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Climate Changes in Africa: Does Economic Growth Matter? A Semi-parametric Approach

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ABSTRACT

This study attempts to further examine the impacts of income on carbon emissions in the African continent through investigation of the existence of an environmental Kuznets curve (EKC). Within the stochastic impacts by regression on population, affluence and technology framework, this is the first study in Africa to explore the income-carbon emissions nexus; using panel data together with a semi-parametric panel fixed effects regression. Our data set refers to a panel of 54 countries in Africa; spanning the period 1990-2014. Our results show evidence in contrast to the EKC hypothesis. Our findings shed new light on the income - CO_2 emissions nexus and supports implementation of certain policies.

Keywords: Per Capita Income, Carbon Emissions, Stochastic Impacts by Regression on Population Affluence and Technology Environmental Kuznets Curve, African Continent
JEL Classifications: Q01, Q28, Q51, Q52

1. INTRODUCTION

The actual and potential impacts of climate change in Africa are large and wide ranging; affecting many aspects of people daily lives. Majority of the climate models predict negative impacts of climate change on agricultural production and food security in large parts of sub-Saharan Africa (SSA). For example, raising of temperature, drying up of soils, increasing in pest and disease pressure, shifting of suitable areas for growing crops and livestock, increasing desertification in the Sahara region, floods, deforestation, and erosion can all be indicators that climate change has already started and represents one of the greatest environmental, social and economic threats facing Africa (Schneider et al. 2007; Black, 2001). Projections estimate that nearly 30% of people in the region are currently undernourished. However, climate change could increase that level to nearly 90% by 2050 which can be viewed as an awaiting disaster (Africa Agriculture Status Report, 2015). Furthermore, climate change is expected to lead to 2-4% annual loss in gross domestic product (GDP) in Africa by 2040 (Intergovernmental Panel on Climate Change, 2007). For instance, flooding in Mozambique only is estimated to cost the country $550 million and to lower the national GDP by 1.5% in 2000. Meanwhile, and from an agricultural perspective, it is estimated that by 2080, between 9% and 20% of SSAs arable land will become much less suitable for farming.

In the last decades debates on climate change issues in Africa has primarily focused on adaptation rather than mitigation since, historically, Africa's contribution to global greenhouse gas emission (GHG) has been relatively small (Winkler and Zipplies, 2009). While the developed countries are responsible for increase in GHGs, there are various activities in Africa that could contribute to the same increase as well. For instance, deforestation would increase the amount of CO_2 in the atmosphere; because when forests (which act as major carbon store) are cleared and trees are either burnt or rot, the stored carbon is released as CO_2 into the atmosphere (Houghton, 2005; Stern et al., 2006). Other anthropogenic ways through which Africa contributes to increase in GHGs include the release of black carbon (including gas flaring and bush burning), methane from waste (poor waste management), and many other industrial activities (The African Ministerial Conference on the Environment, 2011).

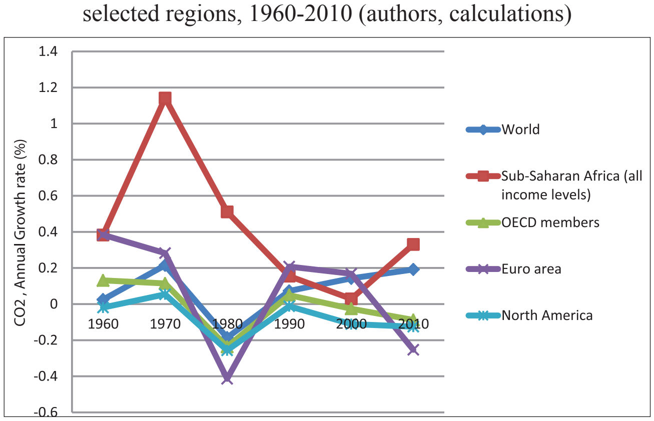
Recent data shows that although SSA countries on average have lower CO_2 emissions compared to some other regions, they have registered a relatively higher CO_2 emissions growth rate. Figure 1 shows CO_2 emissions annual growth rate (%) in SSA and selected regions during the period 1960-2010. From the Figure 1, it is clear that although the growth rate in CO_2 emissions fluctuates over time as well as across all regions, on average SSA registers the highest growth rate. This indicates that the debate should turn to be on how to mitigate the growth in CO_2 emissions rather than adaptation through investigating the key sources of CO_2 emissions.

