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Environmental Entrepreneurship and Eco-Innovation Outputs : A Pathway to Sustainable Development

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ABSTRACT

Ensuring sustainability in the long-run necessitates devoting strategic solutions to the rising environmental problems. Unless nations move to a sustainable growth path characterized by economic development and human development that conserve natural resources better, the increased environmental pollution will have negative effects on population well-being. Sustainability has been seen as an entrepreneurial imperative and policy goal (Washington, 2015). However, some building blocks of theory development regarding this process of structural change remain elusive (Savona and Ciarli, 2019). The substantive for sustainable development in which transition pathways are still lacking (Dosi et al., 2017).

Keywords : Environmental Entrepreneurship, ECO-Innovation, economic development, human development

I. INTRODUCTION

Transition to a sustainable or circular economy is understood as a significant change of course toward more sustainable modes of production and consumption (Markard et al., 2012); this is still a challenge even in the age of "smart growth" (Foray, 2014) and the so-called "industry 4.0" (Schwab, 2017). Transition is dependent on strategy-intensive holistic maneuvers, that is, deliberate, systematic choices that go well beyond new technology (Kanger and Schot, 2018; Schot, 2016; Schot and Kanger, 2018; Velez et al., 2018) Geissdoerfer et al. (2017) defined circular economy as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. Hence, this can be achieved through sustainable production and consumption. Green growth paradigms witness eco-innovation as the leading factor to achieve decoupling; thus, green economy strategies point to the role of eco-innovation as the engine of productivity and employment increases.

Eco-innovation or sustainable or green innovation is any innovations which remedy environmental problems. However, in practice, it is quite difficult to capture and delimit what this entails. Andersen (1999) emphasized the cumulative nature of innovation, the longevity of changing direction in technology, and the 'creative destruction' (Schumpeter, 1911), and then innovation provide sustainability opportunities to environmental entrepreneurs to pursue. Notwithstanding, there is an ongoing problem of how to identify the need for eco-innovation and recognize that sustainability or greening is the economic transformation goal. Johnson and Silveira (2014) highlight the role of government as a political entrepreneur in introducing environmentally innovative technologies. Consequently, the orientation of countries towards sustainable development is seen as an important contribution to sustainable competitiveness, which will enable the generation of wealth without reducing the future capacity to sustain or increase wealth levels (Park et al., 2017; Blagova and Korkova, 2018)

Several researchers proved that eco-innovation influence sustainability achievement. Braungardt et al. (2016) claimed that even though environmental innovations are generally considered an essential element towards a green growth strategy, especially for energy efficiency innovations, the impact on climate can be limited by the so-called rebound effect. They concluded that there is a clear case for ambitious policies to support energy efficiency innovations for the residential sector, which ideally should be complemented by measures to limit the rebound effect. In the green growth strategy, energy efficiency also considers the population's ability to acquire the technologies, and this was not considered in the research. Ding et al. (2016) study whether a relationship exists between green technological change measured as the stock of green patents and both CO2 emissions and emission efficiency and suggested that green technology has not yet played a significant role in promoting environmental protection, although it improved significantly environmental productivity. They added that regional differences do not drive the identified patterns and that the primary evidence is consistent among different areas of the country. The diversity of each country can also be an influential factor in the dynamics of eco-innovation (Aloise and Macke, 2017). Studies aimed at comparing different countries show that the results differ between them. For example, Horbach (2016), comparing 19 countries in Europe, found that the countries of Eastern Europe have a lower (compared to Western Europe) level of environmental development, characterized by a low level of R&D, less environmental awareness among the population, and greater energy intensity in the economy. These studies failed to consider the supply and demand for environmental technologies, the environmental outcomes of eco-innovation.

The gap is clearly shown; this study removes this gap in the literature by examining the complementary role of eco-innovation on sustainable development. The environmental outcomes of eco-innovation are measured by access to clean fuels and technologies in which the rate could likely reduce environmental pollution. Besides, this study considers the interaction between environmental entrepreneurship and economic growth to investigate whether economic development could fulfil the demand for clean technologies. Thus, the high consumption of clean or green products improves energy intensity, reducing environmental pollution.

This research also considers two groups of countries, low-income, and middle-income countries and the aggregated Sub-Saharan Africa countries. The aim of this is to understand how eco-innovation supports sustainable development. Other countries and regions could use this approach to ascertain their sustainability transitions.

