Climate and Development

ISSN: 1756-5529 (Print) 1756-5537 (Online) Journal homepage: www.tandfonline.com/journals/tcld20

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To cite this article: Daniel Kwabena Twerefou, Wisdom Akpalu & Angela Cindy Emefa Mensah (2019) Trade-induced environmental quality: the role of factor endowment and environmental regulation in Africa, Climate and Development, 11:9, 786-798, DOI: 10.1080/17565529.2018.1562868

To link to this article: https://doi.org/10.1080/17565529.2018.1562868

Published online: 13 Jan 2019.

CLIMATE AND DEVELOPMENT
2019, VOL. 11, NO. 9, 786–798
https://doi.org/10.1080/17565529.2018.1562868

RESEARCH ARTICLE

Trade-induced environmental quality: the role of factor endowment and environmental regulation in Africa

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ABSTRACT
This paper investigates whether trade liberalization affects environmental quality (proxied by CO_2 emissions) and, if so, whether the trade-induced emissions originate from differences in countries' economic growth, factor endowment or environmental regulations. We used panel data on 30 African countries and the Generalized Method of Moment estimation techniques. Though we found that trade openness is associated with elevated levels of CO_2 emissions due to comparative advantage originating from factor endowment (i.e. composition effect), the overall effects of trade are seen to have some beneficial effects on environmental quality. Also, relative economic growth lowers emissions (scale effect) perhaps due to technology transfer. Furthermore, the differences in environmental regulations do not directly affect CO_2 emissions while past levels of CO_2 emissions significantly increase the current level due to the cumulative effect of CO_2 emissions. To achieve a significant reduction in emissions, environmental regulations must be enforced in tandem with growth enhancing and production technology choice policies.

ARTICLE HISTORY
Received 17 January 2018
Accepted 7 November 2018

KEYWORDS
Environmental quality; trade openness; environmental regulation; factor endowment; carbon dioxide

1. Introduction

Global climate change, resulting from increased greenhouse gas (GHGs) emissions, continues to threaten lives and property making combating climate change a matter of urgency. According to the Intergovernmental Panel on Climate Change (IPCC, 2014), the quest for economic growth coupled with increasing population is responsible for the increase in GHGs gas such as carbon dioxide (CO_2). Ultimately, if the production mix and techniques of production are immutable, then the higher scale of global economic activities is achieved at the detriment of environmental quality (Grossman & Krueger, 1995). However, economic growth brought about by large-scale production can cause structural transformation – thereby changing the composition and technique of production – enough to offset the damage to the environment. Putting these effects together gives us the inverted U-shaped income-pollution effect known as Environmental Kuznet Curve (EKC) (Grossman & Krueger, 1995; Dinda, 2004).

In line with the debate on economic growth and environmental pollution nexus, many researchers including Antweiler, Copeland, and Taylor (2001); Cole and Elliott (2003a); Keho (2015); Osabuohien, Efobi, and Gitau (2015); Ben Jebli, Ben Youssef, and Ozturk (2015); Al-Mulali, Ozturk, and Solarin (2016) and Adom and Amuakwa-Mensah (2016) have examined the link between environmental pollution and international trade, which has a strong link with economic growth (Sachs & Warner, 1995; Krueger, 1997; Frankel & Romer, 1999). For all these studies, CO_2 emission is a proxy for environmental pollution. Through international trade, CO_2 could be outsourced to other countries, hence it has been argued that accounting for emissions associated with international trade gives a more complete picture of the volume resulting from a country's anthropogenic activities. However, due to the lack of data on imports of CO_2 by developing countries, previous studies have relied on the variables trade openness and FDI inflows as proxies. Two positions emerged on the interrelationship between international trade and the environment. Whiles some studies (see e.g. Managi, 2004; Keho, 2015; Ben Jebli et al., 2015; Al-Mulali et al., 2016), argue that trade is harmful to the environment, due to the high quest to improve income through trade, others such as Antweiler et al. (2001), Ibrahim and Law (2016), and Adom and Amuakwa-Mensah (2016) argue that trade is good for the environment since income precedes demand for high environment quality.

In addition to the inconclusive debate on the relationship between trade openness and environmental quality, it is unclear whether trade-induced emissions originate from differences in countries' factor endowment or comparative advantage measured by the relative capital–labour effect (KLE), or due to country-specific environmental regulation effects (ERE). Studies that have attempted to address these issues, such as Cole and Elliott's (2003a), did not consider the specific situations in Africa and uses the Generalized Least Square estimation technique which suffers from omitted variable bias and unable to correct for endogeneity and the autoregressive structure of the CO_2 emission series. Moreover, the existing studies on Africa so far have only investigated the presence of the EKC and explored the impact of trade openness,

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institutional quality and natural resource endowments on environmental quality (see e.g. Keho 2015; Ben Jebli et al., 2015; Osabuohien et al., 2015; Al-Mulali et al., 2016; and Adom & Amuakwa-Mensah, 2016). This study extends the existing works by weighing in on the effect of trade openness on emissions in Africa, via economic growth, factor endowment and environmental policies. Africa is of interest because, although the continent's contribution to the global CO_2 emissions is currently very small, its rapid economic growth coupled with the rapid urbanization implies the continent could become a major emitter soon (Adom & Amuakwa-Mensah, 2016). It is noteworthy that this study focuses on CO_2 emissions but not degradation of ecosystems (such as capture fish stocks, rainforest and aquifers) or the changes in bio-geochemical cycles on Earth due to anthropogenic activities (Bolin & Cook, 1983). The reason being that such activities are much more difficult to quantify.

We found results that are mixed and puzzling. A country's factor endowment is positively related to CO2 emissions as trade openness increases. However, relative economic growth – measured by relative per capita Gross Domestic Product (GDP) – lowers CO_2 emissions (scale effect) if trade is liberalized, perhaps due to technology transfers. Furthermore, we found that the differences in environmental regulations (i.e. regulations on emission standards) do not directly affect CO_2 emissions. However, past levels of GHG emissions significantly increase the current levels of CO_2 due to the cumulative effect of emissions.

The remainder of the paper is organized as follows. The next section contains the review of literature on the environmental Kuznets curve hypothesis, followed by the specification of the empirical model to be estimated. Section 4, contains the results of the estimations and the last section presents the conclusions.

2. Literature reviews

DeBruyn and Heintz (2002) provided a complete review of the theoretical framework for the EKC hypothesis, which relates income growth to environmental quality. The authors argue that five main factors that can be used to explain the hypothesis include behavioural changes and preferences, income elasticity of demand, technological and organizational changes, structural changes, and demand for environmental quality. Stemming from these theoretical frameworks, two levels of overlapping relationship have been advanced to explain the trade and environment nexus which are well elaborated by Antweiler et al. (2001) and De Melo and Mathys (2010).