Theoretical and empirical studies that address the main source of CO_2 emissions have concurred that energy use and/or consumption and economic growth are the key determinants of environmental quality. Economic growth and CO_2 emissions nexus refer to the environmental Kuznets curve (EKC) hypothesis. The EKC hypothesis states that in the early stages of socioeconomic growth, environmental quality deteriorates with the increase of gas emissions. However, as the economy continues growing beyond a certain threshold (the turning point), emissions begin to decline and environmental quality starts to improve; forming an approximately inverted U-shaped curve. Validity of the EKC hypothesis indicates that income versus environmental protection dilemma can be resolved. In the context of developing countries, finding evidence in support of this hypothesis might have promising implications for sustainable development in the future (Wang et al., 2016).

Testing the validity of the EKC hypothesis or exploring the causal links between income and CO_2 emissions is crucial when designing appropriate policy tools for protecting the environment, debating against global warming, and ensuring sustainable economic development. In addition, Narayan and Narayan (2010) state that, examining the relationship between economic growth and environmental quality allows policymakers to judge the response of the environment to economic growth.

Although extant studies have been conducted to examine the validity of the EKC hypothesis, few studies have been devoted to Africa. Most importantly, the findings of these studies, as we can see later, are mixed. In fact, various factors can be used to explain and justify these contradiction findings. However, the lack of appropriate theoretical model that can be used to describe income and environmental quality nexus as well as the relevant estimated method remains one of the key factors behind these inconsistent findings. With regard to the theoretical framework,

Figure 1: CO_2 annual growth rate (%), in sub-Saharan Africas and selected regions, 1960-2010 (authors, calculations)



previous studies frequently employ either *ad-hoc* model or IPAT model (i.e., population, affluence and technology theoretical model) as proposed by Ehrlich and Holdren (1971). However, the IPAT model is considered purely a simple function form; parsimoniously indicating that anthropogenic environmental impact is associated with multiple driving forces. Thus, it cannot - individually - determine the extent to which each factor affects the environment (Zhua et al., 2012; Liddle and Lung, 2010). Concerning the estimation method, most of the preceding studies employ a parametric panel fixed effects technique to estimate the impact of income on CO_2 emissions. However, using this technique usually yields biased estimators as a result of failure to consider relevant explanatory variables and therefore; leads to potential functional form misspecification (Wang et al., 2015).

Given the dilemma of the climate change in Africa, the present study seeks to fill the literature gap concerning the income - CO_2 emissions nexus in the African region in two principal fashions. First, and to avoid the limitations of IPAT mentioned previously, the present study employs the stochastic impacts by regression on population, affluence and technology (STIRPAT) model. According to York et al. (2010) the STIRPAT model could precisely specify the functional form of the relationship between anthropogenic gas emissions and economic growth. Second, and instead of using the parametric fixed panel; a method that is extensively used in the previous studies, we employ the semi-parametric regression developed by Baltagi and Li (2002). According to Wang et al. (2016), the semi-parametric regression is a consistent estimation method for a dynamic partially linear panel data model with fixed effects. In contrast to the parametric panel fixed effects regression, the semi-parametric panel fixed effects regression is more flexible; which enables addressing of the potential functional form misspecification (Desbordes and Verardi, 2012; Wang et al., 2015). Furthermore, it partially avoids dimensionality problems by combining features of parametric and non-parametric techniques. A further advantage of the semi-parametric panel fixed effects regression is the possible inclusion of a concise economic interpretation of the results. To the best of the author's knowledge, this is the first empirical study in the African region to investigate the EKC hypothesis on income and carbon emission nexus; within the STIRPAT model and using panel data together with semi-parametric panel fixed effects regression. The remaining of the paper is organized as follows. Section 2 briefly describes the empirical evidence from the literature. Sections 3 and 4 examine the models, estimation methods and data sources used to test the EKC hypothesis. Empirical results and related discussion are presented in Section 5. The final section; Section 6 includes concluding comments and policy implications.

