Does Economic integration Damage or Benefit the Environment? Africa's Experience

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Abstract

The leaders of African nations have committed to the establishment of the Continental Free Trade Area (CFTA) over the coming years. Improved links among the African nations, via increased intra-regional trade, have been considered as an essential mechanism to produce desired growth run-overs and to support regional economic improvement. However, remarkable theoretical and empirical evidence has shown that increased trade might damage the environment and therefore may hinder the effort towards sustainable development and poverty reduction on the continent. The present paper seeks to investigate and test the impact of intra-Africa trade using two measurements of environmental pollutants, namely CO2 and MP10 whilst integrating economic growth, and energy consumption. The study used a panel dataset regarding 46 African countries over the period 1990–2017. Given the heterogeneity among these countries, the study employed appropriate techniques and methods that were able to capture the consequences of this problem. The FMOLS procedure suggested that intra-Africa trade improved environmental quality on the continent. In addition, the results confirmed the presence of the Environmental Kuznets Curve (EKC) hypothesis. The findings also indicated that whilst the consumption of energy played a vital role in the deterioration of the environment, its impact remained marginal. Overall the results implied that intra-regional trade and the environment quality were mutually supportive in Africa.

Keywords: Economic Integration, Environment, Trade, Africa, Free Trade Area.

JEL classifications: F15, F10, Q5

1. Introduction

Beginning in 1910, several regional integration initiatives commenced in Africa; the 1970s saw the creation of several regional economic communities on the continent (Awad and Yussof 2017). Currently, 17 regional trade blocs exist on the continent, of which eight are officially acknowledged by the African Union (Anyanwu 2014). Today, the leaders of Africa have committed to the establishment of the Continental Free Trade Area (CFTA). It is well known that there are two vital theoretical incentives for the call for trade blocs, which are the allocation and growth effects of free trade within a regional bloc (Baldwin 1997). The improved connections between the African nations, via increased intra-regional trade, have been considered as an essential mechanism to produce desired growth run-overs and to support regional economic improvement. However, the effects of such initiatives on the environment and climate in the region have been relatively ignored. This may be because debates over the last decade on Africa's climate change issues have mainly been focused on adaptation rather than mitigation because, traditionally, the African nation's impact on global greenhouse gas emissions (GHG) has been comparatively minor (Winkler and Zipplies 2009). Indeed, recent data has shown that although Sub-Saharan African (SSA) countries have reduced CO2 emissions, on average, when compared to other regions, they have recorded a relatively higher CO2 emissions growth rate (Awad and Warsam 2017). Thus, perhaps the discussion should relate to how to alleviate the increase in CO2 emissions by examining the primary sources of CO2 emissions, rather than through adaptation.

From an academic point of view, the existing literature on the impact of trade on environmental quality has identified three mechanisms by which the environment can be affected by trade, which are the scale, technique and composition effects (Ahmed et al. 2017; Shahbaz et al. 2017). The scale effect refers to the increases in pollution and the depletion of natural resources due to economic activities and the higher consumption of goods and energy (Lopez 1994; Grossman and Krueger 1993). Other explanations for this effect hypothesise that trade liberalisation boosts the export capacity of a nation which may result in increased economic growth (export-led growth). Such an increase in economic growth might increase the income level of the country, which may lead the nation to import technology that is environmentally-friendly which aims to improve output levels (i.e. the technique effect). (Grossman and Krueger 1996; Caliendo and Parro 2015; Alam et al., 2016; Ahmed et al. 2017; Shahbaz et al. 2017). The composition effect reflects how the environment is altered by the composition of production which is affected by the relative openness of the country as well as by the nation's comparative advantage. The overall result of the composition effect from trade openness could be either negative or positive, depending on the relative size of the effects of capital-labour and environmental regulation (Shafik and Bandyopadhyay 1992; Selden and Song 1994; Kahuthu, 2006; Managi et al. 2009; Shahbaz et al. 2013; Ertugrul et al. 2016; Ahmed et al. 2017; Shahbaz et al. 2017).

In line with the preceding explanation, Frankel (2008) proposed three scenarios or hypotheses on the effects of trade that do not operate through economic or income channels. The first one is positive, the second one is negative and the last one depends on a country's comparative advantage. Regarding the adverse effect, Frankel called this effect the "Race to the Bottom" hypothesis that demonstrated that when economies are open to global trade and investment, environmental regulations may be lower than they would otherwise be. When domestic environmental standards cause producers' costs to rise, domestic producers may worry that they will become uncompetitive versus firms from other nations. They may caution policymakers on a loss of sales, workers, and investment to foreign competitors. Consequently, domestic producers often use the fear of competitiveness as a way of exerting political pressure on their governments to lessen the burden of standards.

The positive effect refers to the effect of trade on technology and by consequence upon the environment as previously discussed. The final effect, depends on the country's comparative advantage, as stated in the international trade theory. More precisely, developing economies that have relatively poor environmental standards might concentrate on producing dirty goods while richer countries with stronger environmental rules might concentrate on producing cleaner goods. This leads to what is known as the Pollution Havens hypothesis that describes a situation where dirty industries shift from developed to developing countries (Copel and Taylor 2003). As this theories provides the possibility for both a negative and a positive relationship between the environment and trade, the matter should be resolved through empirical analysis (Frankel 2008; Ertugrul et al., 2016; Shahbaz et al., 2017).