Environmental entrepreneurship and Eco-Innovation outputs towards Sustainable Development Path

Given the structural differences between nations, it is expected that eco-innovations and best environmental practices do not spread immediately around the world. Thus, uneven development hampers environmental innovations by less developed countries (Huber, 2008). In this way, Vona and Patriarca (2011) point out that, at certain income levels, economic growth is not harmful to the environment; rather, it allows for progressive reductions in emissions per capita. Therefore, pioneering countries in introducing eco-innovations generally present a high degree of economic development, a highly educated population, and well-developed institutions. Consequently, due to the availability of resources, there is a facilitation of achieving sustainable growth.

Sustainable development refers more directly to genuinely systemic innovation implemented by environmental entrepreneurs, which is green innovation in the transition towards a "clean congruence" (de Jesus et al., 2018). Rather than solely improving resource use, it encourages system redesign (Costantini et al., 2017; Jabbour et al., 2015; Kemp and Never, 2017). On the one hand, it involves the migration to technological eco-innovation, that is, environmentally-sensitive innovation that addresses sustainability concerns and has positive ecological effects (Carrillo-Hermosilla et al., 2009; Colombo et al., 2019; Costantini et al., 2017; Jabbour et al., 2015; Steen and Njøs, 2018). However, sustainable growth also requires the redesign of societal regimes in terms of official and tacit rules, as well as individual and collective behaviours, favouring the emergence of novel business models prominent to eco-innovation (Angelis, 2018; Geissdoerfer et al., 2017; Pieroni et al., 2019). This innovation-based framework extends the "waste core" of circular or sustainable economy reasoning to encompass integrated value creation and resource use. As a result, radical innovations, new business models, and new consumers' behaviours are needed to improve environmental and economic performances, including new jobs and better use of resources.

II. Empirical Model and Methods

2.1 Data

Table 1: List of sampled countries for the whole panel and sub-panels

Panel	Number of Countries	List of countries
Sub-Saharan Africa (SSA)	35 Countries	Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Eswatini, Gabon, Gambia (The), Ghana, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia

Low-Income Countries (LIC)	19 Countries	Benin, Burkina Faso, Burundi, Central African Republic, Chad, Congo Democratic Republic, Gambia (The), Guinea, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Tanzania, Togo, Uganda
Middle-Income Countries (MIC)	16 Countries	Angola, Botswana, Cabo Verde, Cameroon, Congo Republic, Côte d'Ivoire, Eswatini, Gabon, Ghana, Kenya, Mauritius, Namibia, Senegal, South Africa, Sudan, Zambia

Table 2: Variables Measurement and Source

Variables	Description	Data Sources
Environmental Pollution (E.P.)	CO_2 emissions in metric tons as a proxy	**WDI (2019)**
Income per capita (IC)	GDP per capita in US$ constant 2010	**WDI (2019)**
Environmental Entrepreneurship (E.E.)	Renewable energy share (%) as a proxy	**WDI (2019)**
Eco-Innovation inputs (EIN)	Access to clean fuels and technologies for cooking	**WDI (2019)**
Energy Intensity (E.I.)	The ratio of energy use to the GDP at purchasing power parity (MJ/2011 USD PPP)	**WDI (2019)**
Population (POP)	Total population	**WDI (2019)**

2.2 Methodology

We ascertain the role of environmental and eco-innovation outputs on sustainable development in Sub-Sahara Africa by exploring the long-run relationship between eco-innovation and sustainable development and by incorporating the interaction of environmental entrepreneurship and economic growth and eco-innovation outcomes in the Environmental Kuznets Curve. While relying on the literature, the conventional model, which is specified in a panel setting as follows;

$$EP_{it} = \alpha_0 + \alpha_1 IC_{it} + \alpha_2 EE_{it} + \alpha_3 EIN_{it} + \alpha_4 EI_{it} + \alpha_5 POP_{it} + \varepsilon_{it} \quad (1)$$

Considering the literature, we extended the model as follows:

$$EP_{it} = \alpha_0 + \alpha_1 IC_{it} + \alpha_2 (EE * IC)_{it} + \alpha_3 EIN_{it} + \alpha_4 EI_{it} + \alpha_5 POP_{it} + \varepsilon_{it} \quad (2)$$

Where E.P. is a proxy of environmental pollution measured by carbon dioxide emissions, I.C. is the income per capita (GDP); E.E. is environmental entrepreneurship; EIN is eco-innovation; E.I. and POP are energy intensity and population, respectively.

