Urbanization and Environmental Quality in Africa

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Abstract

Africa's rapid urbanization pose challenges for her sustainable development. This paper investigates the environmental impact of urbanization for 49 African countries from 1990 to 2010. Using the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) framework, a recently developed semi-parametric panel fixed-effects regression technique, and two atmospheric air pollutants, namely carbon dioxide (CO_2) and ambient particulate matter (PM_{10}) emissions, the evidence indicates that urbanization reduces environmental pollution. The semi-parametric analysis reveals that the result is more pronounced with PM_{10} but weaker for CO_2 emissions. Moreover, there is no evidence to confirm the Kuznet's hypothesis of an inverted U-shaped curve between urbanization and environmental pollution. To reap the benefits of urbanization, there is need for a strategic urban planning with basic infrastructure investment that promotes a green environment.

Keywords: Urbanization; Environmental Quality; STIRPAT; Semiparametric method; Africa.

JEL Classification: C14; C33; O55; Q2; Q5; R11

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1 Introduction

Urbanization as a demographic indicator, describes the concentration of population in urban areas following economic transformation and social modernization. Recent United Nations (2015) estimates indicate that the world's urban population increased from 30 percent in 1950 to 54 percent in 2014, and is projected to grow by 2.5 billion people (about 66 percent) by 2050, with 90 percent of the increment concentrated in developing regions of Asia and Africa. In Africa, urban population increased from 15 percent in 1960 to 40 percent in 2010, and a further 60 percent increment is projected for 2050 (UN HABITAT, 2010). This boom in urbanization if not properly managed has implications for sustainable development in the region (see Freire et al., 2014; Cobbinah et al., 2015, for a discussion). Thus, a careful analysis of the linkage between urbanization and environmental quality is imperative for designing appropriate sustainable development and climate change policies, as rapid surge in urbanization is expected to increase energy use with expansion in economic activities and, consequently, greater environmental pollution. Hence, this paper attempts to investigate the relationship between urbanization and environmental quality (or pollution) in African countries, especially to identify a definite pattern of the true relationship.

Several theories have tried to explain the environmental impacts of urbanization. This include: the ecological modernization, urban environmental transition, and the compact city theories (Poumanyvong and Kaneko, 2010). The ecological modernization theory argues that environmental problems may increase as societies transit from low to middle stages of development, prioritizing economic growth over a sustainable environment. However, further modernization reduces such damages as societies begin to emphasize environmental sustainability, technological innovation, and a shift towards a service based economy. Meanwhile, the urban environmental transition theory maintains that as societies transit to a manufacturing based economy, atmospheric pollution increases with the wealth of cities. As cities become more wealthier, pollution lessens with improved environmental regulations, technological innovation and structural change in the economy. Moreover, wealthier cities are likely to increase their demand for urban infrastructure and energy-intensive products, which further intensifies pressure on the environment. On the other hand, the compact city theory highlights the benefits of urbanization with the argument that higher urban density facilitates economies of scale for public infrastructure, and thus lowers environmental pressure and damages. However, higher urban density without adequate urban infrastructure provision can lead to environmental damages (Burgess, 2000).

These theoretical propositions suggest that urbanization does have varying environmental impacts (i.e. both negative and positive) across different stages of development with the net effect difficult to gauge. As a result, the urbanization-environment nexus has been subjected to empirical investigation over the past decade. Some studies find evidence of a positive effect of urbanization on CO_2 emissions (Parikh and Shukla, 1995; Cole and Neumayer, 2004; Liddle and Lung, 2010; Poumanyvong and Kaneko, 2010). Within this context, York et al. (2003) using a Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model, find that urbanization affects positively energy footprints and emissions. Cole and Neumayer (2004) find a positive link between urbanization and CO_2 emissions for 86 countries for the period 1975-1998. Poumanyvong and Kaneko (2010) examine the effects of urbanization on CO_2 emissions for different income groups (i.e. low-, middle- and high-income countries), and find a positive relationship for all groups with that of the middle-income group being more prominent. Moreover, there are contrasting evidence to the above mentioned studies (Fan et al., 2006; Sharma, 2011; Sadorsky, 2014). Fan et al. (2006) find a negative correlation between urbanization and CO_2 emissions in developing countries. Sharma (2011) find the urbanization-CO_2 emissions relationship to be negative for high-, middle-, and low-income countries. Sadorsky (2014) examine the urbanization-CO_2 emissions nexus for emerging countries, and find that the effect of urbanization to be mostly positive but statistical insignificant with sensitivity to the estimation technique.