2. LITERATURE REVIEW ON AFRICA

According to Ozcan (2013), there are three empirical research strands examining the above-mentioned topics in the environmental economics literature. The first strand focuses on the environmental pollutants and income nexus, and seeks to examine the validity of the EKC hypothesis. The first empirical study regarding the EKC is attributed to Grossman and Krueger (1991). Thereafter, numerous researchers have tested the EKC hypothesis and arriving to mixed findings (Agras and Chapman, 1999; Dinda and Coondoo, 2006; Friedl and Getzner, 2003; Galeotti et al., 2009; Selden and Song, 1994; Saboori et al. 2012; Holtz-Eakin and Selden, 1995; Stern, 2004; He and Richard, 2010). The second strand comprises studies exploring the growth -energy nexus. These studies date back to the seminal work of Kraft and Kraft (1978). Then, this has been followed by numerous researchers who have tested the growth - energy nexus and arrived to mixed findings (Belloumi, 2009; Bentzen and Engsted, 1993; Erol and Yu, 1987; Ghosh, 2002; Yu and Hwang, 1984). However, all the studies that tend to employ a bivariate model are criticized due to the omitted variables bias and also because they fail to get consensus results. Nevertheless, to avoid this problem, recent studies have started to examine the nexus of energy consumption and economic growth in a multivariate framework (Gurgul and Lach, 2011; 2012; Al-Mulali and Ozturk, 2015; Ben Jebli et al., 2016; Altinay and Karagol, 2004; Al-Iriani, 2006; Apergis and Payne, 2009; Narayan and Smyth, 2008; Oh and Lee, 2004; Soytas and Sari, 2003; Stern, 2000; Yang, 2000; Ozturk, 2010). However, analyzing the growth - environment nexus and growth - energy nexus in a bivariate framework suffers from omitted-variables bias as stated by Saboori and Soleyman (2011). The third stream of research has emerged as reflected by the fact that today numerous studies have gathered both nexuses in a single framework (Ang, 2007; Soytas et al., 2007; Shahbaz and Lean, 2012; Hamit-Haggar, 2012; Ozturk and Acaravci, 2012; Esteve and Tamarit, 2012; Shahbaz et al., 2012; 2013; Tiwari et al., 2013; Akbostanci et al., 2009; Jalil and Mahmud, 2009; Zhang and Cheng, 2009; He and Richard, 2010; Lean and Smyth, 2010; Narayan and Narayan, 2010). Recently, the above mentioned framework has been extended further by including, for example, the impacts of foreign trade and urban population, and human development into the nexus, in order to avoid omitted variable bias in the econometric estimation (Zhang and Cheng, 2009).

In the present study and to conserve space, we would only review some selected studies related to the African region. However, to our knowledge, there are only few studies that analyze economic growth - CO_2 emissions nexus in Africa. Most importantly, even among these few studies, no consensus exists in regards to the impact of income on carbon emission in the region. So, we classify these studies into country-based studies and panel or cross countries-based studies. Based on country - level analysis, Mhenni (2005) tests for the EKC hypothesis for Tunisia during the period 1980-1997. The author employs the generalized method of moments and examines the following pollutants: CO_2 emissions, fertilizers concentration and the number of cars in traffic which serve to calculate an index for environmental quality. The results show that there is no evidence to confirm the EKC for any of these pollutants. Based on the cointegration analysis, Chebbi et al. (2009) examine the same issue for Tunisia and arrive to different results. More specifically, they detect a positive linkage between trade openness and per capita emissions and a negative linkage between economic growth and per capita pollution emissions in the long-run. Also, Fodha and Zaghdoud (2010) investigate the validity of the EKC hypothesis for Tunisia using two indicators for pollutant emissions (SO_2 and CO_2), during the period 1961-2004. Employing the Johansen approach for cointegration, as well as Granger causality test, the study arrives to evidence in support for EKC hypothesis when CO_2 has been used as a proxy for pollutant emissions. In contrast, a monotonically increasing relationship with GDP is found to be more appropriate for CO_2 emissions. The causality results detects a unidirectional causality with income causing environmental changes and not vice versa; both in the short-run and long-run.