As mentioned previously, despite the frequent calls for integration in Africa by policymakers, the implications of such integration on the environment have been neglected or insufficiently addressed. Even for the current regional economic communities (REC) such as COMESA, SADC, EAC UMA, ECCAS, ECOWAS, IGAD, there have been no empirical studies that have addressed the impact of these RECs on the environmental quality of the countries involved. Most of the studies on integration in Africa have been limited to the assessment of the existence of the REC or the identification of the primary determinates of such integration or the effect of such integration on selected macroeconomic variables (Foroutan and Pritchett 1993a, b; Elbadawi 1997; Lyakurwa et al. 1997; Longo and Sekkat 2001; Ogunkola 1994; Carmignani, 2006; Gedaa and Kebret 2008; UNCTAD 2009; Anyanwu 2014; Iheduru, 2014; Murinde 201; Awad and Yussof 2017). We must acknowledge that today there are rising concerns regarding the “non-economic” consequences of globalisation (Stavins 2000). This is because some issues related to globalisation such as unemployment might be considered as a country’s sovereign concern, with the country deciding to what extent it desires to protect its own labour force. However, when we turn to influences on the environment, due to the free rider problem, no nation alone can protect their environment (We all share a common planet). Most importantly, Africa and the intra-trade mechanism might achieve economic growth, but at the same time this may harm the environment and thus attaining sustainable development is hard to achieve[1]. The study by Stern (2009) argued that it is hard to attain sustainable development when challenged by climate change disasters and rising temperatures. Therefore, climate change and poverty are believed to be shared issues that are required to be simultaneously addressed.

The present study employs the panel co-integration technique for 46 African countries over the period 1990-2017 to answer the following questions: Does intra-Africa trade harm or benefit the environment? Are trade and the environment mutually supportive in Africa? This article seeks to address Africa's experiences with this issue and it adds to the existing works in three principal ways. Firstly, as far as the authors know, this is the initial empirical study regarding Africa that has investigated the impact of intra-Africa trade on the environment. The few empirical literatures that do exist, have addressed the environmental issue in Africa and have tried to validate the familiar EKC hypothesis. Even the studies that have incorporated trade openness in their analysis, have only considered total trade and not intra-Africa trade. As mentioned previously, today, the top priority for Africa's leaders is to promote and encourage intra-Africa trade due to the potentially huge benefits. Given the possibility of the negative/positive impact of intra-Africa trade on environmental quality, the priority and the focus should be to determine ways in which the current efforts to promote intra-Africa trade can be fruitfully harnessed to encourage the protection of the environment, besides other targeted objectives.

Secondly, an increasing amount of literature has been produced on the trade–emissions nexus based upon the analysis of single countries, however, to help to understand the continent's push to a multilateral policy agreement on climate change requires a meta-analysis, utilising the continent's trading system. The trade agreements will gain more importance, during future trade-climate talks, when the negotiations involve multiple regional countries including diverse economic structures. Likewise, any trade-environment

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[1] For more information about the impact of climate change on Africa, see Black, (2001); Schneider et al. (2007);

policy will also be implemented based on a group of nations rather than individually between countries. This, therefore, proposes that a panel data analysis on the relationship between trade and environmental quality should be undertaken. Thirdly, present study uses the panel cointegration tests proposed by Pedroni (1999) together with the most recent and appropriate long-run panel techniques. In addition, for robustness, the present study utilised two proxies for environmental quality, namely, CO_2 and MP.

The findings of this study are substantial and provide significant policy implications for the economies referenced in the panels, as well as for regional economic blocks, international trade and environmental organisations. The findings are also vital for further research since they are anticipated to open future directions of this research topic. In the following section, we briefly review the prior literature. The econometric model, data and method of estimation are presented in Section 3, while the results are discussed in Section 4. The study concludes with Section 5 which also includes some policy implications

2. Literature Review, the African context

In this study, to reduce space, we chose to only review studies that related to the determinants of environmental quality in Africa. However, to the best of our knowledge, there are only a limited number of studies that have analysed such matters in Africa. More specifically, the main goal across each of the existing studies has been to examine if the EKC hypothesis was valid for a specific country or group of countries within Africa. Importantly, even among this limited number of studies, there was no consensus regarding an impact of the selected variables namely, income/growth upon the carbon emissions in Africa. Therefore, we have classified these studies into single-based studies and panel or cross country-based studies. Mhenni (2005), based on a economy-level investigation for Tunisia, tested for the EKC hypothesis over the period 1980-1997. The GMM estimator was employed and the following pollutants were examined: CO_2 emissions, the concentration of fertiliser and the number of traffic/cars which acted to estimate an index for environmental quality. The findings showed that the EKC could not be confirmed based on the evidence for any of these pollutants. Chebbi et al. (2009), examined the same matter for Tunisia based on the cointegration analysis, however, they arrived at different results. Specifically, in the long-run, they found a negative linkage between economic growth and per capita pollution emissions and a positive association between trade openness and per capita emissions. In addition, Fodha and Zaghdoud (2010) investigated if the EKC hypothesis was valid for Tunisia by employing two proxies of pollutant emissions, namely SO2 and CO2, over the period 1961-2004. They employed the Johansen approach for cointegration, together with the Granger causality test, the evidence from their study supported the validity of the EKC hypothesis when utilizing CO2 as a indicator for pollutant emissions. By contrast, they found that a monotonically increasing relationship with GDP was more applicable for CO2 emissions. The results of the causality tests discovered, both in the short-run and long-run, a unidirectional causality with income causing environmental variations and not vice-versa;

