Countries, 2008-2020
Source: Authors' construct, 2023

For our energy variables: primary energy consumption, renewable energy consumption, hydroelectricity consumption, and fossil fuel consumption, the data show average values of 23.6%, 54.6%, 44.6%, and 39.7%, respectively. Scrutinizing the data through graphical relationships, we observe that whereas renewable energy consumption and economic complexity are positively related to IGG, fossil fuel energy consumption shows a negative relationship with IGG.

4.2 IGG scores for African countries

This section presents the IGG scores for the sampled country. Specifically, we present evidence of whether or not each country's growth trajectory is both inclusive and green. It is worth stressing that a country's IGG score is determined by its progress across the two domains of IGG (i.e., socioeconomic and environmental sustainability). This implies that an overall positive IGG score indicates a case where a country is performing well with regard to both environmental and socioeconomic sustainability, or when a country's higher performance in social (environmental) sustainability outweighs possible lower performance in environmental (socioeconomic) sustainability. Another possible scenario is that although a country could be making great progress in environmental sustainability, weaknesses in income inequality and quality healthcare could be striking, resulting in an overall negative IGG score. However, a negative IGG score could also mean the reverse of the scenario above or that a country is performing poorly in both the social and environmental aspects of IGG.

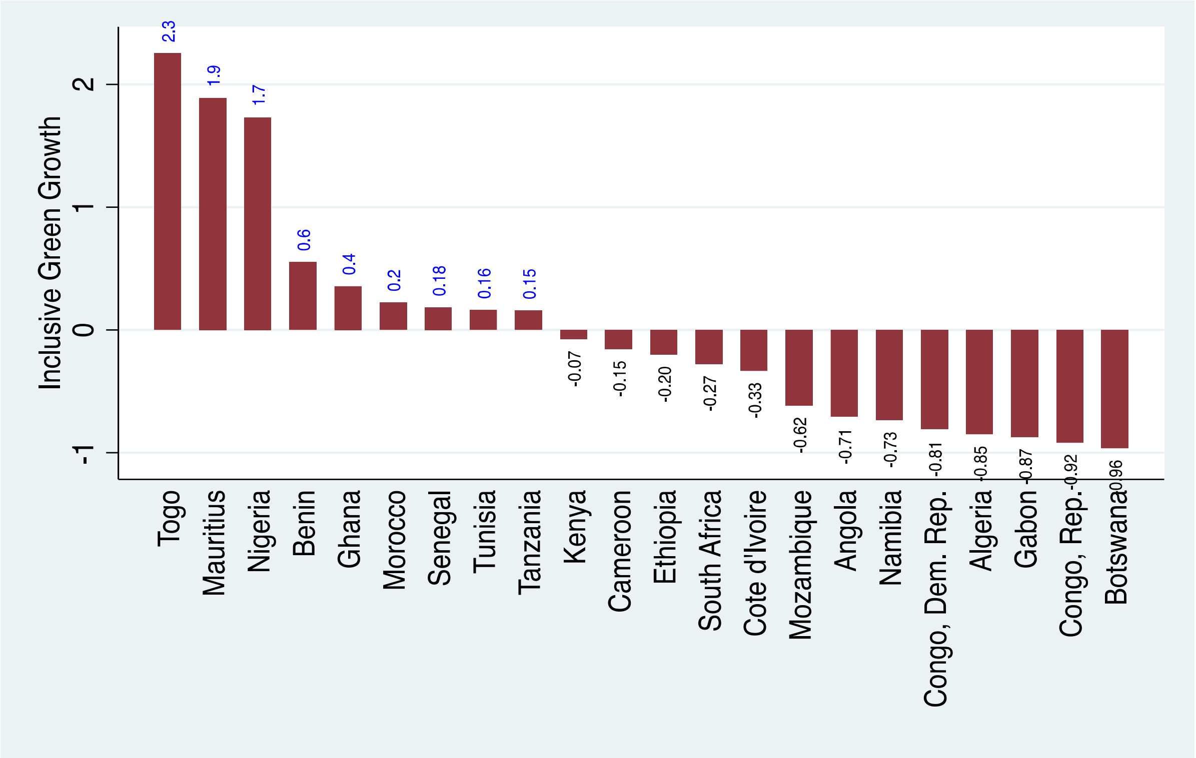

Figure 4: In-country Inclusive Green Growth in African Countries, 2008-2020

Figure 4 indicates that out of the 22 OECD countries considered, only 9 countries have a growth trajectory that is green and inclusive. These countries are Togo (2.3), Mauritius (1.9), Nigeria (1.7), Benin (0.6), Ghana (0.4), Morocco (0.2), Senegal (0.18), Tunisia (0.16), and Tanzania (0.15). With reference to the 2022 Climate Change Report and the 2021 Sustainable Development Report, it is quite clear that the performance of these countries stems from their commitment to social inclusion, social protection, and environmental quality following the inception of the Agenda 2030 and the Paris Agreement (IPCC, 2022; Sachs et al., 2021). For instance, these countries have stepped up the adoption of eco-friendly technologies for the reduction/abatement of CO_2 emissions. Also, these countries are pursuing smart solutions for mobility (e.g., railway development) and improved access to universal healthcare and education are enabling direct cash transfers to the vulnerable in society (e.g., the aged, disabled, etc.). Also, Figure 4 shows that in Africa, deficiencies in IGG are glaring in countries such as Botswana (-0.95), the Congo Republic (-0.92), Gabon (-0.87), Algeria (-0.85), Democratic Republic of Congo (-0.81), and Namibia (-0.73).

4.3 Effects of economic complexity and energy on inclusive green growth

Table 3 presents the results for the effect of economic complexity (ECI) and energy consumption on IGG. For Hypothesis 1, we find evidence that ECI is statistically significant in promoting IGG (Column 2). Specifically, the result indicates that a 1% increase in ECI enhances IGG by 0.36 points. From the SES perspective on IGG, ECI can drive shared prosperity by improving the standard of living of the masses through employment, poverty reduction, and access to a variety of goods and services. Additionally, ECI can build macroeconomic resilience through export diversification, foreign exchange, and entrepreneurship. Crucially, with the implementation of the African Continental Free Trade Area (AfCFTA), ECI can incentivize and sustain the inflow of external capital and increase domestic revenue. This can provide resource for the African governments to invest in IGG projects Concerning the EVS domain of IGG, ECI can also prove crucial for facilitating green innovation and the dissemination of eco-friendly technologies, which are keys for improving air quality and ecosystem preservation (Romero & Gramkow, 2021; Apergis et al., 2018). Also, in Africa, informality and the dependence on the immediate environment are high, ECI can promote IGG by diffusing environmentally sustainable production and consumption practices.

We now turn attention to Hypothesis 2, where we investigate the direct effects of our energy dynamics on IGG. First, the results in Column 3 show that a 1 % increase in primary energy consumption increases IGG by 0.02 points. Similarly, the evidence in Column 4 shows that renewable energy consumption enhances IGG by 0.029 points. Our evidence suggests that renewable energy offers Africa a cost-effective path to realising IGG. For instance, in the health sector, renewable energy solutions can support essential healthcare services such as vaccine storage and the use of modern diagnostic equipment, as well as the ability to conduct complex emergency procedures (e.g., during childbirths or surgery). In the agriculture sector, renewable energy can also help deliver IGG by improving wellbeing through food security. For example, cold storage facilities powered by renewable energy can minimize post-harvest losses, sustaining the incomes of farmers in the process (IEA, 2021). Stand-alone solar water pumps can also provide consistent irrigation for all year-round agriculture production in Africa, where according to the IPCC (2018), climate change is accelerating water stress.