For the south part of the continent, Menyah and Rufael (2010) investigate the long-run and the causal relationship between economic growth, pollutant emissions and energy consumption for South Africa. The data analyze the period between 1965 and 2006 in a multivariate framework which incorporates other variables; such as labor and capital. The authors use the cointegration approach developed by Pesaran et al. (2001) and apply the modified version of the Granger causality test proposed by Toda and Yamamoto (1995). They find a positive and statistically significant relationship between pollutant emissions and economic growth in the short and long runs. The results suggest that South Africa has to forfeit economic growth or lower its energy consumption per unit of output or both to enable it to reduce pollutant emissions. However, in the long-run, some other options might be available. For example, and since South Africa is endowed with adequate sources of renewable energy, it can develop energy substitutes to coal; the main source of CO_2 emissions (Menyah and Rufael, 2010). Likewise, Shahbaz et al. (2013) examine the impacts of financial development, economic growth, coal consumption and trade openness on environmental achievement in South Africa during the period 1965-2008. Their study uses the autoregressive distributed lag (ARDL) bounds testing approach to cointegration to examine the long-run relationship between the variables. Meanwhile, short run dynamics have been analyzed by applying error correction method. Results of the study support long-run link among the variables. Findings show that increase in economic growth raises energy emissions; although financial development lessens it. Furthermore, coal usage has significant negative impact on environmental quality in the country's economy. However, trade openness enhances environmental conditions by decreasing the expansion of energy pollutants. Besides, results prove the presence of EKC (Shahbaz et al., 2013). Meanwhile, Ben Nasr et al., (2015) use data from 1911 to 2010 to include the development process and concept of co-summability[1]; which is created to analyze non-linear long-run relations among perpetual processes. Results of the study does not support the EKC for South Africa for both; the full-sample and the two sub-samples of 1911-1981 and 1982-2010; with the sub-samples decisive by formal tests of structural breaks. That's to say, the study finds that for South Africa to lessen emissions, it will need to forfeit growth. Given the high unemployment, poverty and inequality taking place in the country, this is not regarded as a feasible solution. Therefore, policies intending to promote energy efficiency should be applied to reach a reduction in CO_2 emissions without negatively impacting economic growth (Ben Nasr et al., 2015).

With regard to the panel or cross countries-based studies, Orubu and Omotor (2011) examine the relationship between per capita income and environmental degradation in Africa; using longitudinal data on suspended particulate matter (SPM) and organic water pollutants (OWP). The study aims to estimate EKC for the two indicators of environmental quality and to find if the predicted relationships comply with the inverted U-shaped hypothesis. Results of the empirical study generally suggest that a conventional inverted U-shaped EKC exists for SPM for the African countries included in the study sample. However, regarding OWP, results do not support the existence of the conventional EKC. From a different perspective, Al-Mulali and Sab (2012) investigate the effect of energy consumption and CO_2 emission on GDP and the financial development in 30 SSAs countries using panel data between 1980 and 2008. Findings show that energy[1] consumption has a significant part in increasing both economic growth and the financial development in the studied economies but with the result of high pollution. The study suggest some solutions including; increase in energy productivity by increasing energy efficiency, implementation of energy savings projects, energy conservation. Also, energy infrastructure outsourcing can be regarded as another solution to achieve its financial development and GDP growth and to raise their investment on energy projects to achieve the full energy potential (Al-Mulali and Sab, 2012).

Meanwhile, Kivyiro and Arminen (2014) study the relationship between CO_2 emissions, energy consumption, economic development and foreign direct investment (FDI) in 6 SSAs countries; the Republic of the Congo, the Democratic Republic of the Congo (DRC), Kenya, South Africa, Zambia and Zimbabwe. Based on the ARDL technique, the findings suggest existence of long-run relationship between the variables in all of the countries. The results also support the EKC hypothesis for DRC, Kenya, and Zimbabwe; entailing that there could be an inverted-U-shaped relationship between the level of economic development and environmental deterioration in these countries. Interestingly, these are the countries with the lowest GDP per capita figures in their sample. This suggests that the EKC hypothesis is more likely to hold at low levels of economic development. In addition, FDI shows to increase CO_2 emissions in Kenya and Zimbabwe (which supports the so-called pollution haven hypothesis), while the opposite effect can be observed in DRC and South Africa (which supports the halo effect hypothesis) (Kivyiro and Arminen, 2014).

