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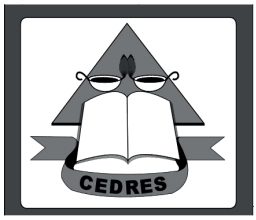

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CO2 emission and economic growth in Sub-Sahara countries : Is there a Kuznets curve?

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Abstract

Worldwide, efforts towards sustainable economic growth are made to conciliate production systems with environmental protection, especially the reduction and/or mitigation of greenhouse gasses (GHG) emissions. The purpose of this study is to find whether there is an environmental Kuznets curve between economic growth and CO_2 emission in sub-Sahara African (SSA) countries for the period (1990 - 2017). The study used Generalized Method of Moment GMM model to determine the relation between CO_2 emission and economic growth for testing the existence of environmental Kuznets Curve following (Grossman & Krueger, (1995); Cole & Rayner, (1997); Bilgili, et al., (2O16) ; Hu, et al., (2O18)) approach. Secondary data (CO_2 emission per purchasing power parity per GDP, GDP per capita; agricultural value added, manufacturing value added per GDP) used in this study were collected from World Bank database. The results showed that there is an inverted U shaped environmental Kuznets curve between CO_2 emission and economic growth in sub-Saharan countries. A GDP threshold of 2 369 477.911 was found. At that point of GDP, the economic growth starts reducing the environmental pollution in SSA countries. In addition, it was found that agriculture sector has positive effect on environment because of its mitigation potential of greenhouse gases emissions. In regard to the findings from this study, it suggested that more investments should support the sustainable agricultural development for the manifold outcomes, including the contributions to increasing countries GDP, the climate mitigation potential, and the achievement of the sustainable development targets in SSA.

Keywords: CO_2 emission; Economic growth, Kuznets Curve, Sub-Saharan Africa

Résumé

A l'échelle globale, les efforts de croissance économique durable visent à concilier les systèmes de production et la protection de l'environnement, particulièrement la réduction et/ou l'atténuation des émissions de gaz à effet de serre (GES). Le but de cette étude est de tester l'existence d'une courbe environnementale de Kuznets entre la croissance économique et les émissions de CO_2 dans les pays d'Afrique subsaharienne (ASS) pour la période (1990 – 2017). L'étude a utilisé un modèle GMM (Méthode des Moments Généralisés) pour déterminer la relation entre les émissions de CO_2 et la croissance économique suivant l'approche de (Grossmanet Krueger, (1995); Cole & Rayner, (1997) ; Bilgili, et al ., (2O16) ; Hu, et al., (2O18)). Des données secondaires (émission CO_2 par unité de PIB, PIB par habitant, valeur ajoutée agricole, valeur ajoutée de production par PIB) ont été collectées de la base de données de la Banque Mondiale. Les résultats montrent qu'il existe une courbe environnementale de Kuznets en forme de U inversée entre les émissions de CO_2 et la croissance économique dans les pays d'Afrique subsaharienne. Un seuil de 2 369 477.911 a été obtenu, valeur de PIB à partir de laquelle la production économique réduit la pollution environnementale dans les pays en ASS. Aussi, les résultats montrent que la valeur ajoutée agricole a un effet négatif sur les émissions de CO_2, signifiant qu'une croissance de la valeur ajoutée agricole réduirait la pollution de l'environnement. Ainsi, il est suggéré que les investissements soutiennent le développement durable du secteur agricole afin de contribuer à une croissance économique soutenue, l'atténuation des émissions de GES et la réalisation des objectifs de développement durable des pays en ASS.

Mots clés : Emission de CO2 ; Croissance économique ; Courbe de Kuznets, Afrique Subsaharienne

1. Introduction

Global warming is claimed to be the main external effect from climate change which is considered as a global public good and a challenge to economies (Nordhaus, 2O19). Why climate change can be considered as a challenge to economies? This is because global warming is now a reality caused mainly by mankind activities and affecting everybody despite the rate of greenhouse gases emissions. The effects of climate change are predicted to be very severe on mankind welfare through various aspects such as health, crop yield, gender or inequalities (Wallace, et al., 2O14)since climate change is considered as a public good this means that its costs or benefits spill outside the market and are not easily captured through market prices. These include positive spillovers like new knowledge and negative spillovers such as pollution. The two key attributes of a public good are "nonrivalry" (i.e. the cost of extending the output to an additional person is zero)and "non-excludability" (i.e. it is impossible to exclude individuals from enjoying it). Hence, the theory of public goods is applied to climate change as well.