Table 3: Effects of economic complexity and energy consumption on inclusive green growth (Dependent variable: IGG)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
IGG (-1)	0.9146***	0.8903***	0.8342***	0.5902***	0.8361***	0.8189***	0.8115***	0.7287***	0.4967***	0.7643***	0.7563***	0.7156***
	(0.0026)	(0.0099)	(0.0493)	(0.0464)	(0.0093)	(0.0051)	(0.0147)	(0.1104)	(0.1094)	(0.0518)	(0.0333)	(0.0590)
Financial development	0.1447	-0.2228	-3.1473***	0.2888	-0.0198	0.4625**	0.6758	-4.5697***	2.2743	-1.5727**	-0.6212	-1.3816*
	(0.0951)	(0.2475)	(0.3972)	(0.4908)	(0.4477)	(0.2114)	(0.4561)	(1.0954)	(2.1497)	(0.7024)	(1.1052)	(0.7521)
ICT diffusion	-0.0017**	-0.0014	-0.0073***	-0.0043	-0.0097***	-0.0084***	-0.0144***	-0.0077**	-0.0021	-0.0075	-0.0345***	-0.0147**
	(0.0008)	(0.0013)	(0.0017)	(0.0046)	(0.0030)	(0.0018)	(0.0027)	(0.0036)	(0.0085)	(0.0054)	(0.0106)	(0.0055)
Foreign direct investment	-0.0022	-0.0016	0.0137***	-0.0230***	-0.0300***	-0.0060**	-0.0289***	0.0228***	-0.0179	0.0083	-0.0080*	0.0131*
	(0.0015)	(0.0017)	(0.0032)	(0.0063)	(0.0065)	(0.0026)	(0.0056)	(0.0077)	(0.0111)	(0.0060)	(0.0046)	(0.0067)
Government effectiveness	-0.0050	-0.1443***	0.5614***	0.9347***	0.3892***	0.2266***	0.2712**	0.4606***	-0.0752	-0.0885	-0.9314***	-0.2449***
	(0.0127)	(0.0473)	(0.0518)	(0.1560)	(0.1126)	(0.0647)	(0.0989)	(0.1002)	(0.1463)	(0.0569)	(0.2633)	(0.0808)
Economic complexity (ECI)		**0.3570*** **						**0.6590*** **	**-3.5537** **	**-0.1123**	**4.0815*** **	**2.1333*** **
		(0.0966)						**(0.2296)**	**(1.3011)**	**(0.2243)**	**(0.6923)**	**(0.5055)**
Primary energy consumption			0.0181***					0.0156***				
			(0.0033)					(0.0054)				
Renewable energy consumption				0.0295***					0.0418***			
				(0.0022)					(0.0145)			
Hydro-electricity					0.0138***					0.0189***		
					(0.0014)					(0.0043)		
Fossil fuel						-0.0110***					-0.0306***	
						(0.0023)					(0.0055)	
OGC electricity							-0.0142***					-0.0151***
							(0.0013)					(0.0050)
Primary energy × ECI								-0.0047*				
								(0.0024)				
Renewable energy × ECI									0.0588***			
									(0.0188)			
Hydro-electricity × ECI										0.0221***		
										(0.0044)		
Fossil fuel × ECI											-0.0523***	
											(0.0073)	
OGC electricity × ECI												-0.0191***
												(0.0044)
Total effect	na	na	na	na	na	na	na	**0.5486** **	**-0.3414**	**0.8733*** **	**2.0034*** **	**1.1788*** **
	na	na	na	na	na	na	na	**(0.1966)**	**(0.5157)**	**(0.2539)**	**(0.5320)**	**(0.3458)**
Constant	-0.0126	0.2810**	0.4471***	-1.0989***	-0.2829*	0.5731***	0.9181***	1.1002***	-2.4796*	0.3260	3.1715***	2.0813***
	(0.0148)	(0.1208)	(0.1073)	(0.1537)	(0.1466)	(0.1338)	(0.1921)	(0.2958)	(1.2522)	(0.2689)	(0.5466)	(0.6683)
Observations	286	286	286	286	286	286	286	286	286	286	286	286
Countries/instruments	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
Wald Statistic	277356***	183416***	741.3***	602.9***	12544***	474832***	24647***	13719***	57.65***	578.3***	4699***	727.4***
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
Hansen P-Value	0.327	0.391	0.417	0.276	0.420	0.110	0.399	0.325	0.690	0.279	0.309	0.346
AR(1)	0.002	0.002	0.005	0.003	0.001	0.002	0.001	0.008	0.052	0.002	0.001	0.002
AR(2)	0.622	0.281	0.165	0.698	0.938	0.175	0.937	0.796	0.185	0.458	0.199	0.217

Note: na is not applicable; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Crucially, with the green growth agenda of the continent in full force, clean energy consumption can also support sustainable mobility and mining.

Similarly, we report that hydroelectricity consumption has a positive and significant effect on IGG (Column 5). Although modest (0.013 points), the result suggests that investing in renewable energy can be a gamechanger for Africa in achieving IGG. For instance, hydroelectricity can improve the quality of life by providing access to lighting, refrigeration, and other essential amenities reliant on electricity. Moreover, hydropower can facilitate industrial activities such as manufacturing, processing, and mining, creating more job opportunities and bolstering economic growth. From an environmental sustainability angle, hydroelectricity, which emits only meagre amount of CO_2, can help Africa mitigate climate change. On the other hand, we find that fossil fuel impedes IGG by 0.01 points. This finding aligns with the empirical result of Sarkodie et al. (2020), which highlights the negative effects of fossil fuel-based energy sources, such as oil, gas, and coal on the environment. These sources accelerate greenhouse gas emissions, air and water pollution, soil depletion, and other environmental problems that pose significant risks to human health and the natural capital. Our results, therefore, provide strong empirical evidence for SDG 7.

We now turn attention to Hypothesis 3, where we examine the contingency effect energy consumption in the ECI-IGG relationship. Overall, the evidence suggests that whereas renewable energy sources condition ECI to promote IGG, non-renewable energy consumption shows otherwise. First, we report a total effect of 0.55 points for the ECI-primary energy consumption interaction term in Column 8. This is obtained by engaging the direct effect of ECI (0.830), the indirect effect of ECI (-0.013), and the mean value of primary energy consumption (23.652). Similarly, we calculate a marginal effect of -0.34 for the ECI-renewable energy consumption interaction in Column 9, which is not statistically significant. Following similar computations, we calculate total effects of 0.87 points, 2 points, and 1.17 points for the ECI-hydroelectricity interaction (Column 10), the ECI-fossil fuel consumption interaction term (Column 11) and the ECI-OGC electricity interaction term (Column 12), respectively. The interpretation of these marginal/total effects should be done with caution. Precisely, the contingency effects of these energy dynamics are appreciated by paying attention to the (i) signs of their interaction with ECI and (ii) conditional and unconditional effects of ECI in Columns 8-12. Concerning the results in Columns 9 and 10, we find that renewable energy (overall) mitigates (but not nullify) the harmful effect of ECI on IGG (-3.55 points) to yield -3.34 points. Crucially, in Column 10, we find that hydroelectricity (a component of renewable energy) nullifies the negative effect of ECI on IGG (-0.11 points) to yield a positive total effect (0.87 points). However, there is strong empirical evidence that fossil fuel and OGC electricity consumption reduce the positive effects of ECI on IGG from 4.08 point and 2.13 points to 2 points and 1.17 points in Columns 11 and 12, respectively. Here, we provide evidence in line with the United Nations' call to identify, where they exist, positive synergies among the SDGs to drive IGG. Our evidence suggests that clean energy moderates ECI to promote IGG.