Although, most studies suggest that the urbanization-pollution relationship is linear, the lack of clear evidence have led researchers to consider the possibility of a non-linear relationship. For instance, Ehrhardt-Martinez et al. (2002) find evidence that relationship between urbanization and deforestation rates in developing nations exhibit an inverted U-shaped relationship using the Environmental Kuznets curve (EKC) model. Their findings implies that deforestation rates increase at the early stage of urbanization, but decline as urbanization advances. They attributed this curvilinear relationship to the effects of urban agglomeration and growing service sector dominance in urban areas. Similar evidence of this hypothesis has been confirmed by Martínez-Zarzoso and Maroutti (2011). Recently, studies have employed non- and semi-parametric regression as a more flexible estimation framework to circumvent possible functional form misspecification bias in determining the true shape of the urbanization-pollution relationship (Zhu et al., 2012; Wang et al., 2015; Xu and Lin, 2015; Wang et al., 2016). Zhu et al. (2012) find little evidence in support of the inverted U-shaped relationship for 20 emerging countries. Also, Wang et al. (2015) confirms this findings for the urbanization-sulphur oxides (SO_2) emissions nexus in China. Wang et al. (2015) and Xu and Lin (2015) find an inverted U-shaped relationship between urbanization and CO_2 emissions for OECD countries and China respectively. Summarizing, the existing evidence on the urbanization-environment nexus is mixed and inconclusive, as the direction and shape of the relationship depends on the choice of countries, data sample and the estimation technique.

To date, studies examining the urbanization-pollution nexus in Africa are nascent. Onoja et al. (2014) finds a positive but insignificant effect of urbanization on CO_2 emissions. Adusah-Poku (2016) using dynamic heterogeneous panel data models find that urbanization contributes positively to CO_2 emissions in Sub-Saharan Africa both in the short and long run. As a contribution to both the literature and current debate on the environmental impacts of urbanization, this paper uses data from a sample of 49 African countries for the period 1990-2010, to further explore the possibility of a definite urbanization-environment relationship. The analysis is performed using the STIRPAT model which has become the reference analytical framework for evaluating the driving forces of anthropogenic environmental change. Also, the paper uses a semi-parametric panel fixed effects estimator proposed by Baltagi and Li (2002) to gauge the urbanization-environment relationship which is *a priori* unknown. This estimation technique circumvents functional form misspecification bias, and accounts for potential non-linearities, parameter heterogeneity. In other words, it does not impose *ex ante* specific functional form but rather allows the data generating process to determine the true shape of the relationship.

Going forward, the balance of the paper is as follows: Section 2 lays out the STIRPAT framework and methodology. Section 3 describes the dataset. Section 4 presents the empirical results of the model estimations; and lastly, Section 5 gives the concluding remarks.

2 Theoretical framework and methodology

The paper uses the IPAT framework to investigate the urbanization-pollution relationship. Ehrlich and Holdren (1971) first proposed the IPAT model ($I = PAT$) to describe the changes in environmental impacts induced by human activities (i.e. so-called anthropogenic effects). The framework assesses the environmental impact of population, affluence, and technology on the environment. The intuition is that environmental impacts (I) are a multiplicative function of population size (P), affluence described per capita of economic activity (A), and the level of technology per unit of consumption and production (T):

$$I = P \cdot A \cdot T \tag{1}$$

The model is simple as it describes the anthropogenic driving forces behind environmental damages as a mathematical relationship. However, the IPAT model is a mathematical identity and is rigid in terms of the proportionality restrictions between the variables.

