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FDI, industrialisation and environmental quality in SSA—the role of institutional quality towards environmental sustainability

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In light of the quest to achieve economic development without compromising environmental quality, we empirically examine whether institutional quality (INSQY) can help moderate the possible harmful effects of foreign direct investments (FDI) and industrialisation on environmental quality in sub-Saharan Africa (SSA). We utilise the Driscoll and Kraay standard error estimation technique on a panel of 45 SSA countries from 2000 to 2019. The results indicate that FDI and industrialisation generally have a significant harmful effect on the environment. Our findings reveal that INSQY directly promotes environmental quality. Notably, the results confirm that INSQY plays a stimulating role in mitigating the adverse effects of FDI and industrialisation on environmental quality. The results further validate the environmental Kuznets curve (EKC) hypothesis in SSA. These findings contribute to environmental sustainability literature and offer policymakers insights on how INSQY can enhance environmental quality. Our empirical results are also robust to different estimation techniques, such as the two-stage least squares. We recommend SSA leaders strengthen institutional capacities, enforce environmental regulations, and implement strict policies to ensure environmental quality while promoting industrialisation and FDI inflows.

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Introduction

Climate change and global warming have become the most serious environmental topics over the past decades because of their possible adverse consequences, such as increasing food insecurity, rising health problems, climate-related disasters and transboundary conflicts, among other socio-economic consequences (Gorus and Aslan, 2019; Jian et al. 2023). It is generally understood that environmental degradation results from greenhouse gas (GHG) emissions, such as carbon dioxide (CO_2), which contribute to global warming (Amin et al. 2020; Amin and Dogan, 2021). The United Nations Framework Convention on Climate Change (UNFCCC) in 1992, later the Kyoto Protocol in 1997 and the Paris Contract in 2015, called on nations to pursue accelerated economic growth without compromising environmental quality (Leggett, 2020). Notwithstanding, a record temperature of 1.7 °C was recorded in 2020, heightening concerns about global warming (Magazzino, 2024). In Sub-Sahara Africa (SSA), available data reveal that CO_2 emissions, which account for approximately 82% of GHG emissions, are witnessing a significant upward trend, particularly in the post-liberalisation period, partly due to industrial emissions (Acheampong et al. 2019; Ashraf et al. 2021; Gorus and Aslan, 2019). For instance, the average CO_2 emissions in SSA increased from 801,760.00 kilotons in 2018 to 823,770.02 kilotons in 2019, representing 2.75% growth (World Bank, 2020). Furthermore, the evidence suggests that SSA suffer the most from the harmful effects of climate change (Atwoli et al. 2022).

Within the scope of achieving accelerated economic growth, there is abundant documentary evidence suggesting that industrialisation and Foreign Direct Investment (FDI) have the potential to positively impact economic growth, particularly for developing countries (Abdouli and Hammami, 2017a, 2017b; Iddrisu et al. 2023; Kang and Martinez-Vazquez, 2022; Ofori and Asongu, 2021a). According to Mahembe and Odhiambo (2014), FDI can stimulate the adoption of new technologies in the production process through technological spillovers and facilitate knowledge transfers in labour training, better organisational management practices and skills acquisition. Despite the numerous benefits of FDI, it could also potentially degrade the host country's environmental quality. The Pollution Haven Hypothesis (PHH) argues that firms seek to relocate carbon-intensive industries from countries with more strict environmental regulations to those with weaker regulations, thereby causing considerable environmental damage (Sarkodie and Adams, 2018; Sarkodie and Strezov, 2019; Kisswani and Zaitouni, 2023). On the other hand, the pollution halo hypothesis argues that FDI helps improve the environment because multinational corporations invest in green technologies in host countries (Seker et al. 2015; Sung et al. 2018; Ali et al. 2020). Similarly, both theoretical and empirical studies have revealed that industrialisation can potentially exert measurable influences on economic growth (Kaldor, 1975; Necmi, 1999). Following the lived experience of the economies of South Korea and China, as well as other experiences in the developed world, African leaders have placed industrialisation at the core of transformational economic growth in Africa (Gui-Diby and Renard, 2015; AfDB, 2017; Zamfir, 2016). This has culminated in the implementation of various policies by African governments, placing industrialisation at the centre of their growth agenda. For example, the New Partnership for Africa's Development (NEPAD), Africa's Agenda 2063 and the African Continental Free Trade Area (AfCFTA) are being implemented to help develop the industrial sector of the continent (Iddrisu et al. 2024; Opoku and Boachie, 2020; Ofori and Asongu, 2021b; UNCTAD, 2021). Nevertheless, increased energy consumption resulting from industrialisation can be a significant source of CO_2 emissions, leading to environmental degradation (Halicioglu, 2009; Munir and Ameer, 2020; Shahbaz et al. 2018; Udemba, 2019).

Also, the environmental Kuznets curve (EKC) hypothesis, pioneered by Grossman and Krueger (1991), suggests that poor or developing countries may end up degrading their environment during the initial stages of economic development until an income threshold is attained before environmental degradation begins to decline (Zakaria and Bibi, 2019; Udemba, 2021; Magazzino et al. 2023). The validity of the EKC means that most SSA countries seeking to attract more FDI inflows and industrialisation face the dilemma of degrading their environment. However, it has been emphasised by the United Nations (UN) Sustainable Development Goal (SDG) 13 on the need to foster sustainable development, that is, pursuing economic growth without compromising the environment and the ability of future generations to meet their own needs, in conformity with some empirical studies (see e.g., Makki and Somwaru, 2004; De Gregorio, 2005; Opoku et al. 2019; Ofori and Asongu, 2021b; Ofori et al. 2022; Duodu and Baidoo, 2022).

The relationship between economic growth, a potential consequence of FDI, industrialisation and the environment remains contentious. The Porter Hypothesis (PH) states that host countries with strict environmental regulations tend to protect the environment by compelling firms to invest in clean and efficient technologies (Porter and Van Der Linde, 1995). This implies that institutional quality (INSQY) is an important explicator in the FDI, industrialisation and environmental quality link (Azam et al. 2021; Barrett and Graddy, 2000; Neumayer, 2002). Therefore, institutions are seen as crucial to the effective execution of national policies that directly affect the management of the environment (Amin et al. 2022). By implication, countries with stringent environmental standards are likely to enhance environmental quality by mitigating the harmful effects of FDI on the environment (Shahbaz et al. 2018; Sabir et al. 2020; Dutt, 2009; Lau et al. 2014).

In light of the above, the need to analyse the potential moderating effect of institutional quality on the relationships between FDI, industrialisation, and environmental quality for the SSA region is compelling and pertinent. First, FDI inflows into SSA have increased substantially even since the coronavirus disease 2019 (COVID-19) pandemic. FDI inflows into SSA reached a record US$83 billion in 2021 from US$1.690 billion in 1990 (UNCTAD, UN, 2022; Iddrisu et al. 2024). Second, SSA economies appear to be expanding due to increased industrialisation. For instance, the absolute size of manufacturing value added, the share of manufacturing exports, and the size of manufacturing employment reveal that the region is enhancing industrialisation (Abreha et al. 2021). Further, the SSA region experienced a 148% increase in jobs in the manufacturing sector between 1990 and 2018 (Abreha et al. 2021). Third, despite the low institutional development in SSA, Oduola et al. (2022) strongly argued that an opportunity exists for the quality of governance in SSA to improve, stressing that most SSA countries are beginning to exhibit gradual improvements in quality. Since SSA suffers the most from the harmful effects of climate-related disasters, there is a need to examine whether the expected institutional improvements in SSA can help mitigate the possible detrimental impact of FDI and industrialisation on environmental quality.

The literature on the critical question of whether INSQY can help mitigate the negative impact of FDI and industrialisation on environmental quality in SSA is very difficult to find. Duodu et al. (2021) and Acheampong et al. (2019) investigated the effect of FDI on environmental quality in SSA, providing valuable insight into the understanding of the relationship between FDI and CO_2 at the macroeconomic level; however, these studies did not account for notable variables such as industrialisation, more importantly, they did not examine the moderating role of INSQY. Another recent study by Mentel et al. (2022) also investigated the effect of industrialisation on environmental quality, focusing on the mitigating role of renewable electricity, but ignored the role of INSQY.