For the control variables, the baseline results reveal some interesting findings. For instance, we find that FDI flows to Africa hamper IGG, confirming the evidence in Ofori et al. (2023c) and Bokpin (2017). Also, we find evidence irrespective of the type of model specification that ICT diffusion reduced IGG, a result which can be attributed to the glaring disparity in access to internet service across the rural and urban divide in Africa (Ofori & Asongu, 2021). It could also be as a result of the high greenhouse gas emission associated with internet access (Shafiei & Salim, 2014). Also, financial development appears to hinder IGG in Africa, although the effects are sensitive to model specification. This is possible considering the low level of financial sector access and efficiency in African (see Ofori et al., 2023c). Finally, governance effectiveness is largely positive and suggests that institutional quality is critical for delivering IGG (Ofori et al., 2022).

4.4. Effects of economic complexity and energy consumption on socioeconomic sustainability

Table 4 presents the results for the effects of ECI and energy consumption on socioeconomic sustainability, which we proxy by the Palma ratio. For Hypothesis 1, we examine the unconditional effects of ECI and energy consumption on SES. Albeit statistically insignificant, the coefficient of ECI (0.27), implies that for countries in their early stages of development, ECI may heighten income inequality. This finding aligns with the concept of the 'creative destruction process,' which suggests that enhanced economic complexity initially fosters the emergence of novel economic sectors, necessitating new capabilities while displacing traditional ones (Aghion & Howitt, 1992). Thus, economic complexity initially favours skilled workers who can secure improved salaries, while unskilled workers are at a greater disadvantage due to their difficulty in adapting to a more complex economy. This evidence corroborates that of Lee and Vu (2020).

In Column 3, we find that primary energy consumption appears to increase income distribution, although empirical evidence is elusive. We also show that primary energy consumption fuels income inequality in Africa. A plausible reason for this result is the high energy poverty in Africa (IEA, 2022). This can perpetuate poverty and income inequality as energy poverty deprives the masses from labour market participation and access to essential services potable water education, and healthcare. However, when we disaggregate primary energy consumption into renewable and non-renewable sources, we find evidence to show that renewable energy consumption promotes fairer income distribution by 0.01% (Column 4). Similarly, hydroelectricity reduces income inequality by 0.2% (Column 5). This result is consistent with the findings of Topcu and Tugcu, (2020), which indicate that renewable energy consumption reduces income inequality in developing countries. On the contrary, we find that energy consumption from fossil fuel (overall) and oil, gas and coal deepen income inequality in Africa by 0.02% (Column 6) and 0.02% (Column 7), respectively.

With all that said, we now focus to Hypothesis 3, where we examine the joint effects of ECI and energy consumption on the Palma ratio. First, we report a combined effect of -0.57 for the ECI-primary energy consumption interaction term in Column 8. We compute this total based on Equation 14 by taking into account the direct effect of ECI on income inequality (-0.619), the indirect effect of ECI on income inequality (0.0021), and the mean value of primary energy consumption (23.653).

Table 4: Effect of economic complexity and energy on socioeconomic in Africa (Dependent variable: Palma ratio)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Palma ratio (-1)	0.5481***	0.4797***	0.4600***	0.5864***	0.4500***	0.4933***	0.4196***	0.7156***	0.5269***	0.5840***	0.3988***	0.5095***
	(0.0175)	(0.0418)	(0.0351)	(0.0501)	(0.0179)	(0.0224)	(0.0162)	(0.0896)	(0.0666)	(0.0731)	(0.0484)	(0.0569)
Financial development	3.3598***	3.1331***	1.9382***	2.9796***	4.1527***	4.4367***	4.6977***	3.3402	2.5420**	6.7515***	2.8739*	5.1670***
	(0.7116)	(0.9049)	(0.5248)	(0.6410)	(1.0214)	(0.4426)	(0.6370)	(2.2641)	(1.1945)	(1.1691)	(1.4730)	(0.9394)
ICT diffusion	-0.0073**	-0.0146*	-0.0125***	-0.0119***	-0.0029	-0.0029	-0.0007	-0.0123*	-0.0109	0.0010	0.0010	0.0075
	(0.0026)	(0.0076)	(0.0031)	(0.0042)	(0.0056)	(0.0028)	(0.0050)	(0.0062)	(0.0097)	(0.0072)	(0.0071)	(0.0063)
Foreign direct investment	0.0319***	0.0345***	0.0519***	0.0304***	0.0846***	0.0332***	0.0760***	0.0146	0.0336***	0.0224	0.0436***	0.0294
	(0.0070)	(0.0083)	(0.0092)	(0.0077)	(0.0114)	(0.0073)	(0.0097)	(0.0227)	(0.0112)	(0.0336)	(0.0055)	(0.0180)
Government effectiveness	-0.3953***	-0.5078	-0.1215	-0.6774***	-1.0103***	-0.9215***	-0.9512***	-0.5421	-0.5288	-0.6400	-0.4158	-0.6335*
	(0.1299)	(0.6541)	(0.0943)	(0.2309)	(0.2313)	(0.1619)	(0.1993)	(1.0838)	(0.8272)	(0.4478)	(0.5951)	(0.3477)
Economic complexity (ECI)		**0.2671**						**-0.6190**	**0.1913**	**-1.1272**	**-1.3531***	**-2.7387*****
		(1.1515)						(1.0878)	(1.4407)	(0.8351)	(0.7056)	(0.6089)
Primary energy consumption			0.0098**					0.0049				
			(0.0042)					(0.0129)				
Renewable energy consumption				-0.0114					-0.0026			
				(0.0068)					(0.0062)			
Hydro-electricity					-0.0196***					-0.0398***		
					(0.0031)					(0.0046)		
Fossil fuel						0.0194***					0.0270***	
						(0.0024)					(0.0052)	
OGC electricity							0.0168***					0.0336***
							(0.0037)					(0.0043)
Primary energy × ECI								0.0021				
								(0.0167)				
Renewable energy × ECI									-0.0012			
									(0.0117)			
Hydro-electricity × ECI										-0.0278**		
										(0.0108)		
Fossil fuel × ECI											0.0280***	
											(0.0079)	
OGC electricity × ECI												0.0305***
												(0.0061)
Total effect	na	na	na	na	na	na	na	**-0.5693**	**0.1249**	**-2.3665*****	**-0.2419**	**-1.2191****
	na	na	na	na	na	na	na	**(1.3857)**	**(1.2525)**	**(0.6843)**	**(0.8125)**	**(0.4781)**
Constant	1.1687***	1.7182*	1.6556***	1.5846***	1.6346***	0.1107	-0.0497	0.0437	1.5818*	-0.1853	0.3742	-2.1999***
	(0.1823)	(0.8280)	(0.2436)	(0.2859)	(0.2584)	(0.1909)	(0.3323)	(0.9698)	(0.8724)	(0.8894)	(0.5930)	(0.7449)
Observations	286	286	286	286	286	286	286	286	286	286	286	286
Countries/instruments	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
Wald Statistic	123923***	1119***	1859***	11078***	2199***	185108***	6505***	900.3***	373.6***	17250***	1656***	1975***
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
Hansen P-Value	0.543	0.959	0.599	0.418	0.543	0.231	0.555	0.809	0.944	0.534	0.867	0.447
AR(1)	0.558	0.744	0.329	0.600	0.209	0.294	0.253	0.486	0.572	0.902	0.377	0.786
AR(2)	0.352	0.377	0.402	0.401	0.553	0.487	0.482	0.306	0.381	0.636	0.844	0.471

Note: na is not applicable; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0

Similar computations yield marginal effects of 0.124 and -2.36 for the ECI-renewable energy consumption and ECI-hydroelectricity interaction terms, respectively. The result for the latter is significant at 1%, suggesting that clean energy is effective for conditioning ECI to equalise incomes in Africa. These results mean that access to reliable, sustainable and affordable energy can promote higher productivity and incomes possibly through cost-savings, especially for women and youth in small-scale enterprises[3]. In addition, access to renewable energy can also help the private sector to integrate green technologies and/or highly productive machines in businesses to save cost and increase incomes (Kouton, 2021; AfDB, 2019). Interestingly, ECI-fossil fuel and ECI-OGC electricity interaction terms also yield marginal effects of -0.24 and -1.22, respectively, although only the latter is statistically significant.

