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Is Trade Bad for the Environment?

Decomposing the Impact of Trade on Environmental Quality

by

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Abstract

The impact of trade on environmental quality has received a considerable attention, both in policy debate and in theoretical literature. However, the empirical evidence on the topic remains lagged. This thesis adds to the empirics by unearthing the relationships and decomposing the effect into scale-technique effect and trade-induced composition effect using Arellano-Bond GMM estimation technique. Contrary to previous studies, the scale-technique effect is ascertained by controlling for the role of government. The study then compares the effect between OECD countries and SSA countries. An aggregated panel data on CO_2 and N_2O spanning from 1983-2008 are used as proxies for environmental quality. The results show that the role of a democratic government in ensuring a favorable scale-technique effect is dominated by the adverse composition effect on CO_2 emissions. However, these effects are both bad for N_2O emissions. These suggest that trade is generally detrimental to the environment. Comparing the results for OECD and SSA countries, the results also show that trade makes SSA countries relatively dirtier because of the global externality of CO_2 emissions. It is therefore imperative that both developed and developing countries broaden their trade policies to encapsulate environmental concerns.

Keywords: Environmental quality, Trade, Arellano-Bond, Scale-technique effect, Composition effect

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1. Introduction

The fifth assessment report on climate change by the Intergovernmental Panel on Climate Change [IPCC] (2014) suggests that the planet earth is currently running a fever (see also Cook et al., 2016). According to them, the global temperature is fast approaching the so-called tipping point – that level where a small increase in temperature will result in a dramatic change of the environment. Interestingly, substantial amount of studies (see e.g. Grossman & Krueger 1991, Safik, 1994; Hertel & Randhir, 2000; Frankel, 2009; Tsurumi & Managi, 2010; Halicioglu & Ketenci, 2015; Gozgor & Can, 2017) indicate that trade-led growth may have a significant impact in this environmental outcome. This is in part due to the dramatically increasing global demand for energy consumption in the quest for higher economic growth and development (Bose, 2010). Currently, energy consumption which depends on fossil fuels is the largest source of production of goods and account for about 68% share of the global anthropogenic greenhouse gas emissions (International Energy Agency [IEA], 2017). Considering that trade between and among countries is ever increasing, with a recent record of about 32% in merchandise trade volume between 2006 and 2016 (World Trade Organization [WTO], 2017), there is a growing concern as to whether free trade is being pushed at the expense of the environment.

The proponents of environmental quality believe that although trade has the capacity to lift nations out of poverty towards economic growth and prosperity, it has also resulted in exporting countries increasing their exploitation of natural environment and resources beyond what would have been required to meet the local consumption need in autarky (see e.g. Copeland, 2013). Moreover, trade liberalization creates the incentive for countries to weaken their environmental policy to protect their local and infant industries and hence the greater likelihood of an increased pollution. Thus, it is argued (see e.g. ed. Gallanger, 2008, p.112) that trade may not be welfare improving when environmental quality is considered - adverse environmental effect can lead to trade policy losses. However, Porter and van der Linder (1995, p.102) and Stoessel (2001) contend that trade-led growth induces cleaner production technology, efficiency via innovations and also causes high income countries to reduce the exploitation of the environment for survival. Hence, trade is beneficial for the environment.

The theoretical underpinning for these arguments stems from the so-called EKC theory[1] which states that at the initial stages of economic development, growth results in environmental degradation but after a certain threshold, further economic growth causes an increase in environmental quality (Grossman & Krueger, 1991; Frankel, 2009; Kearsly & Riddel 2010). Since trade is a key determinant of growth, there is the high possibility of influencing environmental outcome. Closely linked to this is the pollution haven hypothesis (PHH) which posits that differences in environmental policies create comparative advantage for some countries and hence trade will cause polluting industries to relocate to a jurisdiction with less stringent environmental regulations to avoid competition losses[2] and selection effects (Jaffe, Peterson, Portney, & Stavins 1995). Within this rubric, the Hecksher-Ohlin trade theory[3] also suggests that any resulting pollutant produced in one country is also associated with the consumption in another country. The factor endowment hypothesis (FEH) claims that countries that are relatively abundant in capital will have comparative advantage in the production of capital-intensive (dirty) goods and hence tend to export pollution-intensive goods. (Korves, Martínez-Zarzoso, & Voicu, 2011; ed. Gallagher, 2008). In effect, trade will make some countries[4] dirtier and others greener and cleaner.