Against this backdrop, this study distinguishes itself from previous studies and contributes to the literature in several ways: (1) We comprehensively examine the impact of FDI inflows and industrialisation on environmental quality in SSA. (2) We also examined the direct relationship between INSQY and environment quality. (3) More importantly, we contribute to the literature by testing whether INSQY can help mitigate the potentially harmful effects of FDI and industrialisation on the environment in SSA; in doing so, we construct a comprehensive index of INSQY by capturing all the six key individual governance indicators into one aggregate institutional index. (4) We also add to the literature by investigating the EKC hypothesis in relation to SSA. The primary objective of this investigation is to provide essential evidence, information, and a better understanding of policies that can help mitigate the adverse effects of FDI and industrialisation on the environment for key stakeholders.

We employ the Driscoll and Kraay (1998) standard errors estimation methodology, which caters for heteroskedasticity, providing substantially robust outcomes among the cross-sectional units (Hoechle, 2007; Shah et al. 2021). We also adopt the Two-Stage Least Squares (2SLS) estimator, which effectively manages endogeneity as a robustness check. We used data from a panel of 45 SSA countries from 2000 to 2019 and found some significant findings. First, we found that FDI and industrialisation significantly contribute to degrading the environment in SSA economies, which aligns with the PHH. The documented results also show that INSQY helps minimise the negative effects of FDI and industrialisation on the environment. Additionally, we find the presence of an EKC or inverted U-shaped relationship between economic growth and environmental quality in SSA. The results of this study can help policymakers in SSA and their development partners appreciate ways to mitigate the possible risk associated with current policies, such as Agenda 2063 and the AfCFTA, which aim to promote industrialisation and attract foreign capital such as FDI. For example, endogenous growth models pay limited attention to the government's role in economic growth. The results produced in this paper highlight a possible governmental policy for attracting FDI and promoting industrialisation to achieve accelerated economic growth in host economies without compromising environmental quality by strengthening INSQY. Our findings provide the opportunity for compelling policy implications, which we discuss in detail at the end of the study.

The rest of this paper is organised as follows. Section "Theoretical and empirical literature review" provides an overview of the theoretical and empirical literature. In Section "Data and methodology", we present the methodology. Section "Empirical results and discussion " discusses the results of the empirical investigations, and Section "Conclusion and policy implications" concludes with policy recommendations.

Theoretical and Empirical Literature Review

The theoretical linkage amongst FDI, industrialisation, INSQY and their potential impact on environmental quality are discussed within the context of three (3) prominent hypotheses: (i) the EKC hypothesis, (ii) the PHH and pollution halo hypothesis, and (iii) PH.

The EKC hypothesis, pioneered by Grossman and Krueger (1995), suggests a nonlinear (inverted U-shaped) relationship exists between economic growth and environmental pollution. That is, pollution rises during the initial stages of economic development until a threshold beyond which emissions begin to decline. However, Lorente and Álvarez-Herranz (2016) note that wealth alone cannot control pollution; hence, stricter enforcement of environmental regulations is required to help achieve a cleaner environment. From the empirical perspective, the relationship between economic growth and the environment, which tests for the validity of the ECK hypothesis, has generated mixed and sometimes controversial (Magazzino et al. 2023). These studies have adopted different variables, such as nitrous oxide, CO_2, methane, and total greenhouse gas emissions, for the environment. The main results from these studies either confirm or reject (Ben Jebli and Ben Youssef, 2015; Özokcu and Özdemir, 2017; Sapkota and Bastola, 2017) the ECK hypothesis; however, some studies have shown mixed or insignificant results. For example, Opoku and Boachie (2020) examined several economic variables such as FDI, industrialisation, and GDP and their effects on environmental degradation on a panel data set of 36 African economies from 1980–2014, and their results confirmed the EKC hypothesis.

Additionally, by applying an autoregressive distributed lag (ARDL) model to a panel of 55 countries from 1995 to 2020, Ahmed et al. (2022) showed evidence for the EKC hypothesis for the Asia-Pacific region. The results confirmed the presence of the EKC hypothesis for the selected countries. Similarly, Nguyen and Kakinaka (2019), who applied a panel cointegration analysis to 107 countries from 1990 to 2013, also found results that validated the EKC hypothesis. Similar results were obtained by some researchers using different proxies for environmental pollution (Apergis et al. 2017; Ben Amar, 2021; Fosten et al. 2012; Sapkota and Bastola, 2017; Sephton and Mann, 2016). In contrast, Sapkota and Bastola (2017), using time series analysis to examine data from 1980 to 2010 for 14 Latin American countries, concluded that the EKC hypothesis is invalid for 14 Latin American countries. Using the Driscoll-Kraay standard errors technique on 26 OECD countries, Özokcu and Özdemir (2017) also obtained results that did not support the EKC hypothesis. Ben Jebli and Ben Youssef (2015), using the ARDL bounds testing approach and the vector error correction model (VECM) estimation technique for Tunisia from 1980–2009, concluded that the EKC for Tunisia was not valid. On the other hand, Golpîra et al. (2023) examined the EKC hypothesis in OECD countries and found an N-shaped or cubic relationship between economic growth and the environment. The inconsistent conclusions may result from important country differences in the samples used for the study.

Other studies have shown mixed results on the relationship between economic growth and environmental degradation. For instance, Saidi and Hammami (2017) investigated the causal relationships among transportation, economic growth, and the environment of 75 countries during 2000–2014 using the GMM estimation technique, and they revealed a bidirectional relationship with economic growth. Ahmad et al. (2017) tested for the EKC in Croatia using quarterly data from 1992Q1 to 2011Q1 using the ARDL and VECM models. Their findings revealed bidirectional causality between CO_2 and economic growth in the short run. A related study by Neequaye and Oladi (2015)also showed evidence suggesting that economic growth increased CO_2 for 27 selected developing countries from 2002 to 2008 but had opposite results when nitrous oxide was used as a proxy for greenhouse gas. The literature reviewed implies that the relationship between economic growth and environmental degradation requires further study. Thus, we test the EKC hypothesis for completeness for a sample of 45 SSA economies to add to the literature of knowledge.

From the theoretical front, the PHH suggests that as countries open up their economies for trade and FDI inflows, high-polluting multinational corporations facing stringent environmental policies in developed regions may move their investments into countries with weak environmental regulations, thereby polluting the host economies' environments. Therefore, host economies become "pollution havens" (see e.g., Bommer, 1999; Eskeland and Harrison, 2003; Walter and Ugelow, 1979). Thus, a negative relationship between FDI and industrialisation and environmental quality can be proposed under the PHH theory. As developing countries compete to attract FDI into their economies, regulations may be relaxed, allowing polluting firms to relocate from developed countries with stringent regulations into such developing countries.

On the other hand, the pollution halo hypothesis supports the argument that countries with stringent and enforceable regulations may encourage multinational companies to transfer modern and clean technologies from FDI inflows, thereby improving the environment of host countries (Mert and Bölük, 2016; Zhu et al. 2016b). Within the PHH and halo hypothesis framework, some studies have examined the effect of FDI and industrialisation on environmental quality. Shah et al. (2021) adopting the Driscoll and Kraay standard error estimation method for South Asian countries from 2001 to 2019, found a positive relationship between FDI and CO_2. In addition, Shahbaz et al. (2019) examined the association between FDI and carbon emissions for the Middle East and North African (MENA) region during 1990–2015 by applying the generalised method of moments (GMM) and revealed that FDI increases CO_2 emissions. By exploring the impact of industrialisation and FDI on the environment in the Asia-Pacific region from 1995 to 2000, Ahmed et al. (2022), using the ARDL, showed that FDI generally has a significantly negative environmental impact. The evidence from these studies largely confirms the PHH. Wang et al. (2020) also confirmed that FDI inflows deteriorate environmental quality, validating the PHH for China using a panel of 29 provinces from 1994 to 2015.

