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Does foreign direct investment matter for environmental innovation in African economies?

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Abstract
This study investigates the role of foreign direct investment (FDI) in environmental innovation in Africa during 1990–2019. It utilizes the endogenous growth theory to specify an innovation production function, estimated using the seemingly unrelated regression (SURE) method. The study employs four indicators of environmental innovation and also controls for the influence of resource abundance. Key findings from the study show evidence that FDI inflow enhances environmental innovation practices by improving resource efficiency outcomes. In particular, FDI is found to reduce greenhouse gas emission intensity of output and carbon intensity of energy. Further, the effect of FDI on resource utilization and energy productivity is insignificant. Estimates confirm the learning and imitation, and demonstration effects of FDI on resource utilization, though the formal effect is detrimental. The labour market effect is revealed to promote resource efficiency, while resource abundance plays negligible role in environmental innovation in all models. Policy implications are derived.

Keywords Foreign direct investment · Environmental innovation · Resource abundance · Africa

JEL Classification Q55 · Q56 · F21

1 Introduction

The last few decades have witnessed increased economic activities in most countries, including developing ones, resulting in greater economic growth. However, associated environmental pollution arising largely from the heavy reliance on petroleum products has raised major concerns among governments, international

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organizations, researchers and other stakeholders (Adewuyi and Awodumi 2017; Chen and Lei 2018). Most industrialized economies took drastic steps, following the Kyoto Protocol of 1997, by designing innovative measures toward reducing this hazard. Consequently, they design environmental policies and regulations, and set targets, prominent among which are the emission trading system and carbon pricing/tax, which spurred environmental innovative behaviours among firms in developed and some emerging economies. Apart from the adoption of carbon-reducing and energy-saving technologies, most firms in these economies now consider innovative practices that efficiently utilize renewable energy sources to achieve clean production (Chen and Lei 2018). Environmental innovation involves the use of new or improved processes, technologies and products to reduce environmental impact of production activities (Kemp and Oltra 2011 and Liao 2018).

In developing economies, environmental hazards have continued to dominate subject of policy debates among stakeholders in recent years as they become increasingly aware of its potential threats. However, these economies possess limited technological know-how to enhance firms' ability to innovate toward reducing the environmental implication of these activities. External source of knowledge, readily available through foreign investment, therefore becomes rich elements of environmental innovation activities in most developing countries. Thus, less efficient domestic firms are encouraged to adopt innovative environmentally efficient practices and production techniques to remain competitive (Cole et al. 2017; Opoku et al. 2021). But it is equally argued that foreign investment could worsen environmental quality and hinder sustainable development in these economies (Wang and Chen 2014; Shahbaz et al. 2015, Wang et al. 2020). Pollution-intensive industries, in an attempt to avoid the stringent environmental policies in the home countries, outsource the dirty part of their production process or relocate to less stringent economies, such as developing countries some of which are resources-rich. Labour market conditions, ability to learn and imitate as well as the capacity to invest in research and development activities also play important role in the extent to which knowledge is transferred to the domestic economy, Cheung and Lin (2004).

In Africa, average real GDP was more than double between 1990 and 2019 resulting in over 100% rise in carbon emission over the same period. During this period, FDI inflow to most of the counties in the region increased significantly, while their contribution to environmental innovation toward carbon emission reduction is still questionable. For instance, while carbon emission intensity of energy and energy intensity of output only reduced marginally, utilization of energy from renewables and waste followed a declining trend throughout the period 1990–2019. The pertinent questions therefore are: (1) What is the role of FDI in environmental innovation in Africa? (2) Does resource abundance influence such innovation? This study seeks to provide answers to these questions to inform policy formulations toward effective environmental innovation in Africa.

The literature on FDI-environment innovation nexus shows that studies are scarce. Most of the existing studies either focus on the FDI-innovation link with overwhelming interest in patent and R&D investments (Erdal and Göçer 2015; Ning et al. 2016 and Law et al. 2018) or the effect of FDI on environmental quality (Demena and Afesorgbor 2020; Wang et al. 2020; Opoku et al. 2021). Chen et al.,

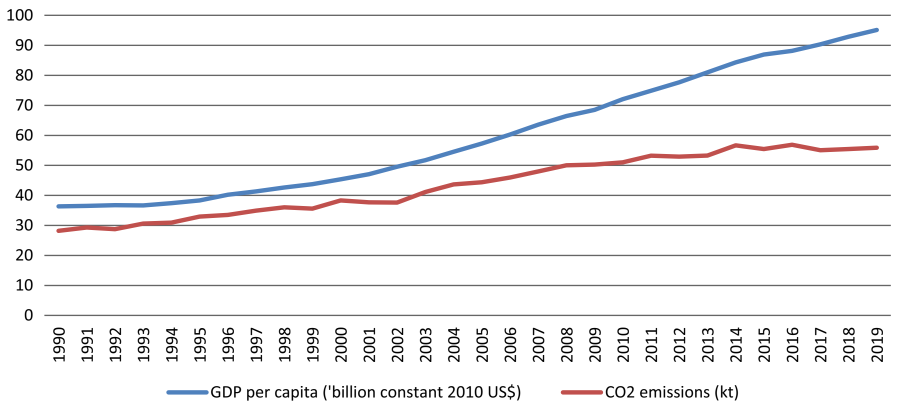

Fig. 1 Real output and carbon emission among selected countries in Africa. Source: Author's computation, data from World Bank World Development Indicators (WDI)

(2017) conducted a similar study for China but only controlled for FDI in eco-innovation with limited implication for policy. This study is necessitated by the continuous upward trend of FDI inflow to Africa and the potentials for environmental innovation through direct economic activities and technology (knowledge) transfer that is important for domestic firms. This study therefore contributes to existing body of literature by investigating the role of FDI in environmental innovation using 21 African countries during the period 1990–2019 based on data availability.

The rest of the paper is structured such that Sect. 2 contains stylized facts on FDI and environmental innovation in the selected economies, while review relevant studies are done in Sect. 3. Section 4 presents the theoretical framework and methodology, and Sect. 5 presents the results from empirical analysis and also discusses the results. Section 6 summarizes the major findings and makes some policy recommendations.

2 Stylized facts about FDI and environmental innovation in Africa

Most African economies have witnessed increased economic growth in the last two or three decades with associated cost in the form of environmental degradation, particularly greenhouse gas emission. For instance, as revealed in Fig. 1, average real output among selected African countries, which stood at about $36 billion in 1990, rose consistently to reach a peak of about $95 billion in 2019. Similar trend is also observed in average carbon emission which rose steadily from about 28,202 kiloton in 1990 to a peak of 56,866 kiloton in 2016. This indicates that the increasing level of carbon emissions in Africa may be linked to the rising level of pollution-intensive economic activities which contributes immensely to economic growth.