The first relationship is based on the theory of comparative advantage resulting from factor endowment that has both direct and indirect composition effect of trade (Managi, Hibiki, & Tsurumi, 2008). According to the factor endowment hypothesis, each trading economy will specialize in production processes that use an abundant factor of production (Feenstra, 2004). However, the environmental externality associated with production and consumption of these goods is not captured in this basic theory of comparative advantage (Harris, 2004). This provides the theoretical basis for the trade-induced environmental effect, the second interrelationship between trade and the environment. The argument is that trade-induced environmental impact results from factor endowment as well as environmental regulations, which are more stringent as income rises. This raises concern for resource-dependent regions like Africa where environmental regulations are less stringent (IPCC, 2001) hence most likely to remain pollution havens. However, several empirical studies have failed to find evidence in support of the pollution haven hypothesis (Cole & Elliot, 2003b; Grossman & Krueger, 1993). This is because profit-maximizing firms will seek the least cost input combinations that generate allowable emissions (Antweiler et al., 2001). Evidently, 'dirty' industries are typically more 'physical' capital intensive (Cole & Elliott, 2002) and less human capital intensive (Cole, Elliot, & Shimamoto, 2003), and may be more competitive where there is capital abundance. As a result, it is possible that the two effects (i.e. the beneficial environmental regulation effect and the detrimental capital intensity effect) may cancel out (Antweiler et al., 2001; Cole & Elliot, 2003b).

The EKC hypothesis has been extensively verified by researchers and policy makers. Using a statistical formulation, Chow and Li (2014) provided a compelling evidence for the existence of the EKC for CO_2 emissions. This relationship has been observed among a range of pollutants and environmentally harmful outcomes such as biodiversity loss, air and water pollution (see Thompson, 2014; Villanueva, 2011; Grossman & Krueger, 1995). However, some empirical studies such as Perman and Stern (2003); Dinda (2004), and Adom and Amuakwa-Mensah (2016) have failed to find empirical evidence to the EKC hypothesis.

Despite the contrasting findings, the EKC remains, by far, the most widely used theoretical framework for examining the income-environment nexus. Moreover, the validation of the hypothesis dwells on the role of international trade in distributing 'dirty' industries (Arrow et al., 1995). This is because international trade influences national output composition thereby altering the incidence, type and level of environmental pollution across nations and regions (Vilas-Ghiso & Liverman, 2006).

Using the World Bank's data on China for the period 1987–1995, Dean (1999) confirmed the existence of trade-environmental Kuznets's curve. Specifically, trade openness was found to be beneficial to the environment. Antweiler et al. (2001) found comparable results when they tested the trade-environment hypothesis for SO_2 using a pooled cross-country time series data for 43 countries over the period of 1971–1996. They decomposed the trade-pollution relationship into scale, technique and composition effect where they found SO_2 emission rising with increasing GDP (depicting a positive scale effect), declining with increasing GDP per capita (depicting negative technique effect) and declining with freer trade (showing negative composition effect). By implication, they concluded that trade-induced SO_2 emission originated from both environmental regulation and technology; and that the two opposing forces seemingly cancel out.

Likewise, Cole and Elliott (2003a), using time series data for the period 1975-1990, estimated the three effects for country-level emission per capita for SO_2, CO_2, NO_2 and biochemical oxygen demand (BOD) using the General Least Square (GLS) estimation approach. They added scale effect to technique effect and called it scale-technique effect. Their result of the

SO_2 emissions largely supports that of Antweiler et al. (2001) but the authors were quick to add that CO_2 and nitrogen oxide is likely to increase with increased trade openness. A beneficial relationship was found between BOD emission, per capita GDP and trade openness; whereas CO_2, and NO_2 emission increases with the trade. An important observation being that their results were unclear as to whether the trade-induced CO_2 emission originated from the environmental regulation or/and factor endowment effect. They found weak evidence and are unable to validate the supposition that the environmental regulation effect and technology effect cancels out.

To critic Cole and Elliott (2003a), Managi et al. (2008) employed the Dynamic Generalized Method of Moment (GMM) estimator to test whether trade liberalization reduces pollution in the Organisation for Economic Co-operation and Development (OECD) and non-OECD countries. The authors found that greater openness to trade negatively affect the emission of all the pollutants (BOD, SO_2, CO_2) in OECD countries. In non-OECD countries, only BOD was found to be declining with increasing trade openness. Also, SO_2 and CO_2 recorded positive signs for both scale-technique effect and composition effect while emissions declined with increasing levels of income in OECD countries but increased with increasing incomes in Non-OECD countries. These, they attributed to the disparity in income and technology advancement in the two groups. They concluded that the trade-induced emission stems from both environmental regulation and technology effects in both OECD and Non-OECD countries, but the two effects did not cancel each other since ERE appeared to have dominated KLE for all pollutants.

A number of studies have been carried out recently to investigate the impact of trade openness on CO_2 emissions in Africa. Keho (2015) and Ben Jebli et al. (2015) found that trade openness worsens environmental degradation, when the later defined trade openness as exports to GDP ratio. However, the variable was found to benefit the environment if it is proxied by the ratio of import to GDP. In addition, Al-Mulali et al. (2016), using dynamic ordinary least square (DOLS) technique, found a detrimental impact of trade openness on the environment but no evidence of the EKC.

Other studies have looked at the joint impact of trade openness and institutional quality, which is often proxied as rule of law, regulatory quality and government effectiveness (Villanueva, 2011; Osabuohien et al., 2015). Osabuohien et al. (2015) investigated the impact of trade on environmental pollution (proxied as CO_2 emissions per capita) across 27 African countries from 1996 to 2010, using the system GMM estimation technique, and found a weak negative effect of trade openness on environmental quality, but a strong lagged effect which is moderated by institutional quality. Similarly, Ibrahim and Law (2016) employed a dynamic panel estimation technique to investigate trade-CO_2 emissions nexus, and the role of institutional quality, in 40 SSA countries from 2000 to 2010. The results revealed that the two variables (trade and institutional quality) generally benefit the environment thereby underscoring the essence of institutional reforms. The recent work of Adom and Amuakwa-Mensah (2016) supports this finding, when the panel two-step system GMM technique was employed to address a potential simultaneity problem. In addition, the effect of trade openness on environmental pollution was found to be independent of institutional quality, which is also beneficial to the environment.

The preceding findings raise doubt about the so-called 'triple win' theory of trade liberalization (Vossenaar, 2013). Thus, the benefits of trade, environmental quality and development do not always move in tandem. It is argued that countries import environmental goods and services (i.e. goods and services that measure or mitigate environmental damages) when income increases, which in turn calls for structural changes, thereby moving country's competitiveness from resource-based outputs to dynamic technological outputs. This gives rise to a situation where resulting scale effect from trade is nullified by the technique effect (Copeland & Taylor, 1994) through investment in Research and Development which allows for more innovative ways of production. The net impact of trade on the environment is determined by the composition effect, which is primarily determined by the country's comparative advantage (Cole & Elliott, 2003a) expressed in the form of the two opposing forces of environmental regulation effect and factor endowment effect (Antweiler et al., 2001).

Furthermore, countries with less stringent environmental regulations turn to provide fertile grounds for pollution haven in the bid to attract Foreign Direct Investments (FDI). Technological development in developing countries depends heavily on technology transfers in the form of FDI (Dasgupta, Laplante, Wang, & Wheeler, 2002; Dean, 2004). When the FDI comes in the form of clean technology, emission growth would be little.Thus, the increasing global concerns about environmental pollution, FDI inflows may not necessarily be harmful to the environment. Indeed developing and emerging economies may tend to rely on technology transfers which comes in the form of FDI to reduce emission (Martin & Wheeler, 1992). In a study that examined the relationship between energy consumption, energy efficiency, income per capita, and FDI among 74 low-, middle-, high-income countries from 1985 to 2008, Pu-Yang, Li-Chao, and Si-Yang (2011) found the intensity of energy consumption to reduce as FDI inflows increase. This is partly because FDI inflows promote environmentally beneficial and efficient energy use. But Pao and Tsai (2011) argue that FDI inflows to developing countries may rather raise CO_2 concentrations.