Similar results were obtained from other studies, which confirmed that FDI leads to environmental pollution (Moreno and Lo'pez, 2008; Ren et al. 2014; Dogan and Seker, 2016; Zhang and Zhou, 2016; Sapkota and Bastola, 2017; Gharni et al. 2020). However, other research findings have suggested that FDI does not deteriorate environmental quality, corroborating the pollution halo hypothesis. For example, Demena and Afesorgbor (2020), adopting a meta-analysis of 65 primary studies on the effect of FDI on the environment, concluded that FDI significantly reduces environmental pollution. In the same vein, Al-mulali, Foon Tang (2013) used the fully modified ordinary least squares (FMOLS) estimation method to estimate data between 1980 and 2009 on Gulf Cooperation Council (GCC) countries and found that FDI reduces environmental pollution; they concluded that energy consumption and GDP growth promote environmental pollution, whereas FDI dampens environmental pollution. Zafar et al. (2019) analysed US data from 1970 to 2015 and found that FDI was helpful in curtailing the ecological footprint, confirming the halo effect. These findings were validated by numerous studies that established that an increase in FDI does not significantly deteriorate environmental quality (Demena and Afesorgbor, 2020; Lee and Brahmasrene, 2013; Mert and Bölük, 2016; Safiullah et al. 2022; Zhu et al. 2016a). Sung et al. (2018) used a 14-year (2002–2015) dataset for 28 subsectors of the Chinese manufacturing sector, where the results from the system GMM showed an inverse relationship between GDP and CO_2 emissions. The literature reviewed thus far reveals inconclusive results, which calls for additional empirical studies to understand the relationship between FDI and environmental quality, especially for SSA countries.

Since industrialisation, which involves transitioning from an agrarian-based to a manufacturing-focused economy, is closely related to natural resources and involves substantial energy consumption, various studies have linked energy with industrialisation and environmental quality. For example, Mentel et al. (2022) investigated the relationship among industry, renewable energy, and CO_2 emissions for a sample of 44 SSA countries from 2000 to 2015. The results from the two-step system GMM estimation revealed that the share of industry in GDP has a significant positive impact on CO_2 emissions, whereas renewable electricity output reduces CO_2 emissions. Ahmed et al. (2022) utilised panel data from 55 countries in the Asia-Pacific region from 1995 to 2020 and the ARDL model to analyse the relationship between industrialisation and the environment. The authors concluded that industrialisation significantly and positively impacts the environment. Using the ARDL testing approach, Mahmood et al. (2020) examined the effects of industrialisation and urbanisation on CO_2 emissions in Saudi Arabia, utilising an annual period from 1968 to 2014. The results revealed that both industrialisation and urbanisation impede the environment through the inelastic effect of industrialisation and the elastic effect of urbanisation on CO_2. By accounting for subregional characteristics in a sample of 46 countries in the Asia-Pacific region during 1991–2017, Zafar et al. (2020) confirmed that industrialisation substantially impacts carbon emissions. Yu and Liu (2020) also confirmed the significant effect of industrialisation on environmental pollution in China. By examining the relationship between industrialisation and CO_2 emissions in Pakistan from 1980 to 2018 using nonlinear ARDL models, Ullah et al. (2020) concluded that industrialisation has a negative impact on the environment. In South Turkey, Akbostancı et al. (2011) found that the changes in total industry and energy intensity are the primary factors determining the changes in CO_2 emissions after employing the log mean Divisia index (LMDI) method from 1995 to 2001.

However, using nonparametric additive models, Xu and Lin (2015) found a U-shaped nonlinear relationship between industrialisation and CO_2 emissions in their data analysis from 1990 to 2011. This finding contrasts with previous research suggesting a positive correlation between industrialisation and CO_2 emissions. Using the ARDL bounds testing approach, Shahbaz et al. (2014) found a positive link between industrialisation and CO_2 emissions in the case of Bangladesh during 1975–2010. Similarly, Ahmed et al. (2022), utilising panel data of 55 countries in the Asia-Pacific region from 1995 to 2020 with the ARDL model, concluded that industrialisation has a positive and significant impact on the environment. Thus, the analysis of the above hypothesis provides critical pathways towards achieving sustainable development and the realisation of carbon neutrality goals in SSA. Regarding the possible role of INSQY in promoting environmental quality, the PH suggests the presence of well-designed environmental regulations in the home country (Porter, 1991). This indicates that INSQY can reduce carbon dioxide emissions, enhance environmental quality, and improve economic growth (Ibrahim and Law, 2016; Salman et al. 2019; Sarkodie and Adams, 2018). For instance, Cheah et al. (2022), studying the impact of INSQY in explaining environmental degradation in Malaysia from 1980 to 2019, made a strong case for promoting strong institutions as a critical tool to promote environmental quality. In a related study, Pata et al. (2024), using quantile regression model on data from 1985 to 2018 in four emerging countries, confirmed that geopolitical risks negatively influence environmental quality. Huynh and Hoang (2019) examined whether INSQY moderated the impact of FDI for 19 developing Asian countries from 2002 to

2015 by using the feasible generalised least squares (FGLS) and system GMM techniques. The authors concluded that INSQY helps reduce the negative impact of FDI on the environment. Similarly, Abid (2016) used GMM and found that a high level of institutions in 25 SSA countries reduced CO_2 emissions from 1996 to 2010.

Herrera-Echeverri et al. (2014) and Kerekes (2011), in their study on the relationship between institutions and CO_2, argued that emerging economies with low per capita income may use their institutional frameworks to favour economic development to the detriment of the environment. Similarly, Ameer et al. (2022) used ARDL simulations to analyse the effects of financial development, INSQY, globalisation, natural resources, trade openness, and renewable and nonrenewable energy consumption on environmental pollution from 1996 to 2017. The study revealed that a decrease in INSQY increases CO_2 emissions. Zhang et al. (2022) studied emissions in Brazil, Russia, India, China, and South Africa (BRICS) using the panel NARDL approach from 1996 to 2019. The study found that INSQY lowered CO_2 directly and indirectly through FDI and economic growth. Salman et al. (2019) used a panel of three East Asian countries from 1990 to 2016 and adopted three different estimation techniques—FMOLS, dynamic ordinary least squares (DOLS) and VECM to determine how INSQY can reduce the CO_2 emissions-growth nexus. The results show a positive and significant interaction between CO_2 and INSQY, indicating that institutions are critical for increasing economic growth and decreasing carbon emissions. Jahanger et al. (2022) investigated the influence of democracy, autocracy, and globalisation on CO_2 emissions in 74 developing countries from 1990 to 2016 by using the stochastic impacts by regression on population, affluence, and technology (STIRPAT) model framework. The results suggest that democracy helps reduce environmental pollution. Other studies have indicated that better institutions promote clean technologies, reducing environmental pollution. For instance, in a research study that investigated the role of INSQY and environment-related technologies on environmental degradation for BRICS economies using data from 1992 to 2016, Hussain and Dogan (2021) found that INSQY and clean technology improve environmental quality.

This review shows that various studies have examined the links between FDI, industrialisation, INSQY, and environmental quality. However, studies on the mitigating role of institutions on FDI and industrialisation on environmental quality in SSA are sparse and difficult to find. Despite efforts by Cheah et al. (2022) and Huynh and Hoang (2019) to investigate the moderating role of INSQY on FDI-environmental quality, they did not explore how institutions may also moderate industrialisation-environmental quality nexus. The industrial sector is acknowledged as a key contributor to carbon footprints, leading to environmental degradation (Akbostancı et al. 2011). Hence, there is a pressing need to investigate whether INSQY can help mitigate the harmful effect of industrialisation on environmental quality. Although Opoku and Boachie (2020) examined the environmental impact of FDI and industrialisation for 36 selected African countries, they did not account for INSQY. Similarly, Duodu et al. (2021) explored the relationships among FDI, institutions, and environmental quality in 23 SSA countries, they did not account for industrialisation. Considering the important role of institutions in governance and enforcement of regulations, examining the joint effect of institutions and FDI and institutions and industrialisation on CO_2 is imperative. For example, countries with stringent environmental standards are likely to enhance environmental quality because countries with adequate laws mitigate the negative effect of industrialisation on environmental degradation (Dutt, 2009; Lau et al. 2014). Therefore, we add to the literature by examining (1) the effect of FDI and industrialisation on CO_2, (2) the direct relationship between INSQY and CO_2, (3) the moderation role of INSQY on FDI-CO_2 nexus and (4) the moderation role of INSQY on industrialisation-CO_2 nexus.