The trend of FDI inflow, carbon intensity of energy and energy intensity of output among selected African economies are depicted in Fig. 2. Average FDI fluctuated frequently but maintained an upward trend for most part of the period 1990–2019

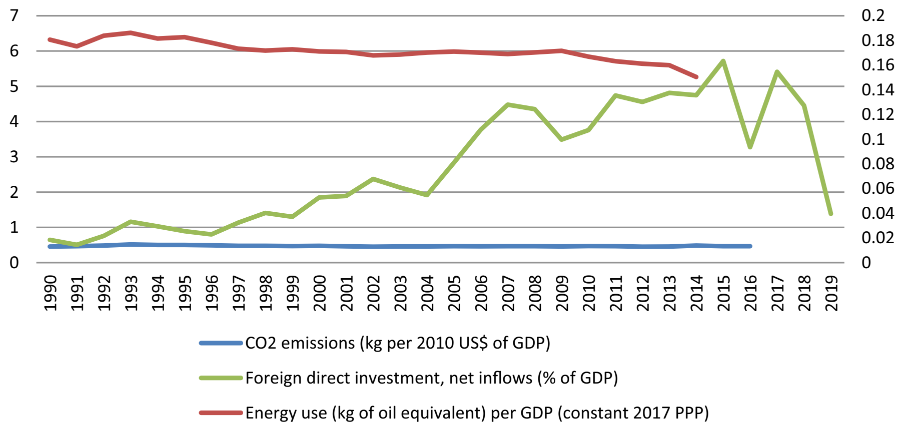

Fig. 2 FDI inflow, carbon intensity of energy and energy intensity of output among selected African Countries. Source: Author's computation, data from World Bank World Development Indicators (WDI)

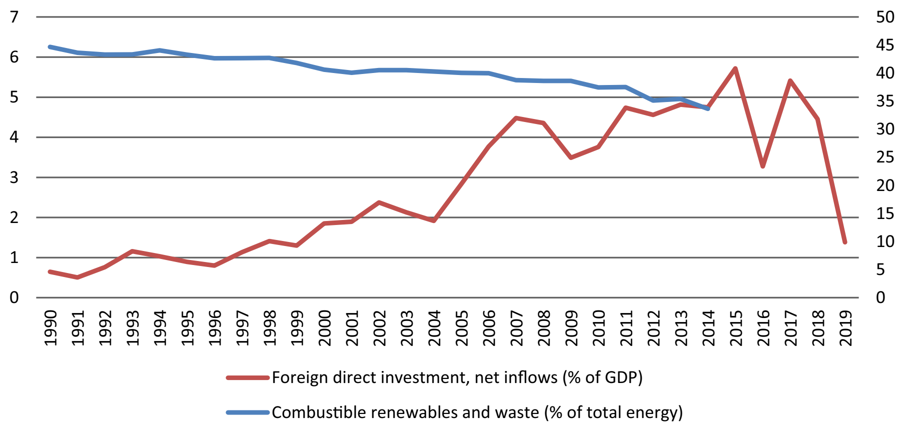

Fig. 3 FDI and energy from combustible renewables and waste. Source: Author's computation, data from World Bank World Development Indicators (WDI)

with a recent double peak of peak of 5.72% and 5.41% of GDP in 2015 and 2017, respectively, after which it fell gradually to 1.38% in 2019, its minimum value over two decades. The presence of foreign investment in these economies appears to improve the level of environmental innovation, as it seems associated with falling energy intensity of output and carbon intensity of energy. For instance, both indicators fell marginally from about 0.19 kg in 1993 and 0.52 kg in 1993 to 0.15 kg (2014) and 0.47 kg (2016), respectively. However, this may not suggest significant implication of FDI for environmental innovation, which becomes a question of empirical analysis.

The relationship between FDI and energy from combustible renewables and waste appears negative as depicted in Fig. 3. In the face of rising FDI, energy use from combustible renewables and waste followed a declining trend over the past three decades, falling continuously from 45% of total energy consumption in 1990 to 34% in 2016. Thus, the presence of FDI appears to encourage technology or practices that promote the utilization of energy from renewable sources, as well as waste, thereby reducing dependence on solid fuels (woods and waste) from this source. This suggests some levels of investment in renewable energy resource as well as greater access to fossil fuel energy, especially from gas and other petroleum products. However, the decline is sluggish perhaps due to the relatively high cost of these alternatives, and the combustion of renewables and waste still remains high.

3 Literature review

The literature on the link between FDI and innovation is still developing, where studies exist both at country-specific and multi-country levels. This link has been established across South America (Isaac et al. 2018), Middle East and North Africa (Nuruzzaman et al. 2018), Europe (Stiebale and Reize 2011 and Sekuloska 2015) and Asia (Liu and Zou 2008; Zhang 2016; Piperopoulos et al. 2017). The direct influence of FDI on the environment has also attracted a number of empirical investigations with results that are still mixed (Demena and Afesorgbor 2020). Recent development in the literature is the interest in the environmental dimension of innovation where important role is assigned to FDI (Peñasco et al. 2016 and Chen et al. 2017).

On the FDI-innovation nexus, studies have emphasized the increasing role of FDI in innovation activities following the associated knowledge spillover. For the case of China, negative binomial regression estimates of Piperopoulos et al., (2017) showed evidence that outward FDI produced positive impact on innovation during 2001 to 2012, though developed country-bound FDI yielded stronger effect than those directed toward emerging economies. These findings are similar to those reported by Liu and Zou (2008) for the same country where system generalized method of moments (GMM) results revealed that both outward and inward FDI significantly drive firms' decision to engage in product innovation between 1997 and 2004. Moreover, using pooled, random and fixed effect techniques, Cheung and Lin (2004) submitted that FDI has positive spillover effects on patent application in China from 1995 to 2000. Similarly, Zhang (2016) employed system GMM to show that knowledge spillovers from foreign investment contributed significantly to the improvement in the performance of research activities in China during 2004–2012. Also, pooled OLS, and spatial and time period fixed effects of Ning et al., (2016) emphasized the role of innovation environment in the FDI-innovation link. Specifically, their estimates indicated that specialized industrial structures could easily absorb FDI knowledge spillovers within the cities with the capacity to disseminate the knowledge to neighbouring cities. They further found that diversified structures provide suitable environment for local innovation practices.

Furthermore, Lin and Lin (2010) studied the case of Taiwan using both logit and negative binomial regression and showed evidence of the significant increasing effect of inward and outward FDI on the determination to engage in product innovation. Among 10 developing Asian countries, Erdal and Göçer (2015) used fully modified OLS to show that FDI significantly contributes to increase in R&D expenditures, as well as patent applications between 1996 and 2013. These findings are further supported by Sivalogathasan and Wu (2014) who employed OLS, fixed and random effect estimators to examine the case of South Asian countries for the period 2000–2011.

Extending the analysis to the case of Brazil in a structural equation modelling technique, Isaac et al., (2018) found that local innovation is significantly improved where subsidiaries of multinationals are relationally embedded with the external local network. For MENA countries, Nuruzzaman et al., (2018) used negative binomial regression to show that the presence of foreign competition promotes imitative innovation among local firms. Sekuloska (2015) utilized OLS technique where findings reveal significant contribution of FDI to R&D investment among Central European and Baltic countries between 2007 and 2012, whereas weak influence is reported for the case of Western Balkan countries due to the poor sectoral directions of FDI.