Following this shortcoming, Dietz and Rosa (1997) developed a stochastic version of IPAT, designated as STIRPAT, which provides a flexible quantitative framework to investigate environmental impacts:

$$I_i = aP_i^b A_i^c T_i^d \varepsilon_i \tag{2}$$

where I, P, A, and T remains as described above; a, b, c and d are parameters of the model; ; ε represents the idiosyncratic error term, and the subscript i denotes observational units (e.g. countries) in a cross-section data. Taking the natural logarithm of Eq. (2) provides a convenient linear specification as follows:

$$lnI_i = a + b\ lnP_i + c\ lnA_i + d\ lnT_i + \varepsilon_i \tag{3}$$

As a refinement to the STIRPAT model, York et al. (2003) maintains that the quadratic terms of the components P, A, and T along with additional environmental impact factors can be incorporated into the model provided consistency with the multiplicative specification is maintained. For example, the quadratic term for affluence (A) is in line with the EKC hypothesis which predicts an inverted U-shaped relationship between economic development and environment impacts. Moreover, urbanization can be introduced along with its quadratic term to capture the potential non-linearities emphasized by the modernization and urban environmental transition theories where higher urbanization density leads to higher pollution at first, and after which it facilitates environmental improvements through economies of scale in the provision of public infrastructures. Consequently, the impact of urbanization on environmental quality can be examined in an extended version of the STIRPAT model with all variables transformed to their natural logarithmic form and estimated coefficients interpreted as elasticities as follows:

$$E_{it} = \beta_1 gdpc_{it} + \beta_2 pop_{it} + \beta_3 enit_{it} + \beta_4 urban_{it} + \beta_5 urban_{it}^2 + \alpha_i + +\tau_t + \varepsilon_{it} \tag{4}$$

where E is a measure of an environmental pollutant in country i at time t; *pop* denotes the population size; *gdpc* is GDP per capita; *enit* denotes technology which is proxied by energy intensity to capture technology damaging effect on the environment; and *urban* is the level of urbanization. α_i represents country-specific effect that is constant with time, and a time-specific effect τ_t to account for time-varying omitted variables and stochastic shocks that are common to all countries.

Within this framework, standard panel data estimation techniques can be used to estimate Eq.(4). However, a major drawback of the above parametric model analysis is that it assumes *ex ante* specific functional form and does not account for parameter heterogeneity across countries in the sample. Moreover, higher polynomial regression, and more generally parametric regression models, have been shown to have undesirable "nonlocal effects" (Magee, 1998). As Yatchew (1998) points out, most economic theory does not identify a specific functional form for the relationship between a dependent variable and the independent variables in a regression. Thus, to avoid possible functional form misspecification in the above parametric framework, a semi-parametric regression framework is used since it relaxes the functional form assumptions and allows the data generating process to determine the true shape of the urbanization-pollution relationship. Given that the true relationship is *a priori* unknown, a semi-parametric partially linear panel model with fixed effects is specified as follows:

$$E_{it} = \beta_1 gdpc_{it} + \beta_2 pop_{it} + \beta_3 enit_{it} + m(urban_{it}) + \alpha_i + \tau_t + \varepsilon_{it} \tag{5}$$

where $m(\cdot)$ is an unknown smooth function with only urbanization, $urban$, entering the regression nonparametrically while other control variables are specified parametrically. This model accommodates the inclusion of more control variables without concerns for the curse of dimensionality problem associated with fully nonparametric models. The presence of the unobserved heterogeneity α_i can be removed through first-differencing:

$$\begin{aligned} E_{it} - E_{it-1} = {} & \beta_1(gdpc_{it} - gdpc_{it-1}) + \beta_2(pop_{it} - pop_{it-1}) + \beta_3(enit_{it} - enit_{it-1}) \\ & + [m(urban_{it}) - m(urban_{it-1})] + \varepsilon_{it} - \varepsilon_{it-1} \end{aligned} \tag{6}$$

To consistently estimate Eq.(6), Baltagi and Li(2002) proposed to approximate $[m(urban_{it})$ $-m(urban_{it-1})]$ by the series differences $p^k(urban_{it}, urban_{it-1}) = [p^k(urban_{it}) - p^k(urban_{it-1})]$ where $p^k(urban)$ are the first k terms of a sequence of functions $(p_1(urban), p_2(urban), \dots)$. In practice, a typical example of p^k series could be a spline, which corresponds to piecewise polynomials with pieces defined by a sequence of smooth knots which when joined smoothly reduces Eq.(6) down to

$$\begin{aligned} E_{it} - E_{it-1} = {} & \beta_1(gdpc_{it} - gdpc_{it-1}) + \beta_2(pop_{it} - pop_{it-1}) + \beta_3(enit_{it} - enit_{it-1}) \\ & + [p^k(urban_{it}) - p^k(urban_{it-1})]\vartheta + \varepsilon_{it} - \varepsilon_{it-1} \end{aligned} \tag{7}$$

for consistent estimation using ordinary least squares. Once parameters $\hat{\beta}$'s and $\hat{\vartheta}$ have been estimated, the values of the unit-specific intercepts $\hat{\alpha}_i$ can be calculated in order to recover the error component residual

$$\hat{u}_{it} = E_{it} - \hat{\beta}_1 gdpc_{it} - \hat{\beta}_2 pop_{it} - \hat{\beta}_3 enit_{it} - \hat{\alpha}_i = m(urban_{it}) + \varepsilon_{it} \quad (8)$$

