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ORIGINAL RESEARCH PAPER

Climate Changes in Africa: Does Urbanization Matter? A semi-Parametric Panel Data Analysis

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ABSTRACT: The present study seeks to examine the impacts of urbanization on carbon emissions through the investigation of the existence of an environmental Kuznets curve (EKC). Using the STIRPAT framework, this is the first study in Africa to explore the urbanization and carbon emissions nexus; using panel data together with semi-parametric panel fixed effects regression. Our data set refers to a panel of 54 countries in Africa spanning the period 1980–2014. We find evidence supports presence of an inverted-U shaped relationship between urbanization and carbon emissions in the region. Overall, our findings suggest that environmental degradation in the continent may be reversible and environmental quality may be recoverable even with growing urbanization.

Keywords: Urbanization, Carbon emissions, STIRPAT environmental Kuznets curve, Climate change.

RUNNING TITLE: Urban Development Patterns in Sustainable Development

INTRODUCTION

It is widely accepted that African continent is most vulnerable to climate change (King, *et al*,. 1998). The impact of climate change in Africa is immense due to the extreme vulnerability of the people in this region to climate change and its huge adverse effect on their livelihood. Severe draughts and floods are causing millions to die or flee their homes every year. In addition, nearly 30% of the people in this region are currently undernourished, but climate change could increase to nearly 90% by 2050 which is a disaster in waiting(Al.Rawashdeh, *et al*,. 2014). Furthermore, projections estimate that climate change will lead to an equivalent of slightly less than 2% to 4% annual loss in GDP in Africa by 2040(Anderson, *et al*,. 2001). . Theoretical as well as empirical studies that address this issue have concurred that energy use and/or consumption and economic growth are the key determinants of environmental quality (Aroure, *et al*,. 2012, Baltagi *et al*,. 2002, and Burton, 2000). However, in addition to energy use and/ or income level, recently urbanization has been identified as one of the significant factors that can explain the quality of the environment (Capello, *et al*,. *2000,* Chen and Lau,. 2008, and Burton, 2000). Urbanisation is always accompanied by an inherent increase of carbon emissions as confirmed by the international Energy Agency(IEA), 70% of the present climate change is caused by rapid urbanisation and this phenomenon is increasing whereby it is expected that 2030, 76% energy related global carbon emissions will be a direct result of rapid urbanization(Cole, 2004). 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 claimed that environmental problems may rise from low to intermediate stages of development. Nonetheless, extra modern-

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ization can reduce such inverse impacts; as societies start to recognize the significance of environmental sustainability. The second is the urban environmental transition theory which purports that 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 the result of advanced environmental regulations, technological progress and structural improvement in the economy. The third is the compact city theory which suggests that a high urban density allows cities to accomplish economies of scale of urban public infrastructure, and decreases car usage, travel length, allocation losses of electricity supply, and minimizing energy consumption and CO_2 emissions(Dietetz and Rosa, 1997, Ehrlich and Holdren, 1971, Fana, *et al* & Herrala and Goel, 2012).

Although Africa on average has lower urban population compared to some regions such as OECD, MENA and North America, they have registered a relatively higher urban population growth rate. For instance, in 2014, urban population in Africa accounts for 37%, this is lower than that of OECD (80%), MENA (60%) North America (81%). However, the story is different when we consider the growth rate of urban population. Figure 1 represents urban population growth (annual %) in Africa and some selected regions during the period 1980-2014. From the figure it is clear that while urban population growth rate in the selected regions and worldwide decline over time, Africa remains the region with highest annual growth rate in urban population.

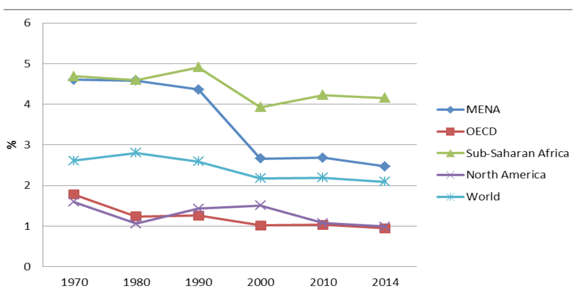

Fig 1: Urban population growth rate (annual %) in Africa and selected region, 1980-2014 [Authors' calculations].

