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Realising the net Impacts of International trade on carbon dioxide emissions for the sustainability of the environment in African countries

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The purpose of this study is to critically assess the relationship between international trade and carbon dioxide (CO_2) emissions to identify the key driving forces in Africa at different income levels. In examining the causal effects of net trade on CO_2 emission loads from 1960 to 2012 with a number of other anthropogenic driving forces, we employed a panel dataset, an augmented STIRPATN models and techniques of Generalised Least Squares to determine the quantitative magnitude impacts of net trade on CO_2 emissions. The results suggest that CO_2 emissions have statistical significant impact on net trade, population size, manufacturing sector and services sector. The final consumption expenditure (annual growth) cannot be used to explain CO_2 emission loads in Africa, as it is not statistically significant at all in different income levels. The estimated results indicate that, the average effect of net trade over CO_2 emissions, when the net trade changes across time and between countries increases by 1%, CO_2 emissions increases by about 1.02 and 2.24% for low income countries and middle income countries, respectively, when all the other predictors are constant.

Key words: International trade, population size, carbon dioxide emissions, net trade.

INTRODUCTION

Previous studies see the role of international trade as crucial to the explanation of increasing carbon dioxide (CO_2) emissions. International trade is regarded as an engine of growth as it provides much needed opportunity for technological transfer, investment and knowledge transfer among others.

The population trends in Africa have fuelled global concern, given its finite resources which engender increasing international trade relationship to complement the available resources within each member countries. The continent has witnessed an explosive growth in human population and a steep increase in resource depletion and environmental problems. These trends have accelerated since 1960, fuelling the debate on the relationship between trade, population and environment impacts (Panayotou, 2000a, b).

In recent times, some studies have maintained that changes in the ecosystem are due to increasing international trade, population change, consumption patterns and human activities through the impacts on the

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distribution of affluence (income), institutional environment and poverty. Furthermore, the environmental problems trends in Africa can create pressures that overwhelm the continent's ability to plan and adapt. There is an increasing concern that a rapidly growing international trade relationship might be one of the key driving forces behind the rising (CO_2) emissions in the continent. CO_2 emissions are one of the key indicators of environmental impacts, contributing to Atmospheric Greenhouse Gas Emissions (AGHGEs) (Shi, 2003).

African continent accounts for only 3.7% out of the total carbon dioxide emissions per year (Canadell, et al., 2009). However, the rapid population growth in Africa suggests an increasing demand for energy such as combustion of wood for fuel- by deforestation and increasing use of kerosene (most households in sub-Saharan Africa still depends on the stove for cooking); emission of carbon monoxide by increasing use of generators because of incessant cut in power supply in some countries; generation of carbon monoxide by increasing use of vehicular movements that are not roadworthy in America and Europe; pollution and carbon monoxide, other used items such as refrigerators, deep freezers, television and chlorofluorocarbons emission.

The cement industry is expanding as new firms are established in most part of the continent to keep pace with population growth (PGH). All the resources are likely to rise which in-turn increases international trade relationship in line with population growth (PGH). The statistical estimates and projection, since 1960, shows an increasing trend of carbon dioxide emissions on the continent, and the suspicion that recent increase in international trade may be responsible. Thus, the comprehension of the continent's contributions and trends of anthropogenic carbon dioxide emissions and international trade are crucial to suggest ways to improve the operational effectiveness aimed at stabilizing the global carbon dioxide emissions.

Despite the important benefits, many previous studies have undergone, very few empirical analysis takes into account the issue of international trade with respect to carbon dioxide emissions. In addition, on a global scale increasing energy consumption has been linked to the renewed aggressive extraction of natural resources from Africa to meet rising demands of industrialized nations and emerging economies: such as Brazil, Russia, India, China and South Africa. Empirical analysis has not extended its reach to examine this gap regarding Africa. Therefore, this study intends to contribute to global trade-environment relationship by investigating empirically net trade as part of the driving forces of environmental impacts in Africa. By contrast, previous studies only examined population, affluence and technology as the key driving forces of environmental threats, since the theoretical framework was designed based on developed economies. The primary objective of the study is to investigate the impacts of openness of the economies on carbon dioxide emissions in African countries at different per capita income levels.

This study is motivated by the desire to have a better understanding of the contributions and trends of anthropogenic carbon dioxide (CO_2) emissions in Africa that have dictated increasing trends since 1960 and to be able to predict future anthropogenic CO_2 emissions. The research also links trade-carbon dioxide emissions in terms of the measurement of the quantity of CO_2 emitted by the sustained increase of African countries trade relationship with the rest of the world in comparison to the emissions of other numerous human activities.

LITERATURE REVIEW

Net trade and CO_2 emissions

Dietz and Rosa (1994a) offer a comparative analysis of studies with the argument that single indicator of study and estimation based on it may be misleading due to the *Netherlands effect*. For example, Ehrlich and Holdren (1971a, 1972b) maintain that much of the environmental impact of a country may be displaced across its borders as a result of the mix between imports and exports and its place in the international division of labour.