Data and methodology

Data. To test the objectives of this paper, we use panel data from 45 SSA countries[1] from 2000 to 2019 due to data availability. We rely on macro data sourced from the World Bank [i.e., World Development Indicators (WDI) and World Governance Indicators (WGI)] and Energy Information Administration (EIA), as shown in Table 1. Environmental quality is the dependent variable and refers to the natural balance of animals, plants, natural resources, and man-made objects designed to sustain human livelihoods and nature.[2] In line with previous studies, we use CO_2 measured in metric tons per emission as a proxy for environmental quality (Albulescu et al. 2019; Opoku and Boachie, 2020). Reduced CO_2 levels suggest an improvement in environmental quality, while elevated CO_2 levels indicate a decline in environmental quality. The main independent variables of interest are FDI, industrialisation and INSQY. FDI is measured as net inflow (% GDP), whereas industrialisation is measured as value addition, including construction (% GDP). We include FDI because it can trigger green innovations and spur environmental progress (Baskurt et al. 2022; Kisswani and Zaitouni, 2023; Muhammad et al. 2021; Neequaye and Oladi, 2015). We aslo include industrialisation on the notion that changes in the total activity of

Table 1 Descriptive Summary and Data Description.

Variable	Measurement	Source	Obs	Mean	SD	Min	Max
Environmental quality	The log of carbon dioxide emissions (metric tons per capita)	WDI	900	−1.038	1.392	−4.116	2.458
FDI	Foreign direct investment, net inflows (% GDP)	WDI	900	3.996	4.13	0.002	16.322
Industrialisation	Industry (including construction), value added (annual % growth)	WDI	900	3.288	7.194	−14.557	13.446
Energy consumption	The log of total energy consumption (Btu)	EIA	900	31.391	1.6	27.56	36.284
Institutional quality	PCA output from 6 institutional quality indicators	Author	900	0.013	2.18	−3.338	5.290
Population density	People per square kilometre of land area	WDI	900	3.584	0.461	2.11	4.497
Economic growth	The log of real GDP growth (constant US$, 2015)	WDI	900	7.122	0.964	5.864	9.581
Economic growth Squared	Squared of the log of real GDP growth (constant US$, 2015)	Author	900	51.653	14.510	34.388	91.801

Note: *WDI* denotes the World Development Indicators; *EIA* represents the Energy Information Administration. This table presents the descriptive statistics of the variables used in the empirical investigations.
Source: Authors' Computation from Research Data, 2024.

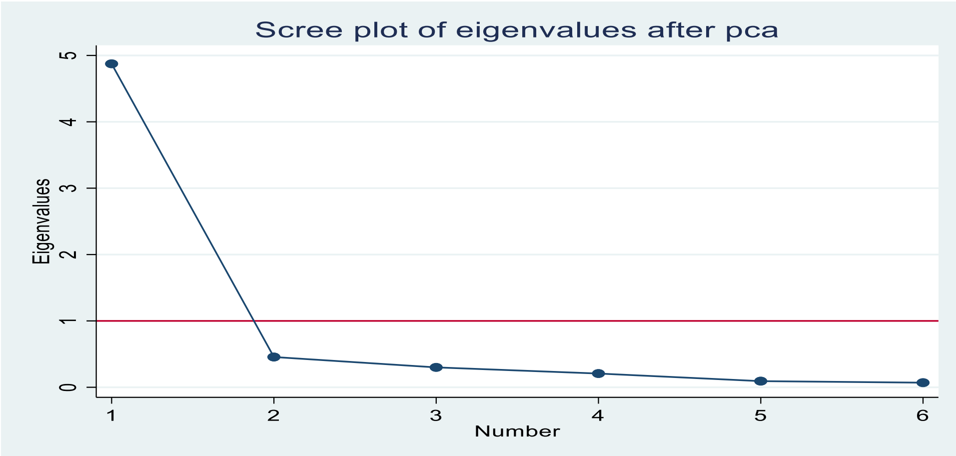

Fig. 1 Scree plot of PCA of institutional quality index. Note: This chart shows at which level an eigenvalue can be accepted to create an index. Source: Authors' Computation from Research Data, 2024.

industries can primarily contribute to environmental degradation (Akbostancı et al. 2011; Xu and Lin, 2015).

As discussed earlier, we focus on INSQY as the moderating variable because it can potentially play a crucial role in promoting environmental quality (Sarkodie and Adams, 2018); hence, the study examines the interactive term between FDI, industrialisation and INSQY, respectively. INSQY is indicative of the domestic institutional function of the host country. The study employs Principal Component Analysis (PCA) to develop an INSQY index using six World Bank's governance variables: control of corruption, rule of law, government effectiveness, political stability and absence of violence, regulatory quality, and voice and accountability (see Table A1). Prior to generating the index, we conduct pre-estimation tests, including the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (see Appendix Table A2). The tests are performed in STATA 17 using the command "*factortest with the six variables*". The KMO statistic of 0.8980 exceeds the threshold value of 0.5, indicating the adequacy of the sample for PCA. The Bartlett test further confirms the interrelation among the variables, with a Chi-square (X^2) value of 6294.047 and a highly significant p-value ($p = 0.000$).

Once the pre-tests confirm the validity of proceeding, we calculate the index using the "*pca*" command, followed by an orthogonal rotation to maximise the variance of squared loadings on each factor (*rotate* command). The index is then extracted using the "*predict insq*, *score*" command. Post-estimation checks, such as the scree plot (Fig. 1) and eigenvalue analysis (see Appendix Table A2), are conducted to ensure the robustness of the PCA results. The PCA results demonstrate robustness, as the extracted components cumulatively explain over 81% of the dataset's variation, with at least one principal component having an eigenvalue greater than 1 (see Fig. 1).

As the literature suggests (Alvarado et al. 2019; Grossman and Krueger, 1995; Khan et al. 2019; Lorente and Álvarez-Herranz, 2016; Muhammad et al. 2021), we control for energy consumption sourced from the EIA, economic growth and population density from WDI. We include energy consumption since higher energy consumption could increase climate breakdown and air pollution, resulting in environmental degradation (Appiah et al. 2021; Jinapor et al. 2023; Sarkodie and Adams, 2018). We include the urban population because SSA's urban areas are mostly associated with high pollution, which could possibly explain the increase in pollution (Brauer et al. 2012; Amegah and Agyei-Mensah, 2017). Economic growth has the potential to pollute the environment for developing countries; hence, we control for the log of GDP per capita (Muhammad et al. 2021; Alvarado et al. 2019; Khan et al. 2019; Grossman and Krueger, 1995). We transform the variables into natural logarithms to address issues of percentage change of coefficient estimates.

A discussion of descriptive statistics for the main variables of interest is presented in Table 1. CO_2 emissions have an average value of −1.038, with maximum and minimum values of 2.458 and −4.116 respectively, suggesting that the SSA region, on average, is associated with low carbon emissions. On a country level, we observe from the raw data that South Africa (2%), Equatorial Guinea (2%), and Seychelles (1.9%) show high carbon emissions, whereas Congo (−3.6%) and Burundi (−3.4) are countries with the least carbon emissions (see Fig. 2). It can also be observed from Table 1 that FDI has a mean value of 3.996% and a minimum of 0.002%, which shows that SSA still has a very low inflow of FDI. The wide variation between the minimum (0.002%) and maximum values (16.322%) of FDI shows potential outliers. This is addressed by winsorising the variables at the appropriate percentiles (Ghosh and Vogt, 2012). At the country level, Seychelles (10.8%) is shown to be the greatest recipient of FDI on average from 2000–2019. The least recipient of FDI among the SSA sample is Comoros (0.547%), as shown in Fig. 3.

