



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

Atif Awad^{1*}, Mohammed Hersi Warsame²

¹Department of Finance and Economics, Faculty of Business Administration, University of Sharjah, UAE, ²Department of Finance and Economics, Faculty of Business Administration, University of Sharjah, UAE. *Email: aawoad@sharjah.ac.ae

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 - CO₂ 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 CO₂ 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 CO₂ 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 CO₂ emissions compared to some other regions, they have

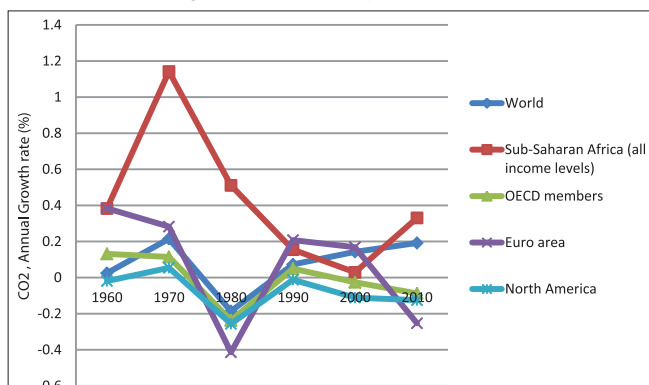
registered a relatively higher CO₂ emissions growth rate. Figure 1 shows CO₂ emissions annual growth rate (%) in SSA and selected regions during the period 1960-2010. From the Figure 1, it is clear that although the growth rate in CO₂ emissions fluctuates over time as well as across all regions, on average SSA registers the highest growth rate. This indicates that the debate should turn to be on how to mitigate the growth in CO₂ emissions rather than adaptation through investigating the key sources of CO₂ emissions.

Theoretical and empirical studies that address the main source of CO₂ emissions have concurred that energy use and/or consumption and economic growth are the key determinants of environmental quality. Economic growth and CO₂ 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 CO₂ 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: CO₂ annual growth rate (%), in sub-Saharan Africa 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 CO₂ 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 - CO₂ 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; Soytaş 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; Soytaş 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 - CO₂ 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: CO₂ 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 Zaghoud (2010) investigate the validity of the EKC hypothesis for Tunisia using two indicators for pollutant emissions (SO₂ and CO₂), 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 CO₂ has been used as a proxy for pollutant emissions. In contrast, a monotonically increasing relationship with GDP is found to be more appropriate for CO₂ 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 CO₂ 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-summability¹; 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 CO₂ 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 CO₂ emission on GDP and the financial development in 30 SSAs countries using panel data between 1980 and 2008. Findings show that energy¹ 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, Kiviyiro and Arminen (2014) study the relationship between CO₂ 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 CO₂ 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) (Kiviyiro and Arminen, 2014).

In another study by Shahbaz et al. (2015), they inspect the dynamic relationship between energy intensity and CO₂ emissions over the period 1980-2012; by incorporating economic growth in the environmental CO₂ 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 CO₂ 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:

$$\ln CE_{it} = \alpha_i + \beta_1 \ln P_{it} + \beta_2 \ln A_{it} + \beta_3 \ln EI_{it} + \beta_4 UR_{it} + \beta_5 A_{it}^2 + T_{it} + \varepsilon_{it} \quad (2)$$

Where countries are indexed by i and time periods by t ; CE_{it} is the amount of CO₂ 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_{it} 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 CO₂ 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:

$$\ln CE_{it} = \alpha_i + \beta_1 \ln P_{it} + \beta_2 \ln EL_{it} + \beta_3 U_{it} + f(LA_{it}) + T_t + \varepsilon_{it} \quad (3)$$

Where the functional form $f(\cdot)$ 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:

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

To consistently estimate the first difference model, the following series of differences are derived to respectively estimate $[f(UR_{it}) - f(UR_{it-1})]$ 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:

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

The curve $f(\cdot)$ 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 - CO₂ 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 - CO₂ emissions EKC hypothesis framework. The findings reveal that the elasticity of CO₂ 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-CO₂ 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)
$\ln A^2$	-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 CO₂ emissions, this impact is marginal. This finding suggests that growing urbanization in Africa contribute to its mitigation of CO₂. Although the affluence variable has significant negative impact on CO₂ emissions, however, its quadratic term appears statistically insignificant. Findings from the parametric fixed effects model confirm the absence of the income - CO₂ 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.