This study pointed out that, the relationship between trade and environmental impacts can be controlled by considering imports and exports with high environmental consequences. However, this position is flawed because substitution within a social system is not taken into account. It is argued that, a country may have relatively low carbon dioxide emissions due to extensive use of nuclear hydroelectric power rather than fossil fuel. An obvious reference to the impacts of nuclear waste is reiterated by Dietz and Rosa (1994a). Their study pointed out that, the disposal of nuclear waste and the disruption of riparian ecosystems are environmental problems. It is suggested that an adequate environmental indicator should be taken into account the effects of net trade and the possibility of displacing impacts. Dietz and Rosa (1994a) suggested that, environmental impacts can be treated as latent variables while specific indicators such as carbon dioxide emissions, tropical wood imports or endangered species serve as observed indicators or proxies associated with the latent variables. In strict accordance with the world system theory, Shi (2003) asks whether the linkages between population and environmental impacts will be robust when the relationship between net trade and emissions is taken into account. This study argues that, changes in emissions across countries may be influenced by imports and exports of dirtier products such as fuel. It was examined the net trade-emission nexus by using non-trade output as a percentage of Gross Domestic Product

(GDP) as predictor.

It claimed that a large share of non-traded GDP may mean a smaller quantity of trade in dirtier industries. Thus, we expect that a country with relatively larger share of non-traded GDP will mitigate emissions than another whose share is relatively small.

Jorgenson (2009) investigated the transnational organization of production in the context of foreign direct investment and carbon dioxide emissions. The study used the method of fixed effects for a panel regression analysis of 37 less developing countries from 1975 to 2000, and examines the impact of secondary sector foreign investment on total carbon dioxide emissions and emissions per unit of production. The empirical findings suggest that, foreign direct investment in manufacturing has a positive relationship with both outcomes. The results also indicate that, the level of economic development and export intensity has a positive association with total emissions and emissions per unit of production.

The world systems theory perspective foregrounds the importance of human-ecology and political perspectives when examining anthropogenic carbon dioxide emissions. Roberts et al. (2003) applied the world system perspective to environmental impacts. The research sampled 154 countries and investigated their contribution to the global economy and their internal class and political forces to estimate on how these factors influence the quantity of CO_2 emissions per unit of economic output. The study concluded that semi-periphery and upper-periphery countries are the least efficient consumers of fossil fuels, consistent findings with Satterthwaite (2009).

Li et al. (2017) studied the effect of trade on fuel related mercury emissions to examine the aggregate energy consumption and environmental emissions. The literature employs a three-scale input-output analysis which accommodates variation in circumstances regarding local, domestic and international activities and evaluated the embodiment fluxes of fuel related mercury emissions in Beijing in 2010, given the mercury intensities for average national and world economies. The results found that international trade is a major contributor of Beijing environmental emissions (Beijing mercury emissions final fuel consumption were 7.79t in 2010, higher by about 3/4 of which is linked to domestic and openness of the economy).

However, the highest level of environmental emissions was due to massive infrastructural development in the capital city. The implication is that modernization is a driver-trigger in the analysis of environmental impacts. The specification used by Liu et al. (2015) is a system dynamic model to estimate energy consumption and carbon dioxide emissions in China for the period 2008 to 2020. Using macro-data, the literature clearly shows that CO_2 emissions per GDP amelioration by about 40 to 45% of 2005 level could be attained in 2020 in China. Even though the structure conducted scenario simulation, to determine the impacts of economic growth rates on the energy consumption and carbon dioxide emissions, some vital variables such as population dimensions and technology were neglected in the determination of environmental impacts.

Consumption is not the only driving forces of environmental impacts. Xu and Lin (2015) analyzed the driver-trigger of carbon dioxide emissions in China's transport sector. A nonlinear inverted U-shaped curve was found to exist suggesting evidence of Environmental Kuznets Curve (EKC) in the sector, as in economic growth depending heavy on road and air transport in the early stage, but deepening on emission-free train-transport at the later stage due to the speed of technological progress at different times. Urbanization is also found to exhibit pattern of EKC. Zhang et al. (2014) used a PEMs method to collect 60 light-duty passenger vehicles (LDPVs) data on-road fuel consumption and CO_2 emissions for China. The study found about 30% gap between on-road fuel consumption and type-approval values. The results among many others, found diesel LDPVs to have 22% energy saving advantage against gasoline counterparts while the literature also reports a strong correlation between fuel consumption and average speed, that is, a reduction in traffic congestion has effect of mitigating distance-based fuel consumption. Loftus et al. (2015) carried out feasibility studies on global decabonization argue that historical carbon intensity and energy intensity rates need to improve and normalized energy technology capacity deployment rates which are important benchmarking comparators to examine the relative feasibility of global decarbonization scenarios for decision makers.