From the foregoing discussions, it is evident that the debate on trade openness–environmental quality nexus is unsettled, necessitating further research especially in developing countries that have lax environment standards. This study investigates the issues within the African context, making it imperative since trade has improved significantly in the region over the last two decades (Adom & Amuakwa-Mensah, 2016), but with little empirical clarity on whether this has impacted the continent's environment. Summary of the literature used is presented as Appendix 1.

3. Methodology

3.1. Empirical model specification

The empirical model employed here follows Cole and Elliott (2003a) who extended the conventional EKC framework (see, Antweiler et al., 2001) to account for the effects of factors such as trade openness, factor endowment, and environmental regulation. Like Antweiler et al., and Cole and Elliot, we surmise that the environmental quality, proxied as CO_2 concentration in the atmosphere follows an autoregressive process, as well as depends on the size of the economy, the preceding factors and their interactions. By interacting, for instance, trade openness and factor endowment, it is possible to measure the extent to which environmental quality is impacted by trade openness, for any given level of factor endowment (i.e. capital–labour ratio). The model therefore allows for comparative advantage to be captured by factor endowment and/or pollution haven motive. Theoretically, increased trade openness is expected to increase pollution levels for economies with higher capital–labour ratio (Cole & Elliott, 2003a). To enrich the discussion on trade openness – environmental quality nexus, environmental quality is proxied as CO_2 emissions (see Cole & Elliott, 2003a; Pao & Tsai, 2011; Ibrahim & Law, 2016; Adom & Amuakwa-Mensah, 2016). This is because CO_2 is the largest emitted Green House Gas (GHG) emanating from anthropogenic activities like combustion of fossil and deforestation (Somerville, et al., 2007). The two variables are used for trade openness in two separate equations, one for each variable, are total trade to GDP ratio (trade intensity) and FDI inflows. This is because African countries depend largely on FDI inflows which correlate with technology transfers and improve capital accumulation (Dasgupta et al., 2002; Dean, 2004) and income. Thus, the transfer of improved technologies through FDI is expected to lower emissions. The empirical model is specified as Equation (1). That is,

$$\begin{aligned}\ln CO_{2it} = {} & \beta_0 + \beta_1 \ln CO_{2it-1} + \beta_2 \ln G_{it} + \beta_3 (\ln G_{it})^2 \\ & + \beta_4 \ln X_{it} + \beta_5 \ln\left(\frac{K}{L}\right)_{it} + \beta_6 \ln\left(\frac{K}{L}\right)^2_{it} \\ & + \beta_7 \ln X_{it} \ln RG_{it} + \beta_8 \ln X_{it} (\ln RG_{it})^2 \\ & + \beta_9 \ln X_{it} \ln\left(R\frac{K}{L}\right)_{it} + \beta_{10} \ln X_{it} \ln\left(R\frac{K}{L}\right)^2_{it} \\ & + \beta_{11} \ln X_{it} \ln\left(R\frac{K}{L}\right)_{it} \ln RG + \beta_{12} ER_{it} + \varepsilon_{it}\end{aligned} \quad (1)$$

where CO_{2it} represent emissions of CO_2 of country i in year t measured in thousand metric tons; X is trade openness measured by the trade intensity (O) or FDI inflows; $\frac{K}{L}$ and $R\frac{K}{L}$ are capital–labour and relative capital–labour ratios, respectively; Gdenotes GDP per capita; RG is relative per capita GDP; ER represent environmental policy and institution effectiveness; β_0 to β_{13} are the coefficients to be estimated and ε is the independent and identically distributed error term. Countries with higher capital–labour ratio are expected to experience elevated levels of emission when trade is liberalized – a phenomenon labelled capital–labour ratio effect (KLE), whereas the beneficial effect of a rising per capital income on emissions, given free trade, is called environmental regulation effect (ERE). The overall effect cannot be determined a priori. Thus, following Cole and Elliott (2003a) $\beta_7 > 0$, $\beta_8 < 0$, $\beta_8 < 0$ and $\beta_{10} > 0$

3.2. Variable definition

The dependent variable, CO_2, is a good proxy for environmental quality since it constitutes the highest proportion (74%) of GHG emissions (IPCC, 2007), which causes climate change. TheCO_2emissions stem largely from human activities like combustion of fossil fuel and deforestation at the country level, and stays in the atmosphere for extended periods of up to 800 years (Forster et al., 2007).

Secondly, per capita GDP (G) captures both scale and technology effect. If production mix and production technology are immutable, then large-scale economic activities can change production technologies in a manner that will reduce emission (Grossman & Krueger, 1995). If this supposition holds, then both scale effect and technology effect (i.e. scale-technology effect) are determined by income effect, running in opposite directions. Such that the dominance of scale effect at the initial phase of countries' economic growth and the dominance of the technique effect at higher levels of income as well as the direct composition effect $\left(\frac{K}{L}\right)$, together explains the inverted-U-shaped relationship between income per capita and pollution. Considering the low per capita income status of the countries considered for this study (see Appendix 2), the income effect is expected to be generally positive. The inverted-U-shaped income-pollution nexus may not exist. However, we sought to explain the trade-induced composition effect as a function of ERE and KLE.

Thirdly, in Cole and Elliott's empirical model, relative income (RG) and capital–labour ratio $\left(R\frac{K}{L}\right)$ are calculated in terms of global averages. In this study, the ratio is expressed in terms of Africa's averages. This is done to avoid over-exaggeration of the income disparity gap between developed and developing countries. The relative GDP per capita (RG_{it}) is calculated using data on all (54) Africa countries. To calculate RG_{it} we first calculate:

$$\text{Africa's per Capita GDP}(G_{At}) = \frac{\sum_i^n G_{it}}{N}$$

where N is the number of countries and G_{it} is the GDP per capita of country i in time t. Using Africa's per capita GDP(G_{At}), the relative GDP per capita for each country is calculated as:

$$\text{Relative per Capita GDP}(RG_{it}) = \frac{G_{it}}{G_{At}}$$

Fourthly, for this study, as noted earlier, two variables are used for trade openness. The first, trade intensity, is defined as the ratio of the sum of exports and imports to GDP, which is generally used in growth literature as a proxy for international trade openness (see Antweiler et al., 2001; Frankel & Romer, 1999). The second is FDI. According to Antweiler et al. (2001), trade openness per se does not influence emissions. Rather the effect of opening the economy will affect the environmental quality through the country's specific comparative advantage. As a result, it is hypothesized that the coefficient should not be statistically significant.

Fifthly, the capital–labour ratio $\left(\frac{K}{L}\right)$ captures a country's direct composition effect. Theoretically, all else equal, capital-intensive, compared to labour-intensive, production processes are hypothesized to generate more pollution (Cole & Elliott, 2002). Therefore, countries with lower capital–labour ratios should, on average, experience reduced pollution. The square of capital–labour ratio $\left(\frac{K}{L}\right)^2$is added to account for the diminishing effects on capital accumulation.