From an empirical point of view, the interrelation between urbanization and CO_2 emissions has been extensively tested recently. The empirical results, however, are diverse. For instance, while some scholars detect positive correlation between the variables (Jenks *et al*,. 1996, jones, 1991, Liddle, 2004), other researchers detect negative correlation (Martinez, 1998, Newman and Kenworthy, 1989). Researchers who support a positive correlation between urbanization and emissions claim that urbanization increases energy demand, generating more emissions. Meanwhile, those who fortify a negative relation believe that urbanization and urban density improve the efficient use of public infrastructure (e.g., public transport and other utilities); lowering energy use and emissions. Although most existing literature assume that the link between urbanization and carbon emissions is linear, a few emerging studies have attempted to incorporate a quadratic term for urbanization into the model to probe the possibility of an urbanization - carbon emissions environment Kuznets curve (EKC). This hypothesis has been confirmed, for instance, by [10] for 88 developing countries and (Martinez, 1998) for a panel of OECD countries. In contrast, the findings of some studies such as (Black, 2001) and (Burton, 2000) failed to confirm the Kuznets hypothesis.

Contradicting debates on the urbanization - environment nexus as well as the current statues of Africa in urbanization and environmental context raise the following question; Does urbanization phenomena increase or decrease environmental deterioration in Africa? The answer to this question, which is the main concern of the present study, has great policy implication. If the relationship between urbanization and environmental degradation is found to be a monotonously (linear) positive relationship, then environmental quality will continue to deteriorate with urbanization. Only when urbanization enters a stage of stagnation, the tendency towards environmental degradation would slow down. Therefore, policy makers should adopt policies that minimize the urbanization process to avoid environmental deterioration. However, if results show a monotonously negative relationship between urbanization and environmental degradation, then environmental quality will continue to improve even with the continuation of the urbanization phenomenon. Hence, policy makers should facilitate rural-urban migration to maintain the quality of the environment. In contrast, if a non-monotonous (nonlinear) curve link is found between urbanization and environmental quality, environmental degradation may be reversible and environmental quality may be recoverable. To the best of the authors' knowledge, this is the first empirical study in Africa continent, to investigate the EKC hypothesis on CO_2 emissions related to urbanization within the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model. This is because preceding studies frequently employ the IPAT theoretical framework as proposed by (Schneider, *et, al,*. 2007). 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 determine the extent to which each factor affects the environment individually (Poumanyvong and *et, al,*. 2010). In addition, instead of using the parametric fixed panel; a method that is extensively used in the previous studies, in the current study we employ the semi-parametric regression developed by (York, 2007). According to Capello(2000), 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 the addressing of potential functional form misspecification [21]. Also, it partially avoids dimensionality problems by combining features of parametric and nonparametric techniques. A further advantage of the semi-parametric panel fixed effects regression is the possible inclusion of a concise economic interpretation of the results.

The remaining sections are organized as follows. Sections 2 and 3 examine the models, estimation methods and data sources used to test the EKC hypothesis. Empirical results and related discussion are presented in Section 4. The final section; Section 5 contains concluding comments and policy implications.

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 analyze environmental impact (York, *et, al,*. 2010). The model specification is

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

In Equation (1), I denotes environmental impact, P, A, and T denote 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 20 MENA countries in the present study. To test the existence of an EKC, (Zarzoso, *et, al,*. 2007) incorporated a quadratic term of the urbanization factor into the STIRPAT model. The addition of a quadratic term of the variable related to urbanization; taking the percentage of urban population as a proxy, stresses the modernization theory in which such a relationship is likely to exist between urbanization and environmental impact (Zarzoso, *et, al,* Zarzoso and Maruotti, 2007). Following previous studies, we derived extended versions of the STIRPAT model to test for the existence of an inverse U-shaped curve link between urbanization and carbon emissions. In this model, all variables except urbanization were converted into natural logarithmic form for direct interpretation as elasticicities. Accordingly, within the EKC hypothesis framework, the augmented model is estimated as

$$lnCE_{ti} = \propto_i + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnEl_{it} + \beta_4 UR_{it} + \beta_5 UR_{it}^2 + T_t + \varepsilon_{it}$$
$$lnCE_{ti} = \propto_i + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnEl_{it} + \beta_4 UR_{it} + \beta_5 UR_{it}^2 + T_t + \varepsilon_{it}$$
(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 maybe interpreted as a proxy for technology level which may damage the environment (Zarzoso, *et, al,*. 2007), whereas the time - specific effect is sometimes interpreted as the effect of technical progress in carbon emissions control overtime (Zhua and Zeng, 2012). Meanwhile, pointed out that prior studies paid little attention to the role of technical progress in air pollution abatement. Neglecting this determinant could drastically underestimate possibilities for countries to reduce pollution levels with urbanization.