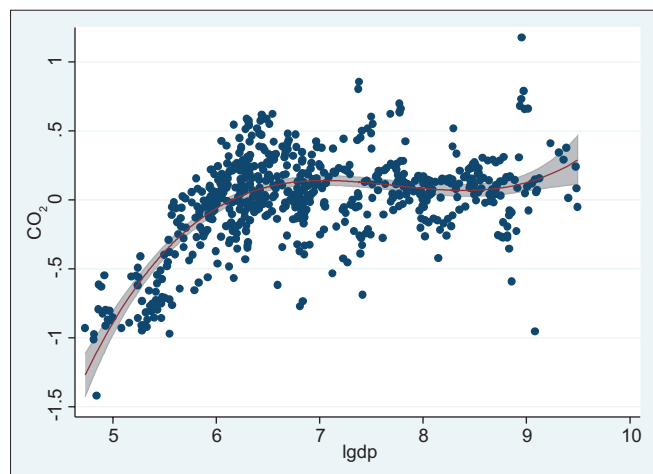
The partial fit for income and CO₂ emissions nexus in the semi-parametric panel fixed effects model is represented in Figure 2. From the plot, it is hard to confirm the existence of an EKC between income and CO₂ emissions in the region. More specifically, CO₂ emissions increase with real GDP, stabilize 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 CO₂ 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 CO₂ emission after this point. The Figure 2

Figure 2: Partial fit of per capita gross domestic product and CO₂ 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



illustrates that after this point CO₂ emission becomes independent from the process of development. Therefore, the observed growth rate in CO₂ 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.

REFERENCES

- Africa Agriculture Status Report. (2015), Youth in Agriculture in Sub-Saharan Africa, Alliance for a Green Revolution in Africa Nairobi, Kenya.
- Agras, J., Chapman, D. (1999), A dynamic approach to the environmental Kuznets curve hypothesis. *Ecological Economics*, 28(2), 267-277.
- Akbostanci, E., Serp, T.A., Tunc, G.I. (2009), The relationship between income and environment in Turkey: Is there an environmental Kuznets curve?. *Energy Policy*, 37, 861-867.
- Al-Iriani, M.A. (2006), Energy-GDP relationship revisited: An example from GCC countries using panel causality. *Energy Policy*, 34(17), 3342-3350.
- Al-Mulali, U., Ozturk, I. (2015), The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA region. *Energy*, 84, 382-389.
- Al-Mulali, U., Sab, C.N.B. (2012), The impact of energy consumption and CO₂ emission on the economic growth and financial development in the Sub Saharan African countries. *Energy*, 39, 180-186.
- Altinay, G., Karagol, E. (2004), Structural break, unit root and causality between energy consumption and GDP in Turkey. *Energy Economics*, 26, 985-994.
- Anderson, D., Cavendish, W. (2001), Dynamic simulation and environmental policy analysis: Beyond comparative statics and the environmental Kuznets curve. *Oxford Economic Paper*, 53, 721-746.
- Ang, J.B. (2007), CO₂ emissions, energy consumption, and output in France. *Energy Policy*, 35(10), 4772-4778.
- Apergis, N., Payne, J.E. (2009), CO₂ emissions, energy usage, and output in Central America. *Energy Policy*, 37, 3282-32826.
- Baltagi, B.H., Li, D. (2002), Series estimation of partially linear panel data models with fixed effects. *Annals of Economics and Finance*, 3, 103-116.
- Belloumi, M. (2009), Energy consumption and GDP in Tunisia: Cointegration and causality analysis. *Energy Policy*, 37, 2745-2753.
- Ben Jebli, M., Youssef, S.B., Ozturk, I. (2016), Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD Countries. *Ecological Indicators*, 60, 824-831.
- Ben Nasr, A., Gupta, R., Ricardo, S. (2015), Is there an environmental Kuznets curve for South Africa? A co-summability approach using a century of data. *Energy Economics*, 52, 136-141.
- Bentzen, J., Engsted, T., (1993), Short-and long-run elasticities in energy demand: A cointegration approach. *Energy Economics*, 15, 9-16.
- Black, R. (2001), Environmental refugees: Myth or reality? *UNHCR Working Papers*, 34, 1-19.
- Burton, E. (2000), The compact city: Just or just compact? A preliminary analysis. *Urban Studies*, 37(11), 1969-2001.
- Capello, R., Camagni, R. (2000), Beyond optimal city size: An evaluation of alternative urban growth patterns. *Urban Studies*, 37(9), 1479-1496.
- Chebbi, H., Olarreaga, M., Zitouna, H. (2009), Trade openness and CO₂ emissions in Tunisia. *ERF 16th Annual Conference*, November 7-9, 2009.