Zhang and Choi (2013) explore the feasible application of the SBM-DEA approach for energy efficiency in China, showing that most regions in China are not efficient in environmental-friendly low energy carbon economy. However, considerable room for improvement is not ruled out. The study attributed environmental energy inefficiency to pure energy inefficiency, and research and development is therefore recommended for the future. Ouyang and Lin (2015) investigated the drivers of energy-related carbon dioxide emissions in China's industrial sector. The findings suggest a long-run relationship between industrial carbon dioxide emissions and the influencing variables (CO_2 emissions per unit of energy consumption, industrial value added, labor productivity and fossil fuel consumption).

The study attributed industrial CO_2 emissions as the key determinant to the coal-dominated energy structure in the country. Liu et al. (2015) examined the effect of population, income and technology on energy consumption and industrial pollutant emissions in China. The research did not find evidence of Environmental

Kuznet Curve (EKC) hypothesis. In addition, the impact of population density, income and technology on energy consumption and pollutant emissions varies at different level of development. The study suggests formulating specific region-oriented emissions reduction strategies for sustainable development in China.

World-system theory (WST)

Wallersetin (1976) first brought the world-system theory into focus in a seminar paper in 1974. The key issue is that, the theory takes a macro-sociological approach in analysing the working of the world capitalist economy as total social system. He described the establishment of the European capitalist economy system as a basis for economic growth and environmental problems.

According to York et al. (2003b), the perspective argues that the regional, inter-regional and transnational division of labour separates world economy into periphery countries (poor countries), semi-periphery countries (emerging economies) and the core countries (developed economies). The developed economies are based on higher skills, the method of production is capital-intensive; the semi-periphery countries are also based towards high skills and tend toward more capital intensive method of production; while the periphery countries uses low skill and labour intensive production (York et al., 2003b). This theory follows the traditional Marxist political economy perspective (TMPEP) and its logic at a global level, and extended its reach to investigate environmental impacts (Burns et al., 1994; York et al., 2003a). The main focus is that all countries of the world are organized into a single world economy that is dominated socially, economically, politically, and military by developed nations (Wallerstein, 1974). According to Halsall (1997), Wallerstein's works provide a detail “understanding of the external and internal manifestations of the modernization process during this period and makes possible analytically sound comparisons between different parts of the world”. The theory structure countries into three main locations: core or wealthy powerful countries, the United States of America (USA), Japan and most Western European countries, these countries control the trade relationship with other countries of the world-. They dominate economically and politically. Semi-periphery or emerging economies like Brazil, Russia, India, China, Mexico and Turkey occupy intermediate power when compared to the periphery; and the periphery like African countries and other less developing countries in the world, “have small typically industrialized economies and lack global political power” (York et al., 2003b). According to York et al. (2003b), economic development is the main driving force of environmental problems, and this is consistent with PEP (Political Economy Perspective).

The underlying point in this theory is that the core countries dominate as the major producers and consumers, but the basic natural resources need for production such as minerals and other primary commodities are extracted from the periphery nations (Frey 1994, 1995; York et al., 2003b). The WST counters the evidence which shows the presence of EKC (Ecological Kuznets Curve) of reduced environmental impacts in core countries through ecological modernization as spurious and untenable. In addition, Roberts and Grimes (1997) criticized the evidence of EKC on the ground that for carbon dioxide (CO_2) emissions, EKC can be “explained by nations at different positions in the world-system being locked into different trajectories of fossil fuel use”, and evidence and findings only exist for local impacts (York et al., 2003b). This vital point draws attention to whether economic development actually reduces environmental problems or shifts them elsewhere (Stern, 1993).

Thus, the assumption that EKC has relevance in developing economies raise a big question, because it is brought about as a result of the relationship between economic development and environmental impacts (Ehrlich and Holdren, 1970, 1971). The implication is, the WST approach regards the example of the Netherlands as combining a very high population density with good environmental outcomes is misleading because one must consider the worldwide relationship between population and the environment. Furthermore, York et al. (2003b) argues that the wealthy nations have the technology to distance themselves from the environmental impacts they have generated. Therefore, it is spurious and misleading to rely on the evidence of the impacts that a country generates within its borders, instead of taking a world-wide system analysis on the impacts. This means that damage to the environment anywhere is damaging to the environment everywhere.

The world-system theory laid emphasis on total impacts and not micro impacts, impacts generated both within and beyond the national borders, and this underlies a “theoretical understanding of threats to sustainability” (York et al., 2003b). It is further argued that environmental problems continually rise with economic growth, but will extend beyond the countries that generated these impacts, in contrast with EKC.