Within the aforementioned framework, we first examined the existence of an urbanization and carbon emissions EKC using parametric panel fixed effects regression. A more flexible method is used to explore this topic in the semi-parametric panel fixed effects model of (Wang, *et, al,*. 2016), which does not place ex ante restriction on the shape of the relationship curve between urbanization and carbon emissions and can therefore address potential functional form misspecification (Martinez, 1998). In the present study, the semi-parametric model for testing the relationship between urbanization and carbon emissions may be described as

$$lnCE_{ti} = \alpha_i + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnEl_{it} + f(UR_{it}) + T_t + \varepsilon_{it}$$

$$lnCE_{ti} = \alpha_i + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnEl_{it} + f(UR_{it}) + T_t + \varepsilon_{it}$$

(3)

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

$$lnCE_{it-1} - lnCE_{it-1} = \beta_1 (lnP_{it} - lnP_{it-1}) + \beta_2 (lnA_{it} - lnA_{it-1}) + \beta_3 (lnEl_{it} - lnEl_{it-1}) + [f(UR_{it}) - f(UR_{it-1})] + T_t - T_{t-1} + \varepsilon_{it} - \varepsilon_{it-1}$$

$$lnCE_{it-1} - lnCE_{it-1} = \beta_1 (lnP_{it} - lnP_{it-1}) + \beta_2 (lnA_{it} - lnA_{it-1}) + \beta_3 (lnEl_{it} - lnEl_{it-1}) + [f(UR_{it}) - f(UR_{it-1})] + T_t - T_{t-1} + \varepsilon_{it} - \varepsilon_{it-1}$$

(4)

To consistently estimate the first difference model, the following series differences are derived to respectively estimate $[f(UR_{it})-f(URi_{t\_1})]$ in line with [27].

$$P^k(UR_{it}, UR_{it-1}) = [P^k(UR_{it}) - P^k(UR_{it-1})]$$

$$P^k(UR_{it}, UR_{it-1}) = [P^k(UR_{it}) - P^k(UR_{it-1})]$$

(5)

where p^k (UR) and p^k (ln A) are the first k terms of a sequence of function (p1 (UR), p2 (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, Eq. (5) can be reduced to

$$u_{it}^{\wedge} = lnCE_{it} - \beta_1^{\wedge} lnP_{it} - \beta_2^{\wedge} lnA_{it} - \beta_3^{\wedge} lnEL_{it} - \alpha_i^{\wedge} = f(UR_{it}) + \varepsilon_{it}$$

$$u_{it}^{\wedge} = lnCE_{it} - \beta_1^{\wedge} lnP_{it} - \beta_2^{\wedge} lnA_{it} - \beta_3^{\wedge} lnEL_{it} - \alpha_i^{\wedge} = f(UR_{it}) + \varepsilon_{it}$$

(6)

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

Data and variables

We investigated whether there is an evidence of a non-monotonic relationship between urbanization and carbon emissions, as postulated by the EKC hypothesis, for a balanced panel of 54 African countries and data spanning 1980–2014. All data for the analysis was collected from the World Bank Development indicators. For this dataset, we applied, and for the first time, parametric and semi-parametric panel fixed effects models. All underlying variables with their descriptive statistics are listed in Table1. It should be noted that all variables except urbanization were converted into natural logarithmic form.