For the control variables, we find that, financial development deepens income inequality. This result is consistent with the argument that in the early stages of economic development, financial development can exacerbate income inequality due to significant disparities in access to financial institutions (Ofori et al., 2022c). Further, we find strong evidence that FDI widens the income disparity gap of Africa by 0.03% (Column 1), confirming the dark sides of FDI in the form of wage dispersion and capital flight (Alvaredo et al., 2017; Ndikumana & Sarr, 2019). Also, we show that ICT diffusion promotes fairer income distribution by 0.007%. This is in line with empirical evidence that digital infrastructure promotes social progress via economic growth, access to knowledge and opportunities, cost-effective research, and improved healthcare (Ofori & Asongu, 2021).Finally, we find a negative and statistically significant effect of government effectiveness on income inequality (0.4%), suggesting that strong institutional quality in terms of prudent macroeconomic management, sound policies, and productive investments is key to shared prosperity.

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[3] For example, firms selling, installing, and maintaining renewable energy-related items.

4.5 Effects of economic complexity and energy consumption on environmental sustainability

Table 5 reports the results for the effects of economic complexity and energy consumption on environmental sustainability (i.e., greenhouse gas emissions [GHG]). For Hypothesis 1, the study reveals that ECI increases, albeit statistically insignificant (Column 2). Concerning Hypothesis 2, the results in Column 3 suggest that primary energy consumption increases greenhouse gas emissions. Specifically, a 1% increase in primary energy consumption increases GHG emissions by 0.013%. This concurs with the argument by Khan et al. (2022) that the energy requirements of sophisticated economies may hinder environmental progress. Further, with the exception of renewable energy consumption, we find that all the energy dynamics, namely, hydroelectric power, fossil fuel energy, and OGC electricity consumption directly do not have significant effects on greenhouse gas emissions. In particular, our result shows that an improvement in renewable energy consumption by 1% decreases greenhouse gas emissions by 0.004% (Column 4). For the Hypothesis 3, the findings in Columns 8-12 reveal that energy consumption does not condition ECI to promote environmental sustainability. Additionally, their corresponding total effects statistically significant at any of the conventional levels.

As evident in Column 1, our auxiliary variables show some interesting findings. Firstly, we find a positive and statistically significant relationship between financial development and greenhouse gas emissions. This implies that financial development impedes environmental progress, possibly through the materialisation effect (Zhang, 2011). Secondly, we show that every 1% improvement in ICT diffusion reduces greenhouse gas emissions by 0.005%. This finding is consistent with evidence by Asongu and Odhimabo (2019) and Higón et al. (2017) that ICT diffusion has the potential to decrease CO_2 emissions from both households and firms. Thirdly, our evidence demonstrates that FDI leads to an increase in greenhouse gas emissions, confirming the pollution haven hypothesis. Precisely, a 1% rise in capital flows to Africa corresponds to a 0.032% increase in greenhouse gas emissions. This finding aligns with that of Opoku and Boachie (2020).

Table 5: Effects of economic complexity and energy on environmental sustainability (Dependent variable: GHG)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
GHG (-1)	0.8785***	1.1352***	0.7292***	0.8371***	0.8435***	0.7581***	0.8725***	1.1515**	1.0067***	0.9296***	0.9109***	0.9436***
	(0.0097)	(0.1771)	(0.0712)	(0.0204)	(0.0133)	(0.0468)	(0.0104)	(0.4162)	(0.2183)	(0.2457)	(0.1929)	(0.2784)
Financial development	0.2424*	-3.4269**	-1.5194***	0.1562	0.4949***	0.6007	0.2872**	-4.9815	-4.8783	-2.0257	-2.5812	-2.2543
	(0.1366)	(1.6346)	(0.5143)	(0.2100)	(0.1410)	(0.5822)	(0.1378)	(3.2425)	(3.6189)	(2.4594)	(1.7075)	(2.3666)
ICT diffusion	-0.0057***	0.0021	-0.0089***	-0.0067***	-0.0073***	-0.0093***	-0.0058***	-0.0013	0.0073	0.0077	0.0001	0.0054
	(0.0014)	(0.0067)	(0.0021)	(0.0011)	(0.0013)	(0.0030)	(0.0015)	(0.0100)	(0.0099)	(0.0106)	(0.0086)	(0.0123)
Foreign direct investment	0.0032**	0.0214*	0.0064	0.0035*	0.0019	-0.0029	0.0029	0.0103	0.0097	0.0017	0.0131	-0.0054
	(0.0014)	(0.0104)	(0.0051)	(0.0018)	(0.0031)	(0.0026)	(0.0017)	(0.0170)	(0.0196)	(0.0271)	(0.0093)	(0.0311)
Government effectiveness	0.1108***	0.1251	0.3603***	-0.0040	0.0897*	0.2164**	0.1043**	0.1328	-0.0044	-0.2197	0.5630	-0.0260
	(0.0308)	(0.7652)	(0.1169)	(0.0467)	(0.0481)	(0.0812)	(0.0395)	(1.2128)	(1.1149)	(0.9960)	(0.7411)	(0.7732)
Economic complexity (ECI)		1.4074						1.1137	2.8045	2.5083	1.3385	0.8620
		(1.0180)						(1.4541)	(2.8879)	(2.0912)	(1.2318)	(1.5853)
Primary energy consumption			0.0131***					0.0164				
			(0.0038)					(0.0319)				
Renewable energy consumption				-0.0048**					-0.0213			
				(0.0020)					(0.0345)			
Hydro-electricity					0.0009					-0.0084		
					(0.0006)					(0.0139)		
Fossil fuel						-0.0053					-0.0127	
						(0.0050)					(0.0137)	
OGC electricity							-0.0001					0.0011
							(0.0003)					(0.0111)
Primary energy × ECI								0.0252				
								(0.0301)				
Renewable energy × ECI									-0.0243			
									(0.0331)			
Hydro-electricity × ECI										-0.0155		
										(0.0233)		
Fossil fuel × ECI											-0.0082	
											(0.0206)	
OGC electricity × ECI												0.0097
												(0.0183)
Total effect	na	na	na	na	na	na	na	**1.7091**	**1.4782**	**1.8173**	**1.0124**	**1.3465**
	na	na	na	na	na	na	na	**(1.5852)**	**(1.5524)**	**(1.3274)**	**(1.0562)**	**(1.1141)**
Constant	1.3187***	0.4866	3.0979***	1.9733***	1.6022***	2.8969***	1.3783***	0.5522	3.1649	2.8168	3.0262	2.0923
	(0.0609)	(1.7760)	(0.7737)	(0.2526)	(0.1088)	(0.5173)	(0.0654)	(3.6379)	(2.8626)	(2.8403)	(2.3571)	(2.7625)
Observations	286	286	286	286	286	286	286	286	286	286	286	286
Countries/instruments	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
Wald Statistic	2.624e+06***	3073***	151827***	113088***	276800***	32891***	840742***	3048***	2241***	4540***	21144***	8010***
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
Hansen P-Value	0.430	0.936	0.638	0.262	0.272	0.673	0.348	0.953	0.909	0.937	0.938	0.937
AR(1)	0.075	0.038	0.035	0.080	0.081	0.078	0.077	0.045	0.044	0.072	0.054	0.075
AR(2)	0.893	0.874	0.626	0.868	0.895	0.797	0.889	0.578	0.634	0.921	0.915	0.490

Note: na is not applicable; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Fourthly, we find that government effectiveness hampers environmental sustainability in Africa by 0.11% (Column 1). This points to weak institutional and regulatory frameworks in Africa, buttressing the positive effect of FDI on greenhouse gas emissions.

