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The implication of economic growth, industrialization and urbanization on energy intensity in Sub-Saharan Africa

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Abstract

The aftermath of the 1970 oil price shock coupled with rapid urbanization, rising population growth, industrialization and increased environmental degradation in Sub-Saharan Africa (SSA) have necessitated a paradigm shift of emphasis from energy consumption to a thorough investigation into energy intensity. In spite of this, the evidence for SSA is sparse as both theoretical and empirical literature has not adequately interrogated the effects of urbanization, industrialization and economic growth on energy intensity. Using panel data from 1980 to 2015 covering 36 SSA countries, this study finds answers to this question under the standard Environmental Kuznet Curve (EKC) framework. The system Generalized Method of Moment (GMM) estimation revealed that, in the long run, both urbanization and industrialization tend to increase energy intensity in the 36 selected SSA countries while the contrary is established for FDI and trade openness. Inflation was also found to be associated with rises in energy intensity in SSA. Additionally, our finding confirms the existence of a valid EKC hypothesis for energy intensity; the existence of an inverted U-shaped relationship between economic growth and energy intensity in SSA. Finally, it is observed that the SADC zone of the region, in particular, is exhibiting rising energy intensity as compared to the ECOWAS sub-region.We discuss some policy options that could potentially improve energy efficiency in the sub-region.

JEL Classification: L9; O1; O4

Keywords: Energy intensity, Urbanization, Industrialization, Economic growth, System Generalized Method of Moment

1. Introduction

Achieving sustainable development remains an issue of great concern to the world at large and in particular for sub-Saharan Africa. Though several sectors need to be coordinated to promote sustainable growth, one sector that is pivotal in the quest for sustainable development is the energy sector. To this end, various studies have recognized the positive linkages between energy consumption and economic growth (see Parikh and Shukla, 1995; Sambo, 2008; Kwakwa and

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Aboagye, 2014). Sahu and Narayanan (2011) further argued that energy has been universally and globally recognized as one of the most essential and indispensable input for economic growth, human capital development, and sustainable development among others.

The aftermath of the 1970 oil price shock coupled with rapid urbanization, rising population, industrialization, and increased environmental crisis have however, resulted in a paradigm shift of emphasis from energy consumption to a thorough investigation into energy intensity– the ratio of energy consumption to GDP (i.e. the efficient use of energy as an input for production). Observably, the past few decades have seen a rejuvenation of studies on energy intensity following the increasing interdependence on energy and the volatile nature of the energy market in SSA as the region continues to have its own share of energy crisis. Today, as a result of high energy prices, many of the energy-consuming sectors such as the industrial, residential, and commercial and transport in the region operate at very high costs making it quite difficult for some industries to remain in competitive business.

In spite of this, studies on energy had concentrated mostly on the relationship between energy consumption and economic growth with little emphasis on energy intensity (Sadorsky, 2013; Adom et al, 2012; Adom and Bekoe, 2012; Kwakwa, 2012; Jones, 1989; Parikh and Shukla, 1995; Poumanyvong and Kaneko, 2010). Meanwhile, studies on energy intensity are particularly useful and extremely important to uncover its key determinants for appropriate policy considerations as the region attempts to achieve sustainable development. Further, against a milieu of concerns about climate change, peak oil, and energy security issues, reducing energy intensity has gained much popularity in contemporary growth agenda and it is often advocated as a way to at least partially mitigate these impacts (Sadorsky, 2013). Moreso, empirical research on energy had placed little attention on the existence of an inverted U-shaped relationship between economic growth and energy intensity in the ongoing discourse.

The main objective of this paper is to examine how industrialization, urbanization and economic growth impact energy intensity. The paper also seeks to ascertain whether the relationship between energy intensity and economic growth is linear or non-linear. Finally, the paper examines the effect of location (sub-regional blocs) on energy intensity. The study adds to the empirical literature on the phenomenon and offer essential policy insights. In the section that follows, a brief review of empirical literature on energy intensity is carried out. In section three, methods, modeling and data issues are discussed while section four presents and discusses results generated from estimating the empirical models specified within the standard EKC framework. Section five concludes and highlights some theoretical and policy implications of the results/findings obtained in section four.