The curve $m(\cdot)$ can be easily estimated by regressing $\hat{u}_{it}$ on $urban_{it}$ using flexible estimation methods such as kernel or spline regression. Here, we use the B-spline regression model of order $k = 4$.

3 Data

The urbanization-pollution nexus is investigated with sample panel data set of 49 African countries over the period 1990–2010 (see Table A1 in Appendix for country listing). In the empirical analysis, population is measured as total population, affluence which captures economic prosperity is measured as real GDP per capita (constant 2005 US dollars), and urbanization is the fraction of urban population in the total population. Following other scholars (see Liddle and Lung, 2010; Poumanyvong and Kaneko, 2010; Martínez-Zarzoso and Maroutti, 2011; Sadorsky, 2014), technology is measured using energy intensity. Energy intensity is often expressed as total energy use per dollar GDP. Here, energy intensity is measured as total primary energy consumption per dollar GDP (Btu per year 2005 PPP US dollars). Environmental pollution is captured using two atmospheric air pollutants, namely, CO_2 emissions and ambient particulate matter (PM_{10}). CO_2 emissions (metric tons per capita) include burning of fossil fuels and cement manufacturing, but excludes emissions from land use such as deforestation. PM10 captures fine suspended particles less than 10μm in diameter, and is capable of penetrating deeply into the respiratory tract, causing significant health damage to humans and animals. The data on per capita carbon emissions, and ambient particulate matter, population size, GDP Per capita and urbanization is sourced from the World Bank's *World Development Indicators* online database while energy intensity is obtained from the International Energy Statistics of the U.S. Energy Information Administration (EIA)[1]. Table 1 presents the descriptive statistics with all variables are transformed to their natural logarithmic form.

[1] Available at http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

Table 1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO_2 emissions					
co2pc	1008	−1.165	1.432	−4.481	2.328
pop	1008	15.730	1.543	11.156	18.887
enit	1008	7.922	0.841	5.189	10.279
gdpc	1008	6.616	1.101	4.243	9.675
urban	1008	3.513	0.499	1.689	4.451
PM_{10} emissions					
pm10	987	4.019	0.705	1.768	5.759
pop	987	15.856	1.366	12.841	18.887
enit	987	7.909	0.839	5.189	10.279
gdpc	987	6.541	1.033	4.243	9.675
urban	987	3.482	0503	1.689	4.451

4 Empirical results

Given the choice of two pollutants measure of CO_2 and PM_{10} emissions, Eq. (4) is estimated for each pollutants using parametric and semi-parametric panel fixed effects respectively. Table 1 presents the empirical results for the urbanization-CO_2 emissions nexus. For the parametric model, Column (2) shows the inclusion of urbanization and its quadratic term (*urbansq*). As earlier mentioned, Martínez-Zarzoso and Maroutti (2011) acknowledged the possibility of an EKC hypothesis similar to the income-environment relationship for the urbanization-environment nexus. Therefore, it is necessary to validate the possible existence or non-existence of such hypothesized relationship.

The coefficient estimate of affluence (*gdpc*) in Column (1) is positive and significant at 1% level. Thus, a 1% increase in income will lead to a 0.99% increase in carbon emissions per capita. This implies that further expansion in economic activities which is associated with increase in per capita income intensifies more environmental pollution in continent, and in the case of carbon emissions will exacerbate the environmental effects of global warming and climate change. The population variable has a positive coefficient but is not statistically significant This result may suggest that population size is not a major driver of the environmental impacts of carbon emissions in the continent. The coefficient estimate of the energy intensity variable is positive and statistically significant; and this suggest that a 1% increase in energy intensity will cause a 0.27% increase in carbon emissions.