Overall, our series of post estimation tests suggests that the results are reliable for policy considerations. First, the study passes the test for the validity of the overidentification restriction. Also, we have established the joint significance levels of all the interaction terms. Further, we have accounted for sensitivity in our results by excluding South Africa from the sample. Additionally, we show that all our models are empirical sound since all the Wald statistics are statistically significant at 1%. Finally, we assess the robustness of the estimates using the Driscoll-Kraay pooled least squares estimator. The results largely confirm our main findings in Tables A.7, A.8 and A.9 (see Supplementary File)

4.6 Sensitivity results: estimates without South Africa in the sample

We now turn attention to the effects of economic complexity and energy consumption on IGG, SES, and EVS, excluding the effect of South Africa in the sample. This is because Figure 3 suggests that South Africa can have a huge impact on the effect of ECI on IGG or its socioeconomic and environmental sustainability domains. Thus, the essence of this sensitivity analysis is to assess the effect of South Africa's high ECI score in our sample. The results become interesting when we compare the estimates of our sub-sample (i.e., without South Africa) in Table 6 to that of our full sample in Tables 3-5.[4] Our analysis reveals that ECI has a significant impact on IGG in Africa, regardless of whether South Africa (SA) is included in the sample or not. This implies that countries in Africa can promote IGG by focusing on developing their productive knowledge/capacities. However, it is worth noting that the magnitude of the effect of ECI on IGG, socioeconomic sustainability and environmental sustainability differs when SA is included in the sample compared to when it is excluded. Specifically, we find that when SA is included in the sample, the effect of ECI on all the three outcome variables is larger compared to when SA is not included.

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[4] For the full results, including estimates for the control variables, see Tables A.4-A.6 in the Supplementary File.

Table 6: Summary of results for the effects of economic complexity and energy consumption on IGG, SES, and EVS

Variables	**Inclusive green growth estimates (with SA)**	**Inclusive green growth estimates (without SA)**	**Remarks**
ECI	0.357***(0.0966)	0.3317*** (0.0975)	Effect without SA appears smaller than with SA
Primary energy	0.0181***(0.0033)	-0.0048** (0.0022)	Negative effect without SA compared to positive effect with SA
Renewable energy consumption	0.0295***(0.0022)	0.0328*** (0.0025)	Effect without SA appears larger than with SA
Hydroelectricity	0.0138*** (0.0014)	0.0168*** (0.0018)	Effect without SA appears bigger than with SA
Fossil fuel	-0.0110***(0.0023)	-0.0110*** (0.0025)	Effect without SA is the same as with SA
OGC electricity	-0.0142***(0.0013)	-0.0167*** (0.0015)	Effect without SA appears smaller than with SA
Total effects			
Primary energy × ECI	0.5486**(0.1966)	0.5850**(0.2045)	Effect without SA appears bigger than with SA
Renewable energy × ECI	-0.3414 (0.5157)	-0.4793 (0.3230)	Effect without SA appears smaller than with SA
Hydro-electricity × ECI	0.8733***(0.2539)	1.2777*** (0.2240)	Effect without SA appears bigger than with SA
Fossil fuel × ECI	2.0034*** (0.5320)	1.7369*** (0.5877)	Effect without SA appears smaller than with SA
OGC electricity × ECI	1.1788*** (0.3458)	1.6253*** (0.3630)	Effect without SA appears bigger than with SA
Variables	**Palma ratio estimates (with SA)**	**Palma ratio estimates (without SA)**	**Remarks**
ECI	0.2671 (1.1515)	0.2121 (0.3790)	Effect without SA appears smaller than with SA
Primary energy	0.0098**(0.0042)	-0.0268** (0.0104)	Negative effect without SA compared to positive effect with SA
Renewable energy consumption	-0.0114 (0.0068)	-0.0147*** (0.0050)	Effect without SA appears smaller than with SA
Hydro-electricity	-0.0196***(0.0031)	-0.0037 (0.0044)	Effect without SA appears bigger than with SA
Fossil fuel	0.0194*** (0.0024)	0.0057 (0.0044)	Effect without SA appears smaller than with SA
OGC electricity	0.0168***(0.0037)	0.0032 (0.0044)	Effect without SA appears smaller than with SA
Total effects			
Primary energy × ECI	-0.5693 (1.3857)	0.1391 (0.8905)	Positive effect without SA compared to negative effect with SA
Renewable energy × ECI	0.1249 (1.2525)	-0.1401 (0.3635)	Negative effect without SA compared to positive effect with SA
Hydro-electricity × ECI	-2.3665***(0.6843)	0.1698 (0.2708)	Positive effect without SA compared to negative effect with SA
Fossil fuel × ECI	-0.2419 (0.8125)	0.1740 (0.3559)	Positive effect without SA compared to negative effect with SA
OGC electricity × ECI	-1.2191** (0.4781)	0.3624 (0.2835)	Positive effect without SA compared to negative effect with SA
Variables	**Greenhouse gas emissions estimates (with SA)**	**Greenhouse gas emission estimates (without SA)**	**Remarks**
ECI	1.4074 (1.0180)	0.7515* (0.3705)	Effect without SA appears smaller than with SA
Primary energy	0.0131***(0.0038)	0.0204*** (0.0049)	Effect without SA appears bigger than with SA
Renewable energy consumption	-0.0048** (0.0020)	-0.0045 (0.0027)	Effect without SA appears bigger than with SA
Hydro-electricity	0.0009 (0.0006)	-0.0012 (0.0008)	Negative effect without SA compared to positive effect with SA
Fossil fuel	-0.0053 (0.0050)	-0.0029 (0.0058)	Effect without SA appears bigger than with SA
OGC electricity	-0.0001 (0.0003)	0.0010 (0.0006)	Positive effect without SA compared to negative effect with SA
Total effects			
Primary energy × ECI	1.7091 (1.5852)	0.1195 (1.0219)	Effect without SA appears smaller than with SA
Renewable energy × ECI	1.4782 (1.5524)	0.8187 ((1.4592)	Effect without SA appears smaller than with SA
Hydro-electricity × ECI	1.8173 (1.3274)	0.3308 (0.7001)	Effect without SA appears smaller than with SA
Fossil fuel × ECI	1.0124 (1.0562)	0.3721 (0.2446)	Effect without SA appears smaller than with SA
OGC electricity × ECI	1.3465 (1.1141)	0.2950 (0.4648)	Effect without SA appears smaller than with SA

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

The results can be attributed to the fact that South Africa boasts as one of the countries with a well-developed health, industrial, educational, and social inclusion systems which outperform those of its counterparts among SSA countries.

5. Conclusion and policy implications

This study contributes to the current discourse on sustainable development by providing evidence-based recommendation on how Africa can grow green and inclusive. Our contribution is based on three objectives. First, we investigate whether economic complexity and energy consumption unconditionally promote IGG in Africa. Furthermore, the study examines the moderating influence of energy consumption (disaggregated into renewable and non-renewable) on the relationship between economic complexity and IGG. The empirical analysis is based on macro data for a panel of 22 African countries from 2008-2020. Based on the instrumental variable regression and the Driscoll-Kraay pooled least squares estimator, the following findings are established. First, out of the 22 countries examined, only 9 demonstrate a growth trajectory that is both green and inclusive. Second, we find strong empirical evidence that both economic complexity and energy consumption are significant for promoting IGG in Africa. When we disaggregate the latter, we find that whereas renewable energy boosts IGG, non-renewable energy shows otherwise. Third, we find that the effect of ECI on IGG changes significantly when the moderating effects of renewable and non-renewable energy consumption are considered. Notably, while non-renewable energy dampens the IGG-inducing effect of ECI, renewable energy amplifies it. Fourth, regarding the two dimensions of IGG, our evidence shows that when compared to environmental sustainability, the ECI-energy consumption pathway is more important for socioeconomic progress. Finally, we find some interesting findings when South Africa is excluded from the sample. Precisely, we find that the conditional and unconditional effects of ECI on IGG reduce when South Africa is excluded from the sample. This highlights the influence of South Africa's economic complexity in the relationships examined.