However, the empirical evidence and verification for trade's impact on the environment remains lagged and inconclusive. So far, there are two major strands in the literature on this topic. The first group of studies stems from environmental economics and are concerned with the analysis of income and pollution. The major objective is to test the validity of EKC hypothesis. Thus, the model specification make use of income and its quadratic term – to account for the inverted u-shaped relationship between pollution and income. Trade openness is treated as a peripheral variable and the coefficient is interpreted as a sign of environmental impact of trade (see e.g. Grossman & Krueger 1993; Jeffe et al., 1995; Frankel & Rose, 2005; Korves et al., 2011; Jafari,

[1] The Environmental Kuznet Curve (EKC) was borrowed from the work by Kuznets (1955) that found an inverted U-shaped relationship between income and inequality.

[2] Intuitively, environmental regulations increase the cost of major input used in pollution-intensive production and hence reduced the comparative advantage.

[3] Herein refers to as the factor endowment hypothesis

[4] According to the PHH developing countries will become dirtier because of relatively lax environmental standards However, the FEH suggest that pollution will fall for developing countries since they do not have comparative advantage in pollution-intensive goods.

Farhadi, & Zimmermann, 2017) . The results from these studies are best described as mixed – the relationship between trade and environment differs across countries, pollutant and time.

The second group of studies emanating from international economics argues that the above approach puts the several channels through which trade affect the environment in a black box (see e.g. Cole, 2003; Antweiler, Copeland & Taylor, 2001). Thus, the intricate and complex relationship between trade, income and environment is not well diagnosed if not completely ignored. It is quite difficult to find a unique relationship between trade and environment as trade has different ways of affecting the environment. For instance, an increase in inputs to satisfy the increasing level of production generated by the economic development of a country caused by trade will have a negative impact on the environment (Copeland, 2013). This is called the scale effect. However, trade tend to have a positive impact when economic growth expands the Research and Development (R&D) sector, which results in cleaner production techniques – the technique effect. McCarney and Adamowicz (2005) have shown that the role of governance can even influence this outcome. Also, the comparative advantage a country possesses in terms of factor endowments and differences in environmental regulations has another implication on the environment. Such effect is termed the composition effect. If the comparative advantage lies in factor endowments, high income countries are expected to have greater emissions compared to low income countries. However, developing countries with laxer environmental standards will have comparative advantage in "dirty" industries and hence environmental degradation might result (Jeffe et al., 1995). Therefore, the net impact of trade on the environment depends on the relative size of scale, technique and composition effect.

Works along these lines have been accumulating after the influential study by Grossman and Krueger (1991, 1993, 1995). Extending their analysis by developing a theoretical framework to decompose the effect into scale, technique and composition effect for 108 cities of mostly developed countries, Antweiler, Copeland and Taylor (1998, 2001) find evidence for positive scale effect, negative technique effect and negative composition effect on SO_2 *concentration*. The study, however, concludes that overall, trade is good for the environment. Empirical work by Cole and Elliot (2003) maintained similar conclusion for SO_2 *emission* but found that when the analysis is applied to NO_2, CO_2 and energy use, trade openness may increase pollution. Subsequent study by

Managi, Hibiki, and Tsurumi (2009) sought to address the possible simultaneity bias between emission, trade and income. According to them, trade and income run in both directions and hence treating them as strictly exogenous determinants of pollution may be erroneous (see also Cialani, 2017, p.194). By deriving three system of equations: one for trade (using gravity model), another for income (using endogenous growth model) and emission, Managi, Hibiki, and Tsurumi (2009) sort out this econometric problem using GMM in lieu of appropriate instrumental variables. Their results show that trade is generally beneficial to the environment of OECD countries but damaging for non-OECD countries especially when SO_2, CO_2 emissions are considered.

To this end, little evidence has been found for developing countries due to their economic composition – more unskilled labor to capital in production compared to developed countries. This makes the economic cost of pollution in developing countries relatively much smaller (ed. Gallagher, 2008). In fact, none of the studies have specifically investigated the evidence for Sub-Saharan African (SSA) countries. Thus, based on the theoretical framework by Antweiler, Copeland and Taylor (2001), the present study examines the impact of trade on environmental quality by decomposing it into scale-technique[5] and trade-induced composition effect and compares the results for OECD countries and SSA countries.