- Desbordes, R., Verardi, V. (2012), Refitting the Kuznets curve. *Economics Letters*, 116(2), 258-261.
- Dietz, T., Rosa, E.A. (1997), Effects of population and affluence on CO₂ emissions. *Proceeding of the National Academy of Science of the USA*, 94, 175-179.
- Dinda, S., Coondoo, D. (2006), Income and emission: A panel data based cointegration analysis. *Ecological Economics*, 57, 167-181.
- Ehrlich, P.R., Holdren, J.P. (1971), Impact of population growth. *Science*, 171, 1212-1233.
- Erol, U., Yu, E.S.H. (1987), Time-series analysis of the causal relationships between US energy and employment. *Resources Energy*, 9, 75-89.
- Esteve, V., Tamarit, C. (2012), Threshold cointegration and nonlinear adjustment between CO₂ and income: The environmental Kuznets curve in Spain, 1857-2007. *Energy Economics*, 34(6), 2148-2156.
- Fodha, M., Zaghoud, O. (2010), Income and environmental degradation in Tunisia: An empirical analysis of the environmental Kuznets curve. *Energy Policy*, 38(2010), 1150-1156.
- Friedl, B., Getzner, M. (2003), Determinants of CO₂ emissions in a small open economy. *Ecological Economics*, 45(1), 133-148.
- Galeotti, M., Manera, M., Lanza, A. (2009), On the robustness of robustness checks of the environmental Kuznets curve hypothesis. *Environmental and Resource Economics*, 42(4), 551-574.
- Ghosh, S. (2002), Electricity consumption and economic growth in India. *Energy Policy*, 30, 9-125.
- Grossman, G.M., Krueger, A.B. (1991), Environmental impacts of a North American Free Trade Agreement. *National Bureau of Economic Research Working Paper 3914*. NBER 1991. Cambridge, MA.
- Gurgul, H., Lach, L. (2011), The role of coal consumption in the economic growth of the Polish economy in transition. *Energy Policy*, 39, 2088-2099.
- Gurgul, H., Lach, L. (2012), The electricity consumption versus economic growth of the Polish economy. *Energy Economics*, 34(2), 500-510.
- Hamit-Haggar, M. (2012), Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. *Energy Economics*, 34(1), 358-364.
- He, J., Richard, P. (2010), Environmental Kuznets curve for CO₂ in Canada. *Ecological Economics*, 69, 1083-1093.
- Holtz-Eakin, D., Selden, T.M. (1995), Stoking the fires? CO₂ emissions and economic growth. *Journal of Public Economics*, 57, 85-101.
- Houghton, R.A. (2005), Aboveground forest biomass and the global carbon balance. *Global Change Biology*, 11, 945-958.
- Intergovernmental Panel on Climate Change. (2007), *The Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.
- Jalil, A., Mahmud, S.F. (2009), Environment Kuznets curve for CO₂ emissions: A cointegration analysis for China. *Energy Policy*, 37(12), 5167-5172.
- Kiviyiro, P., Arminen, H. (2014), Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa. *Energy*, 74, 595-606.
- Kraft, J., Kraft, A. (1978), On the relationship between energy and GNP. *Journal of Energy and Development*, 3, 401-413.
- Lean, H.H., Smyth, R. (2010), CO₂ emissions, electricity consumption and output in ASEAN. *Applied Energy*, 87, 1858-1864.
- Liddle, B., Lung, S. (2010), Age-structure, urbanization, and climate change in developed countries: Revisiting STIRPAT for disaggregated population and consumption-related environmental impacts. *Population and Environment*, 31(5), 317-343.
- Mhenni, H. (2005), Economic development, adjustment and environmental quality: The case of Tunisia for a contingent valuation study. *Mediterranean Journal of Economics, Agriculture and Environment*, 4(2), 36-42.
- Menyah, K., Wolde, R. (2010), Energy consumption, pollutant emissions and economic growth in South Africa. *Energy Economics*, 32(2010), 1374-1382.
- Narayan, P.K., Smyth, R. (2008), Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. *Energy Economics*, 30, 2331-2341.
- Narayan, P.K., Narayan, S. (2010), Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. *Energy Policy*, 38, 661-666.
- Newman, P.W.G., Kenworthy, J.R. (1989), *Cities and Automobile Dependence: An International Sourcebook*. Aldershot: Gower Technical.
- Oh, W., Lee, K. (2004), Causal relationship between energy consumption and GDP: The case of Korea 1970-1999. *Energy Economics*, 26(1), 51-59.
- Orubu, C.O., Omotor, D.G. (2011), Environmental quality and economic growth: Searching for environmental Kuznets curves for air and water pollutants in Africa. *Energy Policy*, 39(7), 4178-4188.
- Ozcan, B. (2013), The nexus between carbon emissions, energy consumption and income in Middle East countries: A panel data analysis. *Energy Policy*, 62(2013), 1138-1147.
- Ozturk, I. (2010), A literature survey on energy-growth nexus. *Energy Policy*, 38(1), 340-349.
- Ozturk, I., Acaravci, A. (2012), The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics*, 36(c), 262-267.
- Pesaran, M.H., Shin, Y., Smith, R.J. (2001), Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16, 289-326.
- Saboori, B., Soleymani, A. (2011), CO₂ emissions, economic growth and energy consumption in Iran: A cointegration approach. *International Journal of Environmental Sciences*, 2(1), 44-53.
- Saboori, B., Sulaiman, J., Mohd, S. (2012), Economic growth and CO₂ emissions in Malaysia: A cointegration analysis of the environmental Kuznets curve. *Energy Policy*, 51, 184-191.
- Schneider, S.H.S., Semenov, A., Patwardhan, I., Burton, C.H.D., Magadza, M., Oppenheimer, A.B., Pittock, A. Rahman, J.B., Suarez, S.A., Yamin, F. (2007), *Assessing key vulnerabilities and the risk from climate change*. In: *Climate Change*. Cambridge, UK: Cambridge University Press. p779-810.
- Selden, T.M., Song, D. (1994), Environmental quality and development: Is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and Management*, 27(2), 147-162.
- Shahbaz, M., Lean, H., Buysed, J., Shahbaz, M. (2012), Environmental Kuznets curve hypothesis in Pakistan: Cointegration and Granger causality. *Renewable and Sustainable Energy Reviews*, 16, 2947-2953.
- Shahbaz, M., Lean, H.H. (2012), Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy Policy*, 47(7), 473-479.
- Shahbaz, M., Ozturk, I., Afza, A., Ali, A. (2013), Revisiting the environmental Kuznets curve in a global economy. *Renewable and Sustainable Energy Reviews*, 25, 494-502.
- Soytas, U., Sari, R., Ewing, B.T. (2007), Energy consumption, income and carbon emissions in the United States. *Ecological Economics*, 62, 482-499.
- Soytas, U., Sari, R. (2003), Energy consumption and GDP: Causality relationship in G7 countries and emerging markets. *Energy Economics*, 25, 33-37.
- Stern, D.I. (2002), Explaining changes in global sulfur emissions: An econometric decomposition approach. *Ecological Economics*, 42, 201-220.
- Stern, D.I. (2004), The rise and fall of the environmental Kuznets curve. *World Development*, 32, 1419-1439.