Our findings have significant policy implications. To begin with, African countries should prioritise the development of complex economic systems that promote the production of diverse and ubiquitous eco-friendly products, while also taking methodical, consistent steps to manage risks posed by external shocks. This could be accomplished to some extent by putting more emphasis on innovation, knowledge, science, and entrepreneurship, as well as expanding sectors such as finance, tourism, agriculture, trade, the blue economy, and the creative arts. We also encourage African countries to form partnerships and alliances that promote environmental preservation and protection. Furthermore, the environmentally-degrading effect of ECI and energy consumption necessitates effective programmes that assist vulnerable households and small- and medium-sized businesses in the acquisition and utilisation of clean technologies. Furthermore, we urge African governments to increase investments in renewable energy production. This can be achieved if institutions like the European Union, African Development Bank, and World Bank assist African countries in harnessing the continent's renewable energy potential. Finally, we recommend that African economies undergo structural changes to shift further towards clean energy, stronger government fiscal discipline, the creation of more and better jobs, increased female labour-force participation, and more affordable modern energy services for households.

We acknowledge limitations of this study. For instance, we did not analyse economic complexity into trade, research or technology. We recommend that other researchers explore this perspective in their contribution to the IGG discourse. Additionally, we did not explore whether the ECI-energy consumption-IGG relationship differ across the five sub-regions of Africa. This is because of data constraint on economic complexity for most African countries. We suggest that future researchers revisit these relationships should data become available.

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APPENDICES

Table A.1: Preliminary test results

Test	Test Statistic	P-value	abs
Groupwise Wald test	86.98***	0.000	–
Friedman’s (2007) cross-sectional dependence test	73.228***	0.000	0.681
Frees' (2004) cross-sectional independence test	3.810***	0.000	0.681
Wooldridge’s (2002) test for autocorrelation	3713.988***	0.000	–

Note: The results are obtained from an *Equation*, with inclusive green growth as the outcome variable, and **abs** is the average absolute correlation of the residuals.

Table A.2: Unit root test results

Variable	Level	First difference	Stationary
Inclusive green growth	-0.525	-4.332***	Yes
Financial development	-2.218**	-3.970***	Yes
ICT diffusion	-1.670	-2.913***	Yes
Foreign direct investment	-2.482***	-5.416***	Yes
Government effectiveness	-2.104*	-4.821***	Yes
Economic complexity	-0.658	-3.558***	Yes
Primary energy consumption	-1.782	-3.044***	Yes
Hydroelectricity	-1.072	-3.508***	Yes
OGC electricity	-0.894	-3.346***	Yes
Fossil fuel	-0.675	-3.986***	Yes
Renewable energy consumption	-1.196	-4.240***	Yes

Note: Critical values at 10% (-2.07), 5% (-2.15), and 1% (-2.32)

Table A.3: Summary statistics of IGG variables

Variables	N	Mean	SD	Min	Max
unemp	286	9.266	7.454	.942	29.22
fish	286	281051.97	315214.74	0	1500000
undernourish	286	17.082	11.788	0	67.5
infant mort	286	44.62	19.384	12.5	88.1
methane	286	24724.161	28764.809	0	127900
lifeexp	286	63.125	6.92	49.913	77.063
Gvc	286	6.891e+10	1.043e+11	2.200e+09	5.000e+11
Gpc	286	6764.64	5178.046	835.612	22869.801
forest	286	31.56	23.021	.777	91.821
fertility	286	4.169	1.269	1.36	6.621
health	286	4.723	1.889	0	9.981
co2pc	286	1.403	1.749	0	8.569
araland	286	14.108	12.719	0	48.722
weathchg	286	-98.009	618.8	-2500.7	1867.6
sanit	286	43.49	26.755	5.331	97.435
water	286	71.011	17.524	30.895	99.867
temp	286	1.116	.404	-.499	2.291
Gini	286	53.622	9.064	0	72.877
co2fossil	286	40131.263	94800.619	0	485745
bcfossil	286	3.13	5.647	0	27.96
n2ofossil	286	21.868	28.369	0	121.829
pm25fossil	286	24.155	75.051	0	511.896
ozonemort	286	6.694	4.542	0	18.741

Table A.4: Correlation matrix for IGG variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
(1) unemp	1																						
(2) fish	0.0566	1																					
(3) undernourish	0.0025	-0.278***	1																				
(4) infantmort	-0.455***	-0.010	0.350***	1																			
(5) methane	-0.202***	0.358***	-0.0387	0.267***	1																		
(6) lifeexp	0.233***	0.008	-0.375***	-0.871***	-0.209***	1																	
(7) gvc	0.132*	0.509***	-0.261***	0.164**	0.626***	-0.162**	1																
(8) gpc	0.661***	-0.005	-0.307***	-0.607***	-0.186**	0.501***	0.117*	1															
(9) forest	0.0479	-0.112	0.345***	0.333***	-0.167**	-0.345***	-0.246***	-0.141*	1														
(10) fertility	-0.502***	-0.049	0.437***	0.880***	0.261***	-0.768***	0.0067	-0.762***	0.525***	1													
(11) health	0.338***	0.231***	-0.127*	-0.349***	-0.0240	0.161**	0.0824	0.290***	-0.488***	-0.462***	1												
(12) co2pc	0.553***	0.142*	-0.377***	-0.447***	-0.0452	0.300***	0.299***	0.626***	-0.202***	-0.561***	0.464***	1											
(13) araland	-0.370***	0.111	-0.332***	0.0228	0.139*	0.0007	0.163**	-0.0855	-0.229***	-0.0572	-0.0975	-0.138*	1										
(14) weathchg	-0.0229	0.047	-0.116*	-0.0482	-0.299***	0.0296	-0.0467	0.124*	-0.145*	-0.164**	0.194***	0.0431	0.120*	1									
(15) sanit	0.443***	0.190**	-0.465***	-0.663***	-0.140*	0.708***	0.206***	0.758***	-0.357***	-0.779***	0.332***	0.547***	-0.0417	0.218***	1								
(16) water	0.608***	0.107	-0.496***	-0.715***	-0.308***	0.622***	0.121*	0.802***	-0.334***	-0.834***	0.325***	0.562***	0.0332	0.249***	0.783***	1							
(17) temp	-0.0577	0.114	-0.263***	-0.337***	0.0400	0.487***	0.078	0.0715	-0.229***	-0.263***	-0.0512	0.0299	0.121*	-0.0488	0.293***	0.236***	1						
(18) gini	0.114	-0.112	0.417***	0.300***	-0.230***	-0.548***	-0.206***	-0.224***	0.254***	0.305***	0.165**	0.0428	-0.219***	0.0732	-0.451***	-0.275***	-0.313***	1					
(19) co2fossil	0.364***	0.381***	-0.353***	-0.173**	0.322***	0.0364	0.573***	0.284***	-0.245***	-0.277***	0.424***	0.813***	-0.0287	0.0127	0.327***	0.308***	0.0532	0.115	1				
(20) bcfossil	0.313***	0.396***	-0.391***	-0.252***	0.310***	0.162**	0.516***	0.275***	-0.296***	-0.325***	0.434***	0.793***	-0.0756	0.0239	0.378***	0.327***	0.113	0.0185	0.969***	1			
(21) n2ofossil	-0.129*	0.344***	-0.100	0.116	0.905***	-0.157**	0.559***	-0.150*	-0.266***	0.107	0.107	0.0971	0.137*	-0.309***	-0.131*	-0.254***	0.0552	-0.092	0.443***	0.418***	1		
(22) pm25fossil	0.304***	0.325***	-0.281***	-0.181**	0.183**	0.0279	0.396***	0.213***	-0.156**	-0.239***	0.399***	0.777***	-0.0537	0.0134	0.254***	0.259***	0.0543	0.233***	0.930***	0.901***	0.373***	1	
(23) ozonemort	0.310***	0.304***	-0.206***	-0.227***	-0.0143	0.302***	0.130*	0.140*	-0.391***	-0.294***	0.462***	0.241***	-0.158**	0.0800	0.322***	0.324***	0.100	-0.120*	0.217***	0.269***	-0.057	0.138*	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.5: Principal components and eigenvalues for IGG index