Economic growth, as an increase in the production capacity of a country achievement, is always followed by external effects on the environment irrespective of the source of growth. Either industrialization, land cultivation, transportation, or any other sector economic growth is followed by GHG emissions which pollute the environment (Smith & Martino, 2007) and induces a situation in the long term which acts against the wellbeing of individuals (Ward, 2006). Among the GHG emissions, carbon dioxide (CO_2) ones are considered to be indicative of environmental pollution and are mostly used for climate change monitoring. CO_2 is emitted from both natural sources (eruptions of volcanoes, decomposition of organisms, etc.) and human activities (burning fossil fuel, cement production, deforestation and biomass burning, etc.).

The economy of Sub-Sahara countries has shown enormous growth during the last decade (CEA, 2017). Consequently, the energy consumption especially in industrial sector has added pollution to the

environment, in addition to pollution from agricultural sector which mainly contribute to sub-Saharan economic growth. The emission from the agricultural sources is estimated to about 14% of the total GHG emitted (Smith & Martino, 2007). Nevertheless, it is noticed that the agricultural sector is facing great challenges, including vulnerability of farmers due to the lack of or insufficient irrigation system, pesticides, extension services, infrastructures and research funding to adapt and cope with climate change effects. Regarding the industrial sector, the total proportion of industries to GDP is about 25.1%, even if the sector is less developed (Goujon & Kafando, 2012). In this regard, many researchers find it relevant to examine the relationship between environmental pollution and economic growth. Most of the time, the results of these studies are linked to the Environmental Kuznets Curve (EKC); which is considered to be an inverted U-shaped relationship between per capita income and environmental degradation. It was the findings of (Grossman & Krueger, 1991) and (Shafik & Bandyopadhyay, 1992) in the early 1990's through cross-country analysis.

Many factors such as population growth, urbanization, agricultural activities, young industrialization and manufacturing from some emerging countries may contribute to a huge emission of GHG or the development level may also highly contribute to the protection of the environment. The question is now why one will think about the existence of an EKC in Sub-Saharan Africa with low rate of pollution compared to developed or industrialized countries? Numerous studies have been conducted word widely to find the existence of EKC for both developed and developing countries (Adu & Denkyirah, (2O18); Aldy, (2005); Khalid &Wei, (2012)) existence of EKC between economic growth and co_2 emission. Hence, there still room for investigating the possible relation between agricultural value added and environment degradation since the agricultural sector is the main contributor to economic development in sub-Sahara Africa. In addition, the agricultural sector is one of the main sources of CO_2 (up to 14% of the total CO_2 emitted globally of all sectors). This is the basis for exploring the possible existence of EKC between CO_2 emission and economic growth in SSA to

offer policy relevant knowledge to support sustainable development of the region.

The general objective of this paper is to explore the relationship between the GHG, especially CO_2 emission and the economic growth of the Sub-Saharan region. Specifically, it consists of (i) determining the existence of Kuznets curve between CO_2 emission and economic growth for Sub-Saharan countries; (ii) analyzing the impacts of agricultural value added on environment in the Kuznets curve framework.

The remainder of the paper is organized as follow: The first section presents the literature Review while the second section expose the Methodology use in the study and the third section presents the Keys findings and discussion which is followed by conclusion.

2. Literature Review

This section will consist of presenting the theoretical and empirical review around the environmental Kuznets curve. The environmental Kuznets curve is an inverted U-shape relationship between economic growth and environmental degradation. There are others greenhouse gases which can be used to measure environment degradation like CH_4, and N_2O but in this study CO_2 was considered for environmental degradation measurement. Various econometric approaches are used to test such hypothesis like ARDL, VECM, GMM and fixed or random effect findings in the empirical review.