The current study is therefore, significant in many respects. Firstly, it employs an updated data of carbon dioxide (CO_2) emissions which are emitted in large quantities in recent time, have a noxious impact on the environment and are highly regulated (IEA, 2017). The study also make use of nitrous oxide (N_2O) emissions - a local pollutant which has been neglected in previous studies and policy debate but has catastrophic effect on the environment (IEA, 2017). In fact, none of the studies have used nitrous oxide. Antweiler, Copeland and Taylor (2001) used SO_2 concentration data spanning the period 1971-1996 of 109 cities. Cole and Elliot (2003) utilized data for CO_2 , SO_2 and BOD emissions of 32 developed and developing countries covering the period 1975-1995 while Managi, Hibiki, and Tsurumi (2009) made use of 88 countries covering the period 1973 to 2000. The data used in this study however has 100 countries as full sample spanning the period of

[5] The reason for this term is because;. the scale effect demands the use of site specific factors such as GDP/Km^2 and pollution *concentration* which is not use in this study but instead real income per capita and pollution *emissions*. Also, contrary to previous work, the scale-technique effect is ascertained by controlling for political regime.

1983 to 2008. A sub-sample of 27 OECD and 33 SSA countries are selected. Secondly, this study adds to the gap in the existing literature by using dynamic panel models and the Arellano-Bond estimation technique. This sorts out the weakness of possible endogeneity between trade and income[6] which previous studies hardly consider. Thirdly, from the perspective of a broad policy direction, this study presents an empirical proof of the decomposition of trade on environmental quality for OECD and SSA countries; the findings will increase the knowledge of governments and policy makers about what kind of environmental policies will be appropriate to reduce pollution caused by free trade. In addition, without a change of policy, pollution may continue to rise. This study, therefore, describes the possible consequences and inherent risk of the situation of no policy. Finally, the findings may go a long way to contribute towards resolving the conflict between domestic environmental policies and international trade and investment policies.

The remainder of the paper is organized as follows. The theoretical underpinning of this study as well as review of previous approaches and findings are captured in section 2. The methodology and empirical approach for this study are captured in section 3. Econometric issues pertaining this study is capture in section 4 with discussions on empirical results of the study being dealt with in section 5. Section 6 provides the conclusions and recommendations.

2. Trade and Environment Nexus

There is a mutual compatibility and reinforcing relationship between the theory of trade and environment (ed. Gallagher, 2008). It is therefore not surprising that there have been theoretical successes in linking trade openness and environmental quality. This section provides both theoretical and empirical review and evidence of trade impact on the environment and how studies have decomposed the effects. It deals with the question; will trade openness lead to more pollution emissions and to what extent?

2.1 Decomposition of Trade Impact on Environment

[6] As detected by Antweiler, Copeland and Taylor (2001), Frankel (2009), and Frankel and Rose (2005). The reason for neglecting such limitation is in part due to paucity of data to investigate, and the convenient use of static panel models and fixed and random effect estimation techniques that ignores possible endogeneity problems.

The impact of trade on the environment has been decomposed into three distinct effects: scale effect, technique effect and composition effect (WTO, 2009). The scale effect refers to an increase in economic activity resulting from trade and its effect on pollution. Greater energy use is required to increase economic activity and therefore may lead to higher emissions (WTO, 2017). Copeland and Taylor (2004, p.8) described scale effect as an increase in the value of production, measured in autarky price ratio and its impact on pollution. Trade will lead to an increased use of the resources (land, labor, capital) to increase the level of production. This increased in production will, in turn, require an increased energy use which rely on fossil fuels and as a result will lead to higher levels of pollution. Thus, the scale effect predicts that trade-induced rise in income will cause an increase in emissions and pollutions (the EKC relationship). The WTO report on trade and climate change (2009) also contains an argument that increased trade will lead to a greater use of cross-border transportation services, which also adds to the greenhouse emissions. However, showing this relationship empirically has been quite difficult.