2. Literature Review

The theory of energy intensity takes its roots from the hypothesis of dematerialization according to which there is a reduction in material and energy consumption along the path of economic growth. Recalde and Ramos-Martin (2012) reveal that dematerialization supports the Environmental Kuznets Curve (EKC) which assumes the existence of an inverted-U shaped relationship between economic growth and environmental degradation. The EKC hypothesis asserts that environmental degradation increases with economic activity up to a turning point after which income increases tend to improve environmental quality. Thus, the EKC hypothesis is

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based on the concept of intensity of use, implying that energy intensity can be explained by income (economic growth). As a result, earliest studies on energy intensity focused largely on income (economic growth) with little emphasis on any other factors that can prominently influence intensity. However, subsequent and many recent studies have reported some other factors that remarkably influence energy intensity but given the focus of this paper, we emphasize greatly on urbanization, industrialization and economic growth.

2.1 Urbanization

Urbanization is a concept used to describe the large movement of rural population to urban centers of a country and/or a rise in the rate at which the urban population grows relative to the non-urban population or total population. It is often associated with such consequences such as increased pressure on existing urban facilities, infrastructure, and a rapid rise in the demand for goods and services. In other to meet the demands of the additional population, there is the need to expand these facilities alongside with increase in production in response to the demand by the increasing urban population, a situation which requires massive energy consumption which eventually results in energy intensive production or higher energy intensity. However, the increased production may lead to economies of scale and thereby increasing energy demand and reducing energy intensity. Sadorsky (2013) using both dynamic and static panel models investigated the effects of urbanization on energy demand and intensity. In the long-run, he found mixed results regarding the relationship between urbanization and energy intensity. While urbanization was not a significant determinant of energy intensity in the static model, it was found to be significant in the dynamic specifications and slightly larger than unity.

Mishra et al. (2009) studied the impact that urbanization has on energy intensity in a sample of Pacific Island economies. They found that urbanization had a negative impact on energy intensity in New Caledonia, but a positive impact in Fiji, French Polynesia, Samoa and Tonga. This indicates that urbanization tends to improve energy intensity in New Caledonia and otherwise in Fiji, French Polynesia, Samoa and Tonga. Krey et al. (2012) used integrated assessment models to analyze the impact of urbanization on residential energy use in China and India. They found that residential energy use is not very sensitive to urbanization directly but the relationship between urbanization and energy use depends upon how labor productivity affects economic growth. Poumanyvong and Kaneko (2010) used panel data techniques to estimate the impact of income, urbanization, industrialization, and population on energy use in a sample of 99 countries covering the period 1975 – 2005. They found that the impact of urbanization on energy use varies by income class. Specifically, urbanization decreases energy use in the low-income group, while it increases energy use in the middle- and high-income groups. Contrary to the findings of Poumanyvong and Kaneko (2010), Parikh and Shukla (1995) used a pooled data set on both developed and developing countries from 1965–1987 to investigate the impact of urbanization on energy consumption. For total energy intensity models, they found the urbanization elasticity also varies between 0.28 and 0.47

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2.2 Industrialization[3]

Industrialization refers to the introduction and application of new, modern and sophisticated equipments and techniques to the production of existing and new goods and services (Sadorsky, 2013). Usually, industrial activities use more energy than does traditional agriculture or manufacturing implying that industrialization has a positive impact on energy intensity. Samouilidis and Mitropoulos (1984) studied the effects of industrialization on energy intensity in Greece and found the long-run elasticities of industrialization of energy intensity in the range of 0.90 to 1.96 while short-run elasticities ranged from 0.17 to 0.46. Similarly, Poumanyvong and Kaneko (2010) using panel data techniques on 99 countries covering the period 1975–2005, found that the impact of the share of industrial activity in the economy on energy consumption is positive, but statistically significant for only the low- and middle income groups.