Table 1 also indicates a low level of industrialisation in SSA since industry averaged 3.288% of GDP with minimum and maximum values of −14.557% and 13.445%. The data for the SSA sample suggest that Ethiopia has been developing its industrial level since, on average, industry contributed 12% to GDP from 2000 to 2019. However, the Central African Republic (−24%) has the least industrialisation (see Fig. 4). Table 1 shows that the INSQY for the SSA sample is weak since the mean value (0.013) falls within the low institution range. On the country level, Mauritius (5.2%) is associated with improved institutions and governance, whilst Congo Republic (−3.66) has a weak institution and governance (see Fig. 5). Table 1 shows that energy consumption has a mean value of 31.391% with its maximum and minimum values of 36.284% and 27.56%, respectively, which attests to the assertion by Appiah et al. (2021) that SSA is gradually increasing energy consumption.

We also provide some discussion on the issue of multicollinearity using the pairwise correlation matrix and Variance Inflation Factor (VIF) which are presented in Table 2. We identified that apart from population density, all the variables have significant associations with environmental quality. Additionally, we found a low correlation between the independent

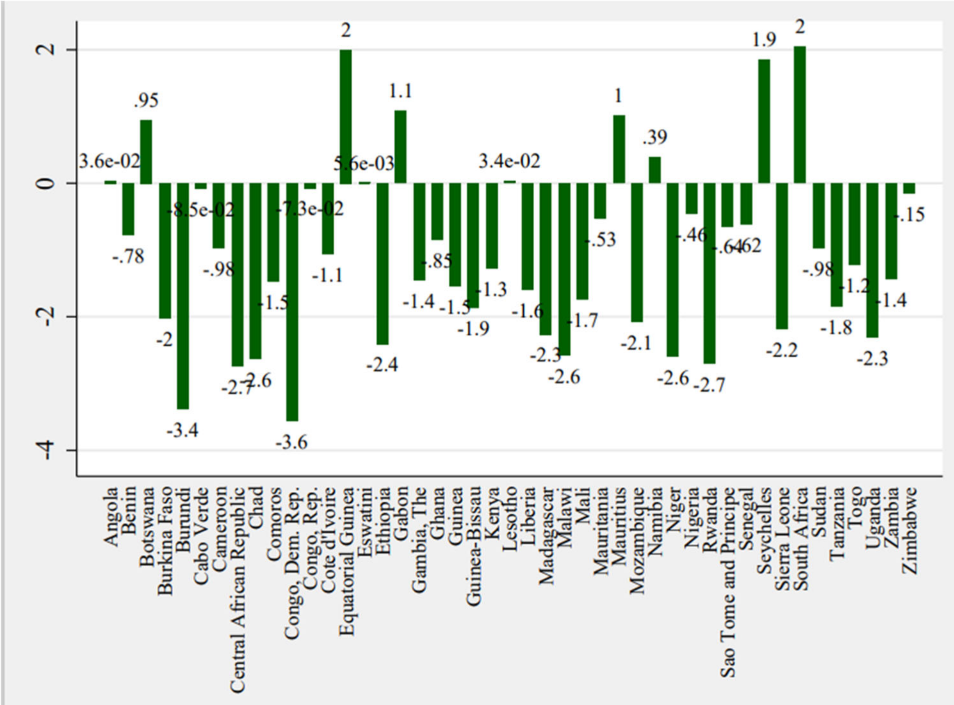

Fig. 2 In-country log of carbon dioxide (metric ton per capita) 2000–2019. Source: Authors' Computation from Research Data, 2024.

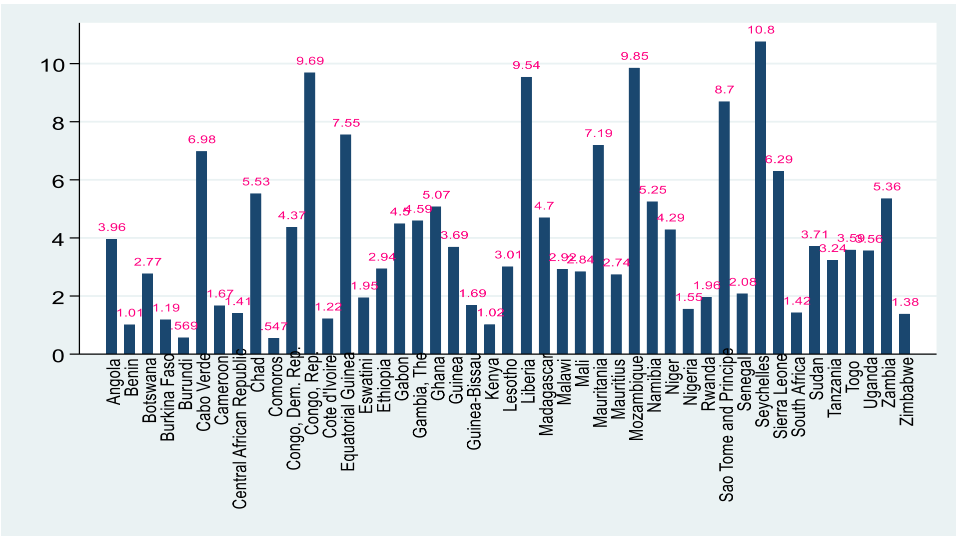

Fig. 3 In-country FDI flow (% GDP) 2000–2019. Source: Authors' Computation from Research Data, 2024.

variables, except for the correlation between energy consumption and economic growth, which has a moderate correlation with a coefficient of 0.628. As this situation could potentially result in multicollinearity, we conducted a test of multicollinearity using VIF, which is also presented in Table 2. VIF result illustrates that multicollinearity is not evident, as the VIF for each variable is below 5 and the average VIF is below 10.

Model specification. Following the discussion in Section "Theoretical and empirical literature review", Eq. (1) first tests the direct impact of FDI, industrialisation and INSQY on environmental quality in SSA. Subsequently, we examine the interactive effect of INSQY with FDI and industrialisation on environmental quality in SSA using the panel model specified in Eq. (2). The empirical model specified in Eq. (2) is based on the PH, which states that strict environmental regulations in the home country encourage or compel firms to invest more in clean and efficient technologies.

$$EQ_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 INDS_{it} + \beta_3 INSQY_{it} + \beta_4 EC_{it} + \beta_5 POP_{it} + \beta_6 GDP_{it} + \beta_7 GDP^2_{it} + \varepsilon_{it} \quad (1)$$

$$EQ_{it} = \varphi_0 + \varphi_1 FDI_{it} + \varphi_2 INDS + \varphi_3 INSQY_{it} + \varphi_4 EC_{it} + \varphi_5 \mathrm{POP}_{it} + \varphi_6 \mathrm{GDP}_{it} + \varphi_7 GDP^2_{it} + \varphi_8 (FDI \times INSQY)_{it} + \varphi_9 (\mathrm{IDS} \times INSQY)_{it} + e_{it} \quad (2)$$

From the above equations, EQ_{it} denotes environmental quality of the countries over time, which is proxied by CO_2; FDI_{it} denotes net FDI inflows (% GDP); IDS_{it} denotes industrialisation, which is proxied using industry (including construction) as a percentage of GDP, and INSQY_{it} represent institutional quality for countries

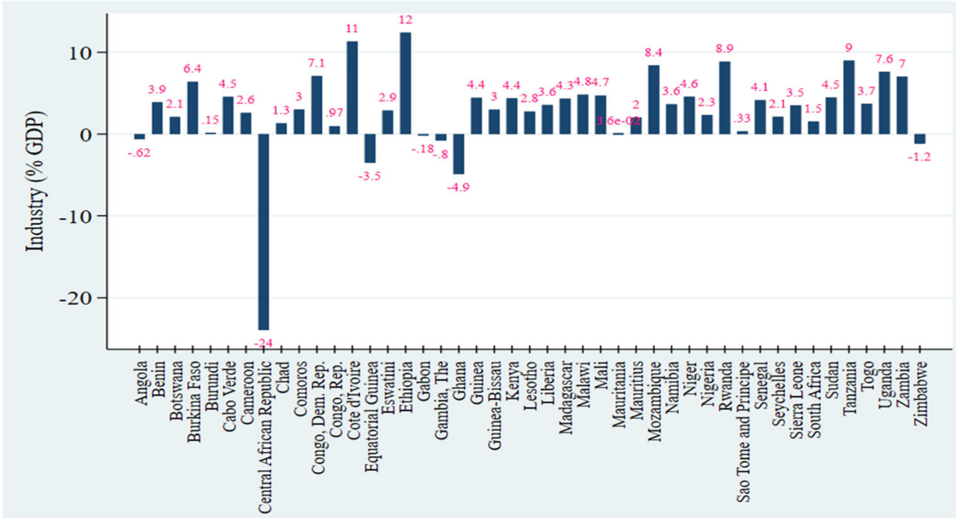

Fig. 4 Country-level industry value addition (% GDP) 2000–2019. Source: Authors' Computation from Research Data, 2024.