Turning to the variable of interest, urbanization has a negative and statistically significant effect on carbon emissions. A 1% increase in the urbanization rate is likely to reduce carbon

Table 2: Parameter estimates of urbanization-CO_2 emissions

	PAR-FE (1)	PAR-FE (2)	SEMI-PAR (3)
gdpc	0.9976***	0.9983***	0.5047**
	(0.0525)	(0.0525)	(0.1958)
pop	0.1033	0.1312	0.3746
	(0.1965)	(0.2166)	(0.2915)
enit	0.2725***	0.2741***	0.0224
	(0.0910)	(0.0904)	(0.0813)
urban	−0.3726*	−0.0610	
	(0.1899)	(0.8169)	
urbansq		−0.0569	
		(0.1616)	
Constant	−10.2413***	−11.0755***	
	(2.7067)	(3.4972)	
N	1008	1008	960
R^2	0.8105	0.7963	4.3114

Note: Country and time dummies are included in all models. PAR-FE and SEMI-PAR denotes parametric and semi-parametric panel fixed effects models respectively. Robust standard errors in parenthesis. ***, **, * indicates 1%, 5% and 10% significance level.

emissions by 0.37%. This implies that high urbanization may lower environmental pressure through economies of scale in public infrastructure as argued by the compact city theory. Therefore, an efficient and adequate provision of infrastructure can help obviate the potential harmful effect of higher urbanization in Africa. This result sharply contrast with the positive relationship obtained by Onoja et al. (2014) and Adusah-Poku (2016). Considering the inclusion of its quadratic term in Column (2) of Table 1, the urbanization variable along with its quadratic term are both statistically insignificant. This means that the possibility of an inverted U-shape relationship between urbanization and carbon emissions is not supported by data. In other words, the modernization and urban environmental transition theories which admits the possibility of both positive and negative effects of urbanization on environmental degradation may not hold for African countries. While this result seems interesting at first sight, we emphasize caution as the model specification assumes that the effects of urbanization on carbon emissions follows a common trajectory for African countries, and does not capture countries heterogeneity in terms of stage of development,

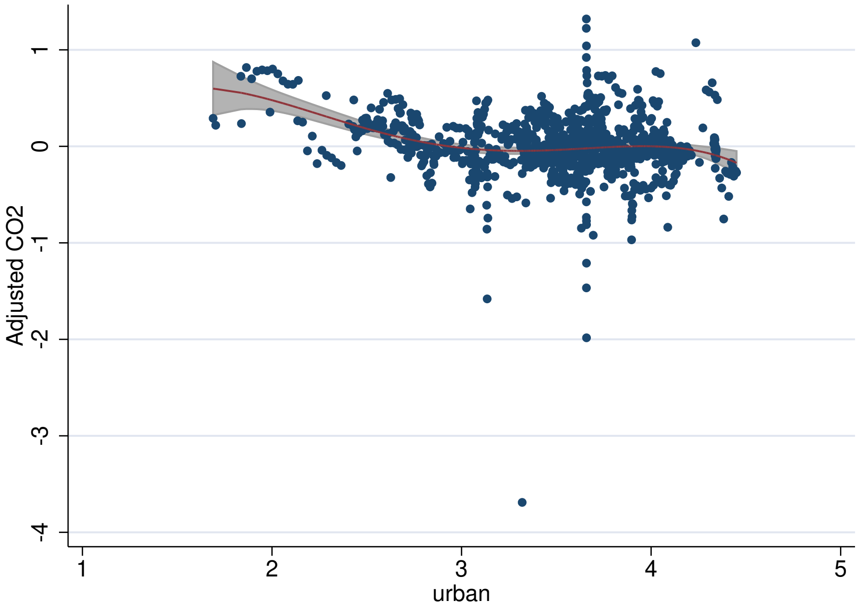

Figure 1: Partial fit of urbanization and CO_2 emissions relationship: Points in graph are estimated partial residuals for CO_2 emissions; maroon curve represents fitted values for adjusted effects of other explanatory variables, and bounded by the 95% confidence bands.

resource endowments, and socio-political institutions etc.

For the semi-parametric model in Column (3) , only the income variable is statistically significant while population and energy intensity are not significant . For the urbanization variable, Figure 1 presents a partial fit of the relationship between urbanization and carbon emissions. Unlike parametric models that yields a unique coefficient estimate, non-parametric and semi-parametric models provides a partial regression plots that describes the relationship between the dependent variable and the regressor of interest holding all other regressors constant at a fixed point (say, the mean). The resulting relationship appears to decline but is relatively flat. Although consistent with the negative effect of urbanization in Column (1), the shape of the relationship suggest that the urbanization-carbon emissions nexus is weak for Africa. This is understandable as CO_2 emissions which is the most important source of greenhouse gases is a global air pollutant and to which Africa countries contribute the least emissions compared to developed countries.