In another study by Shahbaz et al. (2015), they inspect the dynamic relationship between energy intensity and CO_2 emissions over the period 1980-2012; by incorporating economic growth in the environmental CO_2 emissions function; using data of SSAs countries. Results of their study show that in the long run, the relationship between real GDP per capita and carbon emissions is non-linear; at regional level. This confirms the empirical presence of inverted-U shaped relationship between economic growth and CO_2 emissions. However, the hypothesis is not validated in the short-run for the continent. Nonetheless, in the short and long runs, energy turns up to be a positive and significant factor for the level of emission in the continent (Shahbaz et al., 2015).

The review of the extant studies that examine the African region demonstrates the absence of any consensus in regards to the nature of the relationships between income and carbon emission as described by the EKC hypothesis. The conflicting results of these studies may be attributed to country-specific policies, the use of different energy consumption and income measures, the econometric methodology, omitted variable bias, model specifications or the varying time spans of the studies. However, most importantly, all these studies, however, have weaknesses that this study aims to address. They mainly involve the use of *ad-hoc* model specifications which are not based upon solid theoretical models. As a result, the findings of the present study may prove beneficial and relevant value-added for policy-makers seeking to implement appropriate policies that can maintain environmental quality within the region.

3. THEORETICAL FRAMEWORK AND METHODOLOGY

To address the limitation of IPAT, we employ a stochastic version of IPAT designated STIRPAT; which provides a relative quantitative framework to investigate the environmental impact of income progress (Dietz and Rosa, 1997). The model specification is:

$$I_i = ap_i^b A_i^c T_i^d \varepsilon_i \quad (1)$$

In Equation (1), *I* denotes environmental impact, *P, A,* and *T* stand for population, affluence, and technology factors respectively. Explanatory variable coefficients to be estimated are represented by *a, b, c*, and *d*; *ε* represents random error; and subscript i denotes the panel unit; which refers to 54 African countries in the present study. To test the existence of the EKC, York et al. (2010) incorporate a quadratic term of the per capita GDP factor into the STIRPAT model. Following previous studies, we derive extended versions of the STIRPAT model to test for the presence of an inverse U-shaped curve relationship between per capita GDP and carbon emission. In this model, all variables except urbanization are converted into natural logarithmic form for direct interpretation as elasticities. Accordingly, within the EKC hypothesis framework, the augmented model is estimated as:

$$\begin{aligned} \ln CE_{ti} = {} & \alpha_i + \beta_1 \ln P_{it} + \beta_2 \ln A_{it} + \beta_3 \ln EI_{it} + \beta_4 UR_{it} \\ & + \beta_5 lA_{it}^2 + T_t + \varepsilon_{it} \end{aligned} \quad (2)$$

Where countries are indexed by *i* and time periods by *t*; CE_{it} is the amount of CO_2 emissions of country *i* in year *t*; A is GDP per capita; *P* is the total population; *EI* is energy intensity; *UR* is the level of urbanization; α_i represents a country-specific effect that is constant with time, and a time specific effect T_t may be used to account for time-varying omitted variables and stochastic shocks that are common to all countries. Energy intensity may be interpreted as a proxy for technology level which may damage the environment (Zarzoso et al., 2007), whereas time-specific effect is sometimes interpreted as the effect of technical progress in carbon emission control overtime (Stern, 2002). Meanwhile, Anderson and Cavendish (2001) point out that prior studies paid little attention to

1 The basic idea behind co-summability can be explained as follows: There is no doubt that co-integration theory is an ideal framework to study linear relationships among persistent (non-stationary) economic time series. However, the inherent linearity in the concepts of integration and co-integration makes it unsuitable to study non-linear long-run relations among persistent processes, which is clearly the case when testing the EKC.

the role of technical progress in air pollution abatement. Ignoring this determinant could drastically underestimate possibilities for countries to decrease pollution levels with economic growth.