Sixthly, in order to capture the indirect composition effect, the relative capital–labour ratio has been intereacted with trade openness $\left(\text{i.e. } \ln X \ln\left(R\frac{K}{L}\right)\right)$. The relative capital–labour ratio, which is the capital–labour ratio of each country expressed as a ratio of the average capital–labour ratio of the continent, is estimated through a series of computations. First, *gross capital formation* is used as a proxy for capital (K) and *total population* is used as a proxy for labour (L). Secondly, Africa's Average Capital (K_{At}) is calculated as a simple average for each year as:

$$\text{Africa's average capital } (K_{At}) = \frac{\sum_i^N K_{it}}{N}$$

Where, N is the number of countries. Similarly, the Africa's Average Labour is calculated as

$$\text{Africa's average labour } (L_{At}) = \frac{\sum_i^N L_{it}}{N}$$

and

$$\text{Africa's average capital} - \text{labour ratio } (\text{ARKL}_{At}) = \frac{K_{At}}{L_{At}}$$

Thus, the indirect composition effect is captured by interacting trade openness with relative capital–labour ratio $\left(\ln X \ln\left(R\frac{K}{L}\right)\right)$. The coefficient of this variable captures the effect of relative capital–labour ratio on CO_2 emission, for various levels of trade openness. It is expected that capital intensity and pollution intensity are positively correlated (Cole & Elliott, 2002). Since Africa is a labour-abundant continent, it is expected that the sign of the coefficient of the variable will be negative. The term $\ln X \ln\left(R\frac{K}{L}\right)^2$ is included to account for the quadratic relationship and we expect its coefficient to have a positive sign.

Furthermore, the sign of the coefficient of the interaction of trade openness with relative per capita income ($\ln X \ln RG$) is expected to be positive. This is because in low-income countries, trade openness precedes elevated levels of emission due to lax environmental regulations. The interaction between trade openness and the square of relative per capita income (i.e., $\ln X(\ln RG)^2$) is included to capture the quadratic effect hence its coefficient is expected to take a negative sign.

Next, it is expected that the impact of trade openness on environmental quality could depend on the interaction between relative per capita income and relative capital–labour ratio. However, as noted by Cole and Elliott (2003a), the elasticity of the environmental quality (i.e. CO_2), with respect to trade openness, could either be increasing or decreasing in the product of the two variables. This is because, for example, a country with relatively higher growth rate and capital–labour ratio may not necessarily be emitting less CO_2.

Finally, an additional extension made to Cole and Elliott is the inclusion of *Environmental Policy and Institution Effectiveness* (ER) indicator from the World Development Indicators of the World Bank which is a measure on the scale of 1 (weaker) to 6 (stringent) to explain the impact of environmental policy on emission growth, since it is believed that lax environmental policies intensify pollution. Environmental regulations in most Africa countries are adjudged less stringent (IPCC, 2001; OECD, 2011). Consequently, the coefficient of the ER term is expected to carry a positive sign.

3.3. Estimation technique and data

The data set used for this study has spatial or location units (e.g. regions and countries), which could create problems of spatial heterogeneity and spatial dependence (Arbia & Piras, 2005). As shown in Appendix 3, the cross-sectional independence test strongly rejects the null hypothesis of cross-sectional independence, which suggest that the GLS is bias hence the need to estimate a more robust dynamic model, system GMM.[1] In addition, the GLS method when employed in modelling economic growth across regional units, rests on the implicit assumption of absolute convergence, which may not be the case. The stylized fact is that, there exist significant differences in the growth rates and per capita GDP across countries and regions as predicted by Solow (1956) conventional convergence theory. Therefore, countries conditionally converge to a steady state that is region-specific (Solow, 1956), but not to a general steady state as implied by the GLS model (used by Cole and Elliott). Another setback of Cole and Elliot's model is that it did not recognize the endogeneity that may arise between income and trade openness. As a result, this study employs the System GMM dynamic panel estimation, which addresses unobserved country heterogeneity, endogeneity, omitted variable bias, and measurement error (Bond, Hoeffler, & Temple, 2001). This estimator produces the least bias and highest precision when the series is persistent. Moreover, the estimator has the best small sample properties in terms of sample bias and precision (Blundell & Bond, 1998). The results are compared with that of the GLS estimation employed by the earlier studies as a robust check.

In recent years, attention has been drawn to the positive impact of international environmental policy effectiveness on local policy as elaborated by the *Brussel effect* and *California effect* elaborated by Bradford (2012) and Vogel (1995) respectively. Thus, domestic CO_2 emission reduction may not be coming from domestic policy effectiveness but rather international policy effectiveness. The use of GMM addresses issues related to omitted variable bias which permits us to ensure that domestic CO_2 emissions are largely influenced by domestic policy effectiveness.

Data for the study was sourced from World Bank's World Development Indicators (WDI) covering 30 Africa countries[2-] spanning from 1990 to 2014. These countries were selected from the 54 independent African countries based on data availability.

4. Results and discussions

We begin by presenting the panel unit root test of the series employed, followed by the panel regression results. The Fisher's Augmented Dickey-Fuller (ADF) and Im-Pesaran-Shin (IPS) unit root tests were carried out. The results of both tests

(Table 1) suggest that all the series are stationary at levels. By implication, the long run relationship between CO_2 emissions and the independent variables could be estimated, devoid of the problems of spurious or unrelated regressors (Costantini and Martini, 2010). We proceed to employ the system GMM technique to estimate Equation (1). Seven different equations are estimated as shown in Table 2. The Sargan and the second order Arellano-Bond tests indicate that there is no autocorrelation problem hence the instruments used in the estimations are valid. As shown by the Sargan test, the *p*-values improved consistently by the introduction of each additional term. It is worthy of note that, the lesser the *p*-value is from 1.0, the better the model specified. Thus, our discussion will focus on model 7 which is the full model. As a robustness check, pooled Ordinary Least Squares (OLS), Random Effect and Fixed Effect (FE) models were also estimated and the results of the FE is reported (see Appendix 4). The Lagrangian Multiplier (LM) and the Hausman tests indicate that the FE models are the most preferred.

With regards to the explanatory variables that have statistically significant coefficients, first, the CO_2 emission is path dependent or autoregressive. This is expected since past levels of GHG emission significantly increases the current level which is quite consistent as there is a lag effect of CO_2 emissions. The elasticity coefficient indicates that a percentage increase in the current year CO_2 emissions will increase that of next year by a quarter of a percentage point less. The implication is that, all things being equal, there is a diminishing ability of the biosphere to absorb atmospheric CO_2 concentration, spelling profound consequences if no actions are taken to regulate emissions (Walker & Steffen, 1997).

Next, the coefficient of the logarithm of the one period lag per capita GDP is negative, whereas its squared term is positive. The implication being that, lack of considerable degree of regulations on CO_2 emissions in the countries under consideration has resulted in a rising CO_2 emission as per capita income increases. This is consistent with the findings of Cole and Elliott (2003a) about two pollutants: SO_2 and BOD, but not CO_2 emissions, which is highly regulated. The result also suggests that the scale effect, which results in environmental degradation, dominates the technique effect, which is beneficial to the environment at later stages of development. This implies that, in the case of Africa, even the rich may not consider environmental quality as a public good, given the current levels of CO_2 emissions. This finding contrasts with the assertions of Beckerman (1992) who argued that income has an improving effect on environmental quality. This is also in contrast to the conclusion of studies like Lin, Omoju, Nwakeze, Okonkwo, and Megbowon (2016) and Adom and Amuakwa-Mensah (2016) that economic growth (as a proxy for income growth) does not significantly account for rising CO_2 emission. Thus, this finding epitomizes the lax environmental policies and inadequate enforcement of environmental regulations in most African countries (see e.g. OECD, 2011, for similar conclusions).

Table 1. Panel unit root test with cross-sectional dependence removed.