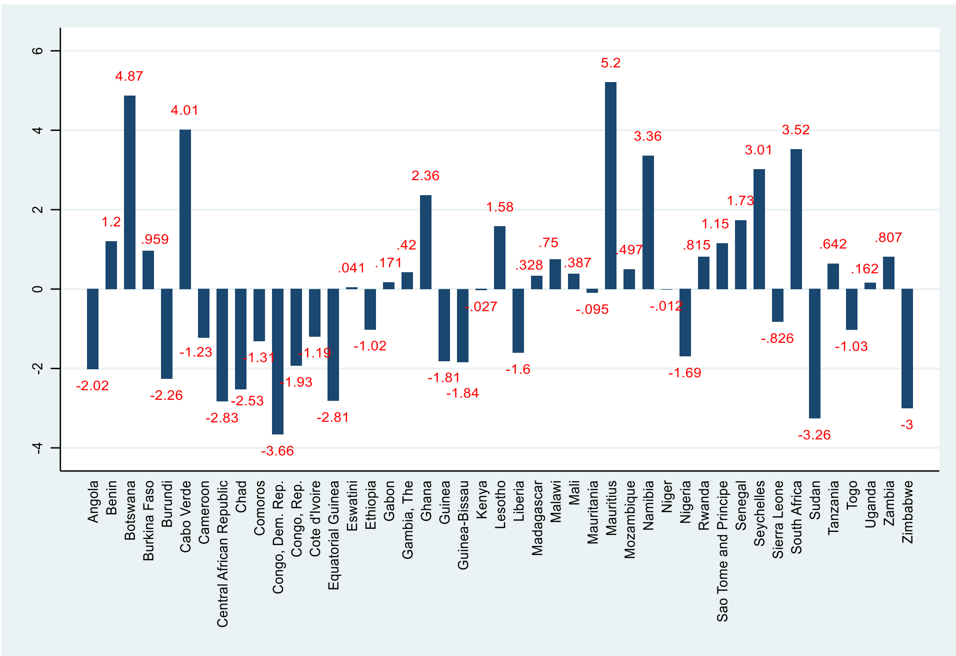

Fig. 5 In-country institutional quality index, 2000–2019. Source: Authors' Computation from Research Data, 2024.

Table 2 Pairwise Correlation.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	VIF
(1) logCo2	1.000							1.780
(2) FDI	0.146	1.000						1.230
(3) INDS	−0.150	0.024	1.000					1.170
(4) INSQY	0.430	0.053	0.076	1.000				1.110
(5) logTEC	0.337	−0.103	0.106	0.086	1.000			1.040
(6) logPoP	0.661	0.251	−0.159	0.180	0.206	1.000		1.410
(7) logGDP	0.933	0.129	−0.134	0.414	0.319	0.628	1.000	1.780
Mean VIF								1.230

Note: *EQ* environmental quality, *FDI* foreign direct investment, *INSQY* institutional quality index, *POP* population density, *GDP* economic growth, *EC* energy consumption.
Source: Authors' Computation from Research Data, 2024.

Table 3 Results of Driscoll Kray standard error panel regression.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign direct investment (FDI)	0.008**			0.007**	0.007*		0.007*
	(0.004)			(0.003)	(0.003)		(0.003)
Industrialisation (INDS)		0.002**		0.002***		0.002**	0.002**
		(0.001)		(0.001)		(0.001)	(0.001)
Institutional quality (INSQY)			−0.037*	−0.037**	−0.029**	−0.032*	−0.026**
			(0.019)	(0.018)	(0.016)	(0.016)	(0.014)
Energy consumption	0.240***	0.245***	0.249***	0.240***	0.246***	0.249***	0.246***
	(0.039)	(0.038)	(0.038)	(0.039)	(0.038)	(0.036)	(0.037)
Urban population	0.414***	0.411***	0.292*	0.321*	0.287*	0.279	0.276
	(0.142)	(0.144)	(0.163)	(0.162)	(0.161)	(0.164)	(0.162)
Economic growth	1.728***	1.914***	2.049***	1.851***	1.838***	2.136***	1.927***
	(0.247)	(0.283)	(0.305)	(0.268)	(0.296)	(0.304)	(0.293)
Economic growth square	−0.088***	−0.102***	−0.105***	−0.091***	−0.089***	−0.111***	−0.095***
	(0.018)	(0.021)	(0.021)	(0.018)	(0.019)	(0.021)	(0.019)
FDI × INSQY					−0.003**		−0.002**
					(0.001)		(0.001)
INDS × INSQY						−0.002***	−0.002***
						(0.000)	(0.000)
Constant	−17.866***	−18.618***	−19.070***	−18.246***	−18.309***	−19.355***	−18.588***
	(0.782)	(0.871)	(0.745)	(0.719)	(0.699)	(0.880)	(0.851)
Observations	944	944	944	944	944	944	944
Number of groups	45	45	45	45	45	45	45

Note: This table reports the results of the estimation equation; standard errors are in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

over time, measured using an index from the PCA output as discussed earlier; EC_{it} is the log of total energy consumption (BTU) for countries over time; and PoP_{it} is population density measured as the number of people per square kilometre of land area. GDP_{it} is economic growth countries over time, measured with the log of GDP per capita (constant US$, 2015) and to capture EKC, we used the squared of economic growth denoted with GDP^2_{it}. While β_0 and φ_0 are constants or the intercepts, β_{1-7} and φ_{1-9} are the coefficients to be estimated. Unobserved variables are captured as ε_{it} and e_{it}.

Estimation technique. The paper employed Driscoll and Kraay methodology (DKraay) to examine the nexus between FDI, industrialisation and institutional quality on environmental quality in SSA. Dkraay is a statistical approach used to estimate robust standard errors in panel data models, particularly when dealing with cross-sectional dependence,[3] heteroscedasticity,[4] and autocorrelation[5] (Iheonu, 2019; Sarkodie and Strezov, 2019; Shah et al. 2021). Owing to the drive for trade and industrialisation integration among SSA countries, the likelihood of cross-sectional dependence and other related characteristics emerges, which can be effectively addressed using the DKraay methodology. To begin, we conducted tests for cross-country dependence, heteroskedasticity, and autocorrelation, with the results presented in the appendices (see Tables A.3–A.5). These tests confirmed the presence of cross-country dependence, heteroskedasticity, and autocorrelation in our data, necessitating the use of DKraay. Additionally, since DKraay relies on fixed effects estimation, a Hausman test was performed to determine the suitability of the fixed effects model (Shah et al. 2021). The results, provided in the appendix (see Table A.6), confirmed that the fixed effects estimator was appropriate, supporting our decision to proceed with the DKraay estimation. Subsequently, we applied the DKraay methodology to estimate our model.