2.3 Economic growth/Income

Damette and Seghir (2013) argued that the energy-income nexus literature was initiated by the seminal work of Kraft and Kraft (1978) who examined the causal link between energy consumption and economic growth for the USA for the period 1947-1974 and found a unidirectional causality relation from GNP to energy consumption. Jumbe (2004) revealed that the result of the Kraft and Kraft study carries an implicit notion that the low level of energy dependence enabled the USA to pursue energy conservation policies. Also, Metcalf (2008) studied 46 continental states of the United States of America, excluding North Dakota and Wyoming between 1970 and 2001. Their state level analysis revealed that rising per capita income and higher energy prices have played an important part in lowering energy intensity. He further argued that income predominantly influence energy intensity through changes in energy efficiency rather than through changes in economic activity. Per the findings of his study, Metcalf (2008) concluded that some policy intervention was needed to achieve the Bush's Administration goal of an 18 percent reduction in carbon intensity by the end of that decade.

Damette and Seghir (2013) empirically investigated the relationship between economic growth and energy intensity in 12 oil exporting countries from 1990 to 2010. Using recently developed panel econometric techniques, the authors found that there exists a long-run equilibrium relationship between energy intensity and economic growth. Furthermore, the empirical evidence from a dynamic panel error-correction model revealed a short-run unidirectional causality from energy intensity to economic growth, whereas in the long-run, it is economic growth that determines the energy consumption trend. Moreover, Ozturk et al. (2010) using data from 1971-2005 and employing a panel cointegration and causality techniques on 51 low and middle income countries found a unidirectional causality from economic growth to energy demand for the low income countries and a bidirectional causality for the middle income countries. Contrarily, Parikh and Shukla (1995) used a pooled data set on developed and developing countries from 1965–1987 to investigate the impact of economic growth on energy intensity. The study revealed that the income elasticity varies between 0.25 and 0.47 for the total energy intensity models. Galli (1998) using Fixed Effects and Random Effects estimates on 10 Asian economies over the period 1973–1990 found some evidence of a non-linear relationship

[3] The definition of industrialization provided by this paper to include mining is inspired by the World Bank's definition of Industry. The World Bank (2016) defines Industry to correspond to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in ***mining***, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas.

between energy intensity and income for the Fixed Effects specification but no statistically significant evidence of this relationship in the Random effects specification.

Furthermore, Harris and Prakash (2012) estimated the causal linkages between electricity consumption and economic growth in Mauritius using time series data for three decades starting from 1961. Applying cointegration models, they found results which suggest unambiguously that there is a unidirectional causal relationship running from electricity consumption to economic growth in the short run with no causal relationship in the long run.

2.4 Trade openness, Foreign Direct Investment and price level

Trade, which comprises of export and imports of goods and services, potentially leads to productivity gains via stronger competition for domestic firms due to the presence of foreign owned firms and rivaling imports. Such productivity gains are likely to influence energy intensity. Hubler (2009) studied energy intensity effect of trade in China and argued that imports directly improve productivity, especially if the imported goods have better characteristics than the domestically produced goods. Imports indirectly create productivity spillovers via imitation of the imported products and via improved application of methods adopted together with the imported goods. Cole (2006) investigated the relationship between trade energy intensity in a panel of 32 developed countries for the period 1975–1995. The elasticities obtained ranged from −1.1 to −0.1 depending on the specification of the regression model implying that greater openness to trade in these countries had improved energy efficiency/intensity during the period between 1975 and 1995.

FDI has been found to directly improve productivity in the destination country especially when the foreign owned enterprises are more productive than the domestic ones. Foreign direct investment plays an important role in energy efficiency through the transfer of advanced, modern and sophisticated technology and know-how. Hubler (2009) concluded that technology spillovers from FDI and trade are responsible for the decline in energy intensity in China. Fisher-Vanden et al. (2004), in turn, suggested that foreign ownership, which facilitates technological transfer, decrease energy intensity. However, it is also important to know that greater export of energy intensive products and primary products could increase industrial energy intensity.