As for the southern part of the African region, Menyah and Rufael (2010) investigated both the long-run and the causal relationship between economic growth, pollutant emissions and the consumption of energy for South Africa. The data analysed spanned between 1965-2006 in a multivariate framework which incorporated additional variables; such as labour and capital. The cointegration approach developed by Pesaran et al. (2001) was used by the authors and they also incorporated the Toda and Yamamoto (1995) modified version of the Granger causality test. They found, in both the short and the long run, a positive and statistically meaningful relationship between pollutant emissions and economic growth. The findings suggested that South Africa must forgo economic growth or lower its energy consumption per unit of output or both to allow it to decrease pollutant emissions. However, over the long-run, some alternative options might be feasible. As an example, South Africa has multiple potential sources of renewable energy, thus it may develop renewable energy as a substitute to coal which is the country's main source of CO2 emissions (Menyah and Rufael 2010). Similarly, Shahbaz et al., (2013) examined the effects of economic growth, financial expansion, coal consumption and trade on environmental progress in South Africa spanning the period 1965-2008. The study employed the ARDL to investigate the long-run relationship between the variables. The short-run dynamics were analysed by utilizing the error correction method (ECM). The findings of the study supported a long-run connection between the variables. The results showed that increasing economic growth raised energy emissions; while financial development reduced emissions. Furthermore, the use of coal had a significant negative influence on environmental quality and on South Africa's economy. Trade openness was shown to enhance environmental situations by decreasing the expansion of energy pollutants. Besides, the results proved the existence of an Environmental Kuznets Curve (Shahbaz et al., 2013). Meanwhile, Ben Nasr et al., (2015) used data covering the period 1911-2010 to examine the development process and the idea of co-summability; which was created to analyse the non-linear long-run relationships among perpetual processes. The findings of this study did not indicate the presence of the EKC for South Africa for both the full sample and the two sub-samples that covered 1911-1981 and 1982-2010 respectively; with the sub-samples decisive by formal tests of structural breaks. The study found that if South Africa wished to reduce emissions, it would be required to forgo growth. Because of the high unemployment level, poverty and inequality within the country, this was not considered a feasible solution. Therefore, policies promoting energy efficiency should be used to reduce CO2 emissions without unduly impacting economic progress (Ben Nasr et al., 2015).

Awad Yossof (2016) used cointegration and causality techniques to study the relationship between electricity production (EP), economic growth and employment in Sudan covering the period between 1980 and 2013. The findings indicated a long run relationship between the variables. The study's test for a causality relationship detected the presence of a short-run bi-directional relationship between energy generation and economic growth. The analysis of causality additionally detected the presence of a long-run as well as a strong long-run bi-directional relationship between each pair of the variables. In summary, the findings suggested that even in the short-run, a decrease in the electricity production would lead to a reduction in economic growth, and vice versa. Thus, the results supported the Sudanese government's recent efforts in the expansion of EP, since this should have a major impact on Sudan's economic development. Khobai et al. (2017) examined the relationship between the consumption of energy, carbon dioxide (CO2) emissions, economic growth, trade openness and urbanisation in South Africa between 1971 and 2013. The results of the VECM showed the existence of a unidirectional causality flowing from CO2 emissions, economic growth, trade openness and urbanisation to energy consumption and from energy consumption, CO_2 emissions, trade openness and urbanisation to economic growth.

Regarding panel data or cross country-based analyses, Orubu and Omotor (2011) examined the relationship between environmental degradation and per capita income within Africa. They used longitudinal data about suspended particulate matter and organic water pollutants. Their study sought to estimate the Environmental Kuznets Curves (EKC) for the two indicators of pollution that they had selected and to examine if the predicted relationships complied with the inverted U-shaped hypothesis. The findings of study largely suggested that a conventional inverted U-shaped EKC existed for the suspended particulate matter (SPM) for the nations in Africa that were included in the study. Interestingly, the results for organic water pollutants (OWP), did not support the presence of the conventional EKC. Al-Mulali and Sab (2012) investigated the effects of the consumption of energy and CO_2 emissions on the GDP and financial development in 30 Sub-Saharan African economies employing panel data spanning 1980 and 2008. The results showed that the consumption of energy played a significant role in raising both economic growth and financial expansion in the nations studied, however, this resulted in high levels of pollution. The study suggested various solutions including; increasing energy productivity by improving energy efficiency, the implementing of energy saving projects and energy conservation. Additionally, the outsourcing of energy infrastructure may be regarded as a possible solution to attain financial development and GDP growth and to increase the level of investment on energy schemes to attain full energy potential (Al-Mulali and Sab, 2012).