The technique effect refers to the fall in pollution as a result of using improved technologies of production. According to Korves et al. (2011) there is a general consensus among researchers that more than 75% of technological transfer is as a result of international trade. The discovery of pollution-reducing technologies which comes as a result of research and development (R&D) reduces pollution per capita. Thus studies have argued that the technique effect has a positive impact on environmental quality (Copeland & Taylor, 2004; Cole & Elliot, 2003; Stoessel, 2001).

The composition effect however depends on the comparative advantage of a country in pollution-intensive goods and differences in environmental policies between countries (factor endowment hypothesis versus pollution haven hypothesis). If comparative advantage exist due to factor endowment (capital-labor ratio), then the factor endowment hypothesis suggests that high income countries with high capital-labor ratio will have comparative advantage in pollution-intensive goods and hence environmental degradation might result as compared to developing countries (Korves et al, 2011). However, since regulations increase the cost of producing dirty goods and also pollution abatement is costly, developed countries suffer from comparative disadvantage in pollution-intensive goods. However, developing countries enjoy comparative advantage in pollution-intensive industries, hence becoming pollution haven (Korves et al., 2011). Thus, it is predicted that developing countries with laxer environmental regulations would be made dirtier (lose) whiles developed countries become clean (gain). Therefore, the composition effect is ambiguous and depends on the relative size of the capital-labor ratio effect and pollution haven effect. Table 1 summarizes the factor endowment hypothesis and pollution haven hypothesis.

Table 1: Factor Endowment Hypothesis vs Pollution Haven Hypothesis

Country Type	Comparative Advantage	Effect on Pollution
Factor Endowment Hypothesis		
Developing country (labor abundant)	Non-pollution intensive goods	Decrease in pollution
Developed Country (capital abundant)	Pollution intensive goods	Increase in pollution
Pollution Haven Hypothesis		
Developing Country (Lax environmental regulations)	"Dirty" Industries	Increase in pollution
Developed country (Stringent environmental regulations)	"Clean" Industries	Decrease in pollution

2.2. Framework for the Decomposition

The theoretical setup for the decomposition of the environmental effect of trade used in this study follows the one developed by Antweiler, Copeland and Taylor (1998, 2001). The model is simple, highly intuitive, with more realistic assumptions and resolves measurement problems and complexities surrounding trade and pollution.

The model assumes a small open economy with N agents, using two inputs, capital (K) and Labor (L) and producing two final goods X and Y. Sector X is capital intensive and hence generates pollution as a by-product. Sector Y is labor intensive and generates no pollution. By also assuming constant returns to scale they used the iso-unit cost functions as the production technology of each sector. That is, Cx(w,r) and Cy(w,r) for both industry X and Y respectively. Also crucial to the model is the assumption that countries differ in sizes, location and distance and trade restrictions. It is therefore important to distinguish between local prices and international price ratio. Using Y as a numeraire (i.e. Py = 1) the domestic price ratio of X and Y is denoted as P whiles the common international price ratio is given as P^w. Therefore, P can be written in terms of P^w as:

$$P = \alpha P^w \qquad (1)$$

where α measures trade friction. It is important to note that $\alpha > 1$ implies a country imports dirty good X whiles an $\alpha < 1$ means a country exports dirty good X.

Antweiler, Copeland and Taylor (2001) simply find a function for pollution emission by subtracting pollution abatement from what is called the "base level pollution" where each unit of X produced generates one unit of pollution. The pollution emission function is given as

$$z = X - \lambda E(X_a, X) \qquad (2)$$

Where $\lambda E(X_a, X)$ is the abatement for a given base level pollution, X. X_a is the amount of resources abated. They noted that though there is abatement cost, X industry uses the same factor intensities hence one can treat units of X inputs as abatement. This means that a firm with a gross output of x units, and allocate x_a units into abatement, can have a net output as $x_n = (1 - \theta)$. Where $\theta = x_a / x$ measures the abatement intensity. Therefore assuming that $E(X_a, X)$ is homogeneous, concave and increasing in Xa and X, then equation (2) can be simplified as follows:

$$z = e(\theta)x \qquad (3)$$

where $e(\theta)$ is emission per unit of X produced and is reducing in θ. By selecting a unit base year price, the pollution function (z) can be disintegrated into scale, composition and technique effects as;

$$z = ex = e\varphi S \qquad (4)$$

In a differential form $\hat{z} = \hat{S} + \hat{\varphi} + \hat{e}$ (4.1)

Where S is the scale effect which shows a percentage change in pollution emissions as a result of a change in the size of the economy. φ is the share of pollution-intensive good X in total output and indicate the composition effect. Finally, e denotes the technique effect. This study includes the role of governance which influences technique effect. According to McCarney and Adamowicz (2005), democratic countries are more responsive to increased demand for environmental quality as income grows and hence indicate a high technique effect from trade. It may be that democratic government leads to greater levels of environmental regulations. The ^ indicates that the variables are in terms of percentage change.