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	7.659	3.548	0.333	0.333
Comp2	4.110	1.351	0.179	0.512
Comp3	2.759	1.064	0.120	0.632
Comp4	1.695	0.473	0.074	0.705
Comp5	1.222	0.271	0.053	0.758
Comp6	0.951	0.043	0.041	0.800
Comp7	0.908	0.218	0.040	0.839
Comp8	0.690	0.110	0.030	0.869
Comp9	0.581	0.073	0.025	0.895
Comp10	0.508	0.131	0.022	0.917
Comp11	0.377	0.024	0.016	0.933
Comp12	0.353	0.044	0.015	0.948
Comp13	0.309	0.085	0.013	0.962
Comp14	0.223	0.045	0.010	0.972
Comp15	0.178	0.058	0.008	0.979
Comp16	0.120	0.004	0.005	0.984
Comp17	0.115	0.040	0.005	0.989
Comp18	0.075	0.025	0.003	0.993
Comp19	0.050	0.006	0.002	0.995
Comp20	0.044	0.008	0.002	0.997
Comp21	0.036	0.009	0.002	0.998
Comp22	0.027	0.017	0.001	1.000
Comp23	0.010	.	0.000	1.000

Table A.6: Eigenvectors for IGG variables

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9	Comp10	Comp11	Comp12	Comp13	Comp14	Comp15	Comp16	Comp17
unemp	0.227	-0.033	0.320	-0.131	0.210	0.200	0.043	-0.113	0.091	0.268	0.118	-0.307	-0.231	-0.601	-0.002	0.207	-0.099
fish	0.133	0.225	-0.102	0.164	0.122	0.021	0.599	-0.286	0.403	-0.298	0.019	0.088	-0.285	0.046	0.220	-0.160	0.090
undernourish	-0.239	0.041	0.211	0.051	0.260	0.012	-0.212	0.317	0.258	0.092	0.552	0.322	-0.321	0.062	-0.069	-0.054	0.223
infantmort	-0.266	0.236	0.053	0.015	-0.067	0.158	0.195	0.188	-0.279	0.117	-0.150	0.275	-0.046	-0.128	0.358	0.075	0.068
methane	0.009	0.359	-0.298	-0.058	0.241	0.215	-0.199	0.066	0.114	0.025	0.042	-0.114	0.277	0.013	0.104	0.155	0.206
lifeexp	0.228	-0.262	-0.222	-0.073	0.138	-0.238	-0.061	0.061	0.050	-0.236	0.246	-0.074	0.013	0.194	-0.195	0.020	0.051
gvc	0.148	0.326	-0.172	-0.080	0.037	0.300	0.203	0.139	0.009	0.366	-0.083	0.003	-0.170	0.275	-0.573	-0.122	-0.231
gpc	0.262	-0.149	0.134	-0.234	-0.002	0.347	-0.077	0.050	0.169	0.134	-0.022	0.263	0.242	0.118	0.299	-0.349	0.134
forest	-0.184	-0.017	0.215	-0.428	0.048	-0.031	0.380	-0.007	0.244	-0.142	0.181	0.028	0.546	-0.092	-0.226	0.120	-0.065
fertility	-0.311	0.199	0.011	-0.029	0.040	-0.045	0.167	0.085	-0.116	0.050	-0.061	0.085	0.188	0.023	-0.122	0.151	0.194
health	0.186	0.084	0.176	0.436	0.116	0.011	-0.225	-0.296	0.122	-0.069	-0.225	0.520	0.232	-0.201	-0.345	0.122	0.024
co2pc	0.293	0.106	0.221	-0.179	-0.125	-0.040	-0.063	0.072	-0.138	-0.053	0.064	0.151	0.107	-0.010	0.064	-0.437	-0.228
araland	0.011	0.004	-0.356	0.058	-0.584	0.102	0.028	-0.299	-0.001	0.226	0.535	0.190	0.069	-0.160	0.008	0.098	-0.037
weathchg	0.065	-0.071	0.044	0.540	-0.282	0.116	0.135	0.561	0.283	-0.028	0.005	-0.287	0.247	-0.163	-0.032	-0.115	0.025
sanit	0.296	-0.153	-0.068	-0.043	0.030	0.166	0.076	0.307	0.052	-0.121	-0.021	0.282	-0.054	0.189	0.208	0.623	-0.375
water	0.297	-0.200	0.033	-0.066	-0.084	0.126	0.097	-0.084	-0.005	0.244	-0.129	-0.088	0.014	0.190	-0.039	0.194	0.682
temp	0.112	-0.082	-0.308	-0.035	0.200	-0.592	0.137	0.160	0.180	0.527	-0.142	0.193	0.094	-0.206	0.134	-0.076	-0.045
gini	-0.077	0.126	0.452	0.166	-0.139	-0.220	-0.031	-0.209	0.232	0.351	0.026	-0.173	0.067	0.502	0.166	0.152	-0.178
co2fossil	0.244	0.321	0.111	-0.081	-0.139	-0.139	0.010	0.111	-0.116	-0.012	0.065	0.011	-0.018	-0.056	-0.041	0.026	0.047
bcfossil	0.262	0.285	0.064	-0.057	-0.074	-0.206	0.007	0.173	-0.153	-0.164	0.028	-0.022	-0.070	-0.070	-0.055	0.009	0.176
n2ofossil	0.058	0.382	-0.220	-0.031	0.134	0.044	-0.358	-0.098	0.248	-0.041	0.031	-0.220	0.169	-0.001	0.230	0.012	-0.118
pm25fossil	0.220	0.291	0.171	-0.070	-0.200	-0.293	-0.014	0.072	-0.046	-0.113	0.109	0.011	-0.024	-0.004	0.030	0.196	0.160
ozonemort	0.174	-0.012	0.038	0.363	0.433	0.038	0.239	-0.087	-0.514	0.102	0.394	-0.085	0.283	0.117	0.116	-0.048	-0.051

Variable	Comp19	Comp20	Comp21	Comp22	Comp23	Unexplained
unemp	0.077	0.230	-0.093	-0.025	0.038	0
fish	0.084	0.004	-0.063	-0.010	-0.026	0
undernourish	0.065	-0.138	0.059	0.064	0.014	0
infantmort	0.047	0.390	0.504	-0.102	0.044	0
methane	0.069	-0.102	-0.095	-0.544	-0.089	0
lifeexp	0.122	0.682	0.193	-0.070	-0.054	0
gvc	-0.079	0.075	0.061	-0.038	0.066	0
gpc	-0.390	0.254	-0.253	0.080	-0.034	0
forest	-0.074	-0.134	0.266	0.014	0.041	0
fertility	0.320	0.304	-0.615	0.330	0.042	0
health	0.006	0.084	0.094	-0.017	0.013	0
co2pc	0.661	-0.105	-0.005	-0.137	0.126	0
araland	0.006	0.026	-0.034	0.026	0.074	0
weathchg	0.047	0.046	0.011	0.002	-0.002	0
sanit	0.094	-0.127	-0.098	0.096	0.038	0
water	0.301	-0.180	0.228	0.132	0.056	0
temp	-0.008	-0.074	-0.007	-0.011	0.011	0
gini	-0.010	0.138	0.038	-0.078	0.052	0
co2fossil	-0.087	-0.058	0.091	0.292	-0.766	0
bcfossil	-0.332	-0.057	0.029	0.194	0.584	0
n2ofossil	0.120	0.060	0.214	0.491	0.137	0
pm25fossil	-0.128	0.087	-0.197	-0.382	0.013	0
ozonemort	-0.086	-0.091	-0.004	0.056	0.008	0