2.1. Environmental Kuznets Curve : What does the theory said?

The theory of public goods, fundamental to environmental economics nowadays, was developed by Samuelson, (1954), the first American Nobel laureate in Economics. This theory applies to climate change since it is considered as a negative externality or “public bad” in the form of greenhouse-gas (GHG) emissions rather than a public good of improved knowledge. However, climate change is a particular thorny externality because it is global. Global externalities, whose impacts are indivisibly spread over the entire world. These global externalities are different from

local or national public goods because they resist the control of both markets and national governments.

Governance is a central issue in dealing with global externalities because effective management requires the concerted action of major countries. This is justified by the theory of Pigou, (1920) who suggested that government can ask firms polluters to pay a tax to address environment issues. His point of view was criticized by Coase, (1960) who thought that paying a tax is not an optimal way of valuing environmental degradation. He suggested that "the agent who is affected by pollution can pay the agent who pollutes in case the cost is less than the impact of pollution on him or He that pollutes can also pay to the other part if the payment is less than the cost of polluting". This is because it helps maximizing the collective or the social benefit which was not obvious in the case of Pigou taxation. In the meantime, Hotelling, (1931) developed another theory in the context of natural resources economics since some extraction activities of these resources can release GHG and contribute to global warming. The author intervenes because of two major reasons: the intervention of the government and the monopoles in the market of extractive resources. According to the author, this market must function into an environment of pure and perfect concurrence. He concluded that the price of the extractive goods must be function of the interest rate rather than the product itself. That will be the optimal way of managing natural resources. Nevertheless, economic growth and development are relevant in achieving environmental protection even ifthere were for long, a traditional view that economic growth and environmental quality are conflicting purpose. Some authors likeBeckerman, (1992) have come with more explanation showing that only high economic growth or development level could ensure good environment quality. He then claims that, "there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best and probably the only way to attain a decent environment in most countries is to become rich''.In the same line, Simon Kuznets has come with a non-linear relationship between environmental degradation and CO_2 emissions which have gain the attention of lot of researchers provoking a large body of theoretical and

empirical literature. An inverted U-shape relationship between economic growth and environmental degradation is described by the EKC meaning that, environmental degradation increases with economic growth, reaches its maximum level and decreases when the economy reaches the given critical high level of income. In this regard, economic activities not only contribute to environmental degradation but also at some levels of economic development are relevant to environment protection. The figure 1 is an illustration of the above explanation.

The environmental Kuznets curve (EKC) is the derived curve from the first Simon Kuznets curve which consists of establishing the relationship between the economic growth and inequalities. Since economics moves from ordinary growth to green growth, it was found necessary to establish a relationship between economic growth and environmental degradation to insure sustainable development. The major ideas around sustainable development consist of taking into account the externalities (Nordaus, 2019; Stern, 2007). This means that some economics activities have either good or bad effects on the environment. Environment itself offers goods and services which are not always marketable (for which there is no price in the market). These goods have features of public goods. Their major characteristics are Non-Rivalry, (meaning that the cost of extending the output to an additional person is zero) and Non excludability (meaning that it is impossible to exclude individuals from enjoying it).