MATERIALS AND METHODS

Data sources and samples observed

Data sources, descriptions and analysis

The study constructs an unbalanced time series cross-section (TSCS) data set of 51 countries in Africa for the period 1960 to 2012. The study period (1960 to 2012) is based on the availability of the data according to the classification of World Bank into Low Income Countries in Africa (LICA), Lower Middle Income Countries

(LMICA), Upper Income Countries in Africa (UICA) and High Income Countries in Africa (HICA). The size of the sample changes according to the model specification. The excluded countries are mostly Islands whose data are not available from the World Bank between the period under investigation, and Southern Sudan who became independent 3 years ago.

The African continent consists of a list of sovereign countries, partially recognized and unrecognized states (Somaliland, and Sahrawi Arab Democratic Republic) and dependent territories, that is, non-sovereign territories (French Southern and Antarctic Lands, Saint Helena, Ascension and Tristan da Cunha, Canary Islands, Ceuta, Madeira, Mayotte, Melilla, Plazas de Soberanda, Reunion and Lampedusa and Lampione), all located on the African continental plate (National Geographic, 2011; De Waal, 2010; Freshfield, 1869; Rennell, 1830; von Strahlenberg, 1730; Theiler, 1982). However, by international convention, they are considered European (De Waal, 2010).

In addition, the Island of Socotra is on the continent of the African plate, but part of Yemen territory (Freshfield, 1869; National Geographic, 2011; Theiler, 1982). This study considered only the sovereign states on the continent due to data availability. Of the 54 sovereign states in Africa, the research investigates 51 countries which yield a good coverage of the independent countries on the continent. We collected online data from the World Bank Africa Development Indicators. We are now positioned to investigate our anthropogenic environmental impacts by mapping the driving forces into our modified STIRPAT frameworks.

Variables

Response variable: For our outcome variable, we used the World Bank data analysis in 2013 for per capita carbon dioxide emissions, and related emissions in Africa, comprising agricultural methane emissions, agricultural nitrous oxide emissions, carbon dioxide emissions from residential buildings and commercial public services, energy related methane, methane emissions, nitrous oxide emissions including industrial and energy processes, other greenhouse gas emissions, HFC, PFC, and SFG (thousand metric tons of CO_2 equivalent) and PM10, country level (micrograms per cubic metre).

Of these emissions, we examine only carbon dioxide emissions stemming from the burning of fossil fuels and manufacture of cement, which include CO_2 produced during consumption of solid, liquid and gas fuels, and gas flaring. We gathered this information from the World Bank Development Indicator (2013), which was originally provided by Carbon dioxide Information Analysis Centre, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee and USA.

Population size: The population size refers to the total population or total number of people in geographically sovereign states. Population size is the total number of human beings occupying a specified sovereign country in Africa.

GDP per capita (2005 constant prices US$) (affluence): The GDP per capita is sourced from the World Bank Development Indicator (2013) national accounts data, and OECD National Accounts data files. The GDP per capita refers to the gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy, plus any product taxes, and minus any subsidies not included in the value of the products. It is calculated without making deductions for the depreciation of fabricated assets or for the depletion and degradation of natural resources. Data are in 2005 constant US dollars, permitting comparisons across African countries over time.

Technology: The information on technology is derived from the World Bank Development Indicator (2013) national accounts data and OECD National Accounts data files. This study does not enter into the controversy surrounding technology but represents technology with two structural indicators: manufacturing as a percentage of GDP and services as a percentage of GDP. This is consistent with many studies of ecology and modernisation. Manufacturing as a percentage of GDP is the manufacturing sector of value added which is expressed as a percentage of GDP.

The services are the value added expressed as a percentage of GDP. The services' correspond to International Standard Industrial Classification (ISIC) divisions 50 to 99, and comprise value added in the wholesale and retail trade, including hotels, restaurants, transport, and government, financial, professional, and personal services such as education, health care, and real estate services. In addition, it also includes imputed bank service charges, import duties, and any statistical discrepancies noted by national compilers as well as discrepancies arising from rescaling. The value added is defined as the net output of a sector after summing up all outputs and subtracting intermediate inputs. The measurement calculates value added without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.

According to the World Bank Development Indicator (2013), the industrial origin of value added is determined by ISIC (International Standard Industrial Classification). In addition, for Vehicle Assembly Building (VAB) countries, gross value added at factor cost is used as the denominator.

Final consumption expenditure (FCEG): We derived data on final consumption expenditure (FCEG) (annual % growth) from the World Bank Development Indicator (2013) data files, and the catalogue sources of World Development Indicators consist of World Bank national accounts data and OECD National Accounts data files. The FCEG is the average annual growth of final consumption expenditure based on constant local currency. Aggregates are based on constant 2005 US dollars. Final consumption expenditure (formerly total consumption) is the sum of household final consumption expenditure (formerly private consumption). It includes any statistical discrepancy in the use of resources relative to the supply of resources.