Using general equilibrium analysis of demand and supply, Antweiler, Copeland and Taylor (2001) identify the pollution demand and supply by private sector. For the purpose of this study, the analysis is extended to include exporting and importing countries. In their model, they find that pollution demand is determined by scale, capital abundance and the international price ratio for pollution intensive goods and pollution tax. On the supply side, pollution is a function of pollution tax which is also influenced by the level of income in a country[7]. The reduced form equation for the demand and supply analysis is given by:

$$\hat{z} = \pi_1 \hat{S} - \pi_2 \hat{e} + \pi_3 \hat{k} - \pi_4 \hat{T} + \pi_5 \hat{p}w + \pi_6 \hat{\alpha} \qquad (5)$$

Where π_i are positive and all variables are assumed to be exogenous. New variables k, represents capital labor ratio, T represents 'country type', $\hat{p}w$ shows the Stolper-Samuelson effect. $\hat{S}$ is the scale effect. The technique effect is represented by $\hat{e}$ with an opposite expected sign to the scale effect. The composition effect is denoted by $\hat{\alpha}$, which shows whether the country in question is an exporting/importing country. As noted above, if $\alpha > 1$ the country is an importer of pollution-intensive good and hence trade will imply that $\hat{\alpha} < 0$. We can infer then that for a country with a comparative advantage in the production of clean good, trade will improve environmental quality. However , if $\alpha < 1$ then the country is an exporter of pollution-intensive good and hence trade will mean that $\hat{\alpha} > 0$. This simply implies that trade will increase pollution for the country with comparative advantage in the dirtier good. We can therefore examine the impact of trade on pollution across different countries.

[7] This is based on the assumption that increased in real income will raise the demand for environmental quality (Cole, 2003).

This model shows why the empirical evidence of trade on environment is mixed because there is no unique relationship between trade and emissions. According to Cole (2003, p.564), the effect is heavily dependent on a country's comparative advantage which is accounted for by the capital labor ratio and pollution haven effect. Differences in tax on emissions for countries imply that pollution intensive industries relocate to a laxer environmental regulation country. Since developing countries have laxer environmental policies, they will have a comparative advantage in the production of pollution intensive goods. Therefore a country's characteristics in terms of relative factor abundance and relative income determine how trade affects the environment.

2.3 Earlier Findings

The empirical literature on trade and environment continues to accumulate in terms of measurement of key variables and methodological techniques. With regards to measurement, the studies have expanded in three different directions: (1) model specification (2) indicators of environmental quality (2) measuring the strength of the impact.

Ever since Grossman and Krueger (1991) empirically analyzed the impact of NAFTA on SO_2 concentration, a body of works has emerged to investigate the impact of trade openness on the environment in a considerable detail. Usually, the empirical strategy of early studies is to extend the basic EKC model and regress trade openness alongside other control variables on a measure of environmental quality (see e.g. Grossman & Krueger, 1993; Shafik & Bandyopdhyay, 1992; Safik 1994; Selden & Song, 1994; Tobey, 1990, Panayotou, 1997). Although using the EKC model is simple and shows direct relationship between trade and environment, Stern (2004) contends that EKC model is highly susceptible to econometric misspecification. Aslanidis (2009) also argues that the EKC specification is statistically weak and very restrictive. In fact such polynomial model is merely descriptive and arguably fail to answer the question as to whether trade actually changes environmental quality – they are seemingly unrelated (Aslanidis, 2009). Thus, it becomes quite difficult to unearth the factors of pollution which have specific policy implication (Dinda, 2004, Lieb 2003). Perhaps the most important development in the literature is the use of empirical specification based on the theoretical model of Antweiler, Copeland and Taylor (2001). This specification is powerful in isolating the environmental impact of trade and even more usefully, decomposing the effects into scale, technique and composition effect and finding their respective magnitudes .