To check the validity of the Environmental Kuznets Curve hypothesis, we estimate and formulate the following non-linear multiple regression equation:

$$EP_{it} = \alpha_0 + \alpha_1 IC_{it} + \alpha_2 IC_{it}^2 + \alpha_2 (EE * IC)_{it} + \alpha_3 EIN_{it} + \alpha_4 EI_{it} + \alpha_5 POP_{it} + \varepsilon_{it} \tag{3}$$

Where I.C. and IC^2 represent income per capital in its level but also quadratic form, meanwhile, EE*IC represents the interaction between environmental entrepreneurship and economic growth; EIN is eco-innovation; E.I. and POP are energy intensity and population, respectively.

To reduce issues of heteroscedasticity, data about each series were converted into natural logarithms. Hence, the log-transform of Equation (3) is therefore expressed as;

$$lnEP_{it} = \alpha_0 + \alpha_1 lnIC_{it} + \alpha_2 lnIC_{it}^2 + \alpha_3 \ln(EE * IC)_{it} + \alpha_4 lnEIN_{it} + \alpha_5 lnEI_{it} + \alpha_6 lnPOP_{it} + \varepsilon_{it} \tag{4}$$

Where i, t, and ε represent the country, period, and the error term, respectively. Also the parameters α_1, …., α_6 Represents environmental pollution long-run elasticity's concerning income per capita, environmental entrepreneurship and economic growth, eco-innovation outputs, energy intensity, and population.

We set this relationship with the logic that when countries reach some levels of development, environmental entrepreneurial activities, and economic growth improve environmental quality problems, eco-innovation outputs promote sustainability through the adoption of clean technologies. Based on the EKC hypothesis expressed in equation 7.4, we expect a positive sign of α_1 but a negative sign of α_2. This depends on the country level of economic development of a country and involvement in clean technologies development.

Considering the ARDL model with fixed lag order, the ARDL model, including the long-run estimates equation, is then formulated as:

$$\begin{aligned} \Delta lnEP_{it} = {} & \alpha_{0i} + \phi_{1i}\big[lnEP_{it-1} - \theta_{1i}(lnIC_{it} + lnIC_{it}^2 + \alpha_3 \ln(EE * IC)_{it} + \alpha_4 lnEIN_{it} + \alpha_5 lnEI_{it} \\ & + \alpha_6 lnPOP_{it})\big] + \sum_{j=0}^{m-1} \lambda_{ij}\, \Delta lnEP_{it-j} + \sum_{j=0}^{m-1} \delta_{ij}\, \Delta lnIC_{it-j} + \sum_{j=0}^{m-1} \delta_{ij}\, \Delta lnIC_{it-j}^2 \\ & + \sum_{j=0}^{m-1} \delta_{ij}\, \Delta \ln\, (EE * IC)_{it-j} + \sum_{j=0}^{m-1} \delta_{ij}\, \Delta lnEIN_{it-j} + \sum_{j=0}^{m-1} \delta_{ij}\, \Delta lnEI_{it-j} + \sum_{j=0}^{m-1} \delta_{ij}\, \Delta lnPOP_{it-j} \\ & + \varepsilon_{it} \end{aligned} \tag{5}$$

Where ϕ is the error correction term measuring the speed of adjustment in the long-run equilibrium while Θ_i is the long-run relationship between environmental pollution and income per capita, environmental entrepreneurship and economic growth; eco-innovation outputs; energy intensity, and population, δ displays short-run estimated parameters. The difference term (∑) represents the fixed lag length, that is, ARDL (1,1,1,1,1,1) provides the quick-run effect of each explanatory variable.

2.3 Descriptive Statistics

The findings from Table 3 shows the summary statistics with a mean and standard deviation of environmental pollution, income per capita, environmental entrepreneurship and economic growth; eco-innovation outputs; energy intensity, and population for selected Sub-Saharan African countries (SSA), low-income countries (LIC) and middle-income countries (MIC) sub-panels. We found that the standard deviation of environmental pollution has high volatility (1.380) in SSA aggregated panel and low in MIC. As for income per capita, SSA has the highest standard deviation (1.069). Environmental entrepreneurship and income growth (EE*IC) have a low standard deviation (0.428) in MIC and high (0.797) in SSA. Eco-innovation, the highest standard deviation (1.699) in the groups, was found in SSA; this could be due to the increased use of clean fuels and technologies. Energy intensity low standard deviation (0.415) is found in LIC, which means there is less energy use for production. In contrast, the population low standard deviation (0.851) is found in the MIC population size is under control, and the country could fulfil the various needs.