In contrast to most of the existing studies, maximum likelihood estimation of Stiebale and Reize (2011) indicated that acquisition of firms by foreign companies produces significant decreasing effect on R&D expenditures on innovation and propensity to perform innovation activities among German firms during 2002–2007. This finding is also evident in GMM estimates of Law et al., (2018) where negative effect of FDI on innovation is reported among 75 developed and developing countries during 1996–2010.

The direct effect of FDI on environmental quality yielded mixed results, and the debate on the validity of pollution haven and pollution halo for developing countries is yet to be resolved. Demena and Afesorgbor (2020) highlight the positive contribution of FDI to a cleaner environment through spillover of green technologies to domestic industries, despite the potential environmental cost due to increased emissions that may undermine the associated economic gains. The findings are consistent with those obtained by Opoku et al., (2021) for 22 Sub-Sahara African countries during the 1995–2014 period. However, Wang et al., (2020) found a deteriorating effect of FDI on environmental quality in a panel of 29 provinces in China 29 provinces 1994 and 2015, supporting the pollution has hypothesis.

Very few empirical studies that consider environmental innovation activities attributed significant role to FDI. This is evident in Chen et al., (2017) where fixed and random effect methods revealed that direct and indirect technology transfer through FDI is a significant driver of eco-innovation in China during 2001–2015. Using seemingly unrelated regression method, Pan et al., (2019) considered a panel data on 30 provinces in China between 2003 and 2016 and reported a significant positive influence of FDI on energy efficiency. For the same country, Pan et al., (2020) employed the spatial Durbin model to show that reverse technology spillovers of OFDI improve carbon productivity during the period 2004–2016. This effect is however found to vary across Chinese regions with strong positive effect in the eastern and economically developed regions. On the contrary, estimates from the spatial econometric model adopted by Xin-gang et al., (2018) revealed that the spillover effect of FDI inhibits the speed at which energy intensity declines between 2005 and 2014. They also found that FDI plays important role in the conditional energy intensity convergence among Chinese 30 provinces. Meanwhile, a U-shaped relationship between FDI and environmental efficiency is indicated by the DEA and regression estimates of Yang and Li (2019) for the 30 provinces during 2007–2016.

Among Spanish firms, bivariate probit model of Peñasco et al., (2016) suggests that international factors, such as FDI, exert modest influence on eco-innovativeness of firms, while public subsidies from international sources do not play significant role. These findings further corroborate Gao and Zhang (2013) where structural equation modelling results for China indicated that local innovation capacity, hence environmental efficiency, is significantly enhanced by foreign investment between 2005 and 2009. However, Awodumi (2020) found evidence of detrimental effect of FDI on environmental efficiency in most West African countries. Few other studies attributed environmental innovation to factors such as tightened pollution targets (Carrion-Flores and Innes 2010), regulatory stringency influence (Ghisetti and Pontoni 2015), innovative public procurement (Ghisetti 2017) and persistent open knowledge search (Mothe and Nguyen-Thi 2016). Jin et al., (2019) reported that parent company cross-border environmental regulation drives environmental innovation behaviour in China through the parent company.

The foregoing reveals that a number of studies exist in the literature on FDI-innovation nexus, while few others which focusses on environmental innovation have limited role provided for FDI, especially in Africa. In particular, while Chen et al., (2017) only controlled for FDI, Peñasco et al., (2016) considered international sources of funding for innovation purposes with no role provided for FDI. Moreover, in Africa, where foreign investment provides the required technology and skill spillover and environmental issues are growing concerns, the link between FDI and environmental innovation is hardly investigated. This study thereby contributes in this regard by providing empirical evidence on this FDI-environmental innovation link among African countries.

4 Theoretical framework and methodology

4.1 Theoretical framework

This study follows the endogenous growth theory where technological progress is incorporated in production processes. In particular, the theory holds that, in addition to primary inputs (labour-L and capital-K), technological progress or knowledge is a key driver of long-run growth of an economy (Stiroh 2001). In the production of environmental innovation output, the theory stresses the importance of efficiency (A) of the production system which is a reflection of knowledge from internal and/or external sources:

$$Y = f(A, L, K) \quad (1)$$

where $A = A(\text{FDI})$

$$Y = f(FDI, L, K) \quad (2)$$

In the innovation production function represented by Eq. 2, FDI is a critical source of external knowledge spillover through which initial knowledge level in the host economy is enhanced toward the production of environmental innovation (Zhang 2016). This is partly in line with the narrow definition of the national system of innovation that relates R&D activity to the production of goods and services that turns science and technology output into economically useful innovations (Scerri 2016). Cheung and Lin (2004) identifies three channels through which FDI influences innovation activities. First, FDI generates knowledge spillovers through learning and imitation of designs of new and improved technologies and products by domestic firms. Further improvement and ability to effectively apply such knowledge lead to the creation of new innovative products through reverse engineering. The second channel relates to the labour market effect with the flow of skilled labour from foreign firm to their domestic counterparts, as workers move from one job or firm to another. This is particularly important where the labour market is vibrant and effective in matching workers with firms that require the specific innovative skills of such worker. The third channel could be traced to the demonstration effect as domestic firms are challenged to be innovative by the presence of foreign firms. The physical presence of foreign investment (and foreign products) threatens the competitiveness and existence of domestic firms in the host countries. This stimulates innovative behaviours among these firms, which is important for the creation of new and improved varieties of products that may not occur prior to the entry of foreign firms.

Horizontal knowledge spillover allows firms within the same industry to benefit from FDI presence, while vertical spillover flows to local suppliers through technology licensing and staff trainings (Cheung and Lin 2004). In developing economies, such spillovers may be deliberate as foreign firms employ workers on contract basis as well as offer scholarships and industrial attachment trainings. In certain instances, foreign firms particularly engage in environmental practices as part of their corporate social responsibility to encourage domestic firms to be environmentally friendly in their activities. Thus, foreign direct investment (FDI) offers least expensive channel of direct and indirect technology transfer and allows intra-industry knowledge spillover to developing countries (Damijan et al. 2003; Chen et al. 2017; Chukwu et al. 2022). However, internal capabilities are generally weak, in these countries (Ning et al. 2016). Consequently, as much as foreign investment is a critical factor in innovative activities, especially where the environment and resource sustainability are integrated elements, institutional environment, as well as the levels of initial knowledge, skill of labour and financial market development may alter the intended outcome.

4.2 Model specification and estimation technique

Following from the theoretical framework and consistent with Cheung and Lin (2004) and Zhang (2016), environmental innovation depends on FDI, as well as labour (L), capital (K) such that:

$$EI_{it} = f(L_{it}, K_{it}, FDI_{it}) \tag{3}$$

The role of per capita income in the production of innovation has been emphasized in the literature (Cheung and Lin 2004; Zhang 2016; Chen et al. 2017 and Law et al. 2018). In the developing country context such as sub-Saharan Africa, per capita income reflects the ability to innovate and the potential to move toward the research frontier (Zhang 2016). Besides, it also indicates the capacity to absorb knowledge and spillovers. Environmental innovation could also be influenced by the level of financial development and trade openness (Cheung and Lin 2004; Law et al. 2018 and Ho et al. 2018). In particular, while financial development reflects the ability of domestic financial sector to effectively finance environmental innovation activities, trade openness indicates the exposure of an economy to international competitiveness that could spur innovation behaviour.