STIRPAT model

Beginning with the challenge of ImPACT identity, an attempt to investigate potential action and policy levers to alter environmental impacts was carried out by Waggoner and Ausubel (2002), through reformulating IPAT identity into ImPACT identity. The study decomposed T into consumption per unit GDP (C) and impact per unit consumption (T), implying that I = PACT. For example, an investigation of carbon dioxide emissions employing IPAT framework show that total emissions (I) are the product of population (P), affluence, that is per capita GDP (A), and carbon dioxide emission per unit GDP (T) whereas, the ImPACT framework states that total carbon dioxide emissions are equal to the product of P, A, energy consumption per unit of GDP (C), and carbon dioxide emissions per unit of consumption (T). The main objective of the ImPACT framework is to determine the variables that can be altered to minimize environmental impacts and the principal factors which influence each variable.

The STIRPAT model has its root in the refinement of IPAT and

ImPACT identities by Dietz and Rosa (1994a). The STIRPAT equation is:

$$I_i = aP_i^{\alpha} A_i^{\beta} T_i^{\varphi} e_i \tag{1}$$

Equation 1 can be linearized by taking logarithms on both sides of the equality.

$$\ell n(I_i) = a + \alpha \ell n(P_i) + \beta \ell n(A_i) + \varphi \ell n(T_i) + e_i \qquad i = 1, .., n \tag{2}$$

Where: Constant "a" scales the model,
α, β and φ are the exponents of the population (P), affluence (A) and technology (T),
"e" is the error term
Subscript "I" shows all the explanatory variables and error term (e) vary across observational units. The exponents can be interpreted as elasticities in Equation 2. The STIRPAT model contains the IPAT as a special case, namely: $a = \alpha = \beta = \varphi = e = 1$ and the ImPACT identity: $a = \alpha = \beta = \varphi = e = 1$. This can also be derived from Equation 1 by setting a = α = β = φ = e = 1. In the case of the STIRPAT framework, any of the elasticity coefficients can be greater than 1, or less than 1, or may be equal to 1. In a panel data analysis, the Equation 2 above becomes:

$$\ell n(I_{it}) = a + \alpha \ell n(P_{it}) + \beta \ell n(A_{it}) + \varphi \ell n(T_{it}) + e_{it} \tag{3}$$

Where: "t" is the time period or the year.
The STIRPAT model is employed as a starting point because it allows an additive regression model in which all the variables can be conducted in logarithmic form, facilitating estimation and hypothesis testing (York et al., 2003a), the limitations of both IPAT and ImPACT. In addition, the York et al. (2003a) study used the STIRPAT model refined by Dietz and Rosa (1994a), and combined T with the error term, rather than estimating it separately to conform to the IPAT framework, which York et al. (2003a) T to balance I, P and A. The modifications yield:

$$\ln(I_{it}) = a + \alpha \ln(P_{it}) + \beta \ln(A_{it}) + \theta \ln(M_{it}) + \psi \ln(S_{it}) + e_{it} \tag{4}$$

The approach of this study is slightly different from York et al. (2003a, 2003b) modifications, as this study considered T as an important variable that should be disaggregated into manufacturing sector and services sector and estimated, instead of making the blanket assumption that T could be treated as part of the error term as in York et al. (2003a, 2003b). Thus, we identify two important components of technology that need to be empirically tested to achieve part of the objective of the impact of human activities on emissions. The identified disaggregated technologies are: manufacturing sector as a major component of GDP and services sector as a component of GDP (Shi, 2003). This is consistent with the economic modernization perspective and neoclassical economic growth theory which maintained that structural factors play crucial role in mitigating environmental impacts. Both theories argued that "the shift occurring away from manufacturing economies and toward service economies is commonly identified as a potential solution to environmental problems, because service economies are presumed to be less dependent on natural resources than industrial economies" (York et al., 2003b).

More still, the percentage of manufacturing and the percentage of services captured the difference in T. It is expected that economies whose GDP outputs are heavily derived from manufacturing will be energy-intensive which will produce higher emissions. By contrast, economies whose GDP is largely derived from services will be less energy-intensive and produce lower emissions (Shi, 2003). By incorporating the disaggregated T variable into the Equation (3), this research specifies our model as:

$$\ell n(I_{it}) = a + \alpha \ell n(P_{it}) + \beta \ell n(A_{it}) + \theta \ell n(M_{it}) + \psi \ell n(S_{it}) + e_{it} \tag{5}$$

Where: M is the manufacturing sector as a major component of GDP (percentage of GDP), and
S is the service sector as a major component of GDP (percentage of GDP),
θ and ψ are the exponents of M and S; and all others are as defined above.
The priori expectation is that all the elasticity coefficients α, β, θ and ψ are expected to be positive.