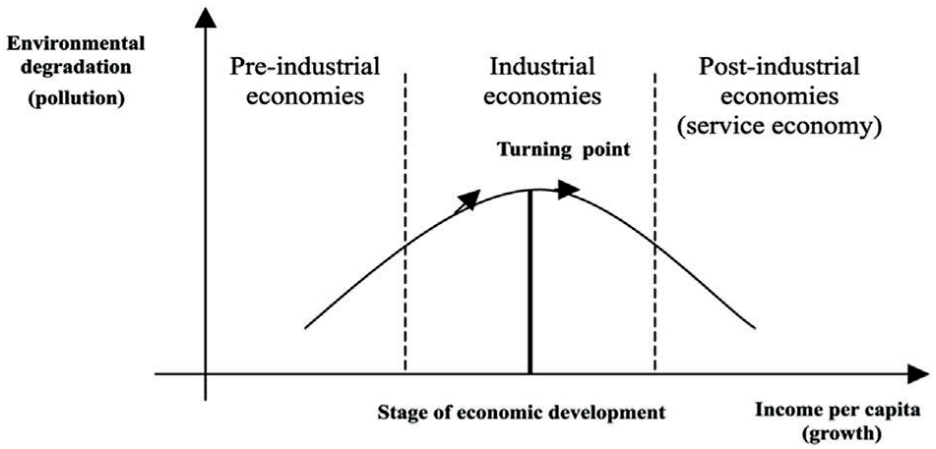

Figure 1: Environmental Kuznets Curve ***(Source: Panatoyou, 1993)***

The EKC concept was introduced in the early 1990s by Grossman and Krueger (1991). The main idea is that as the economic growth is increasing, it is also necessary that environmental quality is maintained or improved (World Commission on Environment and Development, 1987). In fact, as revenue increases, the demand for improvements in environmental quality will rise. Some authors like Beckerman,(1992) have given more explanation to this point of view claiming that, "there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best and probably the only way to attain a decent environment in most countries is to become rich». Thus, the traditional view that economic growth and environmental quality are conflicting purpose depends on the scale effect. Indeed, According to Panatoyou, (1993), the argument of Environmental Kuznets curve is that "at higher levels of development, structural changes towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology, and higher environmental expenditures, result in leveling off and gradual declining of environmental degradation".

2.2. Empirical Background on CO_2 emission and economic growth in a Kuznets curve framework

Many studies have been conducted worldwide, both for developed countries and developing countries, to determine the existence of environmental Kuznets curve between CO_2 emission and economic growth. Some of them confirm the existence of the environmental Kuznets curve while others did not. (Yao, et al., 2O19)build renewable energy consumption rate (RER) index to represent the energy structure of a country and proposes a U-shaped RKC (renewable energy Kuznets Curve) hypothesis between RER and economic growth. They also examined the dynamic relationship between RER and the EKC hypothesis using two panel data sets of 17 major developing and developed countries as well as six geo-economic regions of the world during the period 1990-2014. Panel co-integration tests indicated that a

long-run relationship exists among economic growth, RER and carbon emission. They also employed the fully modified ordinary least squares (FMOLS) and the dynamic ordinary least squares (DOLS) techniques to estimate the co-integration coefficients of the panels and individual countries/regions, respectively. The results verified both the EKC and RKC hypotheses, indicating that a 10% rise in RER would lead to 1.6% carbon emission reduction. It is also found that the RKC turning points of individual countries and the entire samples in general take place before the turning points of the respective EKCs. Yusuf, et al., (2O19) examined the role of technology innovation in testing the environmental Kuznets Curve in Indonesia by taking the annual time series data over the time period 1980-2017. The study used high technology exports as a proxy of technology innovation to examine the long run relationship between economic development, technology innovation and carbon dioxide emission in Indonesia. These authors applied the advance econometrics to serve the purpose of investigation and therefore used the FMOLS and DOLS for assessing the presence of long-run relationship between the variables. Utilizing the framework of Kuznets Curve, the results of FMOLS and DOLS approaches confirm the valid long run relationship between technology innovation and environmental degradation in Indonesia. The empirical results indicated that technology innovation has negative and significant impact on CO_2 emission in the long run. Al-Hussaini, (2O19) investigated the relationship of energy utilization and financial management and expansion in influencing environmental degradation of Kuwait. Their study used time series data from 1981 to 2017 and an ARDL approach. The findings confirm that financial management have a positive outcome on environmental degradation in Kuwait which suggests that the financial management is one of the main sources of increasing environmental degradation in Kuwait over the long run. Likewise, it tends to be discussed that all components including economic growth, energy consumption and financial management assume a noteworthy contributor to worsening the environmental condition in Kuwait and confirm the EKC in the country. Balsalobre-Lorente & Osundina, (2O19), examined the EKC hypothesis for Brazil, Russia, India, China and South Africa (BRICS) over the period 1990–