Thus, the econometric model is specified thus:

$$EI_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 HCAP_{it} + \beta_3 CAP_{it} + \beta_4 FDEV_{it} + \beta_5 TO_{it} + \beta_6 GDP_{it} + \mu_{it} \tag{4}$$

where FDEV, TO and π are financial development, trade openness and random error, respectively. *CAP* and *HCAP* are physical and human capita, respectively. Human capital is used instead of labour to accommodate the skill in labour in the production of environmental innovation. Country and time are represented by i and t, respectively. The labour market; learning and imitation; and demonstration effects of FDI on environmental innovation are captured through the interaction of employment, human capital development and GDP per capita, respectively, with FDI. The level of employment reflects the ability of the labour market to effectively provide jobs for those actively seeking one that match their skills. Human capital provides the necessary and required skills to effectively learn and imitate environmental innovative practices and methods from foreign investments in production processes, while income per capita largely measures the capacity of domestic firms to invest in research and development that can enhance environmental innovation. The selected counties are further classified based on their relative abundance of natural resources to account for the role of resource abundance in innovation practices as foreign investment may be attracted by the relative abundance of resources which may in turn influence technology transfer for innovation activities.[1] Thus, Eq. 4 is re-specified:

$$\begin{aligned} EI_{it} = \beta_0 &+ \beta_1 FDI_{it} + \beta_2 HCAP_{it} + \beta_3 CAP_{it} \\ &+ \beta_4 FDEV_{it} + \beta_5 TO_{it} + \beta_6 GDP_{it} + \\ &+ \beta_7 RDUMMY_{it} + \beta_8 EFDI_{it} + \beta_9 HFDI_{it} \\ &+ \beta_{10} GFDI_{it} + \beta_{11} RFDI_{it} + \mu_{it} \end{aligned} \tag{5}$$

where RDUMMY is a binary digit representing resource abundance such countries are scored 1 if resource-rich and 0 if resource-poor. The variables *EFDI, HFDI,*

[1] This classification is contained in Table A of the Appendix. Resource-rich countries have total natural resources rents (% of GDP) of at least 5% between 2010 and 2019 (World Bank World Development Indicators 2020). The 5% benchmark is in line with World Bank-IMF, (2014).

GFDI and *RFDI* are the interaction of employment, human capital, GDP per capita and resource abundance with FDI. The indicators of environmental innovation utilized in this study are classified into two categories. First is the renewable energy and waste utilization and the second refers to the resource efficiency outcomes.

Environmental innovation is expected to encourage adoption of production techniques and practices that promote utilization of renewable energy sources and conversion of wastes into energy. Thus, as a measure of renewable energy and waste, the study uses total energy from combustible renewables and waste *(CRW)* in line with Bruno (2018). Further, environmental innovation activities are critical to the efficiency with which energy resources are utilized such that less energy is consumed per unit of output produced or more output is produced per unit of energy consumed. Such efficiency is also reflected in the amount of pollution generated per unit of output and per unit of energy consumed. This study therefore measures energy efficiency outcomes using energy productivity (energy per output—*EINT*), greenhouse gas (GHG) emission intensity (carbon emission per output—*CGDP*) and carbon intensity of energy (carbon emission per energy—*CINT*) following studies such as Ghisetti and Pontoni (2015), Zhang et al., (2017) and Gente and Pattanaro (2019) and Hojnik et al., (2018). Thus, Eq. 5 is re-specified for each of the four dependent variables, with λ_i as the country-specific effect:

$$\begin{aligned} CRW_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 HCAP_{it} + \beta_3 CAP_{it} \\ + \beta_4 FDEV_{it} + \beta_5 TO_{it} + \beta_6 GDP_{it} + \\ + \beta_7 RDUMMY_{it} + \beta_8 EFDI_{it} + \beta_9 HFDI_{it} \\ + \beta_{10} GFDI_{it} + \beta_{11} RFDI_{it} + \lambda_i + \mu_{it} \end{aligned} \tag{6}$$

$$\begin{aligned} CGDP_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 HCAP_{it} + \beta_3 CAP_{it} \\ + \beta_4 FDEV_{it} + \beta_5 TO_{it} + \beta_6 GDP_{it} + \\ + \beta_7 RDUMMY_{it} + \beta_8 EFDI_{it} + \beta_9 HFDI_{it} \\ + \beta_{10} GFDI_{it} + \beta_{11} RFDI_{it} + \lambda_i + \varepsilon_{it} \end{aligned} \tag{7}$$

$$\begin{aligned} CINT_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 HCAP_{it} + \beta_3 CAP_{it} \\ + \beta_4 FDEV_{it} + \beta_5 TO_{it} + \beta_6 GDP_{it} + \\ + \beta_7 RDUMMY_{it} + \beta_8 EFDI_{it} + \beta_9 HFDI_{it} \\ + \beta_{10} GFDI_{it} + \beta_{11} RFDI_{it} + \lambda_i + \gamma_{it} \end{aligned} \tag{8}$$

Table 1 Variables and their measurements. Source: author compilation

Variable	Description	Measurement
Dependent variable (resource utilization indicator)		
CRW	Energy from combustible renewables and waste	Combustible renewables and waste (ratio of total energy)
Dependent variable (resource efficiency outcomes)		
CGDP	Carbon emission intensity of output	CO2 emissions (kg per 2010 US$ of GDP)
EINT	Energy intensity of output (Energy productivity),	Energy use (kg of oil equivalent) per $1,000 GDP (constant 2017 PPP)
CINT	Carbon intensity of energy	CO2 intensity (kg per kg of oil equivalent energy use)
Independent variables		
FDI	Foreign direct investment	Foreign direct investment, net inflows (% of GDP)
FDEV	Financial development	Domestic credit to private sector (ratio of GDP)
GDP	Gross domestic product (income) per capita	GDP per capita (constant 2010 US$)
CAP	Physical capital	Gross fixed capital formation (ratio of GDP)
HCAP	Human capital	School enrolment, primary (gross), gender parity index (GPI)
TO	Trade openness	Trade (ratio of GDP)
EMP	Employment	Employment to population ratio, 15 +, (modelled ILO estimate)
RDUMMY	Resource abundance	Dummy: 1 if resource-rich; 0 otherwise

$$\begin{aligned} EINT_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 HCAP_{it} + \beta_3 CAP_{it} \\ + \beta_4 FDEV_{it} + \beta_5 TO_{it} + \beta_6 GDP_{it} + \\ + \beta_7 RDUMMY_{it} + \beta_8 EFDI_{it} + \beta_9 HFDI_{it} \\ + \beta_{10} GFDI_{it} + \beta_{11} RFDI_{it} + \lambda_i + \pi_{it} \end{aligned} \tag{9}$$

Equations 6–9 are estimated in a step-wise manner using the Seemingly Unrelated Regression (SURE) method. The method is considered due to the possibility of correlation among the error terms as the four measures of environmental innovation are related. Zellner (1962) developed the SURE estimator which accounts for autocorrelations and that allows different dependent variables to have similar or different sets of independent variables. The method estimates the parameter of all equations in a simultaneous fashion, resulting in greater efficiency and reliability of coefficient estimates and standard errors (Keshavarzi et al. 2013). The study also tests for possible endogeneity by estimating a two-stage least square (2SLS) model and conducting relevant tests to obtain key statistics that reveal the presence of endogeneity. In particular, the Durbin and Wu-Hausman tests are conducted with the null hypothesis that variables are exogenous, which when accepted will support the use of SURE, rather than 2SLS or other instrumental variable regression analysis.