Kivyirom and Arminen (2014) studied the relationship between the consumption of energy, CO_2 emissions, economic development and foreign direct investment (FDI) in 6 Sub-Saharan African countries; the Democratic Republic of the Congo, Kenya the Republic of the Congo, Zambia, South Africa and Zimbabwe. Using the autoregressive distributed lag (ARDL) approach, the results suggested the existence of a long-run relationship between the examined variables in each of the economies. The findings also supported the hypothesis of the EKC for the DRC, Kenya, and Zimbabwe; suggesting that there could be an inverted-U-shaped relationship between the level of economic development and environmental deterioration in those nations. It is worth noting that these were the countries that had the lowest GDP per capita levels in the study's sample. This suggested that the hypothesis of the EKC is more likely to be valid at low levels of economic development. Additionally, FDI was shown to increase CO2 emissions in both Kenya and Zimbabwe (which supported the pollution haven hypothesis), while an opposite outcome was detected in the DRC and South Africa (which maintained the halo impact hypothesis) (Kivyiro and Arminen, 2014).

Shahbaz et al. (2015) examined the dynamic relationship between energy concentration and CO2 emissions covering the period 1980-2012; they incorporated economic growth into the environmental CO2 emissions function; the data used was from Sub Saharan African countries. The findings from their study indicated that in the long run, at the regional level, the relationship between real GDP per capita and carbon emissions was non-linear. Empirically, this confirmed the existence of an inverted-U shaped relationship between economic growth and CO2 emissions. It should be noted that in the short-run the hypothesis was not validated for the continent. Nonetheless, in both the short and long run, energy was shown to be a significant and positive factor affecting the level of emissions on the region (Shahbaz et al., 2015). Ben Jebli and Yousse (2017) investigated the dynamic causal links between the real gross domestic product (GDP), per capita renewable energy consumption, agricultural value added (AVA), and carbon dioxide (CO2) emissions, on a panel of five North African nations covering the period 1980–2011. The results showed that increases in the GDP or in the consumption of renewable energy (including combustible and waste) increased CO2 emissions, whilst increases in agricultural value added reduced CO2 emissions. Recently, using a different approach, Awad and Abugamos (2017) further examined the effects of income on carbon emissions in the MENA region by investigating the existence of an Environmental Kuznets Curve for a panel of 20 MENA countries covering the period 1980-2014. Within the Stochastic Impacts by regression on population, affluence and technology framework the results detected signs to confirmation an inverted-U shaped relationship between income and CO2 emissions in the MENA region. Using the same approach Awad and Warsam (2017) examined the impacts of income on carbon emissions for a panel of 54 African countries spanning the period 1990-2014. The results of the semi-parametric panel fixed effects regression showed evidence in contrast to the EKC hypothesis. Using the same technique, Awad & Abugamos (2017a) examined the effects of urbanisation on carbon emissions by investigating of the presence of an

Environmental Kuznets Curve (EKC) for a panel of 20 economies in the MENA region over the period 1980–2014. The findings indicated little signal to support an inverted-U shaped relationship between urbanisation and carbon emissions in the region. Finally, Awad and Abugamos (2017b) examined the influences of urbanisation on carbon emissions via the examination of the presence of an Environmental Kuznets Curve (EKC) for a panel of 54 economies in Africa over the period 1980–2014. The results of the semi-parametric panel fixed effects regression indicated evidence supporting the presence of an inverted-U shaped relationship between urbanisation and carbon emissions in the area.

The review of the existing literature examining Africa has demonstrated the lack of any consensus regarding identifying the key determinates of environmental quality. The contradictory results of these studies may be due to policies specific to countries, using of different measures of energy consumption and income, the econometric methodology used, omitted variable bias, the specification of the models used or different time spans of the studies. In addition, most of the empirical studies on the environmental issue in Africa were single–country-based studies. Nevertheless, to assist in understanding Africa's push towards a multilateral strategy agreement on climate change will require meta-analysis, using the continent's trading system. The trade agreements will acquire more importance, during the future trade-climate negotiations, the if the negotiations comprise regional countries at varying income levels. Similarly, any trade-environment policy adopted should be based on a group of countries rather than individually between nations. Consequently, this concept proposes that there is a requirement for a panel data investigation on the relationship between trade and carbon emissions.

3. Methodology

This section describes the data and framework that were employed to construct the empirical investigation of the relationship between the environment and intra-trade. In order to show the theoretical associations among intra-trade, environmental quality and income per capita, we initially defined environmental quality (EQ) as a function of intra-trade (TO) and per capita income and the square of per capita income (GDP and GDP^2) as shown below:

$$EQ = f(TO, GDP, GDP^2) \tag{1}$$

Equation 1a shows that a strong role was played by income in influencing the environmental outcome, therefore, the EKC was incorporated into our analysis. It was important to choose a suitable indicator of environmental quality as it was a key variable in the analysis of this study. The environmental effect of trade might adopt many forms of pollution. Indeed, different proxies have been utilised to assess and measure environmental quality in numerous studies (see for example Frankel and Rose 2005; Kellenberg and Mobarak 2008; Frankel 2008; Managi et al. 2009; Shahbaz et al. 2013; Shahbaz et al. 2017; Ahmed et al.2017). However, the findings have differed between indicators and countries, which has confirmed the dispute that the trade-environment nexus is a country and/or a proxy specific phenomenon. In the present study, our main concern was not about which environmental indicator is affected by intra-Africa trade, but about the impact of intra-trade on the environmental quality however it is measured. Because in the end all of the indicators are somehow interrelated and will lead to a change in environmental quality. In this study, we employed two measures for environmental quality, however, the objective was for robustness checking only and nothing else. According to the scale effect, trade affects environmental quality by increasing the demand for energy for the production and transportation of imported/exported goods. The EIA, (2013) predicted that carbon emissions in developing economies would be 127% higher than in developed economies by 2040. Empirical studies, such as Pao and Tsai, (2010); Alam et al., (2011); Wang et al., (2014) maintained that the EIA's prediction may become true because of the permanent high energy demand in developing countries. We added total energy consumption (per capita) in our model, thus, Equation 1 can be shown as follows[2]

[2] In some recent studies, instead of considering total energy consumption, they have considered the consumption of energy whilst goods are transported via air, road and rail

$$EQ = f(TO, GDP, GDP^2, TEC \quad (2)$$

Where TEC refers to the total energy consumption. The specific log linear version of Equation 2 can be written as follows:-

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$$logEQ_{it} = \beta_0 + \beta_1 logTO_{it} + \beta_2 logGDP_{it} + \beta_3 logGDP^2_{it} + \beta_4 logTEC_{it} + \epsilon_{it} \quad (3)$$

Here, EQ represents the CO2 emissions (metric tons per capita), i represents the country (46 countries) and t represents time (1990-2017). For robustness, Equation 1 was re-estimated using another air pollution measure which is MP which is air pollution measured as mean annual exposure (micrograms per cubic meter). GDP is the real GDP per capita in constant US$ (2010). TO represents the intra-Africa trade measured as the total exports of a country to other African countries plus the total imports of that country from other African countries scaled by the worldwide total export and import of that country (all in terms of US$). TEC is the total energy consumption (per capita), ε is the disturbance term and Bs are the elasticities. There are three reasons for transforming the data into the natural logarithmic form. The first is to attain direct elasticities and provide more consistent and efficient results. Secondly, the log-linear specification increases the stationarity of the series. Thirdly, heteroskedasticity is reduced Shahbaz et al., (2013a; Lau et al., 2014; Ertugrul et al. 2016; Ha Le et al. 2016). The World Development Indicators data series provided all of the annual series for these variables except data related to the intra-trade variable which was gathered from the International Monetary Fund (IMF, DOTS). The data covered 46 African countries (see the list of these countries in the appendix 1) for the period 1990-2017.

Ahmed et al. (2017), however, in our case data related to this measure were not available for our sample.

Table 1 Correlation matrix

Variable	LCO	LMP	LTO	LGDP	$LGDP^2$	LTEC
LCO	1	-0.16	-0.48	0.91	0.91	0.18
LPM	-0.16	1	-0.10	-0.05	-0.06	-0.12
LTO	-0.49	-0.10	1	-0.49	-0.49	-0.17
LGDP	0.90	-0.05	-0.49	1	0.91	0.16
$LGDP^2$	0.90	-0.06	-0.48	0.91	1	0.16
LTEC	0.18	-0.12	0.17	0.16	0.16	1

Source: author calculation

Table 2 Descriptive statistic

Variable	NO. observation	Mean	Max	Min
LCO	1084	-1.18	2.31	-4.53
LPM	1084	3.63	5.32	2.20
LTO	1084	2.55	4.98	-0.63
LGDP	1084	6.93	9.92	4.75
$LGDP^2$	1084	49.11	98.40	22.57
LTEC	1084	11.40	15.40	7.13

Source: author calculation

3-1 Estimation approaches

This section illustrates the steps that have been implemented to obtain the objective of the study. The steps commenced with the cross-sectional dependence test, followed by unit root testing and thereafter panel cointegration testing and then, as the last step, estimating the long run relationship. Nonetheless, the first step, the cross-sectional dependence test, remains the key step since it determines the appropriate test and methods in the following steps.

3.1.1 Cross-sectional dependence

As intra-trade suggests an increasing and resilient interdependence between nations, it is important to consider the influence of cross-sectional dependence in cross-nation panels. Shahbaz et al. (2017) observed that the existence of cross-sectional dependence in cross nation panels may be due to unobserved common shocks that turn out to be an element of the error terms. Therefore, according to (Driscoll and Kraay 2001), should cross-sectional dependence exist in the data but not be accounted for in the investigation, it may lead to inconsistent standard errors of the estimated parameters. For robustness purposes, four different tests we used to verify cross-sectional dependence. The tests used were the Breusch and Pagan (1980) LM test, the Pesaran (2004) scaled LM test, the Pesaran (2004) CD test and the Baltagi et al. (2012) bias-corrected scaled LM test. The results of the cross-sectional independence tests are displayed in Table 3, the tests were applied to all of the variables. The results clearly show that, for each selected variable, the null hypothesis of cross-sectional independence was rejected. Thus, the existence of cross-sectional dependence under a fixed effect (FE) specification was implied. We continued by performing panel unit root tests taking cross-sectional dependence into consideration