2014, while considering agricultural activities, energy use, trade openness and mobile use as driving forces of environmental degradation. The methodologies applied for testing the impact of selected independent variables on carbon emissions in BRICS are the DOLS and the FMOLS for long run regression. The results verify an inverted U-shaped connection between carbon emissions and economic growth. These findings confirm the unfriendly impact of agriculture on the environment. Also, Electricityconsumption and trade openness likewise exhibit similar impacts on carbon emissions meaning that the interaction between electricity consumption and agricultural activities has an additional pernicious effect on the environment. (Mikayilov, et al., 2O18) analysed the relationship between the economic growth and CO_2 emissions in Azerbaijan while conducting a co-integration analysis over the period 1992-2013. For getting more robust results, Johansen,ARDLBT, DOLS, FMOLS and CCR methods to explore co-integration and estimate long-run coefficients areemployed. The results from thedifferent co-integration methods are consistent with each other and show that the economic growth has positive and statistically significant impact on the emissions in the long-run implying that the EKC hypothesis does not hold for Azerbaijan. (Song, et al., 2O18) used an input-output model to analysis the link between energy use and GHG Emissions. The outcomes of this study show that the amount of GHG and energy utilization reduces based on future planning inChina and related sectors. Alsan, et al., (2017) examined the validity of inverted U-shaped EKC by investigating the relationship between economic growth and environmental pollution for the period from 1966 to 2013 in USA. Their study uses bootstrap rolling window estimation method to detect the possible changes in causal relations and also obtain the parameters for sub-sample periods. The results show the existence of inverted U-shaped EKC in the USA. Lacheheb, et al., (2015) examined the existence of EKC hypothesis between economic growth and CO_2 emission in Algeria for the period 1971-2009 using autoregressive distributed lag co-integration framework. Data were retrieved from World Bank Development Indicators and findings revealed that EKC hypothesis does not exist. Adu & Denkyirah, (2O17) tested the EKC hypothesis by

analyzing the relationship between economic growthand environmental pollution (carbon dioxide emission, CO_2 and combustible renewable waste, CoWaste) using a panel dataset from 1970 to 2013 for selected West Africancountries with similar income status. The results revealed that economic growth in the short-runsignificantly increases CO_2 emissions and CoWaste but does not significantly decrease CO_2emission and CoWaste in the long-run. The non-significant relationship between economicgrowth and environmental pollution indicates the non-existence of EKC in West Africa. Theresults of the study further revealed a very low turning point at which CO_2 emission and CoWaste start to decrease; however, the non-existence of the EKC implies that the relationshipbetween economic growth and environmental degradation in West Africancountries cannot be explained by an inverted U-shaped curve.

(Zhao, et al., 2O17)analyzed the decoupling impact of economic growth on CO_2 emissions. The outcomes of this study indicated that, energy intensity level and economic activity had the critical influence on all sectors, and industrial sector was the most important factor which affects the decoupling in China. Antonakakis, et al., (2O17) analyzed the dynamic interrelationship basedon output–energy–environment nexus, CO_2 emissions, energy use and economic growth from the period of 1971–2011. The outcomes show that, the effect of the several kinds of energy CO_2 emissions on energy use and economic growth is heterogeneous and there is the bidirectional causal link between total economic growth and energy use. Bekhet & Matar, (2O17) explored the relationship among financialdevelopment, CO_2 emissions, economic growth and energy usebetween 1980 and 2011. The findings revealed that economicgrowth increased CO_2 emissions in some countries like, Qatar,Saudi Arabia, while financial development was the main driver for reduction of energy emissions. He, et al., (2O17)investigated the relationship between CO_2 emissions, affluence, populationand technology. The results revealed that there is U relationshipbetween CO_2 emissions and urbanization in three regions, and CO_2 emissions increase the income**.**Baloch, et al., (2O17)examined the impact of incomeinequality and economic growth on environmental degradation in

Pakistan using ARDL bounds testingapproach for the period 1966–2011. Empirical resultsfor the aggregate CO_2 emissions and its four sourcessuch as CO_2 emissions from solid fuel, liquid fuel andgaseous fuel consumption as well as electricity andheat production confirm the existence of long run co-integratedrelationship between income inequality, economic growth and environment degradation. Theestimated results indicated that carbon emissions increase as the income gap expands in Pakistan. Besides the negative impact of industrial share and population density on CO_2 emissions. Hence, the hypothesis of EKC is not valid for Pakistan during the study period.