		Fisher's ADF		IPS	
Variable	Variable definition	Statistics	*P*-values	Statistics	*P*-values
CO_2	CO_2	11.3878	.0000	−2.1767	.0148
G	GDP per capita	6.1591	.0000	−2.6969	.0035
(*RG*)	Relative GDP per capita	3.7990	.0001	−3.7691	.0001
O	Trade intensity	7.1253	.0000	−3.4232	.0003
$\left(\frac{K}{L}\right)$	Capital–labour ratio	4.5265	.0000	−2.3639	.0090
$\left(R\frac{K}{L}\right)$	Relative capital–labour ratio	5.3774	.0000	−3.9215	.0000
FDI	Foreign direct investment	3.0790	.0010	−1.8551	.0318
ER	Environment regulations	11.1031	.0000	−2.7697	.0028

Source: Authors' estimation.

The impact of the CO_2 emissions originating from the direct composition effect, proxied by the capital–labour ratio, which measures the countries' comparative advantage, produced a statistically significant positive sign. Thus, from the estimated coefficients, the elasticity of the CO_2 emissions, with respect to openness, has a U-shaped relationship with the capital–labour ratio, implying a detrimental composition effect after a certain threshold of the ratio. This finding is supported by Cole and Elliott (2003a), and Managi et al. (2008) for non-OECD countries. However, the coefficient of the interaction of openness and relative per capita GDP, and the square of the later (which explains the ERE) are both negative signifying beneficial impact on environmental quality owing to trade intensity. This finding that emission decreases with trade openness at an increasing rate affirms our initial supposition that Africa is a raw material trading region and as such, initial trade-induced CO_2 emission reduction is relatively small, but the rate increases with increasing levels of industrial activities. Furthermore, the coefficient of the variable 'environmental regulation' is not statistically significant. This suggests that the decrease in CO_2 emissions due to the scale-technique effect and the ERE term does not necessarily reflect a case of stringent environmental regulations across the countries studied. It could simply mean that production processes, which are largely primary production, are less pollution intensive by their very nature at the initial phase of development.

The weak impact of trade on environmental quality may have a differential impact on different countries dependent on the stage at which the country involves itself in trade and the state of development of its industries. Specifically, countries that join the trading community before setting up industrial capacity such as Togo, Ghana, etc., may tend to be 'resource feeders'. A recent report by the African Development Bank (AfDB) noted that the structure of manufactured exports in Africa is resource-based and is of low technology.[3] Such countries may import more processed commodities at the higher price but sell their exports cheaply. Under such conditions, it is going to be very difficult for them to develop without a comprehensive and effective industrial policy.

Moving on to the second leg of the indirect composition effect (i.e. KLE) captured by the interaction term between trade intensity and country's relative capital–labour ratio is found to be negative at 95% confidence level whereas the square term recorded a statistically significant positive sign. This result corroborates the KLE supposition in Equation (1). As already discussed, low capital–labour ratio countries experience declining levels of pollution with increasing trade openness. This is characteristic of most Africa countries and as such, not

Table 2. System GMM estimation results of trade effect on CO_2 emissions.

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)	Model (9)	Model (10)
Lagged $\ln CO_2$	0.88140***	0.85270***	0.92199***	0.92022***	0.92856***	0.88359***	0.86986***	0.86972***	0.83153***	0.73721***
	(0.133)	(0.149)	(0.083)	(0.067)	(0.054)	(0.086)	(0.104)	(0.102)	(0.115)	(0.109)
$\ln G$	−0.68468**	−0.64597**	−0.80234**	−0.81069**	−0.93876**	−0.81653**	−0.89271***	−0.89221***	−0.86209**	−0.80555**
	(0.256)	(0.263)	(0.358)	(0.380)	(0.367)	(0.330)	(0.319)	(0.321)	(0.357)	(0.304)
$(\ln G_{it})^2$	0.54787***	0.58069***	0.53123***	0.48107**	0.70121***	0.66421***	0.52835**	0.52848**	0.53897**	0.52902**
	(0.124)	(0.146)	(0.176)	(0.182)	(0.202)	(0.204)	(0.220)	(0.220)	(0.230)	(0.218)
$\ln X$		−0.06674	−0.15183**	−0.14936**	−0.32941***	−0.46082***	−0.43704***	−0.43677***	−0.49154**	−0.50025**
		(0.082)	(0.059)	(0.057)	(0.076)	(0.118)	(0.133)	(0.128)	(0.195)	(0.189)
$\ln\left(\frac{K}{L}\right)$			0.04617	0.04490	0.03682	0.03879	0.21288	0.21256	0.22297	0.30638*
			(0.034)	(0.030)	(0.032)	(0.025)	(0.143)	(0.147)	(0.148)	(0.167)
$\ln\left(\frac{K}{L}\right)^2$				0.01285	0.01111	0.00998	0.00912	0.00909	0.01154	−0.00031
				(0.012)	(0.012)	(0.015)	(0.016)	(0.015)	(0.018)	(0.015)
$\ln X \ln RG$					−0.11309**	−0.23013***	−0.20635**	−0.20637**	−0.25999*	−0.24680*
					(0.045)	(0.074)	(0.085)	(0.086)	(0.133)	(0.126)
$\ln X (\ln RG)^2$						−0.04298*	−0.05742**	−0.05747**	−0.05524**	−0.04818**
						(0.022)	(0.022)	(0.023)	(0.026)	(0.022)
$\ln X \ln\left(R\frac{K}{L}\right)$							−0.04299	−0.04321	−0.08087**	−0.08667**
							(0.037)	(0.036)	(0.034)	(0.039)
$\ln X \ln\left(R\frac{K}{L}\right)^2$								−0.00010	0.00781*	0.00751*
								(0.004)	(0.004)	(0.004)
$\ln X \ln\left(R\frac{K}{L}\right) \ln RG$									−0.03640	−0.02616
									(0.024)	(0.023)
ER										0.09347
										(0.064)
Constant	−1.63185**	−1.79237	−0.56285	−0.00405	−1.85248	−1.54133	−0.07102	−0.07396	−0.22269	−0.34124
	(0.805)	(1.202)	(0.710)	(0.779)	(1.140)	(1.326)	(1.692)	(1.693)	(1.781)	(1.705)
Observation	254	243	191	186	186	186	186	186	186	186
AR 1: *P*-value	.000	.000	.001	.001	.001	.001	.002	.002	.002	.003
AR 2: *P*-value	.119	.119	.169	.171	.169	.252	.249	.252	.215	.186
Sargan: *P*-value	.603	.555	.814	.813	.765	.649	.611	.589	.520	.402

Note: Robust standard errors in parentheses.
***$p < .01$, **$p < .05$, *$p < .1$.

surprising. However, the trade-induced CO_2 emission will fall to a threshold point and begin to rise. This is consistent with theory, in that as capital intensity in production increases with freer trade, emissions will invariably increase. These results generally reflect the outcomes estimated using the FE (see Appendix 4) as a robust check.

Nevertheless, in all, it is quite unclear whether the environmentally degrading composition effect outweighs the desirable scale-technique effect. These findings suggest, with increasing free trade, African countries are rather specializing in production processes that make use of inputs that generate significant amounts of CO_2. This sharply contrasts the notion that the types of trade the continent engages in have its comparative advantage in labour-intensive methods and that it does not require high energy use and as such should be environmentally cleaner than capital-intensive productions (see, Cole & Elliott, 2002). In sum, our results do not support the hypothesis that trade is generally good for the environment and that ERE and KLE cancel out as supposed by Antweiler et al. (2001).