- Stern, N., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., Crane, D., Cruickshank, S., Dietz, S., Edmonson, N., Garbett, S.L., Hamid, L., Hoffman, G., Ingram, D., Jones, B., Patmore, N., Radcliffe, H., Sathiyarajah, R., Stock, M., Taylor, C., Vernon, T., Wanjie, H., Zenghelis, D. (2006), *Stern Review: The Economics of Climate Change*. London: HM Treasury.
- Stern, D.I. (2000), Multivariate cointegration analysis of the role of energy in the U.S. macro economy. *Energy Economics*, 22, 267-283.
- Tiwari, A.K., Shahbaz, M., Hye, M.Q.A. (2013), The environmental Kuznets curve and the role of coal consumption in India: Cointegration and causality analysis in an open economy. *Renewable and Sustainable Energy Reviews*, 18(3), 519-527.
- Toda, H.Y., Phillips, P.C.B. (1993), Vector auto-regressions and causality. *Econometrica*, 61, 1367-1393.
- Wang, Y., Han, R., Kubota, J. (2016), Is there an environmental Kuznets Curve for SO₂ emissions? A semi-parametric panel data analysis for China. *Renewable and Sustainable Energy Reviews*, 54, 1182-1188.
- Wang, Y., Zhang, X., Kubota, J., Zhu, X., Lu, G. (2015), An empirical study of the environmental Kuznets curve for environmental quality in Gansu province. *Ecological Indicators*, 56, 96-105.
- Winkler, H., Zipplies, R. (2009), Taking on a fair share: The Goliath of Africa's emissions. In: Zipplies, R., editor. *Bending the Curve: Your Guide to Tackling Climate Change in South Africa*. Cape Town: Africa Geographic.
- Yang, H.Y. (2000), A note on the causal relationship between energy and GDP in Taiwan. *Energy Economics*, 22, 309-317.
- York, R., Rosa, E.A., Dietz, T. (2010), Ecological modernization theory: Theoretical and empirical challenges. In: Redclift, M.R., Woodgate, G., editors. *The International Handbook of Environmental Sociology*. 2nd ed. Cheltenham, UK: Edward Elgar. p77.
- Yu, E.S.H., Hwang, B.K. (1984), The relationship between energy and GNP: Further results. *Energy Economics*, 6, 186-190.
- Zarzo, I.M., Morancho, A.B., Lage, R.M. (2007), The impact of population on CO₂ emissions: Evidence from European countries. *Environmental Resource Economics*, 38, 497-512.
- Zhang, X.P., Cheng, X.M. (2009), Energy consumption, carbon emissions, and economic growth in China. *Ecological Economics*, 68, 2706-2712.
- Zhua, H., You, W., Zeng, Z. (2012), Urbanization and CO₂ emissions: A semi-parametric panel data analysis. *Economics Letters*, 117, 848-850.