(Alam, et al., 2O16) investigated the effect of population growth, income andenergy use on CO_2 emissions. They concludedthat, CO_2 emissions increased with increasing the income and energyuse in four selected countries, and there existed the significant link betweenpopulation growth and CO_2 emissions in India and Brazil and insignificant relationship in China and Indonesia. Chaabouni, et al., (2O16) analyzed the relationship between economic growth, health expenditures and CO_2 emissions from 1995 to 2013. The findings showed that there existed a bidirectional link between health expenditures, economic growth and CO_2 emissions in all selected countries except the low-income group's countries. The EKC confirmed, however, threshold level of income is not achieved; electricity consumption and energy use increase CO_2 emissions, and imports and exports have the positive and negative relationship with CO_2 emissions respectively. Wang, et al., (2016) analyzed the link between energy use and CO_2 emissions, and also impactfactors of energy-related CO_2 emissions from the period of 1995–2011 in China. The outcomes of this study indicated that urbanization level economic level and industry proportion were the main drivers in CO_2 emissions.

(Shahbaz, et al., 2O15) examined the relationship between CO_2 emissions and economic growth and energy intensity over the period of 1980–2012. The outcomes of this article proved that, energy intensity increased CO_2 emissions, also, there is a bidirectional causality relationship between CO_2 emissions and economic growth, and energy

intensity Granger causes CO_2 emissions and economic growth. (Alam, 2O16) explored the relationship between oil consumption, economic growth, internationalization, CO_2 emissions, trade openness and financial development during the time period of 1980–2012. The outcomes of this article demonstrated that, there exists a significant long run relationship between oil consumption, economic growth, internationalization, CO_2 emissions, trade openness and financial development, there existed a bidirectional link between oil consumption, internationalization, economic growth and CO_2 emissions, and oil consumption and economic growth had the significant effect on CO_2 emissions in these countries.

(Khalid & Wei, 2012) investigated the EKC between carbon emission and other four variables (energy consumption, economic growth, trade openness and population) using auto regressive distributed lag (ARDL) methodology for Pakistan from the period of 1971 to 2008. The results do not support EKC in a short-run, whereas the long-run inverted U-shaped hypothesis was confirmed between carbon emission and growth, energy consumption, trade openness and population density. Saboori n, et al., (2012) attempted to establish a long-run as well as causal relationship between economic growth and CO_2 emissions for Malaysia. For the period (1980 - 2009), the EKC hypothesis was tested utilizing the ARDL methodology. The findings suggested the existence of a long-run relationship between per capita CO_2 emissions and real per capita Gross Domestic Product (GDP). An inverted U-shape relationship between CO_2 emissions and GDP was found in both short and long-run.Aldy, (2005) make additional contributions to the EKC literature by using a novel data set self-constructed of state-level. The results based on standard EKC specifications illustrate that per capita CO_2 emissions may follow an inverted U-pattern with respect to per capita income for the USA during the 1960 to 1999 period. Regarding all these findings we can notice few attention is paid to effect of agricultural sector on environment pollution. This study will address the agricultural aspect.

3. Methodology

This section consists of presenting the model used for analysis while justifying its choice and then data sources accompanied with variables descriptive statistic. The GMM is used in the study to avoid all the bias which can appear and related to autocorrelation of errors or endogeinity between CO_2 emission and economic growth: The data used in the study are secondary data from World Bank Database on Sub-Sahara countries spanning the period (1990 – 2017). The analytical model will be first presented followed by data sources and then descriptive statistics.