4.3 Data and variables description

This study utilizes data that spanned over the period 1990–2019 for 21 African countries classified on the basis of their total natural resources rents (% of GDP), as presented in Table A in Appendix. All data are gathered from the World Bank, World Development Indicators (WDI).[2] The variables utilized in the regression analysis, including measurement, are described in Table 1. All variables are in their natural log form, except FDI (due to the possibility of negative values), which is measured as a percentage of GDP.

5 Empirical results and discussion

5.1 Preliminary analysis

The summary statistics of the different variables are reported in Table 2. The statistics reveal that average foreign direct investment is 0.03% of total GDP with maximum and minimum values of 49% and 3%, respectively. Energy from combustible renewables and waste has a mean of 50.44% of total energy among selected African countries, ranging from 0.03% to 95.36%, while average carbon emission per dollar of output is 0.49 kg with minimum and maximum values of 0.01 kg and 1.55 kg,

[2] Missing values are interpolated using 5-year moving averages. For financial development, domestic credit to private sector by banks (% of GDP) is utilized for Morocco and Namibia due to unavailability of data on domestic credit to private sector (% of GDP).

Table 2 Summary statistics

	CAP	CGDP	CINT	CRW	EINT	EMP	FDEV	FDI	HCAP	TO	GDP
Mean	22.21	2.22	1.66	39.62	169.82	56.93	29.94	2.82	101.03	71.52	2871
Median	21.67	0.39	1.45	40.94	112.43	55.04	18.67	1.58	104.45	65.38	1674
Maximum	93.55	60.06	4.30	93.90	990.08	83.07	160.12	50.00	145.43	165.65	11,949
Minimum	2.00	0.01	0.02	0.01	57.77	30.61	0.49	-8.70	51.25	20.72	200
Std. dev	8.49	8.24	1.06	27.15	133.14	14.61	30.54	5.22	18.13	26.49	2637
Skewness	1.36	5.15	0.33	0.12	2.73	0.14	2.09	4.87	−0.33	0.84	1
Kurtosis	10.98	30.30	1.79	1.77	13.23	1.64	7.51	34.64	3.16	3.43	4
Jarque–Bera	1863.51*	22,353.87*	49.61*	41.01*	3531.61*	50.48*	993.72*	28,768.83*	11.95*	78.61*	254.26*
Observations	630	630	630	630	630	630	630	630	630	630	630

Author's computation: *,**,*** represent significance level at 1%, 5% and 10%, respectively

Table 3 Correlation analysis

	CAP	CGDP	CINT	CRW	EINT	EMP	FDEV	FDI	HCAP	GDP	TO
CAP	1										
CGDP	0.28	1									
CINT	0.04	0.34	1								
CRW	−0.17	−0.37	−0.51	1							
EINT	0.09	0.11	−0.65	0.39	1						
EMP	0.06	−0.34	−0.22	0.18	0.17	1					
FDEV	0.08	0.09	0.17	−0.37	−0.19	0.04	1				
FDI	0.09	0.11	−0.03	−0.16	0.00	0.03	0.21	1			
HCAP	0.22	0.41	0.27	−0.49	−0.17	−0.34	0.26	0.28	1		
GDP	0.05	0.03	0.39	−0.60	−0.59	−0.09	0.55	0.26	0.48	1	
TO	0.30	0.17	0.06	−0.23	−0.11	0.03	0.20	0.26	0.11	0.20	1

Author's computation, *,**,*** represent significance level at 1%, 5% and 10%, respectively

Table 4 Test of cross-sectional dependence. Source: Author computation

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
CAP	1279.14*	51.14*	50.78*	3.72*
CGDP	995.66	37.31*	36.94*	−0.84
CINT	1671.85*	70.31*	69.94*	0.47
CRW	2281.30*	100.04*	99.68*	25.62*
EINT	2324.84*	102.17*	101.81*	0.86
EMP	2373.56*	104.55*	104.18*	1.47
FDEV	1945.15*	83.64*	83.28*	26.37*
FDI	600.05*	18.01*	17.65*	15.49*
GDP	3477.16*	158.40*	158.03*	37.28*
HCAP	1915.89*	82.21*	81.85*	10.59*
TO	1072.54*	41.06*	40.70*	12.54*

* indicates the rejection of null hypothesis of cross-sectional independence (CD test)

respectively. Also, energy intensity of output ranged from 0.05 kg of oil equivalent to 1.20 kg of oil equivalent with an average value of 0.19 kg. Average carbon intensity of energy is 1.64, reaching a maximum of 4.30 kg and minimum value of 0.06. In addition, the mean pe capita income among selected countries stood at about $2,643 ranging from $160 to $11,907. The statistics also show that GDP per capita is the most volatile among the variables, while human capital is the least volatile.

Results of correlation analysis reveal that FDI has negative relationship with all the environmental innovation indicators, but it is positively associated with other explanatory variables as reported in Table 3. It is also observed from the results that the relationship among all the variables ranges from weak to moderate. This

Table 5 Panel unit root test results

Variable	Levin, Lin & Chu t*		Im, Pesaran and Shin W-stat		ADF e Fisher Chi-square		PP e Fisher Chi-square		CIPS		Decision
	Level	First Diff	Level	First Diff	Level	First Diff	Level	First Diff	Level	First Diff	
CAP	−2.05**	−12.23*	−1.50**	−14.31*	53.70***	265.52*	65.14*	423.62*	−2.11***	−5.31*	I(0)
CGDP	−3.19*	−11.16*	−3.53*	−15.32*	91.17*	286.19*	101.58*	572.42*	−2.67*	−5.75*	I(0)
CINT	−3.14*	−13.23*	−2.44*	−16.60*	65.71*	312.38*	98.86*	535.84*	−2.4*	−5.33*	I(0)
CRW	−2.45*	−12.36*	−0.003	−13.28*	34.84	244.58*	37.96	432.69*	−1.88	−5.10*	I(1)
EINT	−2.16*	−9.49*	−0.09	−11.39*	46.44	205.50*	54.88***	427*	−1.75	−5.07*	I(1)
EMP	−1.20	−4.09*	1.07	−5.86*	28.67	110.91*	16.62	171.98*	−0.75	−3.25*	I(1)
FDEV	−3.35*	−21.85*	−2.76*	−15.02*	87.08*	216.63*	63.70*	327.92*	−2.79*	−4.80*	I(0)
FDI	−3.93*	−13.84*	−4.45*	−17.68*	86.68*	336.30*	164.43*	531.48*	−3.85*	−5.65*	I(0)
GDP	−0.18	−5.68*	4.32	−8.17*	16.79	149.64*	15.87	244.38*	−0.94	−4.11*	I(1)
HCAP	−5.57*	−8.84*	−1.79**	−12.84*	66.09*	237.55*	74.59*	393.16*	−2.16**	−4.80*	I(0)
TO	−1.20	−12.77*	−0.86	−13.63*	44.65	252.36*	48.38	467.50*	−2.00	−5.20*	I(1)