Endogeneity bias

Many scholarly outputs in the global community of STIRPAT users have employed the STIRPAT model because it allows for unobserved and omitted variables which are constant over time but may be correlated with some of the explanatory variables, for example, the initial level of technological efficiency and the possibility of using several lags of the instruments to control endogeneity bias.

The STIRPAT permits GMM estimation of dynamic models. In addition, it also allows the use of fixed effects or random effects, generalised least square/feasible generalised least square (GLS/FGLS), panel corrected standard error (PCSE) estimation techniques, thereby paving way for the analysis of the impact on growth of the driving forces that change over time, as well as exacerbating measurement error (Sianesi and Reenen, 2002; Temple, 1999). Baltagi (2008), Hsiao (2003), and Wooldridge (2010), stated that in a general panel data analysis, we have:

$$y_{it} = \alpha_i^* + \beta_i x_{it} + e_{it} \qquad i = 1, ..., N \qquad t = 1, ..., T \tag{6}$$

Where x is a scalar exogenous variable (k =1), and e_{it} is the error term with mean zero and constant variance σ_u^2. The parameters α_i^* and β_i may be different form different cross-sectional units, although they stay constant over time. Following this assumption, a variety of sampling distributions may occur. According to Baltagi (2008) and Hsiao (2003), such sampling distributions can seriously mislead the least-squares regression of y_{it} on x_{it} when all NT are used to estimate the model:

$$y_{it} = \alpha^* + \beta x_{it} + e_{it} \qquad i = 1, ..., N, \qquad t = 1, ..., T, \tag{7}$$

With respect to equations 6 and 7, Hsiao (2003) considers the situation that the data are generated as in either of the two cases below:

Case 1: Heterogeneous intercept ($\alpha_i^* \neq \alpha_j^*$), homogeneous slope ($\beta_i = \beta_j$). The study maintains that in these cases, pooled regression ignoring heterogeneous intercepts should not be used, since the direction of the bias of the pooled slope estimates is different from that identified priori; 'it can go either way'.

Case 2: Heterogeneous intercepts and slopes $(\alpha_i^* \neq \alpha_j^*, \beta_i \neq \beta_j)$. Hsiao (2003) and Wooldridge (2010) state that a straightforward pooling of all NT observations, assuming identical parameters for all cross-sectional units, would lead to nonsensical results because it would represent an average of coefficients that differ greatly across individuals.

Baltagi (2008), Hsiao (2003), and Wooldridge (2010) also consider the classic analysis of covariance procedures. In this case, the studies took into account the assumption that the parameters characterizing all temporal cross-sectional sample observations are identical, and examined a number of specifications which permits differences in behaviour across individuals as well as over time. For example, "a single-equation model with observations of y depending on a vector of characteristic X" stated as follows:

(i) When slope coefficients are constant, and the intercept varies over individuals, we have:

$$y_{it} = \alpha_i^* + \sum_{k=1}^{K} \beta_k x_{kit} + e_{it}, \qquad i = 1, \ldots, N, \quad t = 1, \ldots, T, \tag{8}$$

(ii) When slope coefficients are constant, and the intercept varies over individuals and time, we have:

a.

$$y_{it} = \alpha_{it}^* + \sum_{k=1}^{K} \beta_k x_{kit} + e_{it}, \qquad i = 1, \ldots, N, \quad t = 1, \ldots, T, \tag{9}$$

(iii) When all coefficients vary over individuals, we have:

$$y_{it} = \alpha_i^* + \sum_{k=1}^{K} \beta_{ki} x_{kit} + e_{it}, \qquad i = 1, \ldots, N, \quad t = 1, \ldots, T, \tag{10}$$

(iv) When all coefficients vary over time and individuals, we have:

$$y_{it} = \alpha_{it}^* + \sum_{k}^{K} \beta_{kit} x_{kit} + e_{it}, \qquad i = 1, \ldots, N, \quad t = 1, \ldots, T, \tag{11}$$

In each of the above cases, the model is classified further, based on whether the coefficients are assumed to be random or fixed as in Baltagi (2008) and Hsiao (2003). Nerlove (2005); and Hsiao (2003) point out that models with constant slopes and variable intercepts such as Equations 8 and 9 are "most widely used when analysing panel data because they provide simple yet reasonably general alternatives to the assumption that, the parameters take values common to all agents at all times".

Furthermore, the analysis of covariance basically tests two aspects of the estimated regression coefficients: the homogeneity of regression slope coefficients and the homogeneity of regression intercept coefficients. The procedures for testing these two cases are:

1. Test whether or not slopes and intercepts simultaneously are homogeneous among different individuals at different times.
2. Test whether or not the regression slopes collectively are the same.
3. Test whether or not the regression intercept are the same.

Inclusion of additional variables in STIRPAT model

Unlike the IPAT and ImPACT frameworks, the STIRPAT permits the researcher to introduce other predictors by entering them into the basic equation. However, York et al. (2003a) argue that caution is required to ensure that additional variables are conceptually consistent with the multiplicative specification of the model.