DKraay with a fixed-effects estimator technique is superior to baseline estimators such as ordinary least squares (OLS) because it overcomes the problem of cross-country dependence that characterises panel data sets and is robust to general forms of spatial and temporal dependence (Iheonu, 2019; Sarkodie and Strezov, 2019; Shah et al. 2021). Another plausible reason we adopt the DKraay methodology is its ability to accommodate missing values and its flexibility without imposing any restrictions or limiting the number of panels. Most SSA countries are associated with limited data (Jinapor et al. 2023; Iddrisu, 2024); hence, DKraay is used. Following the work of Sarkodie and Strezov (2019), we conducted a post-estimation test using the marginal effects technique.[6]

Although DKraay effectively addresses heteroskedasticity, cross-sectional dependence, autocorrelation and accommodating missing values, it is less capable of managing endogeneity. Endogeneity often arises from factors such as reverse causality, specification errors, and omitted variables (Agbloyor et al. 2013; Osabohien et al. 2022; Iddrisu et al. 2024). This study may face challenges related to omitted variables and reverse causality between environmental quality, FDI, and industrialisation. It is, therefore, crucial to empirically test whether these issues could undermine the relevance of the DKraay results. To address this, we applied the 2SLS estimator, which effectively manages endogeneity. We used the more effective 2SLS, which is the "xtivreg2" with a feasible two-stage generalised method of moment (GMM2s) option.[7] The GMM2s option improves efficiency over the one-step estimator by incorporating an optimal weighting matrix and includes diagnostic tests like the Hansen test for instrument validity and Durbin-Wu-Hausman for endogeneity (Baum et al. 2016; Schaffer and Stillman, 2016; Schaffer, 2020; Iddrisu et al. 2024; Iddrisu, 2024).

Empirical results and discussion

The Driscoll-Kraay results for FDI, industrialisation, INSQY and environmental quality. We estimate the regression models using the DKraay estimated through fixed-effect regression, and the results are presented in Table 3. We started with the discussion of the direct effect of FDI and industrilisation on environmental quality. The results from Table 3 show that FDI inflows contribute to environmental degradation which hampers environmental quality. The reported coefficient (0.008) in column (1) of Table 3 is positive and statistically significant. This outcome aligns with the PHH, suggesting that FDI inflows have a negative impact on the environment, which reinforces previous research findings (see Opoku and Boachie, 2020; Sarkodie and Strezov, 2019; Zhang and Zhou, 2016). This result can be explained by the tendency of many SSA leaders to ease environmental laws and regulations in an effort to attract vital FDI. As a result, multinational companies often relocate their polluting operations to SSA, leading to detrimental effects on the environment (Jinapor et al. 2023).

We also find that industrialisation significantly increases CO_2 emissions for the SSA sample, with a coefficient of 0.002 at the 5% significance level, as shown in column (2) of Table 3. The positive effect of industrialisation on CO_2 emissions implies that industries' total activities could be detrimental to environmental quality. The results provide evidence in support of the EKC, where an effort to attain greater economic growth and development through industrialisation may ultimately contribute to environmental degradation. Since diverse policies (e.g., NEPAD and AfCFTA) have been implemented to promote industrialisation, this could deteriorate the environment if unchecked. Our empirical results also corroborate a strand of empirical studies that concluded that industrialisation promotes environmental pollution (see e.g., Zafar et al. 2020; Yu and Liu, 2020; Ahmed et al. 2022; Shahbaz et al. 2014).

Second, we discussed the impact of INSQY on environmental quality. The direct effect of institutions on CO_2 emissions reveals that INSQY can minimise CO_2 emissions, given its significant negative coefficient of 0.037. This finding suggests that INSQY is an effective instrument for reducing carbon dioxide emissions, thereby enhancing environmental quality and economic development (Ibrahim and Law, 2016; Sarkodie and Adams, 2018). This finding indicates that robust institutions are more effective at enforcing environmental regulations and policies designed to lower carbon emissions. The effective implementation of these policies can lead to stricter emission standards for foreign investors, industries, cleaner energy production, and sustainable land use practices. Our findings support some empirical studies (see Abid, 2016; Salman et al. 2019; Zhang et al. 2022).

Third, we are interested in the differential effects of FDI and industrialisation on environmental quality. Hence, we include both FDI and industrialisation in one model, and the results are presented in column (4) of Table 3. The results revealed that FDI (*coefficient of* 0.007) contributes more to CO_2 emissions than industrialisation (*coefficient of* 0.002). Our empirical results indicate that industrialisation negatively impacts environmental quality, but to a lesser extent than FDI, likely due to the relatively low levels of industrialisation in SSA. For instance, industrial contribution to GDP decreased from 37.96% in 1980 to 26.5% in 2015, whereas the share of manufacturing to GDP on the continent decreased from 18% in 1975 to 11% in 2014 (World Bank, 2020). The low level of industrial activities is also evident in our SSA sample, where some countries, such as Angola (−0.62%), the Central African Republic (−24%), Equatorial Guinea (−3.5%), Gabon (−1.8%), Gambia (−0.08%), Guinea (−4.9%) and Zimbabwe (−1.2%), recorded negative industry value added to their economies (see Fig. 4).

Fourth, we examine the existence of the EKC in Africa, as the continent's leaders strive for greater economic growth. The results of Table 3 reveal the presence of the EKC in our results since GDP induces CO_2 emissions, and the squared term of GDP reduces CO_2 emissions. This suggests that in the initial stages of economic development for the SSA sample, growth is achieved with little attention paid to environmental quality. For instance, as economic growth progresses, it often leads to structural changes in the economy, typically accompanied by higher energy consumption (Xu and Lin, 2015). However, in the later stages of economic development, when incomes rise, governments, businesses, and households may invest more in efforts to combat environmental pollution (Dinda, 2004; Song et al. 2013; Lorente and Álvarez-Herranz, 2016).

Fifth, we examine the joint effect of both FDI and institutions and of industrialisation and institutions on environmental performance. Table 3 shows that the unconditional effects of both FDI and industrialisation and their unconditional effects (interaction terms) on environmental quality are statistically significant (see columns 5 and 6). Since FDI has a positive coefficient of 0.007, and its conditional effect has a negative coefficient of 0.03 (see column (5) of Table 3), it implies that while FDI increases CO_2 emissions, INSQY dampens the negative impact of FDI on the environment. In the same vein, industrialisation (*0.002)* increases CO_2 emissions, whereas INSQY dampens the negative effects of industrialisation on the environment, as the interaction coefficient of 0.002 is negative (see column (6) of Table 3). This result is consistent with the findings of Cheah et al. (2022) and Huynh and Hoang (2019). and confirms the intuition raised by the PH that quality institutions in host countries restrict FDIs and industries from investing in cleaner and more efficient technologies.

Sixth, we examine the effect of the control variables on environmental quality. Table 3 shows that all control variables have a statistically significant negative effect on environmental quality (see Table 3). For instance, we find that the urban population enhances CO_2 emissions. This is possible because as the population increases, the rate of infrastructural development increases, with its considerable energy demand arising from the high demand for transportation and machinery needed for energy, high demand for goods and services, and high deforestation (Birdsall, 1992; Shahbaz et al. 2014). We also identified energy consumption as a factor contributing to poor environmental quality. While energy consumption in Africa remains relatively low, there has been a recent uptick in electricity use. This empirical result confirms with some existing studies (Khan et al. 2019; Sarkodie and Strezov, 2019; Zaman and Moemen, 2017). According to these studies, the high emissions rate was due to an increase in the share of fossil fuel consumption for economic activities. This could be because most SSA counties depend on fossil fuel energy consumption (especially coal) to drive their economic activities.

Last, the post-estimation test for the DKraay is discussed and presented in Table 4. Using the marginal effect approach, it is necessary for the coefficients of the marginal effect to align with the coefficients of the DKraay (see Sarkodie and Strezov, 2019). From Table 4, our results are robust since the marginal effect reveals similar results with the DKraay.