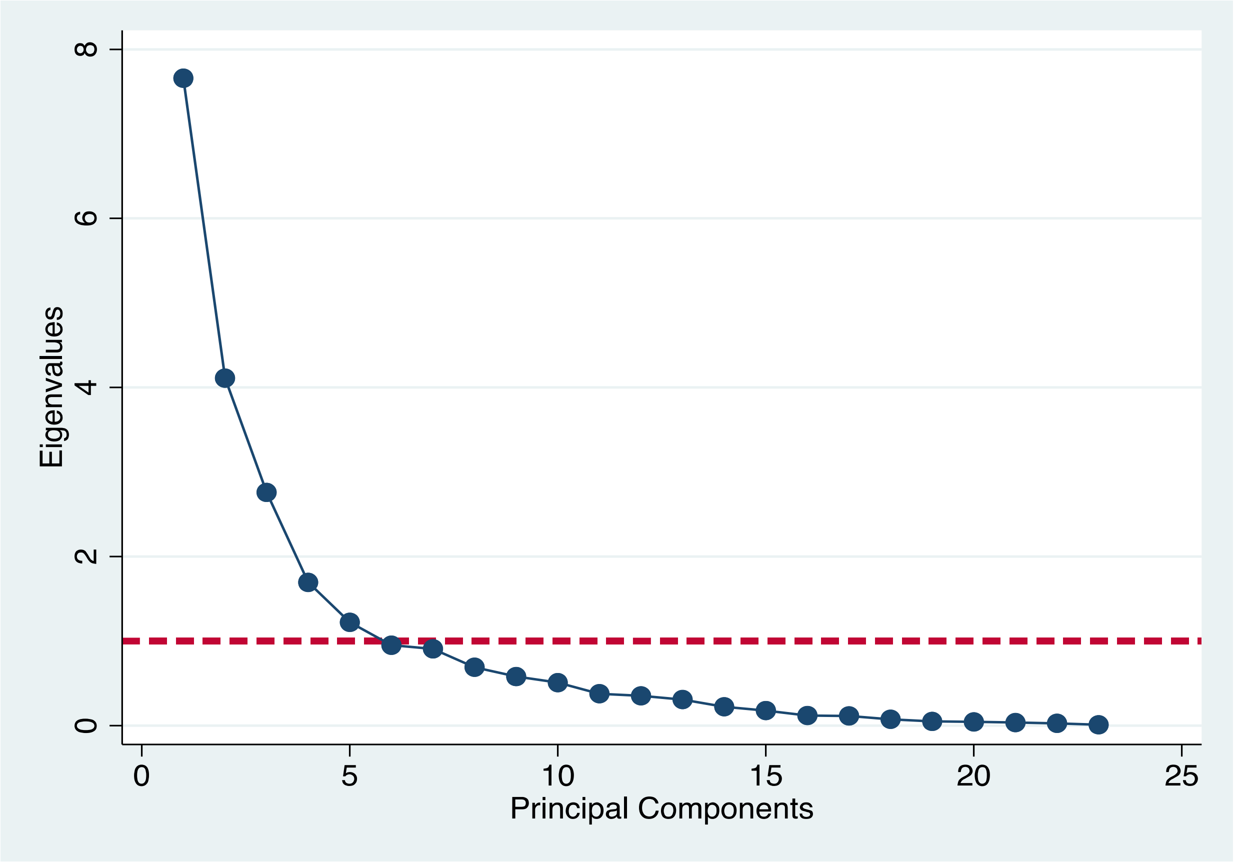

Figure A.1: Scree plot of principal components

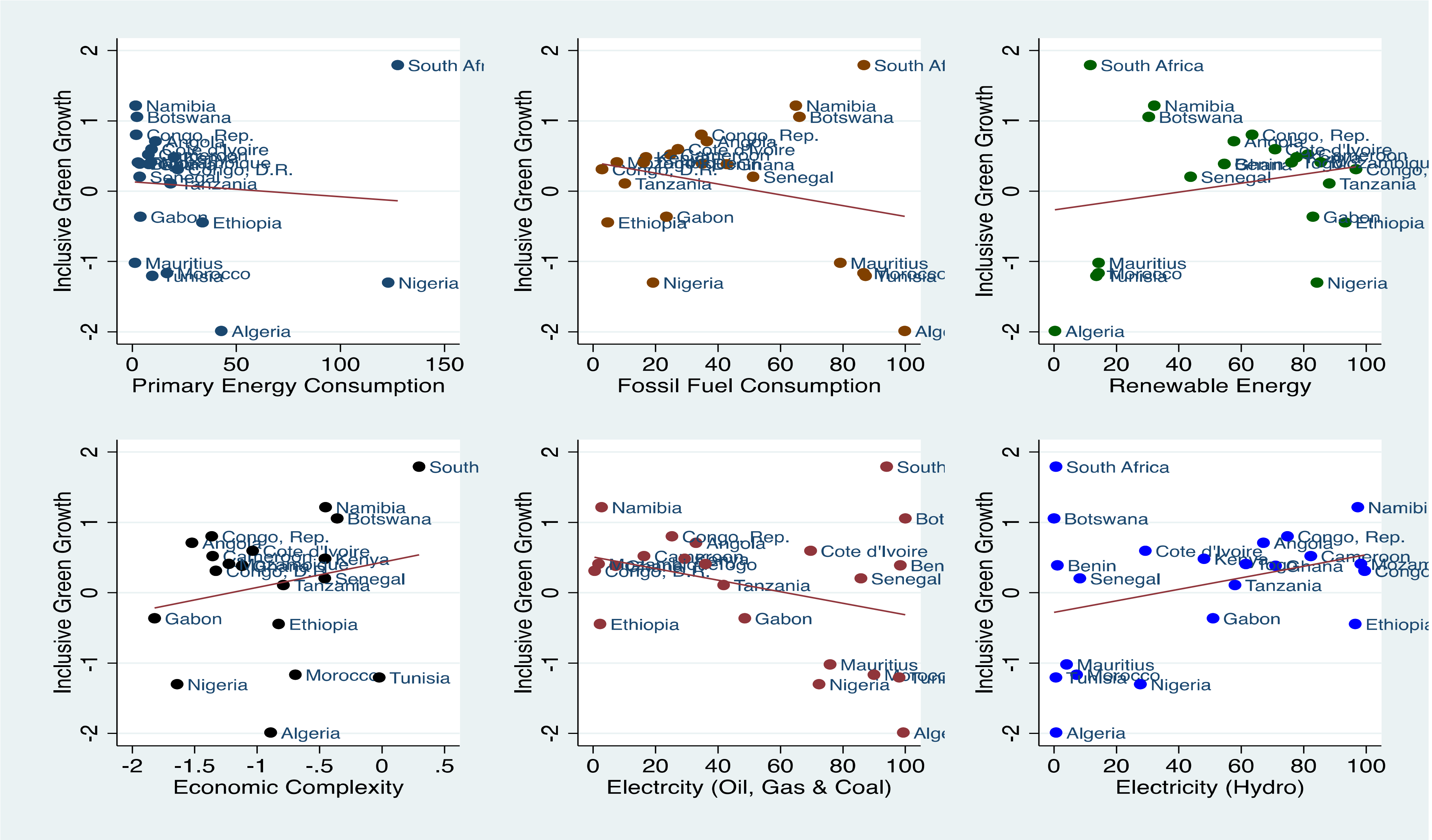

Figure 2: Relationship between ECI, Energy, and IGG in Africa
Source: Author's construct, 2023