Furthermore, the inclusion of the other polynomial, or quadratic, or non-linear terms is theoretically appropriate, but it can make the straightforward interpretation of the elasticity coefficients cumbersome and complicated (York et al., 2003a). For example, all empirical evidence on the environmental Kuznets curve introduced the squared term of affluence (per capita GDP) that permits non-monotonic interaction between a predictor and impact. This is because the modernization economy perspective, political economy, and state of democracy theories argue in favour of other polynomial terms which impact on emissions, predict a non-monotonic linkage between impacts and economic development, and employ a quadratic version of appropriate per capita GDP or per capita GNP (Grossman and Krueger, 1995; Shi, 2003; York et al., 2003a). Thus, the instantaneous elasticity coefficient for any given value of a predictor can be estimated using the first partial derivative, with respect to the appropriate driver variable of the regression model.

Recent studies (York et al., 2003a) have included dummies as additional variables to examine environmental impacts as long as they are conceptually appropriate for the multiplicative specification of the STIRPAT model. However, there may be problems regarding social and political variables that contribute to the determination of impacts, for example, bad governance (corruption), political regime, culture, and so on. Nevertheless, the Transparency International (TI) has succeeded in providing numerical values (corruption perception index (CPI)) that can be used as a measure of bad governance (TI, 1995). Variables such as culture, type of political regime or democracy or socialist system of government are typically represented by nominal or ordinal measurements, and "are not conceptualized for multiplicative modes" (York et al., 2003a). When there is a nominal or ordinal factor with few categories, dummy coding is a simple matter: a series of dummy coded (0 and 1) variables can be employed. The study used the numerical values of corruption perception index provided by the TI as an indicator of the practice of corruption across African countries.

Decomposition of variables in STIRPAT model

York et al. (2003a) foreground the need to refine T, the technology, in our STIRPAT model. Technology comprises many factors that determine environmental impacts. York et al. (2003a) examines three main ways by which T can be utilized in the STIRPAT model.

Technology is interpreted as the antilog of the residual term in the STIRPAT model because the error term consists of all variables other than affluence and population. Technology can be decomposed or disaggregated by introducing new variables in the STIRPAT model, theorized to determine impact per unit of production. Previous studies (Shi, 2003; York et al., 2003a; Jorgenson, 2004; Jorgenson and Clark, 2013) support the idea that additional variables are vital for developing theory and for examining causal structures since, many social-ecological perspectives put forward social factors influencing impact. The ImPACT identity framework is also consistent with additional variables for consideration.

Apart from technology that is disaggregated, other variables can also be decomposed. The works of Shi (2003), Shi (2001), Cramer (1996, 1998), Dietz and Rosa (1994a), and York et al. (2003a) contended that the way a particular variable is decomposed and classified depends on conceptualization. The population as a driving force has also been disaggregated into number of households and average household size in investigating air quality impacts (Cramer, 1996, 1998; Croix and Gosseries, 2012; Cronshaw and Requate, 1997). Liddle and Lung (2010) also disaggregated population into age structure (20 to 34, 34 to 49, 50 to 64), and the estimated results show divergent anthropogenic impacts across age groups. York et al. (2003a) employed the percentage of the population in economically productive age categories as a driving force of carbon dioxide emission impacts. The York et al. (2003a) study considered the disaggregated population as a decomposition of the technology term since age structure was converted from the residual term into the explanatory variable, or the disaggregated population into population size and economically productive population. The benefit of the STIRPAT model is that it can be employed to investigate the components of the predictors (population, per capita GDP, technology, bad governance, openness of the economy) in other models than their original total forms.

FINDINGS

Impacts of net trade and population size on CO_2 emissions

The estimated results indicate that the average effect of net trade over CO_2 emissions, when the net trade changes across time and between countries increases by 1%, CO_2 emissions increases by about 1.02 and 2.24% for Lower Income Countries in Africa (LICA) and Lower Middle Income Countries in Africa (LMICA), respectively, when all other predictors are constant. This further suggests that CO_2 emission impacts rises more rapidly than the predictor. The average effect of population size over carbon dioxide emissions, when the population size changes across time and between countries increases by 1%, CO_2 emissions increases by about 0.74% for LICA, and reduces CO_2 emissions by about 0.51% for Upper Income Countries in Africa (UICA) respectively, holding all other predictors constant. A1 percentage point increase in manufacturing sector value added as a percentage of GDP, when the manufacturing sector changes across time and between countries, increases CO_2 emissions by about 0.21 and 0.45% for LICA and UICA respectively, when all the other predictors are constant. A1 percentage point increase in services sector value added as a percentage of GDP, when the service sector changes across time and between countries, increase CO_2 emissions by about 0.44 and 0.38% for LICA and UICA respectively, when all other predictors are constant.