As a robustness check, the trade intensity is proxied by FDI. As noted earlier FDI inflows increase capital intensity of production, improve physical and human capital accumulation and, consequently, raises income in Africa (Dasgupta et al., 2002; Dean, 2004; UNCTAD, 2013). The results, which are reported in Appendix 5, are similar in some regards to those of the trade openness. The composition effect is corroborated but the scale effect is not statistically significant. However, the coefficient of the interactions of FDI, relative capital–labour ratio and relative GDP per capita is negative. This means that the beneficial effect on CO_2 concentration of FDI depends jointly on the composition and scale-technique effects. Thus, relative per capita income and capital–labour ratio will both lead to a decline in emission concentration, as FDI increases due to say trade openness.

5. Concluding remarks

This paper aims at investigating the effects of income and trade on environmental quality proxied by CO_2 concentration. The study ascertains whether trade-induced emissions originate from differences in countries' comparative advantage, proxied by relative factor endowment, production technology, economic growth or environmental regulation effects. The study found that CO_2 emissions declined with increased income under freer trade but rising relative capital–labour ratio (trade-induced composition effect) was detrimental to the environment, if we have increased trade openness. Thus, instead of emissions increasing with income as trade opens to a point and thereafter falling, emissions rather declined at an increasing rate with freer trade. A situation that can be attributed to the low consumption and production of pollution-intensive goods at the initial phase of development rather than an improvement in income or stringency of environmental regulation.

Given that the overall effect of trade openness is decomposed into scale-technique and composition effects (Antweiler et al., 2001), the results obtained by interacting trade openness, scale-technique and composition effect generally corroborates the assertion that freer trade to some extent is beneficial to the environment in Africa since it promotes the diffusion of clean technology in the form of say FDI. On the other hand, the rising pollution due to trade-induced composition effect implies governments must be concerned about possible 'leakage' of emissions resulting from pollution haven pressure in the domestic capital formation. Indeed, government policies should address the bigger picture of reducing global GHGs, rather than attempting to optimize an individual country's emission performance in the fight against climate change. As a developing destination of trade, African countries would have to critically examine the kind of trade partnerships it signs to. An example of such agreement is the on-going Economic Partnership agreement (EPA) between member states and the European Union (EU). It is apparent that countries in Africa need to develop the human capacity to effectively and meaningfully take part in such trade negotiations and secure deals that are not environmentally challenging, particularly for the pollution-intensive sectors like mining and industries.

We therefore recommend that countries in Africa enhance their trade policies to ensure the use of cleaner technologies and products as well as reducing the adverse effect of trade on CO_2 emissions and formulating policies aimed at enhancing income levels. More should also be done to change the composition of production and trade through value addition to primary product using tax incentives and with the active support of the private sector. Strengthening environmental regulatory institutions to enable them to better enforce environmental laws and regulations as well as ensuring appropriate systems of monitoring, reporting and verifications. Thus, systems should be structured in such a way that any improvement or worsening of the environmental performance due to adverse policies are detected. Furthermore, there is a need to isolate the effects of different policy instruments to determine the potency of each specific instrument. Also trends in the external market conditions and capital stocks should be checked and policies implemented to check any pollution-intensive capital trails. It is noteworthy that the relationship between trade and the climate is not unidirectional since the physical manifestation of climate change can affect the volume and pattern of trade flow. This is a critical issue that is not covered in this study. It is therefore recommended that subsequent studies take this reverse causal relationship into consideration.

Notes

1. A multicollinearity test was performed, and we found high and significant correlation between GDP and an interaction variable that is constructed as the interaction between Trade Openness, Relative Capital-Labor ratio and Relative GDP per capita. However, the exclusion of that variable from the regression does not change the significance level of the coefficient of GDP and vice versa (see Table 2).
2. Egypt, Tunisia, Angola, Cameroon, Côte d'Ivoire, Gambia, Ghana, Lybia, Nigeria, Senegal, Sierra Leone, Togo, Congo, Democratic Republic of Congo, Gabon, Eritrea, Ethiopia, Djibouti, Sudan, Uganda, Kenya, Tanzania, Morocco, Mauritius, Botswana, Mozambique, Namibia, South Africa, Zambia and Zimbabwe.
3. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Brochure_Industrialiser_l_Afrique-En.pdf (Accessed 04/07/2018)

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Adom, P. K., & Amuakwa-Mensah, F. (2016). What drives the energy saving role of FDI and industrialization in East Africa? *Renewable and Sustainable Energy Reviews*, *65*, 925–942.

Al-Mulali, U., Ozturk, I., & Solarin, S. A. (2016). Investigating the environmental Kuznets curve hypothesis in seven regions: The role of renewable energy. *Ecological Indicators*, *67*, 267–282.

Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is free trade good for the environment? *American Economic Review*, *91*(4), 877–908.

Arbia, G., & Piras, G. (2005). Convergence in per-capita GDP across EU-NUTS2 regions using panel data models extended to spatial autocorrelation effects. *Discussion Paper*. Retrieved from www.real.illinois.edu/d-paper/05/05-t-3.pdf

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., … Pimentel, D. (1995). Economic growth, carrying capacity, and the environment. *Royal Swedish Academy of Sciences*, *268*, 520–521.

Ben Jebli, M., Ben Youssef, S., & Ozturk, I. (2015). The role of renewable energy consumption and trade: Environmental Kuznets curve analysis for sub-Saharan Africa countries. *African Development Review*, *27*(3), 288–300.

Beckerman, W. (1992). Economics growth and the environment: Whose growth? Whose environment? *World Development*, *20*, 481–496.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*, 115–143.

Bolin, B., & Cook, R. B. (1983). *The major biogeochemical cycles and their interactions*, Scientific committee on problems of the environment (SCOPE).

Bond, S., Hoeffler, A., & Temple, J. (2001). *GMM estimation of empirical growth models* (Economics Papers, 2001-W21). Economics Group, Nuffield College, University of Oxford.

Bradford, A. (2012). The Brussels effect. *Northwestern University Law Review*, *107*(1), 23–23.

Chow, G. C., & Li, J. (2014). Environmental Kuznets curve: Conclusive econometric evidence for CO2. *Pacific Economic Review*, *19*, 1–7.

Costantini, V., & Martini, C. (2010). The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegrated panel data. *Energy Economics*, *32*(3), 591–603.

Cole, M. A., & Elliott, R. R. (2002). FDI and the capital intensity of 'dirty' sectors: A missing piece of the pollution haven puzzle. University of Birmingham Discussion Paper in Economics.

Cole, M. A., & Elliott, R. J. (2003a). Determining the trade-environment composition effect: The role of capital, labor and environmental regulations. *Journal of Environmental Economics and Management*, *46*(3), 363–383.

Cole, M. A., & Elliot, R. R. (2003b). Do environmental regulations influence trade patterns? *Testing old and new Trade Theories. The World Economy*, *26*(8), 1163–1186.

Cole, M. A., Elliot, R. R., & Shimamoto, K. (2003). *US Specialization in Pollution-Intensive Industries: Factor Intensities versus Environmental Regulations*. School of Economics Studies, University of Manchester.

Copeland, B. R., & Taylor, M. S. (1994). North-South trade and the environment. *The Quarterly Journal of Economics*, *109*, 755–787.