Like any other commodity, energy prices have been a major influence on energy demand, and therefore energy intensity (Fisher-Vanden et al., 2004). The price of energy usually differs significantly from state to state. For instance, electricity prices differ considerably due to the energy requirements of fixed capital (e.g., commercial buildings), the types of technologies in use, fuel availability, the ability to move electricity across large areas (prior to recent innovations in electricity markets), and regulatory requirements. Also, the general price levels in a country could explain variations in energy consumption efficiency. For instance, higher general price levels reduce purchasing power and thereby reducing the amount of energy consumption (and many other commodities). Empirically, Fan, Liao, and Wei (2007) examined energy consumption efficiency in China before the 1992 market reforms and afterwards and found that the own-price elasticity for energy was positive prior to 1992 and negative afterwards, providing further support that the 1992 market reforms are providing the necessary incentives for firms to reduce energy use in response to higher energy prices. Also, Fisher-Vanden et al. (2004) found that rising energy prices contributed significantly to the decline of firm-level energy intensity, with 54.4% of the decline in aggregate energy-use explained by rising energy costs. This conclusion is in line

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with that of Hang and Tu (2007), Kleijweg et al. (1989), Fan, Liao, and Wei (2007), Hang and Tu (2007) and He and Wang (2007).

3.0 Data and Methods

3.1 Specification of empirical model

The paper primarily focuses on the effect of economic growth, industrialization, and urbanization on energy intensity in selected SSA countries. Thus, the key regressand is energy intensity while economic growth, industrialization and urbanization are the key explanatory or treatment variables. To evaluate the EKC in SSA, the squared term of economic growth is included in the set of explanatory variables so that the EKC is said to exist for energy intensity if economic growth is positively signed and economic growth squared has a negative coefficient. Consequently, the starting point of the empirical model is stated as follows:

$$EI = f(Y, Y^2, I, U) \quad (1)$$

Where EI is energy intensity, Y is economic growth, Y^2 is economic growth squared, I and U are industrialization and urbanization respectively. We also include trade openness (T), foreign direct investment (F) and inflation ($\prod$) as control variables and this transforms the basic model in equation (1) above to equation (2) below

$$EI = f(Y, Y^2, I, U, T, F, \prod) \quad (2)$$

Thus, in examining the effect of industrialization, urbanization and economic growth on energy intensity while controlling for FDI, trade openness and inflation, the empirical model is specified in equation (3) as;

$$EI_{it} = \beta_1 + \beta_2 Y_{it} + \beta_3 Y^2_{it} + \beta_4 I_{it} + \beta_5 U_{it} + \beta_6 F_{it} + \beta_7 T_{it} + \beta_8 \prod_{it} + \varepsilon_{it} \quad (3)$$

Equation (3) links energy intensity to economic growth, economic growth squared, urbanization, industrialization, FDI, trade openness and inflation. A positive coefficient on a regressor is an indication of rising energy intensity and the converse holds. In equation (3), *β's* are parameters, and *it* = country *i* at time, *t*. Also, natural log of variables are taken to obtain elasticity coefficients and also to avoid the potential adverse effect of outliers.

3.2 Data, Source and Sample

The study uses unbalanced panel (annual) data on 36 SSA countries from 1980 to 2015. The entire study focuses on SSA countries only and explores data mainly from the databases of the World Development Indicators of the World Bank. The panel dataset used is unbalanced but the dimensions of the panel data set are chosen to include only 36 countries which have reasonable and consistent time length of observations. Thus, both the sample size and period are dictated by data availability.

Energy intensity is measured as units of energy per unit of GDP (constant 2005 PPP). This indicator was obtained from the Sustainable Energy for all (SE4ALL) database of the World Bank. GDP per capita is used as a proxy of income/economic growth. GDP per capita (income) affects energy demand/consumption and thus can directly influence efficient consumption of energy resources. Industrialization is proxied by industry, value added (% of GDP) and comprises value added (net output) in mining, manufacturing and construction, electricity, water, and gas.

Given that industrial activities are extensively energy-dependent they are likely to explain significant changes in energy intensity. Urbanization is a rise in urban population (i.e. people living in urban areas) as a percentage of total population. A rise in urban population is likely to increase energy consumption and thus can influence the level of energy intensity.