Table 2 presents the estimates for the urbanization-PM_{10} emissions nexus. Unlike CO_2 emissions, PM_{10} emissions is more localized and constitute a major source of air pollution in Africa. As in Column (1), all the explanatory variables have negative effects on PM_{10} emissions. Higher income levels reduces PM_{10} emissions by approximately 0.14% and population by 1.28%. Both the income and population variables are statistically significant whereas the energy intensity variables although has a negative impact is not significant.

Table 3: Parameter estimates of urbanization-PM_{10} emissions

	PAR-FE	PAR-FE	SEMI-PAR
	(1)	(2)	(3)
gdpc	-0.1376^{**}	-0.1373^{**}	-0.1641^{**}
	(0.0611)	(0.0615)	(0.0737)
pop	-1.2807^{***}	-1.2916^{***}	-1.2389^{***}
	(0.1229)	(0.1344)	(0.0922)
enit	-0.0379	-0.0385	0.0086
	(0.0597)	(0.0602)	(0.0099)
urban	-0.3119^{**}	-0.4311	
	(0.1364)	(0.5653)	
urbansq		0.0218	
		(0.1083)	
Constant	26.6121^{***}	26.9322^{***}	
	(1.8615)	(2.3498)	
N	987	987	940
R^2	0.7373	0.7374	0.4860

Note: Country and time dummies are included in all models. PAR-FE and SEMI-PAR denotes parametric and semi-parametric panel fixed effects models respectively. Robust standard errors in parenthesis. ***, **, * indicates 1%, 5% and 10% significance level.

The urbanization variable has a negative and significant impact on PM_{10} emissions as higher urbanization density reduces it by 0.31%. The marginal effects of income, population and energy intensity does not change significantly when the quadratic term of the urbanization variable in introduced into the model as reported in Column (2). Income and population are still statistically significant while energy intensity is not significant. However, the existence of a possible inverted U-shape relationship between urbanization and PM_{10} emissions is not supported as both the urbanization variable and its quadratic term are not significant. In the case of the semi-parametric model in Column 3, both income and population have negative coefficients of -0.1641 and -1.2389 respectively and are both statistically significant, while the energy intensity is not statistically significant. The partial fit of the PM_{10} emissions with respect to urbanization reveals a strong negative relationship, which implies that higher urbanization leads to a reduction in environmental pollution particularly for PM_{10} emissions.

In general, the empirical evidence indicate that urbanization has a negative impact

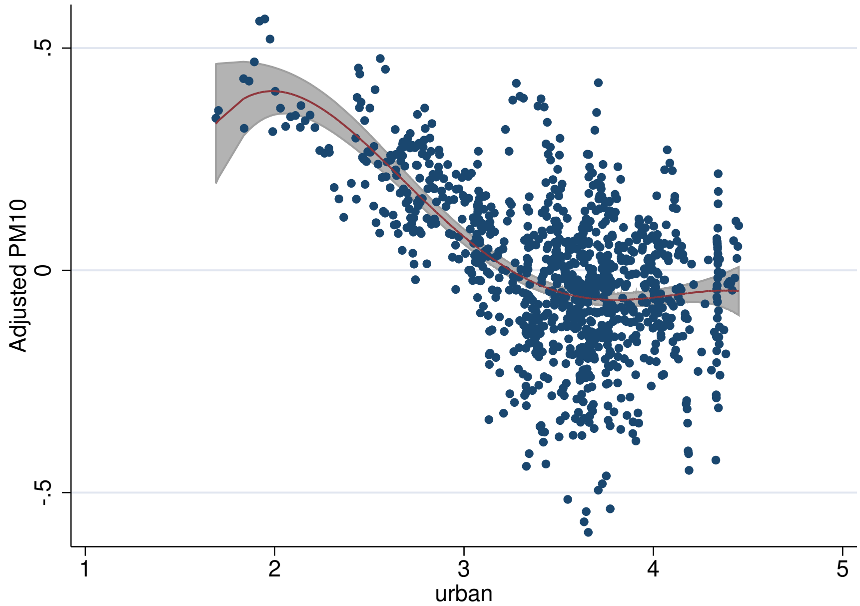

Figure 2: Partial fit of urbanization and PM_{10} emissions relationship: Points in graph are estimated partial residuals for PM_{10} emissions; maroon curve represents fitted values for adjusted effects of other explanatory variables, and bounded by the 95% confidence bands.