3.1. The model

This study follows (Grossman & Krueger, (1995); Cole & Rayner, (1997); Bilgili, et al., (2O16); Hu, et al., (2O18)) approach for analyzing the impact of economic growth on environment degradation in sub-Sahara countries using the generalized Method of Moments GMM model.(Grossman & Krueger,(1995); Cole & Rayner, (1997); Bilgili, et al., (2O16) ; Hu, et al., (2O18))approach consists of considering environmental degradation (CO_2 emission) as a function of GDP, GDP^2 and Renewable Energy Consumption. The model is as followed:

$$C = f(GDP, GDP2, RER)$$

This study considers agricultural value added and manufacture of gdp as other variables explaining environmental degradation. The GMM is usually practiced in the setting of semi-parametric models in which the parameter of interest is finite dimensional. We use the lagged differences of variables and the constant for the variables as instruments to control multi-collinearity because the lagged dependent variable creates an endogeneity problem, the other dynamic estimators such as Mean Group and Pooled Mean Group, Maximum likelihood may not give robust and consistent results. For example, time invariant unobserved effects, which are included in the error term, will be correlated with the lagged dependent variable causing a dynamic panel bias. Hence, Arellano Bond's, (1991) GMM technique is suitable for dynamic panels. A GMM estimator is also efficient when T (time) is not too long and N (countries)

is large. To control for the validity of the instrumental variables for the GMM model the Sargan test will be conducted. Indeed, it is a Chi-square test which determines whether the residuals are correlated with the instrumental variables. We conclude that the instruments are valid and thus there is no indication of instrument mis-specification when we cannot reject the null hypothesis of the Sargan test (Arellano & Bond, 1991).

3.2. Empirical evidence for EKC

Various studies have found the empirical evidence for the existence of an EKC. The data used in these studies are panel data. The following equation (1) helps to test the hypothesis:

$$y_{it} = \alpha_i + \theta_t + \beta_1 x_{it} + \beta_2 x_{it}^{\,2} + \beta_3 z_{it} + \varepsilon_{it} \qquad (1)$$

Where: y is CO_2 emission, x is GDP per LCU. Here, the subscript i and t stands for the countries and the time periods, respectively. $\alpha$is constant and$\beta_k$is the coefficient of the polynomials of income variable. The country specific terms capture all fixed factors inherent to each country, which are not considered in the model. The parameter θ_t denotes a time-varying intercept. Z is a vector of variables which can contribute to environmental degradation. This study considers agricultural value added and manufacturing of GDP.

The Generalized Method of Moments is used in this study to estimate our model because it gives robust results while helping facing endogeneity problems. The second equation is then, the GMM equation, which is essentially a dynamic panel equation that accommodates additionally dynamic effects of the dependent variable,

$$y_{it} = \alpha_i + \theta_t + \beta_1 x_{it} + \beta_2 x_{it}^{\,2} + \beta_3 x_{it} + \Phi y_{(it-1)} + \varepsilon_{it} \qquad (2)$$

The econometric models we construct above allow us to test the environmental Kuznets Curve hypothesis. Thus,when b1 > 0 and b2 < 0 signify an inverted U-shaped Relationship between per capita carbon

emission and per capita GDP. The turning point of EKC is defined by $(-\beta_1/2\beta_2)$. The expected sign ofβ_3 is hypothesized be positive because agriculture and manufacturing activities are supposed to increase CO_2 emission.

3.3. Data source

The data uses in this study are secondary data from the World Bank data for 45 sub-Saharan countries from 1990 to 2017 except Somalia. The dependent variable is CO_2 emission kg per purchasing power parity per GDP (CO_2ppgdp); while the explanatory variables are GDP per capita in local currency (gdpcap); agricultural value added of GDP (Vaagric); manufacturing per GDP (manufact). The descriptive statistics of these variables are given in the following section.