As indicated earlier, we also include trade openness (the sum of exports and imports of goods and services measured as a share of GDP); foreign direct investment (net inflows of foreign investment as a percentage of GDP) and inflation (GDP deflator, annual %). FDI is a regarded as a main source of transferring technologies to developing countries. New and efficient technologies are crucial to stimulating significant improvement in resource utilization in domestic production (Jawaid and Raza, 2012). Thus, FDI provides technological efficiency in an economy and can consequently affect the level of energy intensity. For instance, new, improved and efficient technologies are likely to reduce energy intensity. In addition, inflation, GDP deflator (annual %) included to account for changes in energy consumption/demand and hence energy intensity as purchasing power reduces following increases in input prices. In the paper, inflation is measured by the annual growth rate of the GDP implicit deflator which shows the rate of price changes in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.

4. Results and Discussions

4.1 Stationarity/Unit root test

As a measure of robustness, two different unit root tests (i.e. Fisher ADF and IPS) are computed for the variables at level. Both tests reject the null hypothesis that all the panels contain unit roots at 10% (see Table 1). Thus the evidence is that both tests show that all the variables are stationary in level implying the variables are integrated of order zero *[i.e. I(0)].* This conclusion that the long run relationships between the energy intensity and the set of explanatory variables could be estimated directly without facing the problem of spurious or unrelated regressions (see Costantini and Martini, 2009; Baltagi and Kao 2000; Pedroni, 1999, Pedroni, 2004).

4.2 Estimation of empirical model

The empirical model specified in equation (3) is characterized by endogeneity and collinearity of some regresssors. For instance, the income variable (GDP per capita) which is used as a proxy for economic growth is highly endogenous as it is also determined by energy intensity as well as other regresssors in the model such as trade and FDI. Similarly, industrialization and the urbanization variables are highly correlated. As a result, the empirical model is estimated using the two-step system Generalized Method of Moment (GMM) developed by Arrelano and Bover (1995). The choice of the system GMM is justified on the grounds that it is able to overcome endogeneity and collinearity of regresssors which characterize the basic model of this paper. In addition, the technique is able to overcome econometric problems such as cross-sectional dependence of countries and multi-correlation which are prevalent in macro panel models (Arrelano and Bond, 1991 and Arrelano and Bover, 1995). Furthermore, the technique produces efficient parameter estimates than many techniques such as Ordinary Least Squares (OLS), Random and Fixed Effects particularly in instances of endogeneity and multicollinearity. The vital diagnostic tests for system GMM estimation include but not limited to first and second-order autocorrelation test and a Sargan test statistics of over-identification of instruments employed (Baltagi, 2008; Arrelano and Bond, 1991 and Arrelano and Bover, 1995). The results of the two-step system GMM estimations of the environmental effect of the relevant growth-enhancing factors are presented in Table 2.

Table 1: Fisher Unit root test of variables

	Fisher ADF (Inverse χ2)		IPS (W-t-bar stat)	
Variables	Statistic	Prob.	Statistic	Prob.
Energy intensity	31.07	0.001	-7.770	0.001
Industry, value added(%GDP)	97.88	0.000	4.214	0.000
Economic growth	59.41	0.000	-4.911	0.000
Trade (%GDP)	12.00	0.005	-4.857	0.001
FDI (%GDP)	47.00	0.000	-3.433	0.000
Urbanization (% total population)	30.71	0.000	-5.915	0.000
Inflation rate (annual %)	71.04	0.000	-5.190	0.001

H_0: All the panels contain unit roots/non-stationary

H_1: Some panels are stationary/has no unit root

Table 2: System GMM estimations[4]

Regressors	Coefficient	Std. Err.	z	P>z	95% Conf. Interval	
Lagged energy intensity	0.082	0.006	13.67	0.000	0.055	0.081
Economic growth	0.294	0.094	3.13	0.000	-0.87	-1.460
Economic growth squared	-0.017	0.009	-1.88	0.425	-0.11	-.049
Trade	-0.240	0.008	-30.02	0.000	-0.04	-0.006
Inflation (CPI)	0.005	0.002	2.60	0.009	0.001	0.009
Industrialization	0.400	0.017	23.28	0.000	30.01	30.74
Urbanization	0.230	0.066	3.46	0.001	0.36	0.099
Foreign Direct Investment	-0.007	0.001	-7.94	0.000	-0.006	-0.009
Constant	1.030	1.900	0.54	0.589	-2.71	4.770
Prob.>F	0.000					
AR (1) test (p-value)	0.004					
AR (2) Test (P-value)	0.759					
Sargan Test	23.35					

[4] AR (1) and AR (2) respectively are first-order and second-order autocorrelation test. P-values > 0.05 fail to reject the null hypothesis of the presence of both first and second-order autocorrelation in all specifications. The Sargan test is a test of over-identification of instruments used by the GMM technique. The Sargan test statistics shown in Table 2 indicate that over-identification of instruments used is invalid. These two diagnostics unequivocally confirm the robustness of the model and the results as well.