In general, for observed variables to be symmetric or normally distributed, the normal value for skewness should be 'zero' and the kurtosis value should be 'three.' As per skewness and kurtosis values reported in Table 3, we noticed that none of the series follows a normal distribution. Notably, the negative skewness values are found for income per capita (I.C.) in LIC and MIC for the population in LIC, MIC, and SSA and for EE*IC in MIC, which means the distributions are highly skewed. The positive values of skewness are found with all the variables in SSA except POP, three variables (E.P., EIN, E.I.) in MIC, and three variables (E.P., EE*IC, E.I.) in LIC, which weakly skewed. This indicates that the series, as mentioned above, are flattering to both the left and the right compared to the normal distribution, so the study observations are spread in both positive and negative sides.

Besides, the kurtosis results show that only POP is approximately mesokurtic (kurtosis value approximately the same as the normal distribution), the value found in MIC; meanwhile, the kurtosis results for EE*IC are leptokurtic (kurtosis value greater than normal distribution), found in LIC and SSA. From the results of skewness and kurtosis, we confirmed that none of those, as mentioned above, series satisfies normality conditions, and we affirm that the variables are not normally distributed. This is, therefore, in line with the values of the Jarque-Bera normality test, which attest that the variables are not normally distributed in LIC and SSA as the p-values of all the series (E.P., I.C., EE*IC, EIN, E.I., and POP) are statistically significant at 1%. Meanwhile, in MIC, only the p-values of EIN is significant, which means almost all the series in MIC are normally distributed. This, therefore, implies that the null hypothesis of the normal distribution of variables is rejected for LIC and MIC but accepted for MIC.

Table 3: Descriptive Statistics

Low-Income Countries (LIC)						
Variables	***lnEP***	***lnIC***	***lnEE*IC***	***lnEIN***	***lnEI***	***lnPOP***
Mean	-0.257	7.613	11.486	2.393	1.614	15.732
Standard Deviation	1.080	0.914	0.740	1.528	0.415	1.468
Minimum	-1.887	5.555	9.826	-1.079	0.721	12.967
Maximum	2.290	9.287	13.702	4.348	2.483	17.815
Skewness	0.634	-0.114	0.610	-0.512	0.153	-0.303
Kurtosis	2.496	2.086	3.822	1.837	2.030	1.623
Probability	0.000	0.012	0.000	0.000	0.006	0.000
Jarque-Bera	18.619	8.877	21.651	24.019	10.344	22.643
No. of countries	16	16	16	16	16	16
Observation	240	240	240	240	240	240

Middle-Income Countries (MIC)						
Variables	***lnEP***	***lnIC***	***lnEE*IC***	***lnEIN***	***lnEI***	***lnPOP***
Mean	-2.319	6.007	10.414	1.174	2.165	16.212
Standard Deviation	0.764	0.470	0.428	1.637	0.598	0.851
Minimum	-4.058	4.732	9.307	-1.897	0.647	14.091
Maximum	-0.487	6.937	11.418	4.532	3.468	18.116
Skewness	0.040	-0.269	-0.023	0.614	0.179	-0.116
Kurtosis	2.696	2.578	2.765	2.449	2.632	2.981
Probability	0.556	0.062	0.712	0.000	0.210	0.727
Jarque-Bera	1.176	5.546	0.679	21.492	3.120	0.638
No. of countries	19	19	19	19	19	19
Observation	285	285	285	285	285	285

Sub-Saharan Africa (SSA)						
Variables	***lnEP***	***lnIC***	***lnEE*IC***	***lnEIN***	***lnEI***	***lnPOP***
Mean	-1.376	6.741	10.904	1.731	1.913	15.992
Standard Deviation	1.380	1.069	0.797	1.699	0.590	1.197
Minimum	-4.058	4.732	9.307	-1.897	0.647	12.967

Maximum	2.290	9.287	13.702	4.532	3.468	18.116
Skewness	0.552	0.629	0.847	0.071	0.478	-0.576
Kurtosis	2.887	2.445	3.901	1.712	2.863	2.541
Probability	0.000	0.000	0.000	0.000	0.000	0.000
Jarque-Bera	26.923	41.348	80.521	36.726	20.412	33.666
No. of countries	35	35	35	35	35	35
Observation	525	525	525	525	525	525

2.4 Preliminary Findings

The preliminary findings of the investigation of the complementary role of environmental entrepreneurship and eco-innovation outputs on sustainable development in Sub-Saharan Africa are depicted by conducting preliminary tests. Thus, the Pesaran cross-sectional dependence test and CIPS and CADF panel unit root tests are carried out.