Table 3 cross-sectional dependence test

Variable	Breuch-Pagan LM	Pesaran scaled LM	Bias-correlated scaled LM	Peraran CD
LCO	8762.98*** [0.000]	169.55*** [0.000]	165.89*** [0.000]	30.25*** [0.000]
LPM	11051.58 [0.000]	220.16 [0.000]	219.35 [0.0000]	81.70 [0.000]
LTO	4894.52*** [0.000]	84.82*** [0.000]	83.92*** [0.000]	17.50*** [0.000]
LGDP	12305.87*** [0.000]	254.30*** [0.000]	253.43*** [0.000]	60.03*** [0.000]
$LGDP^2$	12366.38*** [0.000]	255.66*** [0.000]	254.36*** [0.000]	60.48*** [0.000]
LTEC	19041.81*** [0.000]	395.36*** [0.000]	394.23*** [0.000]	121.99*** [0.000
Note: The p-values are in parentheses and reject the independence null hypothesis. **** Shows significance at the 1% level of significance				

3.1. 2 Panel unit root tests

We only utilised the panel unit root tests that allowed us to handle the issue of cross-sectional dependence in our panel dataset. We employed two unconventional unit root tests, specifically, the LLC statistic of Levin et al. (2002) and the CADF statistic of Pesaran (2007). The LLC test was used to assess the null hypothesis that each cross-section in the panel had a unit root as opposed to the alternative hypothesis that all cross-sections were stationary. The test yielded effective results for reasonably sized panels and was sufficiently generalised to allow for "fixed effects, individual deterministic trends and heterogeneous serially correlated errors" (Baltagi, 2009). In the presence of cross-sectional dependence, the cross-sectional dependence problem was controlled for by subtracting the cross-sectional averages from the data, Levin et al. (2002). Pesaran (2007) proposed the use of the cross-sectional augmented Dickey-Fuller (CADF) test statistic in heterogeneous panels with cross-sectional dependence. The standard ADF regressions are enhanced in the CADF test with the cross-sectional averages and their first differences to overcome the influence of cross-sectional dependence. The null hypothesis assumes that all of the series are non-stationary against the alternative hypothesis that only a fraction of the series is stationary.

3-1.3 Panel cointegration test

The extension of time-series cointegration to panel data, in a similar way to the use of the panel unit root tests, is also a recent introduction. The panel cointegration tests suggested up until now may be categorised into two sets: the first set was created based upon the null hypothesis of the presence of cointegration (McCoskey and Kao 1998; Westerlund, 2007), while the second set presumed no cointegration at the null hypothesis (Pedroni, 1999; Kao, 1999; Frankel and Rose 2005; Kellenberg and Mobarak 2008; Frankel 2008; Managi et al. 2009). In this analysis, we employed the Pedroni (1999) panel cointegration method. Seven dissimilar statistics were suggested by Pedroni (1999, 2004) to test for the cointegration relationship in a heterogeneous panel. The bias that is created by potentially endogenous regressors were corrected for in these tests. Pedroni's seven test statistics were grouped into the "between dimension" and the "within dimension" statistics. The between dimension statistics belong to the group mean panel cointegration statistics, while the within dimension statistics belong to the panel cointegration statistics. The test statistics for cointegration were constructed as an extension of the two-step residual-based strategy of Engle and Granger (1987).

3.1.4 Panel cointegration estimates

When the presence of a panel unit root was identified, the question was asked, if a long-run equilibrium relationship existed between the analysed variables and between two or more variables (Ahmed et al. 2017) Each of the methods, fixed effects, random effects and GMM may lead to misleading and unreliable coefficients once applied against the cointegrated panel data (Shahbaz et al. 2017). Due to this scenario, we estimated the long-run models using the Fully Modified Ordinary Least Squares (FMOLS) estimator. Pedroni (2000) developed the FMOLS method to take into account heterogeneous cointegrated panel data. The estimator combines both the problems of simultaneity bias and non-stationary regressors. Pedroni further developed the methodology of Phillips and Hansen (1990) and overcame the second order bias generated by the endogeneity of the regressors which established a semi-parametric correction to the OLS estimator. The FMOLS estimator corrects the dependent variable by utilising the long-run covariance matrices, this has the intention of eliminating the nuisance parameters, the estimator then uses a simple Ordinary Least Squares (OLS) method to estimate the variables corrected for endogeneity.

4. Results and their discussion

It was essential to understand the integrating features of the data before commencing the econometric modelling. As mentioned earlier, for this reason, the CADF and LLC panel unit root tests were used for each of the series. These test results are reported in Table 4 and indicate that the result of the two tests are inconsistent at level for some variables, but at first difference the results are consistent for all the variables . This, therefore, implied that intra-trade, economic growth, pollutant emissions measurement together with energy consumption have a unique order of integration for each panel. There was no indication that any of the variables were I(2), however, at the same time, I(1) integration could not be ruled out for any of the variables.