With regard to urbanization, we follow Wang et al. (2016) and we add urbanization variable as an essential part in the investigation of income - carbon emission nexus. This is because; some possible effects of urbanization on the environmental quality are somewhat and independently debated in three relevant theories. The first is the ecological modernization theory; which claims that environmental problems may rise from low to intermediate stages of development. Nonetheless, extra modernization can reduce such inverse impacts; as societies start to recognize the significance of environmental sustainability. The second is the urban environmental transition theory; where an increase in affluence of cities often leads to an increase in manufacturing activities; leading to massive industrial pollution-related issues as air and water pollution. However, such inverse impacts decrease in affluent cities as a result of advanced environmental regulations, technological progress and structural improvement in the economy. The third is the compact city theory; where high urban density allows cities to accomplish economies of scale of urban public infrastructure, and decrease car usage, travel length, allocation losses of electricity supply, and minimize energy consumption and CO_2 emissions (Burton, 2000; Capello and Camagni, 2000; Newman and Kenworthy, 1989).

Within the aforementioned framework, we first examine the existence of income and carbon emission EKC; using parametric panel fixed effects regression. A more flexible method is used to explore this topic is the semi-parametric panel fixed effects model of Baltagi and Li (2002); which does not place an ex-ante restriction on the shape of the relationship curve between income and carbon emission and can therefore address potential functional form misspecification (Wang et al., 2015). In the present study, the semi-parametric model for testing the relationship between income and carbon emission may be described as:

$$\ln CE_{ti} = \alpha_i + \beta_1 \ln P_{it} + \beta_2 \ln El_{it} + \beta_3 u_{it} + f(lA_{it}) + T_t + \varepsilon_{it} \quad (3)$$

Where the functional form $f(.)$ in the model is unspecified because the income variable is a non-linear input to the model. Unobserved heterogeneous effects can be removed at the first difference:

$$\begin{aligned}\ln CE_{it-1} - \ln CE_{it-1} &= \beta_1(\ln P_{it} - \ln P_{it-1}) + \beta_2(\ln El_{it} - \ln El_{it-1}) \\ &+ \beta_3(U_{it} - U_{it-1}) + [f(lA_{it)} - f(lA_{it-1})] \quad (4) \\ &+ T_t - T_{t-1} + \varepsilon_{it} - \varepsilon_{it-1}\end{aligned}$$

To consistently estimate the first difference model, the following series of differences are derived to respectively estimate $[f(UR_{it})$-$f(URi_{t-1})]$ in line with Baltagi and Li (2002).

$$P^k(lA_{it,}lA_{it-1}) = [P^k(lA_{it}) - P^k(lA_{it-1})] \quad (5)$$

Where $p^k(UR)$ and $p^k(\ln A)$ are the first k terms of a sequence of function ($p^1(UR), p^2(UR),$) and ($p^1(\ln A), p^2(\ln A),$), respectively. In practice, a typical example of p^k series could be a spline; corresponding to piecewise polynomials with pieces depicted by a sequence of smooth knots. Once β coefficients are estimated, the values of unit-specific intercepts α_i can be calculated. Thus, Equation (5) can be reduced to:

$$\hat{u_{it}} = \ln CE_{it} - \hat{\beta_1} \ln P_{it} - \hat{\beta_2} \ln EL_{it} - \hat{\beta_3} U_{it} - \hat{\alpha_i} = f(lA_{it}) + \varepsilon_{it} \quad (6)$$

The curve $f(.)$ can be easily estimated by performing spline regression u_{it} on the UR_{it} variable in Equation (6). We execute a B-spline regression model of order k=4.

4. DATA AND VARIABLES

We investigate whether there is an evidence of a non-monotonic relationship between income and carbon emission; as postulated by the EKC hypothesis, for a balanced panel of 54 African countries and data spanning 1990-2014. All data for the analysis was collected from the World Bank Development indicators. For this dataset, we apply, and for the first time, parametric and semi-parametric panel fixed effects models. All underlying variables with their descriptive statistics are listed in Table 1. It should be noted that all variables except urbanization are converted into natural logarithmic form.