2.5 Cross-Sectional Dependency

The results of the cross-sectional dependence test, as shown in Table 4, stipulate that under the null hypothesis, there is cross-sectional independence. Thus, the null hypothesis is to be rejected in case the p-value of the test statistic is below the significance level. Based on CD test statistics and their subsequent p-values, the p-values for CD tests of all the series in each of the panel, that is, panel LIC, MIC, and SSA are significant at 1%. Globally, the CD tests statistics indicate rejection of the null hypothesis (H_0) of no cross-sectional dependence.

Thus, it is important to consider cross-sectional dependence before policy formulation because it helps to understand the behaviour of variables among themselves in the sub-panels and Sub-Sahara Africa. Considering cross-sectional dependency among the sub-region LIC, MIC and SSA, second-generation unit root test CIPS and CADF are appropriate as it provides accurate and reliable results for our study.

Table 4 : Cross-sectional Dependence Test

Low-Income Countries (LIC)			Middle-Income Countries (LIC)			Sub-Saharan Africa (SSA)		
Variable	**CD-Test**	**P-value**	**Variable**	**CD-Test**	**P-value**	**Variable**	**CD-Test**	**P-value**
lnEP	20.850	0.000	***lnEP***	9.158	0.000	***lnEP***	30.606	0.000
lnIC	42.764	0.000	***lnIC***	40.594	0.000	***lnIC***	83.875	0.000
lnEE*IC	40.297	0.000	***lnEE*IC***	39.16	0.000	***lnEE*IC***	79.805	0.000
lnEIN	28.697	0.000	***lnEIN***	16.237	0.000	***lnEIN***	46.552	0.000
lnEI	9.082	0.000	***lnEI***	6.848	0.000	***lnEI***	18.094	0.000
lnPOP	50.405	0.000	***lnPOP***	42.16	0.000	***lnPOP***	93.97	0.000

2.6 Unit Root Tests

The CIPS and CADF panel unit root tests are robust tests that assume that variables are non-stationary. Table 5 depicts CIPS and CADF statistics estimated with the trend and constant for the exploitation of hidden features. This is, therefore, strong evidence that environmental pollution, income per capita, environmental entrepreneurship, and economic growth (EE*IC), eco-innovation outputs, and energy intensity have unit roots at levels but not at first difference. The CIPS and CADF unit root test results indicate that E.P., I.C., (EE*IC), EIN, and E.I. among country groups are all integrated in order (I(1)) except Population (POP).

Given that the CIPS and CADF test results show that five variables are integrated, we can estimate the ARDL estimation models. We assume a long run mechanism among environmental pollution, income per capita, environmental entrepreneurship and economic growth, eco-innovation outputs, and energy intensity. Consequently, we can directly carry out the PMG-ARDL estimations.

Table 5 : Panel Unit Root: CIPS and CADF Test

Low-Income Countries (LIC)					
CIPS			**CADF**		
Variable	**Level (Cons/trend)**	**First Diff.**	**Variable**	**Level (Cons/trend)**	**First Diff.**
lnEP	-2.271	-3.219***	***lnEP***	0856	-2.092**
lnIC	-2.837	-3.437***	***lnIC***	-2.987	-3.712***
lnEE*IC	-2.836	-3.410***	***lnEE*IC***	-2.874	-4.133***
lnEIN	-2.589	-3.919***	***lnEIN***	**0.591**	**-3.330*** **
lnEI	-2.539	-3.454***	***lnEI***	-0.160	-3.524***
lnPOP	-1.328	-1.358	***lnPOP***	0.753	-0.633
Middle-Income Countries (LIC)					
CIPS			**CADF**		
Variable	**Level (Cons/trend)**	**First Diff.**	**Variable**	**Level(Cons/trend)**	**First Diff.**
lnEP	-1.737	-3.307***	***lnEP***	2.173	-1.664**
lnIC	-2.497	-2.968***	***lnIC***	-5.681	-5.349***
lnEE*IC	-2.509	-3.140***	***lnEE*IC***	-4.351	-5.351***
lnEIN	-3.477	-4.452***	***lnEIN***	-0.765	-3.561***
lnEI	-1.206	-3.265***	***lnEI***	1.074	-2.046**
lnPOP	-2.355	-1.095	***lnPOP***	-3.193	-3.452***
Sub-Saharan Africa (SSA)					

CIPS			CADF		
Variable	Level (Cons/trend)	First Diff.	Variable	Level (Cons/trend)	First Diff.
lnEP	-2.221	-3.358***	*lnEP*	0.795	-4.314***
lnIC	-2.693	-3.185***	*lnIC*	-3.229	-4.672***
*lnEE*IC*	-2.701	-3.272***	*lnEE*IC*	-2.508	4.903***
lnEIN	-3.186	-4.194***	*lnEIN*	-1.574	-6.818***
lnEI	-2.292	-3.392***	*lnEI*	0.341	4.454***
lnPOP	-1.748	-1.555	*lnPOP*	-0.017	-3.648***

*** indicate 1% significance level

2.7 Empirical Findings

Pooled Mean Group (PMG)

Table 5.6 outlines the results of the PMG estimations for the long run mechanism among environmental pollution (E.P.), income per capita (I.C.), environmental entrepreneurship and economic growth (EE*IC), eco-innovation outputs (EIN), energy intensity, and population (POP) in Sub-Saharan Africa countries (SSA) together with the sub-panels which include, low-income countries (LIC) and middle-income countries (MIC) in SSA.