Table GG. Input variables and their descriptive Statistics (source: World bank Database)

Variables	Full name	Obs	Mean	Std. Dev.	Min	Max
CO_2ppgdp	co_2 emission per GDP	1096	0.202	0.191	0.007	1.355
Vaagric	agricultural value added of GDP	1030	26.465	16.899	0.891	93.977
gdpcap	GDP per capital in LCU	1188	406861	974056.6	54.111	39.4649
manufact	manufacturing value added per GDP	963	11.233	46.505	11. 087	531.737

4. Key findings and discussion

Regarding the results, we can firstly say that the instruments used in the model are trade of GDP and external balances of good and services. These instruments are valid since the sargan test is significant (See Table 2). Furthermore, we can notice that there is an inverted U shaped EKC between CO_2 emission and economic growth for Sub-Saharan countries. Indeed, while examining first the coefficients of CO_2 emission and GDP per constant LCU, we have $\beta_1 = 1.18e-8 > 0$ $\beta_2 = -2.49e-15 > 0$ which respects an inverted U shaped curve conditions. The same results are found by Alsan, et al., (2017) who tested the existence of an inverted Kuznets curve in USA for the period of 1966 to 2013. Also, Saboori n, et al., (2012) found the existence of an inverted U shaped curve in Malaysia for the period of 1980 to 2009. This result does not confirm the findings of (Adu & Denkyirah, 2O17) who conducted a study in West Africa that there is no EKC. Our finding may be explained by the fact that some of the African countries are making progress and reaching the level of "Country with intermediary Revenue". Examples of these countries are Senegal, Rwanda, Nigeria. The returning point is$(-\beta_1/2\beta_2)$ meaning that at a level of GDP of 2 369 477.911 the pollution level starts decreasing. As for agricultural value added and manufacturing, the sign is negative with the respective coefficients – 0. 002 and -0. 004. From these results we can say that as agricultural activities increases, the amount of CO_2 released a decrease which was not expected in fact but it is still possible because of the rate of adoption of climate smart Agriculture practices which maximizes greenhouse gases sequestration. The variable manufacturing is not significant; we cannot interpret the sign even if it is negative.

Table2. Dynamic panel-data estimation, two-step system GMM for CO_2 emission and GDP per capita (LCU)

Variables	GMM Estimation	
Dep. Variable: co_2pppgdp	Coef.	P>|t|
co_2pppgdp_1	0.966	0.000
gdpcap	0.0011 e-4	0.015
gdpcap2	-0.00024e-11	0.000
vaagric	0.001	0.099
Manufact	0.023	0.760
Cons	0.009	0.428
Arellano-Bond test for AR(1) in first differences	z = -3.11	Pr> z = 0.002
Arellano-Bond test for AR(2) in first differences	z = -0.49	Pr> z = 0.621
Sargan test	chi2(4) = 5.82	Prob> chi2 = 0.758
Observation:	45	

Source: Author calculation from the World Development Data for the period 2010-2017

5. Conclusion

The purpose of this study is to find whether it exists an environmental U shaped relation, first between CO_2 emission and gross domestic product and then the impact of agricultural sector on CO_2 emission of sub-Saharan countries. The World Bank data for 45 Sub-Saharan countries were used for the period 1990-2017. The Generalized Method of Moments (GMM) model was used for environmental Kuznets curve specification. The results showed the existence of an inverted U shaped EKC between economic growth and the CO_2 emissions for sub-Saharan countries. The returning point is $-\beta_1/2\beta_2$ meaning that at a level of GDP of 2369477.911 the pollution level starts decreasing. Also the agricultural sector helps reducing the emission of greenhouse gases in sub-Sahara countries since the sign of the coefficient is negative. Sub-Saharan countries must still make efforts to clean the environment and adapt to climate change effects in their development process because in reality all sub-Sahara African countries are not really clean. More finance must be granted for research and development or Projects implementation in order to encourage environmental protection programs since cleaning the environment is very costly. Besides preventing the environment for global warming is a must since mankind cannot leave aside his environment. There are some limitations to our study. First the study just considers CO_2 as GHG for environmental degradation measurement. Further studies may consider others GHG while drawing the EKC. Secondly the relation between environmental degradation and economic growth can be analyzed using semi parametric tools or spatial analysis tools. These tools can help knowing how CO_2 emitted in the region can affect the emission of others or how the growth level of one country can affect the emission level of other countries.

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