5. RESULTS AND DISCUSSION

Empirical results for per capita GDP - CO_2 emissions nexus are given in Table 2. Column 1 of the table presents results of the parametric fixed effects regression estimator within the per capita GDP - CO_2 emissions EKC hypothesis framework. The findings reveal that the elasticity of CO_2 emission with respect to energy

Table 1: Descriptive statistics of variables

Variables	Definition	Mean	Min	Max
ln*CE*	Carbon dioxide emissions, metric tons per capita	−1.14	−7.45	2.35
ln*A*	GDP per capita (constant 2005 US$)	6.66	4.23	9.66
ln*El*	Energy use (kg of oil equivalent) per $1,000 GDP (constant 2011 PPP)	5.02	1.61	6.87
ln*P*	Population, total	15.67	11.16	19
UR	Urban population (% of total)	38.05	5.42	86.92

GDP: Gross domestic product

Table 2: Estimates for income-CO_2 emissions models

Variables	Parametric model	Semi-parametric model
Constant	−11.19* (1.44)	-
ln*A*	1.41* (0.38)	-
ln*EL*	0.29* (0.06)	0.13* (0.01)
ln*P*	0.03 (0.04)	0.18 (0.87)
UR	−0.007* (0.003)	−0.009** (0.02)
lnA^2	−0.02 (0.02)	-
Country dummies	Yes	Yes
Year dummies	Yes	Yes
Adjusted R^2	0.66	0.66
Obs	648	603

Cluster-robust standard errors in parentheses. Superscripts *denote statistical significance at 1% levels use is highly significant at the 1% level, and its sign is positive. A 1% increase in energy use leads to 0.29% increase in carbon emission. The estimated coefficient for the population variable is statistically insignificant, although its sign is positive as expected. Although the urbanization variable has significant positive impact on CO_2 emissions, this impact is marginal. This finding suggests that growing urbanization in Africa contribute to its mitigation of CO_2. Although the affluence variable has significant negative impact on CO_2 emissions, however, its quadratic term appears statistically insignificant. Findings from the parametric fixed effects model confirm the absence of the income - CO_2 emissions EKC hypothesis. Column 2 presents estimates of control variables in the semi-parametric panel fixed effects model. The controlled variables have identical sign like the parametric fixed.

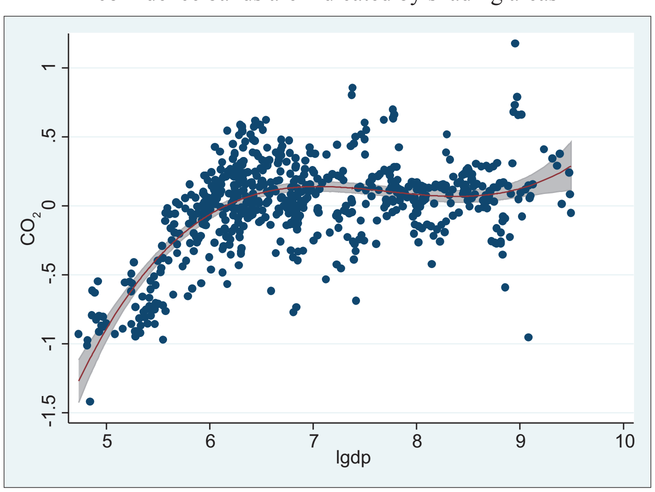
The partial fit for income and CO_2 emissions nexus in the semi-parametric panel fixed effects model is represented in Figure 2. From the plot, it is hard to confirm the existence of an EKC between income and CO_2 emissions in the region. More specifically, CO_2 emissions increase with real GDP, stabilize and again start to increase. Consequently, from the results of the two panel regression methods, we cannot confirm the presence of an EKC between income and CO_2 emissions in African countries.

6. CONCLUSION

This study attempts to further examine the impacts of income on carbon emissions in the African continent through investigation of the existence of an EKC. Within the STIRPAT framework, this is the first study in Africa to explore the income-carbon emissions nexus; using panel data together with a semi-parametric panel fixed effects regression.

Our data set refers to a panel of 54 countries in Africa; spanning the period 1990-2014. From Figure 2, it seems that the region skips or exceeds the turning point, however, no evidence shows a decreasing trend in CO_2 emission after this point. The Figure 2 illustrates that after this point CO_2 emission becomes independent from the process of development. Therefore, the observed growth rate in CO_2 emission in the continent is partly due to energy use and others factors, but not because of growth process. Further studies are required to identify these factors to help policy makers to implement appropriate policies that can maintain environmental quality within the region.

Figure 2: Partial fit of per capita gross domestic product and CO_2 emissions nexus. Points on graph are estimated partial residuals for carbon emission. Maroon curve represents fitted values for adjusted effects of other explanatory variables in the model, and 95% confidence bands are indicated by shading areas



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