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2002). Confronting the environmental Kuznets curve. *Journal of Economic Perspective*, *16*, 147–168.

De Melo, J., & Mathys, N. A. (2010). *Trade and climate change: The challenges ahead*. CEPR Discussion Paper Series 3083, London.

Dean, J. M. (1999). Does trade liberalization harm the environment? A new test. *World Bank*. Retrieved from http://siteresources.worldbank.org/INTABCDEWASHINGTON2000/Resources/dean.pdf

Dean, J. M. (2004). *Foreign direct investment and pollution havens: Evaluating the evidence from China*. Meeting of American Associations.

DeBruyn, S. M., & Heintz, R. J. (2002). The environmental Kuznets curve hypothesis. In J. C. J. M. V. D. Bergh (Ed.), *Handbook of environmental and resource Economics* (pp. 656–677). Oxford: Edward Elgar Publication.

Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics*, *49*, 431-455. Retrieved from www.elsevier.com/locate/ecolecon

Feenstra, R. C. (2004). *Advanced international trade: Theory and evidence*. Princeton, NJ: Princeton University Press.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T. R. B., Fahey, D. W., … Van Dorland, R. (2007). Changes in atmospheric constituents and in radiative forcing. In *Climate change 2007: The physical Science basis. Contribution of Working Group I to the Fourth Assessment report of the Intergovernmental panel on climate change*, edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, . . . H. L. Miller (pp. 121–234). Cambridge, UK: Cambridge University Press.

Frankel, J., & Romer, D. (1999). Does trade cause growth. *American Economic Review*, *89*(3), 379–399.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of the North American free trade agreement. *NBER Working Paper*, *3914*.

Grossman G. M., & Krueger, A. B. (1993). Environment impacts of a North American free trade agreement. In P. M. Garber (Ed.), *The Mexican-US free trade agreement* (pp. 1–10). Cambridge, MA: MIT Press.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, *110*(2), 353–377.

Harris, J. M. (2004). *Trade and the environment*. Global Development and Environment Institute. Retrieved from http://ase.tufts.edu/gdae

Ibrahim, M. H., & Law, S. H. (2016). Institutional quality and CO2 emission–trade relations: Evidence from Sub-saharan Africa. *South African Journal of Economics*, *84*(2), 323–340.

IPCC. (2001). *Climate change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the*

Intergovernmental Panel on Climate Change (edited by J. T. Houghton, Y. Ding, D. J. Griggs, & M. P. Noguer). UK and New York: Cambridge University Press.

IPCC. (2007). *The physical science basis. Contribution of working group 1 to the fourth assessment report of the IPCC*, Cambridge Univ. Press. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4_wg1_full_report.pdf [accessed September 21st, 2016]

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC. Retrieved October 07, 2016, from http://www.ipcc.ch/publications_and_data/publications_and_data.shtml

Keho, Y. (2015). Is foreign direct investment good or bad for the environment? Times series evidence from ECOWAS countries. *Economics Bulletin*, *35*(3), 1916–1927.

Krueger, A. (1997). Trade policy and economic development: How we learn. *American Economic Review*, *87*(1), 1–22.

Lin, B., Omoju, O. E., Nwakeze, N. M., Okonkwo, J. U., & Megbowon, E. T. (2016). Is the environmental Kuznets curve hypothesis a sound basis for environmental policy in Africa? *Journal of Cleaner Production*, *133*, 712–724.

Managi, S. (2004). Trade liberalization and the environment: Carbon dioxide for 1960-1999. *Economics Bulletin*, *17*(1), 1–5.

Managi, S., Hibiki, A., & Tsurumi, T. (2008). Does trade liberalization reduce pollution emissions? *RIETI Discussion Paper Series 08-E-013*. Retrieved from http://www.rieti.go.jp/en/08e013.pdf

Martin, P., & Wheeler, D. (1992). Price, policies and the international diffusion of clean technology: The case of wood pulp production. In P. Low (Ed.), *International trade and the environment. World Bank Discussion Paper 159* (pp. 197–224). Washington, DC: The World Bank.

OECD. (2011). *Foreign direct investment and the environment*. Retrieved from http://www.oecd.org/dataoecd/9/48/2089912.pdf

Osabuohien, E., Efobi, U. R., & Gitau, C. M. (2015). Environment challenges in Africa: Further dimensions to the trade, MNCs and energy debate. *Management of Environmental Quality: An International Journal*, *26*(1), 118–137.

Pao, H.-T., & Tsai, C.-M. (2011). Multivariate Granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. *Energy*, *36*, 685–693. Retrieved from http://dx.doi.org/10.1016/j.energy

Perman, R., & Stern, D. I. (2003). Evidence from panel unit root and cointegration tests that the evironmental Kuznets curve does not exist. *The Australian Journal of Agriculture and Resource Economics*, *47*, 325–347.

Pu-Yang, S., Li-Chao, W., & Si-Yang, C. (2011). On the nonlinear relationship between FDI and energy consumption intensity in an open economy: Analysis based on the framework of environmental Kuznets curve. *Journal of Financial Economics*, *37*, 79–90.

Sachs, J. D., & Warner, A. (1995). Economic Reform and the process of global Integration. *Brooking Papers of Economic Activity*, *1*, 1–95.

Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, *70*(February), 65–94.

Somerville, R., Le Treut, H., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., Prather, M. (2007). Historical overview of climate change. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, … H. L. Miller (Eds.), *Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 93–128). Cambridge: Cambridge University Press.

Thompson, A. (2014). Environmental Kuznets curve for water pollution: The case of Border countries. *Modern Economy*, *5*, 66–69.

UNCTAD. (2013). *Key Statistics and trend in trade policy*. Geneva: United Nations Publication.

Vilas-Ghiso, S. J., & Liverman, D. M. (2006). *Scale, technique and composition effects in the Mexican Agricultural sector: The influence of NAFTA and the institutional. Third North American Symposium on Assessing the environmental effects of trade (2005)*. Oxford: Environmental Change Institute, University of Oxford.

Villanueva, I. A. (2011). Introducing institutional variables in the environmental Kuznets curve (EKC): a Latin American study. In *Proceedings of the international scientific conference eco-trend 2011* (pp. 486–503). Brancusi: House Publisher Academica.

Vogel, D. (1995). *Trading up: Consumer and environmental regulation in a global economy*. London: Harvard University Press.

Vossenaar, R. (2013). *The APEC list of environmental goods. An analysis of outcome and expected impact*. Geneva: International Centre for Trade and Sustainable Development.

Walker, B., & Steffen, W. (1997). An overview of the implications of global change for natural and managed terrestrial ecosystems. *Conservation Ecology*, *1*(2), 2–17.