Urbanization and energy intensity

The elasticity coefficient on urbanization is positive and significant which means that rapid/rising urbanization is associated with a rise in energy intensity in the 36 sampled SSA countries. Specifically, a 1% increase in urban population increases energy intensity by about 0.23% and the converse is also true. This implies urbanization is associated with more energy-intensive economic activities. It is often argued that urbanization is associated with increased pressure on existing urban facilities, infrastructure, and a rapid rise in the demand for goods and services. To produce enough goods and service and to provide enough infrastructure to meet the rising demand of the additional population in urban centers, there is the need to expand existing and/or create new facilities alongside with increase in the production of goods and service. All these processes invariably require massive energy consumption which could eventually result in a rise in energy intensity. Though the increased production activities may lead to economies of scale and can consequently reduce energy intensity, the findings of this paper suggest that even if the latter situation is true, it could be argued that increasing effect of urbanization on energy intensity far outweigh its reducing effect. This conclusion is in sharp contrast with the findings of Mishra et al. (2009) in New Caledonia who found that urbanization had a negative impact on energy use in New Caledonia; Poumanyvong and Kaneko (2010) on low-income countries and Sadorsky (2013) in the long run dynamic model but consistent with Parikh and Shukla (1995) and Poumanyvong and Kaneko (2010) on middle-income countries.

Industrialization and energy intensity

Similarly, the coefficient of industrialization is significant and positive. Particularly, a 1% increase in industrialization (i.e. industrial activities) results in more energy-intensive economic activities by about 0.40% and vice versa. Clearly, industrialization relies extensively on energy through the use of machines and equipment and sophisticated technology. These machines and technology facilitate many industrial activities tremendously which can eventually reduce energy intensity. However, these sophisticated and advanced technologies are scarcely used in the industrial activities undertaken in the region possibly due to the fact that a relatively larger proportion of the industrial firms are micro, small and medium scaled and could hardly afford more sophisticated and less energy-intensive machinery. As a consequence, energy intensity keeps on rising in the face of industrialization in in the 36 sample SSA countries. This finding is consistent with Samouilidis and Mitropoulos (1984) who reported that the effects of industrialization on energy intensity in Greece in both the long-run ranges from 0.90 to 1.96 while short-run elasticities ranges 0.17 to 0.46. Similarly, it is consistent with Poumanyvong and Kaneko (2010) who revealed that the share of industrial activity in the economy on energy intensity is positive for 99 low and middle income countries.

Economic growth and energy intensity

More so, the results reveal that energy intensity increases as the economy grows. In particular, a percentage rise in economic growth increases energy intensity by about 0.23%. Since economic activities require energy consumption, increases in economic activities would be accompanied by increasing energy consumption which would invariably lead to a rise in energy intensity. This finding contrasts that of Metcalf (2008) who maintained that rising per capita income has played a significant role in improving energy intensity. Nonetheless, he was quick to admit that income predominantly influences energy intensity through changes in energy efficiency rather than through changes in economic activity. This finding is however at variance with Parikh and Shukla (1995) and Harris and Prakash (2012). Furthering the analysis, the

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coefficient on the square of economic growth is found to be negative and statistically significant, demonstrating that the relationship between economic growth and energy intensity is non-linear and thus the increasing effect of economic growth on energy intensity breaks down beyond a certain growth threshold. The non-linear relationship between energy intensity and economic growth confirms the assertions of Galli (1998). In particular, Galli (1998) found some evidence of a non-linear relationship between energy intensity and income in 10 Asian economies over the period 1973–1990. Thus, the inverted U-shaped relationship predicted by the standard EKC hypothesis is found to exist for energy intensity in the 36 sampled SSA countries.