Findings in Table 6 indicate that the coefficient of the population is positive and statistically significant at 1%; meanwhile, the coefficients of environmental entrepreneurship and economic growth (EE*IC) and eco-innovation outputs are negative and statistically significant at 1%. Also, the coefficient of energy intensity is negative but not statistically significant. This, therefore, implies that a percentage increase in POP triggers environmental pollution in terms of CO_2 emissions to surge by 1.605% within countries in LIC. Contrarily, environmental entrepreneurship and economic growth (EE*IC) and eco-innovation outputs (EIN) were also witnessed to have a negative and palpable effect on environmental pollution with parameter estimates –2.954 and –0.629, respectively, all at a 1% significance level. This, therefore, insinuates that a 1% surge in both EE*IC and EIN will enhance environmental quality in countries within the LIC by –2.954 and –0.629 correspondingly. As well, the estimated effects of both income per capita and its square confirm the existence of the mechanism between income per capita and its emission of carbon in the inverted U-shape conjuncture. This, therefore, surmises that pollution of the environment in low-income countries is associated positively with income per capita but in a negative way with the square of income per capita. Thus, all things being equal, an increase of 1% in the income per capita would cause a 10.471% rise in environmental pollution but, on the other hand, would enhance environmental quality through the decline in CO_2 emissions by 0.621% when squared.

Further, PMG estimations in middle-income countries (MIC) showed that the coefficient of environmental entrepreneurship and economic growth (EE*IC) is negative and statistically significant at 1%. At the same time, the energy intensity and population (POP) is negative but not statistically significant. Besides, the coefficient of income per capita (I.C.) and eco-innovation outputs (EIN) are positive and significant. Thus, a 1% increase in EE*IC triggers environmental pollution to decline by 1.015, whereas a percentage change in the case of income per capita and EIN causes pollution of the environment to increase by 3.230% and 1.510%, respectively. Further, the negative sign of per capita income square confirms the delinking of environmental pollution and a higher level of income per capita in middle-income SSA economies. The results, therefore, affirm the existence of the EKC conjuncture, which states that the pollution of the environment through the emission of CO2 increases with income per capita at initial stages. The pollution, therefore, starts to decline after the stabilization point as the economies in SSA middle-income countries to achieve sustainable development in the sub-panel.

More so, the final PMG estimation outcome from the Sub-Sahara Africa (SSA) aggregated panel depicts that the coefficients of environmental entrepreneurship and economic growth (EE*IC) and eco-innovation outputs (EIN) are found to have substantial negative effects on environmental pollution. Hence, a 1% increase in EE*IC and EIN, reduces environmental pollution by 1.617%, and 0.241% correspondingly. Meanwhile, a 1% rise in energy intensity (E.I.) and population (POP) escalate environmental pollution by 1.461% and 0.784%, respectively ceteris paribus. Likewise, the influence of both incomes per capita and its square also in SSA acceptance of the existence of the EKC hypothesis.

Specifically, from the PMG estimation results across all panels of SSA countries, the study variables, which include environmental pollution, income per capita (I.C.), environmental entrepreneurship and economic growth (EE*IC), eco-innovation outputs (EIN), energy intensity, and population (POP) are strongly significant, corresponding to the adjustment rates of 2.408% (for LIC), 2.184% (for MIC income SSA states) and 2.241% (for SSA countries) respectively. This, therefore, indicate that each variable in the study panels correspondingly responds speedily to deviances in the long-run equilibrium.