Author's computation, *,**,*** represent significance level at 1%, 5% and 10%, respectively

Table 6 Two-stage least square estimates

	Resource utilization	Carbon intensity of output	Carbon intensity of energy	Energy Intensity
FDI	0.0002(0.0003)	−0.001(0.001)	−0.001(0.001)	−0.0003(0.001)
GDP	−0.068(0.017)*	−0.152(0.046)*	0.073(0.073)	−0.730(0.055)*
CAP	0.010(0.015)	−0.023(0.039)	0.019(0.062)	−0.097(0.048)**
HCAP	−0.001(0.006)	0.041(0.016)*	0.011(0.026)	0.049(0.020)*
FDEV	0.009(0.011)	−0.020(0.028)	−0.016(0.045)	−0.014(0.034)
TO	−0.002(0.009)	0.064(0.035)***	0.097(0.055)***	−0.002(0.030)
RDUMMY	0.003(0.001)	0.002(0.004)	−0.005(0.006)	−0.003(0.004)
C	−0.003(0.001)	0.003(0.003)	0.004(0.005)	0.011(0.004)*
Wald	24.67*	17.85*	6.17	195.78*
R − square	0.032	0.021	0.005	0.243
Obs	609	609	609	609
Durbin	2.200	2.287	1.983	0.035
Wu-Hausman	2.175	2.262	1.960	0.034
Min eigenvalue	36.107	60.702	60.702	36.107
Sargan	10.476***	8.283	2.555	2.708
Bassmann	10.432***	8.282	2.515	2.662

Source: Author's computation, *,**,*** represent significance level at 1%, 5% and 10%, respectively

Instruments (CRW): d_gdp cap hcap fdev rdummy l_fdi d_cap d_hcap d_fdev d_to

(CGDP): d_fdi gdp d_to d_fdev l_cap d_rdummy gfdi

(CINT): d_fdi gdp d_to d_fdev l_cap d_rdummy gfdi

(EINT): l_fdi d_cap d_hcap d_fdev d_gdp d_to l_emp

suggests the absence of multicollinearity problem that may question the validity of the estimates.

Substantial regional and macroeconomic linkages exist among African countries, especially through trade and regional integration. Thus, test of cross-sectional dependence is conducted using the Breusch-Pagan LM, Pesaran scaled LM, Bias-corrected scaled LM and Pesaran CD tests. As indicated in Table 4, the results of all cross-sectional dependence tests reject the null hypothesis of no cross-sectional dependence for all variables across the selected African countries. Thus, all of the variables are cross-sectionally correlated; hence, the series are demeaned before they are used in the analysis (Solberger 2011). Thus, the cross-sectionally augmented Im-Pesaran-Shin (CIPS) unit root test is conducted following Pesaran (2007) to account for the presence of cross-sectional dependence. Again, countries' specific effects are accommodated in Eqs. (6) to (9). Four traditional panel unit root tests are also employed to ensure reliable decision on the stationarity property of each series with results reported. The Levin et al. (2002) tests the null hypothesis that each individual time series has unit root against the alternative hypothesis that each time series is stationary. It also allows for parameters that are homogenous. Im et al. (2003) tests the same null

Table 7 Effect of FDI on resource utilization Source: Author's computation, *,**,*** represent significance level at 1%, 5% and 10%, respectively

	Baseline	Labour market effect	Learning and imitation	Demonstration effect	Resource effect	All
FDI	−0.0002(0.0002)	−0.0002(0.0002)	−0.0001(0.0002)	−0.0002(0.0002)	−0.0002(0.001)	−0.00002(0.001)
GDP	−0.066(0.017)*	−0.066(0.019)*	−0.065(0.017)*	−0.066(0.017)*	−0.066(0.017)*	−0.063(0.017)*
CAP	0.009(0.015)	0.008(0.015)	0.009(0.015)	0.008(0.015)	0.009(0.015)	0.007(0.015)
HCAP	0.003(0.006)	0.003(0.006)	−0.001(0.006)	0.003(0.006)	0.003(0.006)	−0.002(0.006)
FDEV	0.012(0.010)	−0.011(0.010)	0.014(0.010)	0.011(0.010)	0.012(0.010)	0.014(0.010)
TO	0.002(0.009)	0.003(0.009)	0.002(0.009)	0.003(0.009)	0.003(0.009)	0.005(0.009)
RDUMMY	0.003(0.001)**	0.003(0.001)**	0.003(0.001)**	0.003(0.001)**	0.003(0.001)	0.003(0.001)*
EFDI		0.004(0.006)				0.002(0.007)
HFDI			−0.003(0.001)*			−0.006(0.002)*
GFDI				0.0002(0.001)		0.003(0.001)*
RFDI					0.00003(0.001)	−0.0002(0.001)
C	−0.003(0.001)*	−0.003(0.001)*	−0.003(0.001)*	−0.003(0.001)*	−0.003(0.001)*	−0.003(0.001)*
R-Sq	0.041	0.041	0.047	0.041	0.041	0.062
Chi-q	26.07**	26.08*	34.89*	25.80*	26.06	39.29*
Obs	609	609	609	609	609	609