Control variables and energy intensity

Trade

With regard to the control variables, openness to trade is revealed to significantly reduce energy intensity in SSA countries. In particular, a 1% increase in trade activities reduces energy intensity by about 0.24%. This could possibly be attributable to the fact that, trading activities between the region and other regions and even the world economy at large do not rely extensively on energy and/or trading activities make use of highly advanced and sophisticated technology so that the net effect is that, energy intensity is lowered as trade openness increases. This finding is consistent with Hubler (2009) and Cole (2006) who conducted similar empirical investigation in China and 32 developed countries for the period 1975–1995 respectively.

FDI

Similarly, FDI is significant and has elasticity coefficient of -0.007, indicating that a 1% increase in FDI reduces energy intensity by about 0.007%. This finding is plausible given that FDI provides an avenue for the transfer of advanced technology from developed economies to developing ones, which in turn improves productivity in developing regions such as SSA. This finding is consistent with Hubler (2009) and Fisher-Vanden et al. (2004).

Inflation

Inflation rate has a positive and statistically significant elasticity coefficient demonstrating that inflation could also trigger rises in energy intensity in the 36 sample SSA countries. Though inflation is associated with rather a negligible rise in energy intensity (0.005), economic theory might expect that economic agents might tend to resort to less energy-intensive mechanisms following rises in inflation. However, the contrary is established in SSA. Thus, increasing prices is not sufficient to cause any decline in more energy-intensive economic activities.

Sub-regional Analysis of Energy intensity

Finally, the paper examines the extent of variations in energy intensity across four sub-regional blocs in SSA; namely Southern African Development Community (SADC), East African Community (EAC), Economic Community of West African States (ECOWAS) and the Central African Economic and Monetary Community (CEMAC). To this end, four (4) dummies are constructed for SADC, EAC, CEMAC and ECOWAS. For analytical purposes, ECOWAS is used as the reference category partly because it has more countries represented in the sample and that of language heterogeneity. The results of the extent of variations in energy intensity across the four sub-regional blocs in SSA are reported in Tables 3. It is observed that the coefficient of all the sub-regional dummies are positive but it is that of SADC which is statistically significant suggesting that the SADC zone, in particular, is exhibiting rising energy intensity as compared to the ECOWAS sub-region. This new evidence needs special attention in research to properly

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examine the plausible justification for this observed rising energy intensity in the SADC zone relative to the other three sub-regional zones. See table 3.

Table 3: System GMM estimations[5]
Sub-regional Analysis of Energy intensity

Regressors	Coefficient	Std. Err	z-Stats	P>z	95% Conf. Interval	
Lagged energy intensity	0.502	0.084	5.92	0.000	0.336	0.668
Economic growth	0.587	0.171	3.433	0.000	-1.51	0.335
Economic growth squared	-0.071	0.034	-2.088	0.002	-0.061	0.074
Trade	0.0446	0.014	3.33	0.000	-0.722	0.832
Inflation	0.009	0.005	1.72	0.070	-0.011	0.023
Industrialization	0.212	0.113	1.87	0.060	-0.307	0.446
Urbanization	0.2787	0.073	3.78	0.000	0.1342	0.423
Foreign Direct Investment	0.0048	0.001	4.23	0.000	0.0025	0.007
SADC	0.7851	0.185	4.24	0.000	0.4225	1.14
EAC	0.2249	0.255	0.88	0.378	-0.275	0.725
CEMAC	0.6204	0.418	1.48	0.138	-0.199	1.44
Constant	3.4047	1.54	2.21	0.027	0.3863	6.4212
Prob.>F	0.0000					
AR (1) test (p-value)	0.0133					
AR (2) Test (P-value)	0.6964					
Sargan Test	22.564					

The main contribution of this paper relates to the use of a relatively recent panel data (1980-2015) to model the impact of three key variables namely urbanization, industrialization and economic growth on energy intensity in the context of SSA. Besides, control variables based on the empirical literature and the peculiarity of SSA were also included in the model to improve the model fit. While this phenomenon has been partly examined in Asia, particularly oil-rich countries and some developed countries, there is paucity of literature in the SSA region. Furthermore, the empirical technique adopted; the two-step system Generalized Method of Moment (GMM) overcomes the problems of endogeneity, muliticolinearity and cross-sectional dependence of countries which are prevalent in macro panel models.