Table 6 : PMG-ARDL Long Run Estimations

Low-Income Countries (LIC)			**Middle-Income Countries(MIC)**			**Sub-Saharan Africa (SSA)**		
Dependent Variable: D(lnEP)								
	Coef.	**Prob.**		**Coef.**	**Prob.**		**Coef.**	**Prob.**
lnIC	10.471***	0.000	***lnIC***	3.230***	0.000	***lnIC***	2.593***	0.000
$lnIC^2$	-0.621***	0.000	***$lnIC^2$***	-0.134***	0.000	***$lnIC^2$***	-0.064***	0.000
lnEE*IC	-2.954***	0.000	***lnEE*IC***	-1.015***	0.000	***lnEE*IC***	-1.617***	0.000
lnEIN	-0.629***	0.000	***lnEIN***	1.510***	0.000	***lnEIN***	-0.241***	0.000
lnEI	-0.035	0.849	***lnEI***	-0.053	0.309	***lnEI***	1.461***	0.000
lnPOP	1.605***	0.000	***lnPOP***	-0.088	0.687	***lnPOP***	0.784***	0.000
ECT	**-0.229****	**0.030**	***ECT***	**-0.427****	**0.005**	***ECT***	**-0.292*****	**0.000**

* indicated significant at 10%, ** indicated significant at 5%, *** indicated significant at 1%. environmental pollution (E.P.), income per capita (I.C.), environmental entrepreneurship and economic growth (EE*IC), eco-innovation outputs (EIN), energy intensity and population (POP)

III. DISCUSSION

The main findings from the long-run estimation approach of PMG panel ARDL model suggest that, since the time-series panel data are converted into natural logarithm, the parameter estimates are economically equal to the elasticity of environmental pollution (E.P.) concerning income per capita (I.C.), environmental entrepreneurship and economic growth (EE*IC), eco-innovation outputs (EIN), energy intensity and population (POP). Considering the long-term estimation results, one can deduce that among all country panels, income per capita has a significant positive influence on environmental pollution. In contrast, environmental entrepreneurship shows a negative effect (significant) all at a 1% level.

Given the influence of income per capita on environmental pollution, this implies that when income per capita increases carbon dioxide emissions increase and this is not surprising in the SSA region as the human activities are concentrated in the agriculture sector. It was equally demonstrated by Liu and Xin (2019) that with the expansion of the economy, environmental pollution becomes extensive due to the substantial use of emissions-intensive technologies, chemical fertilizers for economic activities (Chen, Y et al., 2019). Consequently, as income per capita across the population of SSA regions increases, the demands of goods and services escalate. This change in demands influences the use of energy but more importantly, unsustainable or dirty energies, which eventually leads to a rise in environmental pollution. The results of Dogan et al. (2017) showed a significant and positive association between income growth and carbon emissions in the case of Turkey, which is consonant with our findings. On the other hand, results of Isik et al. (2019) in the U.S. states showed a positive relationship between income per capita and CO2 emissions but contrary to our findings was not significant.

Further, one of the key findings is that the interaction between environmental entrepreneurship and economic growth (EE*IC) exerts a negative impact on environmental pollution expansion. This means that income per capita expands with the energy demand, especially for electrification in Sub-Saharan African countries by escalating the share of green products. Consequently, the promotion and implementation of the appropriate environmental or green technologies could cater to the energy demand, as a result, reduce environmental degradation and forms a long-term mechanism for sustainable development (Shuang et al. 2020). These research findings are in contrast with the studies of Nasir Mahmood (2019), who showed that countries and economic growth meet energy demands by rather decreasing the renewable energy share in the total final energy. However, our results revealed that with economic growth, there would be an increase in clean technologies in LIC, MIC, and SSA as the region undergoes an economic transformation. Consequently, the pollution level will decrease in the long-run.

Considering variations that occurred from the PMG estimation results among the country groups (panels), eco-innovation (EIN) was witnessed to enhance environmental quality on other word has a negative influence on environmental pollution in both low-income SSA countries and Sub-Sahara Africa aggregated panel. Whereas, in middle-income SSA nations, the former variable was identified to have a positive liaison with environmental pollution. There is no doubt that the negative mechanism between eco-innovation and environmental pollution in SSA low-income countries precisely infers the net impact of eco-innovation on improving environmental quality. This implies that eco-innovation goes beyond the industrial boundaries and comprises a broader community or population that generates changes in a country by creating a path for sustainable development (Urbaniec M., 2015). Hence, eco-innovation can be seen as innovative practices that provide ecological and economic benefits (Lee C. et al. 2018). Thus, this negative impact of eco-innovation outputs indicates that eco-innovation is a significant driving factor of environmental quality in low-income nations and the SSA countries as a whole. This may happen since countries within SSA low-income countries are likely to enact good environmental initiatives during the transformation of their respective economies, and these results in reducing the production of polluting goods from the manufacturing sectors (Angela, 2018). An alternative possibility may also be caused by the awareness and adoption of innovative products such as solar stove, heater, and boiler, the transition from polluting industries that manufacture emission-intensive products or energy-consuming products such as gas cookers, electric stoves to sustainable industries. In alignment with (Tsai-chi, 2017) view, trade activates the introduction of green environmental development, the transfer of knowledge, and also brings a fresh production emittance. However, the positive and statistically significant coefficient of eco-innovation revealed that in the long-run eco-innovation outputs may reduce environmental pollution; this is inconsonant with Brougrand (2016), who believed that the environmental technologies expansion does not affect the environmental performance and efficiency; this could be due to the difference in some economic, social or political setting such as the level of industrialization among countries in the sub-panel, the environmental regulations promoting clean technologies which could be weak as well.