Table 4 Panel root test

Variables	Level			First-difference		
	None	Intercept	Intercept and trend	None	Intercept	Intercept and trend
LLC test						
LCO	-1.17 [0.17]	0.085 [0.20]	0.09 [0.53]	-19.42*** [0.000]	-23.95*** [0.000]	-23.22*** [0.000]
lPM	-0.80 [0.21]	9.88 [1.000]	10.70 [1.000]	-11.25 [0.000]	3.40 [0.99]	2.68 [0.99]
LTO	1.10 0.86]	-7.32*** [0.000]	-5.20*** [0.000]	-31.23*** 0.000]	-32.30*** [0.000]	-25.33*** [0.000]
LGDP	11.30 [1.000]	-1.15 [0.85]	-2.34 [0.009]	-11.55*** [0.000]	-17.44*** [0.000]	-16.06*** [0.000]
$LGDP^2$	11.37 [1.000]	-0.22 [0.41]	-2.40*** [0.000]	-11.52*** [0.000]	-17.11*** [0.000]	-15.53*** [0.000]
LTEC	16.84 [1.000]	1.04 [0.85]	-2.22*** [0.01]	-5.08*** [0.000]	-22.98*** [0.000]	-19.68*** [0.000]
CADF-Fisher Chi-square test						
LCO	109.18 [0.11]	79.96 [0.97]	107.66 [0.12]	468.9*** [0.000]	943.13*** [0.000]	547.66*** [0.000]
LPM	52.83 [0.99]	22.25 [1.000]	22.20 [1.000]	234.65 [0.000]	152.77 [0.000]	144.52 [0.000]
LTO	47.57 [1.000]	229.55*** [0.000]	210.63*** [0.000]	890.84*** [0.000]	917.00*** [0.000]	851.50*** [0.0000]
LGDP	24.33 [1.000]	77.80 [0.82]	132.94*** [0.002]	366.41*** [0.000]	514.98*** [0.000]	516.74 [0.000]
$LGDP^2$	28.42 [1.000]	72.64 [0.90]	131.88*** [0.000]	368.54*** [0.000]	506.98*** [0.000]	422.60*** [0.000]
LTEC	9.79 [1.000]	43.07 [1.000]	160.60*** [0.000]	198.36*** [0.000]	625.74*** [0.000]	516.34*** [0.000]
Note: * **denotes significance at the 1% level of significance.						

We applied the panel cointegration technique, due to the unique order of integration of the variables. We, therefore, examined the long-run relationship between the variables in each panel and for each of the pollutants emissions measured. Table 5. reports the results of the Pedroni (1999, 2004) panel cointegration tests. The Pedroni tests used three between dimension (group) test statistics and four within dimension (panel) test statistics to examine whether the designated panel data were cointegrated. The "within dimension" statistics contained the estimated values of the test statistics based on the estimators that pooled the autoregressive coefficients across the different cross-sections for the unit root test on the estimated residuals. The "within dimension" tests and the "between dimension" tests advocated that there was sufficient evidence to reject the null hypothesis of no cointegration in each panel. We thus concluded that the variables TO, CO, PM, GDP, GDP2 and TEC would move together in the long run. The results remained robust with different measures of the pollutants that were emitted. This result can perhaps be described by the essential channels by which intra-trade is able to influence the environment, including the scale, technique, and composition influences discussed previously

Table 5 Pedroni Residual Cointegration Test

	LCO		LMP	
Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Statistic	Statistic	Statistic
Panel v-Statistic	2.074266***	-11.349616***	17.25****	6.25***
Panel rho-Statistic	-2.090666***	-0.070984	-1.95**	8.68***
Panel PP-Statistic	-6.611807***	-3.702800***	-0.95	7.97***
Panel ADF-Statistic	-6.754801***	-4.776472***	-3.60***	0.06
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic			
Group rho-Statistic	-11.615572***		-2.50***	
Group PP-Statistic	-4.610178***		3.50	
Group ADF-Statistic	-5.704977***		-2.13***	
Note: ***, ** indicate rejection of null hypothesis of no cointegration at the 1% and 5% respectively.				

The long-run elasticity estimates from the FMOLS model are reported in Table 6. Before discussing the results, we checked for the potential multicollinearity problem between regressors in the model. Table 7. Shows the results of the Variance Inflation Factors (VIF) test that was performed in each specification. The findings did not show such a problem in our analysis[3]. Since our model was safe, we moved forward and looked for the FMOLS model result. Clearly, for the two-pollution sources measured, the panel FMOLS estimators produced equivalent results in terms of their statistical significance and sign, however, slightly different sizes in the sizes of the estimated coefficients were noted. High robustness was indicated as each of the coefficients was shown to be statistically significant at the 1% level of significance. For the variable of interest, intra-Africa trade, the results showed that in the long run intra-Africa trade contributed positively and significantly to environmental quality regardless of the pollution measurement. The estimated positive impact of intra-Africa trade on the environment ranged between 11%-13%. As mentioned earlier, it is believed that the impact of trade on environmental quality varies between internal and external sources of pollution. Our finding showed that regardless of the sources of such emissions, intra-trade in Africa contributed positively to environmental quality. It seems that all of the variables on the right-hand side of Equation 3 captured the scale effect of trade (no proxy was used to capture the technology effect or the composition effect). Thus, the positive effect of intra-Africa trade on the environment may be due, even partly, to the scale effect of trade.