It is important to state that results of the two-step system GMM estimations relates to the long run. This implies that the findings of this paper hold in the long run and thus might not be appropriate for short-term policy consideration. Notwithstanding, the findings offer some useful insights into the likely short run dynamics on the implication of economic growth, industrialization and urbanization on energy intensity in Sub- Saharan Africa

5. Conclusions

Plummeting energy intensity is often advocated as a way to at least partially mitigate concerns about climate change, peak oil, and energy security and sustainability. Using a panel data from 1980 to 2015 covering 36 Sub-Saharan African (SSA) countries, this study examined the

[5] See Footnote 2

empirical implications of economic growth, urbanization and industrialization on energy intensity. Using the system Generalized Method of Moment (GMM) estimation technique, the study revealed that both urbanization and industrialization tend to increase energy intensity in SSA while for FDI and trade openness the contrary is established. Analysis of the EKC hypothesis revealed an inverted U-shaped relationship between economic growth and energy intensity in SSA. A sub-regional analysis revealed that energy intensity is still rising in all the sub-regional blocs with the effect been highest for SADC. These conclusions have stern theoretical and policy implications for the existence of the EKC for energy intensity for SSA.

However, given that energy intensity is reduced at higher growth levels, policy instruments that increase per capita income in SSA should be encouraged whiles studies into the economic growth threshold that could optimally reduce energy intensity are imperative. The empirical results further reveal that growths in industrialization and urbanization increase energy intensity. This conclusion does not however imply that the region should discard its policies geared at promoting industrialization. The essential issue at stake relates to how best to minimize the destructive effect of industrialization and urbanization on energy intensity in the region.

Moreover, advancing the reducing effect of FDI and trade on energy intensity may require considerable research and development (R&D) activities as R&D activities have been identified to reduce industrial energy intensity. Moreso, to improve energy intensity, it is important that one gives a considerable attention to and emphasis on the link between industrial energy intensity and key reform parameters, such as privatization, enterprise restructuring and power sector reforms.

In summary, urbanization and industrialization are expected to increase in developing countries overtime. The combined effects of increasing economic growth, industrialization and urbanization will lead to a decline in energy intensity as long as economic growth is sufficiently large enough to offset the increasing impact of urbanization and industrialization in the region’s energy intensity situation. This means the region needs to place substantial focus on economic growth if it desires to reduce energy intensity considerably.

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Appendix

Appendix A: Variables and Proxies

Variable	Proxy
Energy intensity (EI)	Natural log of energy intensity (primary energy use per GDP, constant 2005 PPP)
Income (Y)	Natural log of real per capita GDP (constant 2005 international dollars)
Foreign Direct Investment (F)	Natural log of the share of FDI (net inflows) in GDP
Trade openness (T)	Natural log of (export + import)/GDP
Industrialization (I)	Natural log of industrialization (industry, value added as a % of GDP).
Urbanization (U)	Natural log of urbanization (urban population as a % total population)
Inflation rate(ꞃ)	Natural log of GDP deflator (annual %)

Source: World Bank (2013)

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Appendix B: List of the 36 SSA countries sampled for the study

Angola***	Congo, Dem. Rep.*	Lesotho***	Nigeria****	Swaziland***
Benin****	Congo, Rep.*	Liberia****	Rwanda**	Tanzania**
Botswana***	Cote d'Ivoire****	Madagascar***	Senegal****	Togo****
Burkina Faso****	Ethiopia*	Malawi*	Sierra Leone****	Uganda**
Burundi**	Gabon*	Mali****	South Africa***	Zambia***
Cameroon*	Gambia, The****	Mauritania****	Sudan**	Zimbabwe***
Cape Verde****	Ghana****	Mauritius**		
Central African Rep*	Kenya**	Niger****		

, **, * and **** correspond to countries in CEMAC, EAC, SADC and ECOWAS respectively.*