Appendices

Appendix 1. Summary of literature

Authors (year)	Methods and data	Time Span	Country/sectors	Variables used in the study	Main findings
Antweiler et al. (2001)	GLS: Fixed and Random Effect	1976–1996	43 Countries (both developed and developing)	SO_2	Greater trade openness reduces SO_2 emission.
Al-Mulali et al. (2016)	Fisher type cointegration tests; dynamic ordinary least square (DOLS) and the vector error correction model; Granger causality	1980–2010	Central, Eastern and Western Europe, East and South Asia, the Pacific, East and North Africa and Sub-Saharan Africa	CO_2	Renewable energy consumption negatively on pollution. EKC hypothesis found in regions where renewable energy has a significant correlation with pollution..
Adom and Amuakwa-Mensah (2016).	System GMM	1980–2011	13 East African countries	Energy consumption FDI	Trade is good for the environment
Chow and Li (2014)	statistical formulation			CO2	They provided a strong evidence for CO_2 emissions which validate the EKC hypothesis
Cole and Elliot (2003b)	Maximum likelihood estimators; GLS	1995	60 developed and developing countries	Export; Factor endowment; environmental regulations	Failed to find evidence in support of the pollution haven hypothesis
Cole and Elliott (2003a)	Random effect; Fixed effect	1975–1995	26 developed and 36 developing countries	SO_2, NO_x, CO_2 and biochemical oxygen demand (BOD)	Greater trade openness reduces SO_2 emission. However, CO_2 and nitrogen oxide is likely to increase with increase trade openness.
Grossman and Krueger (1991)	OLS	1977, 1982, 1988	Up to 52 cities in 32 countries	SO2; dark matter capita GDP; various site-related variables, a time trend; trade intensity v	They provide evidence of the existence of EKC
Ibrahim and Law (2016)	Dynamic panel estimation technique	2000–2010	40 Sub-Sahara Africa countries	Trade CO2 Institutional Quality	Trade and institutional quality benefit the environment
Lin et al. (2016)			Africa	CO2 GDP Energy Intensity	Economic development does not significantly cause CO_2 emissions. Rather, energy structure and intensity were the main drivers of CO_2 emissions
Managi (2004)	GLS	1960–1999	63 developed and developing economies	CO2 Trade GDP	Trade openness is harmful to the environment.
Managi et al. (2008)	GMM	1973–1980	83 and 88 countries	SO_2, NO_x, CO_2 BOD	Trade Liberalization Reduce Pollution Emissions?
Osabuohien et al. (2015)	System GMM	1996–2010	27 African countries	Trade, and energy	Weak negative effect of trade openness on environmental quality, but a strong lagged effect moderated by institutional quality.
Pao and Tsai (2011)	Multivariate Granger causality		BRIC (Brazil, Russian Federation, India, and China) countries	CO_2 FDI Energy consumption GDP	FDI inflows in developing countries may raise emissions.
Perman and Stern (2003)	Panel unit root and cointegration tests			SO_2 GDP	Sulfur emissions and GDP per capita may be integrated variables.
Pu-Yang et al. (2011)	GLS	1985–2008	74 low, middle, high income	FDI energy consumption GDP	Increase in FDI flow reduces the intensity of energy consumption and emission.
Thompson (2014)	GLS		30 countries	water pollution GDP	Showed the existence of EKC for countries bordered by river and those without water bordering them

Appendix 2. Descriptive statistics of data

Variable	Number of Observation	Mean	Standard Deviation	Min	Max
ln CO_2	1,081	7.688	1.878	3.245	13.08
ln GDP per Capita	1,236	6.65	1.129	4.242	9.675
ln Capital–labour Ratio	881	5.149	1.362	1.458	9.159
ln Trade Openness	1,194	4.201	0.499	2.406	6.276
ln FDI	1,151	18.2	2.477	2.374	23.17
Environmental regulation	366	3.055	0.542	2	4
Africa's average capital–labour Ratio	1250	336.465	895.167	−433.838	9503.729
Africa's average GDP per capita	1236	1635.279	2545.544	69.57919	15,912.14

Source: Authors' Estimation.

Appendix 3. Test for cross-sectional independence

Pesaran's test			Frees' test
Critical/*P*-value	Average absolute value of the off-diagonal elements	*T*-value	Critical values from Frees' *Q* distribution
29.571, Pr = 0.0000	0.440	5.891	alpha = 0.10: 0.3583 alpha = 0.05: 0.4923 alpha = 0.01: 0.7678

Source: Authors' estimation.

Appendix 4. Robustness check with fixed and random effect models

	FDI		Trade intensity (O)	
CO_2 emission	RE	FE	RE	FE
$\ln G$	0.00796	−0.00442	−0.50212**	−0.57127*
	(0.278)	(0.286)	(0.255)	(0.294)
$(\ln G_{it})^2$	0.10116	0.08265	0.23584	0.17988
	(0.236)	(0.215)	(0.200)	(0.197)
$\ln X$	−0.00374	−0.01682	−0.16257	−0.15360
	(0.025)	(0.035)	(0.197)	(0.216)
$\ln\left(\frac{K}{L}\right)$	0.98445***	1.01973***	1.11197***	1.16081***
	(0.235)	(0.229)	(0.222)	(0.211)
$\ln\left(\frac{K}{L}\right)^2$	−0.00548	−0.00184	−0.02195	−0.01982
	(0.023)	(0.023)	(0.019)	(0.019)
$\ln X \ln RG$	0.03329	0.03301	−0.09556	−0.09042
	(0.042)	(0.053)	(0.146)	(0.161)
$\ln X (\ln RG)^2$	0.00511	0.00553	−0.08588***	−0.08883**
	(0.012)	(0.015)	(0.032)	(0.036)
$\ln X \ln\left(R\frac{K}{L}\right)$	−0.06893***	−0.06806***	−0.26653***	−0.27774***
	(0.013)	(0.013)	(0.055)	(0.067)
$\ln X \ln\left(R\frac{K}{L}\right)^2$	0.00416**	0.00456**	0.00693	0.00744
	(0.002)	(0.002)	(0.004)	(0.005)
$\ln X \ln\left(R\frac{K}{L}\right) \ln RG$	−0.01682**	−0.01579**	−0.01202	−0.01169
	(0.007)	(0.006)	(0.034)	(0.036)
ER	−0.00629	−0.00364	−0.02104	−0.02400
	(0.059)	(0.056)	(0.054)	(0.052)
Constant	1.67110	2.04913	2.71201	3.71204
	(2.128)	(2.135)	(1.994)	(2.213)
Observation	180	180	187	187
R-squared		0.585		0.556
Number of country	30	30	30	30
Hausman test Chi^2	74.97		0.000	

Note: *X* as interacted above represent either FDI or Trade intensity in their respective equations. Note that the results of the Hausman test favours the fixed effect as estimated above.
Source: Authors' Estimation.

Appendix 5. CO_2 equation with FDI

Variables	System GMM
Lagged $\ln CO_2$	0.49158***
	(0.055)
$\ln G$	−0.51904**
	(0.231)
$(\ln G_{it})^2$	0.27543*
	(0.150)
$\ln FDI$	−0.02645
	(0.021)
$\ln\left(\frac{K}{L}\right)$	0.63497***
	(0.121)
$\ln\left(\frac{K}{L}\right)^2$	0.00020
	(0.015)
$\ln FDI \ln RG$	0.01625
	(0.027)
$\ln FDI(\ln RG)^2$	0.00599
	(0.008)
$\ln FDI \ln\left(R\frac{K}{L}\right)$	−0.04378***
	(0.009)
$\ln FDI \ln\left(R\frac{K}{L}\right)^2$	0.00347**
	(0.001)
$\ln FDI \ln\left(R\frac{K}{L}\right) \ln RG$	−0.01209***
	(0.004)
ER	0.00904
	(0.044)
Constant	0.91168
	(1.149)
Observation	179

Note: Arellano-Bond test for AR(1) in first differences: $z = -2.99$ $Pr > z = 0.003$. Arellano-Bond test for AR(2) in first differences: $z = 1.72$ $Pr > z = 0.086$. Sargan test of overid. restrictions: $chi^2(135) = 140.02$ $Prob > chi^2 = 0.366$.