Variables	Definition	Mean	Min	MAX
CE	Carbon dioxide emissions, metric tons per capita	1.04	0.001	10.54
A	GDP per capita (constant 2005 US$)	1608.07	68.57	15592.2
El	Energy use (kg of oil equivalent) per $1,000 GDP (constant 2011 PPP)	198.8	5.42	86.92
P	Population, total	1.61e+07	70000	1.77e+08
UR	Urban population (% of total)	38.04	5.41	86.92

Table 1: Descriptive statistics of variables

Results and discussion

Empirical results for urbanization - 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 urbanization – CO_2 emissions EKC hypothesis framework. The findings reveal that the elasticity of CO_2 emission with respect to energy use is highly significant at the 1% level, and its sign is positive. A 1% increase in energy use leads to 0.23% increase in carbon emission. The findings also show that the elasticity of CO_2 emission with respect to the affluence variable is highly significant at a 1% level, and its sign is also positive. A 1% increase in per capita GDP will result only in a 0.0002% increase in carbon emission which is marginal. The estimated coefficient for the population variable is not significant, although its sign is positive as expected. The urbanization variable and its quadratic term are both highly significant and they have the expected signs. However, the magnitude of their impact on carbon emission is negligible. Findings from the parametric fixed effects model seems to confirm the presence of the urbanization – CO_2 emissions EKC hypothesis. Column 2 presents estimates of the control variables in the semi-parametric panel fixed effects model. The results also indicate that the estimated coefficient for both energy use and affluence variables is highly significant at the1% level and its sign is positive. The results of the semi-parametric panel data model suggest that energy use and economic growth are the main sources for carbon emission in Africa countries.

Variables	Parametric model	Semi- Parametric model
Constant	-2.13* (0.80)	-
Ln A	0.0002* (0.00002)	0.80* (0.14)
Ln EL	0.23* (0.05)	0.50* (0.17)
Ln P	0.05 (0.05)	0.28 (0.68)
UR	0.06* (0.01)	-
UR^2	-0.0006* (0.0001)	-
Country dummies	Yes	Yes
Year dummies	Yes	Yes
Adjusted R^2	0.71	0.61
Obs	648	603
Notes: Cluster-robust standard errors in parentheses. Superscripts "*" and "**" denote statistical significance at1% and5% levels, respectively		

Table 2: Estimates for urbanization – CO_2 emissions models

The partial fit for the urbanization and CO_2 emissions nexus in the semi-parametric panel fixed effects model is represented in Fig. 2. From the plot, it is possible to confirm the existence of an EKC between urbanization and CO_2 emissions in the continent. This finding suggests that most likely there will be an environmental degradation in the continent with growing urbanization, however, once urbanization reaches the turning point, CO_2 emissions starts to decrease. Consequently, from the results of the two panel regression methods, we can confirm the presence of an EKC between urbanization and CO_2 emissions in Africa countries. Overall, our findings suggest that environmental degradation in the continent may be reversible and environmental quality may be recoverable even with growing urbanization.

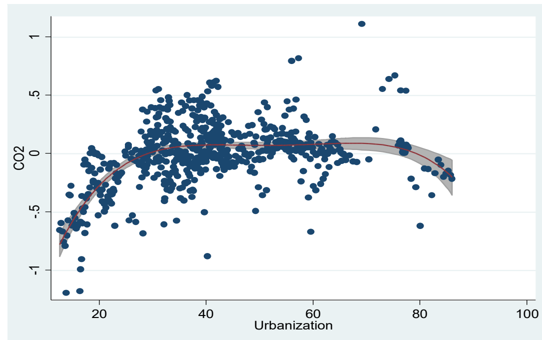

Fig 2 :Partial fit of urbanization and CO_2 emissions nexus. Note: Points on graph are estimated partial residuals for carbon emission. Maroon curve represents fitted values for adjusted effects of other explanatory variables in the model, and 95% confidence bands are indicated by shading.

Conclusion and policy implication

The present study seeks to examine the impacts of urbanization on carbon emissions in Africa region through the investigation of the existence of an environmental Kuznets curve (EKC). Within the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) framework, this is the first study in Africa region to explore the urbanization and carbon emissions nexus, using panel data together with semi-parametric panel fixed effects regression. Our data set is referred to a panel of 54 countries in Africa region spanning the period 1980 – 2014. We find evidence to support an inverted-U shaped relationship between urbanization and CO_2 emissions in the region. Overall, our findings suggest that environmental degradation in the continent may be reversible and environmental quality may be recoverable even with growing urbanization.

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