Table 6 FMOLS technique: Full Panel

Explanatory variables	Dependent variable LCO	Std-Error	Prob	Dependent variable LMP	Std-Error	Prob
LTO	-0.13***	0.0005	0.000	-0.11***	0.0005	0.000
LGDP	1.35***	0.0002	0.000	1.03***	0.0002	0.000
LGDP2	-0.18***	5.29E-06	0.000	-0.07***	5.19E-06	0.000
LTEC	0.006***	5.15E-05	0.000	0.03***	0.5.03E-05	0.000
Note: * **denotes significance at the 1% level of significance.						

[3] We employed the Coefficient Variance Decomposition (CVD) test to help diagnose potential collinearity problems amongst the regressors, again the results, which are not reported here but are available upon request, show the absence of any collinearity problem in our analysis.

The results of the empirical study are shown in Table 6. They revealed that the real GDP had positive effects on the two pollutants measured and was statistically significant. In addition, it was found that there was a negative and significant relationship between the two pollutants measured and the square of the real GDP. We, therefore, had accumulated sufficient evidence to affirm the validity of the EKC hypothesis, over the long-run, for all of the countries in the sample. This result implied that emissions are stimulated, up to a certain point, and then mitigated as the level of real income increases. Our results were consistent with the studies discussed in Section 2 (Shabbaz et al. 2015; Awad and Abougamous 2017a; Awad and Abougamous 2017b).

The results also showed that energy consumption increases, marginally, the level of pollution. As energy consumption is a necessary and crucial resource in the process of production, it is not possible for countries to cease using energy. However, it may be possible for the countries analysed to find alternative options to minimise energy consumption's effects upon the environment. This is relevant because energy consumption has been found to be one of the main contributors to environmental pollution. A possible option according to Wang et al. (2015), may be to upgrade the level of energy efficiency, as poor energy efficiency was shown to be a major contributor to the high level of pollution emissions in China. Another potential option could be to enhance the proportion of renewable energy used against total energy consumption, this option references Shafiei and Salim (2014), Boluk and Mert (2015), Dogan and Seker (2016) and Jebli et al. (2016) who claimed that renewable energy mitigates any increase in CO_2 emissions whereas non-renewable energy is shown to increase the level of pollution . The implication is that policymakers should pay more attention to renewable energy resources as they are environmentally-friendly.

Table 7 Variance Inflation Factors

Variables	Dependent variable LCO		Dependent variable LMP	
	Coefficient Variance	Uncentered VIF	Coefficient Variance	Uncentered VIF
LGDP	3.74E-05	1.225992	4.49E-08	2.796537
LTO	0.000255	1.174450	2.50E-07	1.111099
LTEC	1.38E-05	1.573870	2.53E-09	1.279493
LGDP2	6.61E-05	1.232219	2.70E-11	2.592687

5. Conclusion and recommendations

The present study investigated and tested the effects of intra-Africa trade on two measurements of environmental pollutants, namely CO2 and MP while incorporating energy consumption and economic growth, the study used a panel dataset for 46 African countries. The study covered the period from 1990–2017, this was the most recent data available to the authors when the study was embarked upon. To carry out the empirical analysis, the latest panel estimation techniques were employed. The findings from the panel unit root and tests indicated that all the variables were integrated of I (1). A long-run relationship between the mentioned variables was verified by the Pedroni cointegration tests. The FMOLS method suggested that intra-Africa trade reduced environmental deterioration. In addition, the existence of the EKC hypothesis was confirmed by the results. The results also indicated that although the consumption of energy had a marginal impact on the deterioration of the environment, the impact was significant. Overall the results implied that trade and the environment are mutually supportive in Africa. Thus, the current efforts to promote and facilitate regional integration, at least, through trade, should continue to offer protection for the environment on the African continent.

As we expected, the results of this study are substantial and provide significant policy implications for the economies examined in the panels, as well as for regional economic blocks, international trade and environmental organisations. The results are also imperative for future research as it is anticipated that this study may open further research directions. For example, although, the results show that intra-Africa trade is beneficial for Africa's environmental quality, the important question that requires future study is to identify the exact channel through which the continent gained this optimistic impact (is it due to the scale, technology or composition effect?). Further study is also required to investigate the impact of trade on environmental quality that results from global trade with that of intra-trade (comparative studies). Furthermore, additional specific studies to examine the validity of the "Pollution Haven" hypothesis and the "Race to the bottom" hypothesis in the context of Africa are required.

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Appendix 1 Reporter and partner countries

Algeria	Gabon	Niger
Angola	Gambia	Nigeria
Benin	Ghana	Rwanda
Burkina Faso	Guinea	Senegal
Burundi	Guinea-Bissau	Seychelles
Cabo Verd	Kenya	
Cameroon	Liberia	Sierra
Cen-	Libya	Somalia
Chad	Madagascar	South
Comoros	Malawi	Sudan
Congo, Dem.	Mali	Tanzania
Congo, Rep	Mauritania	Togo
Djibouti	Mauritius	Tunisia
Equatorial	Morocco	Uganda
Egypt	Mozambique	Zambia
Ethiopia		Zimbabwe