Table 8 Effect of FDI on carbon intensity of output

	Baseline	Labour market effect	Learning and imitation	Demonstration effect	Natural resource effect	All
Carbon intensity of output						
FDI	−0.001(0.001)	−0.001(0.001)	−0.001(0.001)***	−0.002(0.001)**	−0.003(0.003)	−0.003(0.003)
GDP	0.036(0.082)	−0.038(0.082)	0.028(0.082)	0.030(0.082)	0.043(0.082)	0.031(0.082)
CAP	0.318(0.072)*	0.315(0.072)*	0.314(0.071)*	0.305(0.071)*	0.315(0.072)*	0.297(0.071)*
HCAP	0.267(0.078)*	0.271(0.028)*	0.295(0.029)*	0.285(0.028)*	0.268(0.028)*	0.306(0.029)*
FDEV	−0.066(0.050)*	−0.067(0.050)	−0.083(0.050)	−0.077(0.050)	−0.060(0.051)	−0.083(0.050)***
TO	0.104(0.043)*	0.106(0.042)*	0.104(0.042)*	0.114(0.042)*	0.103(0.043)*	0.119(0.042)*
RDUMMY	−0.0003(0.007)	−0.001(0.007)	−0.003(0.007)	−0.003(0.007)	−0.0003(0.007)	−0.004(0.007)
EFDI		0.032(0.030)				0.073(0.032)**
HFDI			0.018(0.005)*			0.009(0.007)
GFDI				0.014(0.003)*		0.012(0.005)*
RFDI					0.003(0.003)	0.0004(0.003)
C	−0.0002(0.006)	−0.0002(0.006)	−0.001(0.006)	−0.002(0.006)	−0.0003(0.006)	−0.002(0.006)
R-Sq	0.261	0.217	0.224	0.223	0.217	0.229
Chi-Sq	168.26*	169.39*	186.45*	193.16*	169.14*	200.24*
Obs	609	609	609	609	609	609
Carbon intensity of energy						
FDI	−0.004(0.001)*	−0.005(0.001)*	−0.005(0.001)*	−0.006(0.001)*	0.003(0.005)	0.004(0.005)
GDP	−0.154(−0.129)	−0.150(0.129)	−0.159(0.129)	−0.157(0.128)	−0.0171(129)	−0.173(0.128)
CAP	−0.113(0.117)	−0.118(0.112)	−0.116(0.112)	−0.130(0.112)	−0.105(0112)	−0.135(0.111)
HCAP	0.299(0.044)*	0.306(0.044)*	0.323(0.045)*	0.322(0.044)*	0.296(0.044)*	0.335(0.046)*
FDEV	0.218(0.078)*	0.217(0.078)*	0.204(0.078)*	0.205(0.078)*	0.201(0.079)*	0.175(0.079)**
TO	0.105(0.067)	0.110(0.067)***	0.106(0.067)	0.119(0.066)***	0.106(0.067)	0.134(0.066)**
RDUMMY	−0.004(0.010)	−0.004(0.010)	−0.006(0.010)	−0.007(0.010)	−0.004(0.010)	−0.007(0.010)
EFDI		0.052(0.048)				0.113(0.050)**
HFDI			0.015(0.007)**			−0.005(0.012)

Table 8 (continued)

	Baseline	Labour market effect	Learning and imitation	Demonstration effect	Natural resource effect	All
GFDI				0.018(0.005)*		0.025(0.008)*
RFDI					−0.007(0.005)	−0.011(0.005)**
C	0.004(0.009)	0.004(0.009)	0.003(0.009)	0.001(0.009)	0.004(0.009)	0.001(0.009)
R-Sq	0.107	0.108	0.111	0.116	0.110	0.126
Chi-Sq	74.11*	75.37*	78.57*	87.88*	76.38*	98.00*
Obs	609	609	609	609	609	609

Source: Author's computation, *,**,*** represent significance level at 1%, 5% and 10%, respectively

Table 9 Effect of FDI on energy intensity. Source: Author's computation, *,**,*** represent significance level at 1%, 5% and 10%, respectively

	Baseline	Labour market effect	Learning and imitation	Demonstration effect	Resource effect	All
FDI	−0.0001(0.0005)	0.0005(0.0005)	−0.0002(0.0005)	−0.0001(0.001)	0.001(0.002)	0.001(0.002)
GDP	−0.703(0.054)*	−0.710(0.053)*	−0.706(0.054)*	−0.709(0.054)*	−0.707(0.054)*	−0.716(0.054)*
CAP	−0.100(0.047)**	−0.091(0.047)**	−0.100(0.047)**	−0.100(0.047)**	−0.098(0.047)**	−0.089(0.047)**
HCAP	0.047(0.018)*	0.035(0.018)**	0.048(0.019)*	0.047(0.019)*	0.046(0.018)*	0.030(0.019)
FDEV	−0.011(0.033)	−0.010(0.032)	−0.012(0.033)	−0.012(0.033)	−0.015(0.033)	−0.009(0.033)
TO	−0.005(0.028)	−0.011(0.028)	−0.004(0.028)	−0.004(0.028)	−0.004(0.028)	−0.012(0.028)
RDUMMY	−0.003(0.004)	−0.003(0.004)	−0.003(0.004)	−0.003(0.004)	−0.003(0.004)	−0.002(0.004)
EFDI		−0.081(0.020)*				−0.085(0.004)*
HFDI			0.001(0.003)			−0.003(0.005)
GFDI				0.0001(0.002)		−0.002(0.003)
RFDI					−0.002(0.002)	−0.001(0.002)
C	0.010(0.004)*	0.010(0.004)*	0.010(0.004)*	0.011(0.004)	0.010(0.004)*	0.011(0.004)*
R-Sq	0.243	0.247	0.243	0.243	0.244	0.251
Chi-Sq	189.20*	206.26*	189.87*	191.58*	190.24*	210.91*
Obs	609	609	609	609	609	609

hypothesis but accommodates heterogeneous coefficient (Baltagi (2005). The Fisher type tests (ADF and PP) use different lag lengths in the individual ADF regressions (Baltagi 2005). The results reveal that the series are a combination of variables that are stationary at either levels or first difference, and are used accordingly in regression analysis (Table 5).

5.2 Effect of FDI on environmental innovation

The level of environmental innovation has not been considered a strong factor to influence FDI, especially in developing economies. Rather, FDI has been widely reported to play a critical role in determining how healthy the environment is. Thus, in modelling environmental innovation in Africa, endogeneity is not considered a strong concern given the low level of environmental innovative practices that may not be enough to pull FDI yet (Nnaji and Igbuku 2019). Baseline models are estimated using two-stage least square to probe the possible existence of this problem with results presented in Table 6. The results are less robust compared to SURE method, while the Durbin and Wu-Hausman statistics confirms the absence of endogeneity in the models. Hence, SURE estimates are presented in Tables 7, 8 and 9.

5.2.1 Resource utilization

Results on the effect of FDI on resource utilization are reported in Table 7. In terms of renewable energy resource utilization, results reveal that FDI does not exert a significant effect on total energy from combustible renewables and waste. This result is partly in line with Peñasco et al., (2016) where negligible impact of international factors on eco-innovativeness of firms is found. This may be expected as most foreign investment in Africa, as well as their domestic counterparts, relies on fossil fuel energy, especially petroleum products. Moreover, in most economies in Africa, there appears to be poor regulatory framework and lack of incentives to encourage investment in renewable energy sources and the conversion of waste into energy. The interaction of FDI with each of human capital (negative) and GDP per capita (positive) produced significant effect on resource utilization, suggesting the existence of the learning and imitation, as well as the demonstration effects. In particular, higher incomes tend to increase the effect of FDI on the use of energy from combustible renewables and waste, in spite of the higher capacity of firms to invest in processes and technology that utilize renewables and waste. However, the level of human capital in African countries tends to reduce the influence of FDI on energy from combustible renewables and waste, hence promoting resource utilization.

Results further reveal significant negative effect of income per capita on the consumption of energy from combustible renewables and waste. Thus, 1.0% increase in income per capita led to a fall in the use of this energy by about 0.66% as seen across all the models. This may be plausible as higher income encourages rise in the use of fossil fuels in most African countries as the capacity to finance the consumption of petroleum products, which are largely imported, is enhanced. Again, investment in renewable energy tends to improve, which may reduce reliance on solid fuels such as those from combustibles renewables and waste. However, being resource-rich significantly contributes to high consumption of energy from these sources. No strong evidence of labour market effect of FDI on resource utilization is found. Moreover, trade openness, physical capital and financial development play negligible role in the use of energy from combustible renewables and waste.