The findings suggest that the population size, manufacturing sector, services sector and net trade for LICA are statistically significant at 1, 10, 1 and 1% significance levels, respectively; LMICA suggests that the net trade is statistically significant at 1% significance level; and UICA shows that the population size, manufacturing sector and services sector are statistically significant at 1, 1 and 10% significance levels, respectively (Table 1).

Environmental Kuznets Curve (EKC) means that the interaction between economic development and environmental impacts may produce an inverted U-Shaped curve (York et al., 2003b). This implies that during the first stage of economic development, environmental impacts increases level-off and further, economic development takes place while environmental impacts reduces. This linkage between economic development and environmental impacts is known as the environmental Kuznets curve (EKC), named after economist Simon Kuznets.

DISCUSSION

In this study the magnitude impacts of net trade on carbon dioxide emissions, with other predictors (population size, final consumption expenditure, manufacturing sector and services sector value added as a component of GDP) were investigate, playing a moderating role. The main motivation is to test the validity of the world trade system perspective that it is spurious and misleading to rely on the evidence of the impacts a country generates within its borders, instead of taking a world-wide system analysis on the impacts. This means that, damage to the environment anywhere is damaging to the environment everywhere. The world-system theory laid emphasis on total impacts and not micro impacts. Our findings are closely related to the world system perspective and other literature that examined the causal impact of CO_2 emissions on net trade, established a clear association.

The empirical evidence suggests that net trade performs better in low income countries in Africa (LICA) and middle income countries in Africa (LIMCA), as both consistently positive indicating that net trade is a driver trigger and determinant of carbon dioxide emission loads. The relationship between net trade and carbon dioxide emissions with other predictors playing intervening roles in low income countries in Africa (LICA), middle income countries in Africa (LIMCA) and upper income countries in Africa (UICA) were investigate. The high income

Table 1. The impact of net trade and population size on CO_2 emissions.

Variable	LICA	LMICA	UICA
Intercept	-3.58*** (0.745)	0.876 (1.629)	-9.75*** (1.008)
ℓn(PS)	0.745*** (0.047)	-0.202 (0.155)	-.510*** (0.100)
ℓn(M)	0.216** (0.064)	-0.082 (0.124)	0.457*** (0.104)
$\ell n(S)$	$0.447 *** (0.086)$	$-0.001\ (0.238)$	$0.381 ** (0.121)$
ℓn(FCEG)	-0.048 (0.027)	-0.058 (0.060)	-0.013 (0.011)
ℓn(NTA)	1.023*** (0.149)	2.240*** (0.388)	0.095 (0.080)
Sample	332	163	178

***P < 0.001; **P < 0.01; *P < 0.05. *The coefficients are asterisk according to their levels of significance (coefficient not asterisk are not significant), and the standard errors are in parenthesis. *Our dependent variable and all the explanatory variables are in logarithmic forms. *The GLS/FGLS indicates Generalized Least Squares/ Feasible Generalized Least Squares. * GDP is the Gross Domestic Product. * **ℓ**n means natural logrithms. Baseline Model- Regress per capita Co_2 emissions- **ℓ**n(I) on population Size- **ℓ**n(PS), final consumption expenditure growth- **ℓ**n(FCEG), manufacturing sector value added as a percent of GD- **ℓ**n(M), services sector value added as percent of GDP- **ℓ**n(S) and net trade **ℓ**n(nta). Dependent Variable: ℓn(I), GLS/FGLS.

countries in Africa (HICA) were excluded because Equatorial Guinea is the only country classified as HICA in the continent, and not suitable for a panel data analysis.

The coefficients for ℓn (NTA) have values greater than 1.0 because it shows it is statistically stronger and positive for LMICA than LICA and UICA. In other words, net trade (ℓn (NTA)) has stronger positive impacts on carbon dioxide emission loads in lower middle income countries than low income countries and upper income countries. It is a major driver-trigger of environmental impact for lower middle income countries than in low income countries and upper income countries.

The results of the international-emissions nexus analysis suggest that, there is evidence in our data to indicate that CO_2 emissions has statistically significant impact on net trade, population size, manufacturing sector and services sector. This implies that CO_2 emissions cause positive impacts in net trade intensity, when all other predictors are controlled. The final consumption expenditure is the only variable that has no statistically significant impact, and it cannot be used to explain CO_2 emission load. These findings confirm, support and reinforced the validity of the world system theory that international trade is indeed an important factor that has been neglected by some previous studies in the determinants of the concentration of carbon dioxide emissions in Africa at different income groupings.

Finally, it is suggested that the exchange of goods and services between African countries and the rest of the world should be conducted based on the international trade conventions to avoid a situation where African countries are used as a dumping ground for dirty goods. This is very crucial because the impact of net trade on CO_2 emissions is consistently positive in all the African countries at different income levels.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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