Further, the findings reveal that energy intensity is negative and statistically significant on environmental pollution in low-income countries (LIC). The results, therefore, suggest that the increase of energy intensity LIC affects carbon dioxide emissions; this is inconsonant with several studies that stated that energy intensity instead increases carbon emissions significantly (Katye, 2016). It should be noted that, during the sustainability transition, economic growth remains strong when there is reduced energy intensity through the efficient performance of clean technologies and increased innovation at a national level. The positive and significant effects of energy intensity on environment degradation reveal that very weak implementation of green initiatives results in continuous deterioration of the environment. This is inconsonant with Shahbaz, M, (2016), who believed in a positive relationship between energy intensity and carbon emissions. However, technological change could decrease emissions level in SSA as a whole.

Also, both low-income countries and the SSA aggregated panels showed a strong and significant positive impact on the population on environmental quality. This implies that a general trend that population growth leads to increased carbon dioxide emission (Liu, 2017). The low-income countries tend to have a high population compared to middle-income countries. The high carbon emissions put forward the incident of poverty that prevails in low-income countries. Thus, while population growth might be a reason for the constant growth trajectory, it has an adverse effect due to the constraints of resources and the environment. This is because economic activities and population growth increase ecological disordering as they downgrade the environment; this follows the findings of Farhadi (2017) (Isik, 2019). However, labour input may boost the adoption of cleaner production technology and then decrease the pollution (Sapkota and Bastola 2017).

The coefficient of income per capita and its square in the sub-panels LIC and MIC and the aggregated panel SSA are positive and negative, respectively ceteris paribus. This, therefore, validates the EKC hypothesis in LIC, MIC, and SSA. Consequently, the findings imply that in most countries in Sub-Saharan Africa, economic development is the primary concern. At the same time, environmental problems are eventually ignored, focusing more on solving the rising demand for products between nations. The increased investment in this regard together with together income growth, leads to an escalation of energy demand, especially fossil fuel energy systems in SSA which consequently deteriorate the environment due to the intensive emissions of carbon dioxide. Considering, findings of Omri et al. (2018), during economic transformation, economic, sectorial value-added helps in the improvement of environmental quality. From this point, when economic activities come with the least environmental unsustainability, the economy is then boosted. These EKC effects emerge due to the involvement in sustainable business practices and technology consumption but also awareness of environmental problems in most countries in the SSA countries. The existence of the EKC is consistent with the findings of Youssef et al. (2018) in 17 Sub-Saharan Africa countries. However, it is contrary to the results of Ozokcu and Ozdemir (2017) who showed no existence of the EKC between economic growth and pollution in 26 OECD and 52 Emerging nations.

IV.CONCLUSION

This study explored the complementarity of environmental entrepreneurship and eco-innovation outputs on sustainable development in 35 selected Sub-Saharan Africa countries between 2000 and 2014. For analysis, the countries were classified into the whole sample as 35 Sub-Saharan Africa countries, 19 low-income countries, and 16 middle-income countries. To investigate the mechanism amid environmental entrepreneurship and eco-innovation outputs on environmental pollution in an EKC framework to ascertain the role of environmental entrepreneurship and eco-innovation outputs on sustainable development in Sub-Saharan Africa.

In the long-run, income per capita, together with its square, are positive and negative, respectively, with environmental pollution, thus, validating the presence of the Environmental Kuznets Curve among all panels used in the study. Besides, the interaction between environmental entrepreneurship outputs and income growth, and eco-innovation as variables of interest is evidenced to improve environmental quality in low-income countries (LIC) and Sub-Saharan Africa (SSA) aggregated panel but not in the middle-income countries sub-panel.

Based on the empirical results, we propose that since the interaction between environmental entrepreneurial output and income growth ensures sustainability in SSA. There is the adoption of eco-innovation outcomes; governments in the SSA should draw and implement feasible and sound sustainability strategies with an emphasis on greening the economy.

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