on environmental pollution for African countries. Since urbanization is an aspect of sustainable development, it is expected that it should contribute towards economic growth, poverty reduction, fosters scale and agglomeration effects that encourages productivity and employment as well as provision of infrastructure, and efficient natural resources conservation and management. This implies that urbanization could form part of the solution to ending Africa's current environmental challenges. However, as Africa moves up the urbanization ladder, the major concern raised by scholars is that urbanization occurs in the absence of socio-economic and environmental benefits, and is demographically driven, particularly by natural population growth (i.e. increased fertility rate), and rural-urban migration (Cobbinah et al., 2015). In other words, Africa is rapidly urbanizing while being poor, and beleaguered by unemployment, poverty, insecurity, large infrastructural deficit with inadequate financing (or investment), poor environmental conditions and living standards etc. Hence, higher urbanization as projected in the near future will only exacerbate further negative externalities such as congestion, environmental pollution, health and other natural hazards.

5 Conclusion

This paper examines the urbanization-pollution nexus for a sample of 49 African countries from 1990 to 2010. Using the STIRPAT model as its analytical framework and the semi-parametric panel fixed effects estimator of Baltagi and Li (2002) which mitigates against functional form misspecification, the paper investigates the impact of and characterized the true relationship between urbanization and two environmental air pollutants, namely carbon emissions and ambient particulate matter (PM_{10}) emissions. It also considered the possibility of the Kuznets' hypothesis existing for the urbanization-pollution nexus in Africa. The result indicates that urbanization has a negative impact on environmental pollution. In other words, urbanization supports the improvement in environmental quality by reducing atmospheric air pollutants through economies of scale in the provision of adequate and efficient public infrastructure. This declining effect is weak in the case of carbon emissions but strong for PM_{10} emission which is more localized in the context of African countries. On the other hand, the evidence does not support the EKC hypothesis for the urbanization-environment nexus.

Following from the empirical evidence, the implication is that urbanization could form part of the solution to the environmental challenges in the African continent. However, in the absence of socio-economic and environmental benefits, higher urbanization will only serve to heighten environmental pollution. Thus, since urbanization is inextricable from sustainable development, and can also serve as an engine for structural transformation, there is need for a strategic urban planning that is accompanied with basic infrastructure investments as it provides an opportunity for the adoption of greener technologies, promotion of density and connectivity while avoiding lock-in investment that could prove irreversible in the future (Freire et al., 2014). Since African urban areas are characterized by urban sprawl which is often associated with higher energy demand and increased environmental damage, a strategic urban planning (involving design, development and management) is paramount in combating urban sprawl while increasing urban density. The benefit of a denser urban cities includes lower environmental damage and efficient service delivery especially when accompanied with efficient transport networks and system (emphasis on public transportation) which encourages greater connectivity, as well as efficient energy resource and waste disposal management systems. This will make African cities efficient, manageable, resilient and competitive while ensuring the livelihood and welfare of the populace, efficiency in energy resource utilization, and ultimately promoting green growth.

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Appendix

Table A1: List of countries

Algeria	Comoros	Ghana	Mauritania	Sierra Leone
Angola	Congo Dem. Rep.	Guinea	Mauritius	South Africa
Benin	Congo Rep.	Guinea Bissau	Morocco	Sudan
Botswana	Cote d'Ivoire	Kenya	Mozambique	Swaziland
Burkina Faso	Djibouti	Lesotho[a]	Namibia	Tanzania
Burundi	Egypt	Liberia	Niger	Togo
Cameroon	Equatorial Guinea	Libya[a]	Nigeria	Tunisia
Cape Verde[b]	Ethiopia	Madagascar	Rwanda	Uganda
Central Africa Rep.	Gabon	Malawi	Senegal	Zambia
Chad	Gambia	Mali	Seychelles[b]	Zimbabwe

Note: a and b indicates countries with insufficient data on CO_2 and PM_{10} emissions respectively, and were dropped in the estimation for each atmospheric air pollutants.