Robustness checks. The paper proceeds to conduct some robustness checks using a different estimation technique, the 2SLS, and the results are presented in Table 5. We employed the 2SLS approach to address the limitations of the DKraay, specifically its challenges in handling endogeneity. Our objective was to assess whether these limitations could affect the robustness of the DKraay results. The findings in Table 5 indicate that endogeneity did not affect the robustness of the DKraay results, as the 2SLS method produced outcomes consistent with those of the DKraay. For instance, the DKraay results (see Table 3) indicate that both FDI and industrialisation hamper environmental quality. Similarly, the 2SLS estimation (see Table 5) confirms this finding. Furthermore, both methods demonstrate that when INSQY is accounted for, FDI and industrialisation enhance environmental quality.

Table 4 Results of the marginal effect for Driscoll Kray standard error panel regression.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign direct investment (FDI)	0.008**			0.007**	0.007*		0.007*
	(0.004)			(0.003)	(0.003)		(0.003)
Industrialisation (INDS)		0.002**		0.002***		0.002**	0.002**
		(0.001)		(0.001)		(0.001)	(0.001)
Institutional quality (INSQY)			−0.037*	−0.037**	−0.029**	−0.032*	−0.026**
			(0.019)	(0.018)	(0.016)	(0.016)	(0.014)
Energy consumption	0.240***	0.245***	0.249***	0.240***	0.246***	0.249***	0.246***
	(0.039)	(0.038)	(0.038)	(0.039)	(0.038)	(0.036)	(0.037)
Urban population	0.414***	0.411***	0.292*	0.321*	0.287*	0.279	0.276
	(0.142)	(0.144)	(0.163)	(0.162)	(0.161)	(0.164)	(0.162)
Economic growth	1.728***	1.914***	2.049***	1.851***	1.838***	2.136***	1.927***
	(0.247)	(0.283)	(0.305)	(0.268)	(0.296)	(0.304)	(0.293)
Economic growth square	−0.088***	−0.102***	−0.105***	−0.091***	−0.089***	−0.111***	−0.095***
	(0.018)	(0.021)	(0.021)	(0.018)	(0.019)	(0.021)	(0.019)
FDI × INSQY					−0.003**		−0.002**
					(0.001)		(0.001)
INDS × INSQY						−0.002***	−0.002***
						(0.000)	(0.000)
Constant	−17.866***	−18.618***	−19.070***	−18.246***	−18.309***	−19.355***	−18.588***
	(0.782)	(0.871)	(0.745)	(0.719)	(0.699)	(0.880)	(0.851)
Observations	944	944	944	944	944	944	944
Number of groups	45	45	45	45	45	45	45

Note: This table reports the results of the estimation equation; standard errors are in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5 2SLS results for FDI, industrialisation and environmental quality.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign direct investment (FDI)	0.022***			0.020***	0.020***		0.018***
	(0.007)			(0.007)	(0.007)		(0.006)
Industrialisation (INDS)		0.005***		0.002*		0.003**	0.001*
		(0.002)		(0.001)		(0.002)	(0.001)
Institutional quality (INSQY)			−0.050**	−0.041***	−0.043***	−0.035**	−0.028**
			(0.023)	(0.014)	(0.014)	(0.017)	(0.013)
Energy consumption	0.227***	0.241***	0.263***	0.228***	0.240***	0.255***	0.250***
	(0.035)	(0.029)	(0.027)	(0.034)	(0.035)	(0.030)	(0.032)
Urban population	0.518***	0.548***	0.229	0.433***	0.341**	0.372**	0.325**
	(0.125)	(0.105)	(0.171)	(0.139)	(0.160)	(0.171)	(0.147)
Economic growth	1.251***	1.706***	1.843***	1.223***	1.059***	1.772***	1.573***
	(0.339)	(0.363)	(0.308)	(0.338)	(0.395)	(0.338)	(0.325)
Economic growth square	−0.056**	−0.091***	−0.088***	−0.049**	−0.033	−0.089***	−0.073***
	(0.026)	(0.027)	(0.022)	(0.024)	(0.029)	(0.026)	(0.025)
FDI × INSQY					−0.001*		−0.001**
					(0.001)		(0.001)
INDS × INSQY						−0.001***	−0.002***
						(0.000)	(0.000)
Observations	899	854	899	854	854	854	899
R-squared	0.473	0.465	0.492	0.464	0.463	0.484	0.502
Number of C_ID	45	45	45	45	45	45	45
F-statistic	1708***	2127***	4898***	2035***	1929***	2117***	2516***
Durbin-Wu-Hausman endogeneity test. *P*-values	0.184	0.732	0.449	0.413	0.243	0.936	0.458
Hansen Test, *P*-value	0.120	0.140	0.102	0.204	0.201	0.106	0.125
Kleibergen-Paap rk LM, *P* value	0.0373	0.0895	0.0279	0.197	0.0680	0.0518	0.0862

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

Conclusion and policy implications

We empirically investigate whether INSQY can moderate the otherwise harmful effect of FDI and industrialisation on environmental quality. We employ macro data from 2000 to 2019 for 45 SSA countries using the DKraay estimation technique. Consistent with the literature, the results confirm the EKC hypothesis since economic growth reduces environmental quality at the initial level until a threshold is reached, beyond which economic growth enhances environmental quality. The results also show that both FDI and industrialisation dampen environmental quality. This finding suggests that increased FDI inflows and industrialisation have a harmful effect on the environmental quality of SSA. The result also reveals that quality institutions can promote environmental quality of SSA. Notably, the results reveal that INSQY can mitigate the negative impact of FDI and industrialisation on the environment, underscoring the importance of building institutional capacity in SSA.

We provide some useful, practical policy implications based on the findings of the study. First, SSA governments and policymakers must strengthen their regulatory frameworks by developing and enforcing stringent environmental regulations. These includes enacting well-defined and unambiguous laws and guidelines for companies operating in SSA. There is also the need to put in place the requisite and effective implementation framework to ensure a robust monitoring, enforcement and compliance mechanism for all stakeholders towards achieving sustainable development. Developing and promoting a transparent and accountable decision-making process while ensuring strict adherence to environmental regulations related to FDI and industrial projects is necessary to promote environmental quality. With the rapid advancement of information and communication technology (ICT), SSA can leverage these tools to efficiently disseminate and monitor information. SSA leaders must promote cooperation and coordination to ensure synergy in formulating environmental regulations, such as the Arusha Declaration on eliminating promulgated (POPs) by African nations. SSA countries can also leverage support from reputable international organisations and governments to help build the capacity of regulatory institutions to formulate, implement, and enforce environmental standards effectively. SSA governments are encouraged to adopt incentives and policy proposals, such as tax holidays, public-private partnerships and tax breaks, to encourage FDI inflows and investments in clean technologies (halo). Finally, environmental, institutional, and governance goals must be clearly established and measurable against internationally acceptable standards such as the SDGs.

Limitations

This study undoubtedly contains some limitations. First, since data availability is the primary determining factor of sample selection, some SSA countries were inevitably excluded from the analysis. The sample size can, therefore, be increased as data becomes available in the future. Second. This study focused on a single institutional component index; future studies could explore the effect of the individual unique components of INSQY. Further research can extend this study by examining sectoral FDIs and their relationship with the environment. The empirical analysis of this study should motivate similar research for other developed and developing countries.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

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Notes

1 Angola, Benin; Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, D.R. Congo, Congo, Cote d'Ivoire, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Gambia The, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia; Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

2 See https://www.lawinsider.com/dictionary/environment-quality.

3 Cross-sectional dependence is where observations in different cross-sectional units (e.g., countries, firms, etc.) are not independent of each other, which is a common feature in panel data.

4 Autocorrelation is errors in one time period may be correlated with errors in subsequent periods within the same cross-sectional unit.

5 The methodology provides robust standard errors even when the variance of errors is not constant across observations.

6 Table 4 shows that our results seem robust since the marginal effect reveals similar results to that of the DKraay coefficients.

7 See more information on 2SLS with GMM option: http://www.repec.org/bocode/i/ivreg2.html#:~:text=Citation%20of%20ivreg2-,Description,%2C%20and%20k%2Dclass%20estimators.

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Informed consent

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Additional information

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