5.2.2 Resource efficiency outcome

Resource efficiency outcomes reflect the innovative behaviours and methods that minimize energy use and undesirable outputs in production and consumption processes. Such efficiency is seen in the levels of carbon intensity on output, carbon intensity of energy and energy intensity. Table 8 reports the estimates of the effect of FDI on carbon intensities of output and energy among selected African countries. The baseline estimates do not reveal strong FDI implication for carbon intensity of output, but it has significant reducing effect on carbon intensity of energy. However, with the introduction of relevant channels of influence, FDI significantly contributed to the reduction in carbon emission per dollar of output, as well as per kg of energy use, such that 1.0% increase in FDI led to a reduction in carbon intensity of output ranging from 0.001% to 0.002% and carbon intensity of energy ranging from 0.004% to 0.006%. This is largely in line with most studies that relate FDI to innovation (Sekuloska 2015; Ning et al. 2016 and Sivalogathasan and Wu 2014) and specifically Chen et al., (2017) where FDI is found to promote eco-innovation.

Foreign investments often relocate to developing economies or operate subsidiaries in these countries with superior knowledge that fills a number of gaps. One of such gaps is the technology and innovation gaps which are important for resource efficiency. As much as foreign firms largely utilize non-renewable (petroleum products) energy, they adopt carbon-efficient technologies and contribute significantly to the elimination of greenhouse gas emissions in Africa. Thus, although the presence of FDI may raise the amount of total energy required in production process, associated carbon emission is significantly reduced, reinforced by the natural resource effect. However, the positive coefficients of FDI interaction with each of employment, human capital development and income per capital imply weak labour market, learning and imitation, and demonstration effects which may limit the favourable effect of FDI on resource efficiency. This may reflect the skills gap and the heavy reliance on (and financing of) fossil fuel energy.

Furthermore, trade openness and human capital exert significant positive impact on carbon intensity. For instance, 1.0% improvement in either of these variables raised carbon intensity of output by 0.10% and 0.27%, respectively, in the baseline model, with no significant changes in the coefficients across other models. Similarly, 1.0% improvement in trade openness, human capital and financial development increased carbon intensity of energy by about 0.13%, 0.30% and 0.22%, respectively. This indicates that, in Africa, openness to trade encourages importation of carbon-intensive equipment and products, while the development of the financial sector tends to finance production and consumption activities that increase environmental pollution. These developments tend to hinder the adoption of carbon-reducing technologies, reinforced by the significant positive effect of physical capital on carbon intensity of output with an elasticity of 0.32. Resource abundance and income do not significantly influence both carbon intensities per dollar of output and per energy use, implying that income and natural resource endowment do not necessary give environmental innovation advantage to some countries on the country.

In terms of energy intensity, no effect of FDI is found in all models. The results indicate that FDI does not significantly influence energy productivity in Africa (Table 9). In essence, the rising consumption of fossil fuel for both production and consumption activities in the quest for sustained economic growth is not linked to the presence of foreign investment. This is not consistent with the findings of Pan et al., (2020) where FDI is found to promote energy efficiency. The influence of FDI on energy intensity becomes beneficial through the labour market effect as revealed by the negative coefficient. This implies that robust labour market condition, where employment is effectively matched with the required skills, is key for promoting environmental innovation in the face of high consumption of fossil fuel. However, no significant learning and imitation; demonstration and resource abundance effects are found for energy intensity in Africa.

Furthermore, human capital development had significant positive effect on energy intensity. Thus, 1.0% improvement in human capital led to 0.05% increase in energy intensity, indicating a reduction in energy productivity, while the influence of GDP per capita is significant negative. Thus, higher income (with elasticity of 0.71) may increase the capacity of African economies to invest in energy-saving techniques of production and innovative practices that reduce fossil fuel consumption. Results also show that physical capital may significantly promote the production of innovation activities in the form of resource efficiency outcomes, as 1.0% increase in physical capital reduced energy intensity by about 0.1%. This simply reflects the rising role of energy-efficient technology in production processes as more machines and equipment are employed with high consumption of fossil fuel. The effect of trade openness, financial development and resource abundance on energy intensity is negligible.

6 Conclusion and policy implication

This study investigates the role of FDI in environmental innovation in Africa during 1990–2019. The study employs the endogenous growth theory to specify an environmental innovation production function analysed using the seemingly unrelated regression technique. The study estimates a baseline model, as well as models that investigate the channels of transmission of FDI into environmental innovation.

Findings from this study reveal that FDI inflow promotes environmental innovation practices and techniques that increase resource efficiency outcomes through reduction in carbon emission intensities of output and energy. Estimates also reveal that FDI could not contribute significantly to the utilization of renewable energy and energy productivity, given its insignificant effect on total energy from combustible renewables and waste, and energy intensity. Moreover, the influence of resource abundance on environmental innovation is found to be insignificant. Thus, resource abundance plays negligible role in environmental innovation activities in Africa irrespective of the presence of FDI.

The study finds some evidence of learning and imitation, as well as demonstration, effects of FDI on resource utilization, though the formal effect is detrimental. These effects are also found to worsen resource efficiency outcomes as evidence in the positive influence on carbon intensities of output and energy. Meanwhile, the labour market effect is revealed to promote resource efficiency as indicated by the negative coefficients of the interaction of FDI with employment in the carbon and energy intensity models. Resource abundance encourages the use of energy from combustible renewable and waste, and does not play any significant role in influencing the link between FDI and resource efficiency outcomes. This suggests its limited role in promoting environmental innovation in Africa.

A number of policy implications are derived from the foregoing for sustainable environmental innovation practices in Africa. First, African countries must harness the benefits that FDI brings through technology transfers for the purpose of environmental innovation. Consequently, particular attention must be paid to labour market condition in the quest to improve resource efficiency outcomes, given the strong evidence of labour market effect of FDI. Thus, labour market must be vibrant to allow easy movement and matching of workers between domestic and foreign firms. Second, efforts must be made to increase the capacity to innovate across the continent to strengthen the demonstration effect of FDI in order to promote resource utilization. Third, it is important for African economies to be safe and environmentally attractive to clean foreign investment that can spur environmental innovation.

Appendix

See Table 10.

Table 10 Classification of selected countries by resource abundance. Source: Author, resource-rich countries have total natural resources rents (% of GDP) of at least 5% between 2010 and 2019 (World Bank World Development Indicators 2020). The 5% benchmark is in line with in line with World Bank-IMF (2014)

Resource-rich	Resource-scarce
Congo Rep	Benin
Congo D.R	Kenya
Gabon	Mauritius
Algeria	Morocco
Togo	Senegal
Ghana	Namibia
Mozambique	Botswana
Nigeria	
Cameroon	
Zimbabwe	
South Africa	
Cote d’Ivoire	
Tunisia	
Egypt	

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