Antweiler, Copeland and Taylor (1998, 2001) make a huge attempt to theoretically and empirically show the decomposition using a general equilibrium theory of trade and environment via the use of Fixed effect and Random effect models. They show that pollution depends on capital-labor ratio, country type, scale effect and differences in environmental policies. Contrary to previous studies (Grossman & Krueger, 1993, 1995; Safik, 1994) which concentrate on using growth, trade openness and pollution levels and then interpret the results as a signal of relative strength of scale and technique effect, Antweiler, Copeland and Taylor (2001) estimates the scale, composition and technique effect by using general equilibrium analysis on relative pollution concentration, GDP/Km^2, relative income per capita and trade openness. Specification-wise, the study interacts trade with capital labor ratio and income at different levels to account for differences in factor endowment, environmental policies, scale and technique. By leveraging on panel data spanning from 1971-1996 for 109 cities, the study finds positive scale effect, negative technique effect, negative composition effect on SO_2 concentration. The study, concludes that the net impact of trade is beneficial for the environment. However, none of these studies considered greenhouse gases which are the initial concern for the environmental quality and climate change.

Cole and Elliot (2003) on the other hand include greenhouse gas emissions in their study. By closely following the theoretical framework by Antweiler, Copeland and Taylor (1998, 2001), and employing the fixed effect and random effect models, the study investigates trade openness on four environmental quality indicators: SO_2, CO_2, NO_x and Biochemical Oxygen Demand (BOD) emissions. They use cross-sectional data for 32 developed and developing countries covering the period of 1975-1995. Due to the use of national pollution *emissions*, the study decomposes the effect into scale-technique and composition effect. The study finds that overall; trade openness increases CO_2 and NO_x emissions and energy use as a result of the huge scale-technique effect that outweighs composition effect. This means that increase in trade would increase production and output which would subsequently increase emissions, however, the pollution abatement technologies used are not large enough to counter such growth. The results however suggest that trade openness reduced BOD emissions.

Although Antweiler, Copeland and Taylor (2001) and Elliot and Cole (2003) are able to investigate the impact of trade and income on environment in greater detail, the studies have been criticized on econometric grounds. The criticism of the econometric technique is related to issues such as endogeneity, multicollinearity, heteroscedasticity, omitted variables bias, and the need to check for possible cointegration between income, trade and pollution (Leib, 2003; Stern, 2004; Managi et al., 2009; Wagner & Grabarczyk, 2016). According to Managi, Hibiki, and Tsurumi (2009) and Frankel and Rose (2005), simultaneity bias between income, trade and emissions have been ignored though it may impair the results. They argue that trade and income have two-way relationships. More openness can increase income and the greater the income of a country, the greater the likelihood of increasing trade. To address this, the endogeneity of trade must be modelled separately.

Following the idea of Frankel and Rose (2005), Managi, Hibiki, and Tsurumi (2009) use three systems of equations: the gravity model specification for trade, endogenous growth model for income and finally the environmental quality equation. Quite uniquely, Managi, Hibiki, and Tsurumi (2009) employ dynamic panel model and apply the differenced GMM in lieu of appropriate instrumental variable that controls for endogeneity of income and trade. This also allows them to separate the short-term and long-term relationships between trade and environmental quality. The study use panel data on CO_2 and SO_2 emissions of 88 countries spanning the period 1973-2000 and BOD emissions of 93 countries in 1980-2000. They conclude that trade openness is beneficial in OECD countries. However, trade deteriorates the environmental of non-OECD countries through increased in SO_2 and CO_2 emissions although BOD falls. After the dynamic adjustment process, they also find that the overall impact is huge in the long term than short-term. Finally, the study finds evidence for scale-technique effect and trade-induced composition effect.

Interestingly, a more recent study by Jafari et al. (2017) also employs the dynamic model with Arellano-Bonds's GMM estimation. However, the study uses the traditional EKC approach and concludes that trade has no significant impact on the environment. What also stood out in this study is that the role of government had a significant negative impact for the pollution in developing countries. In fact it has currently become popular in the empirical literature to investigate the role of governance on trade-led environmental degradation (see e.g. Bernard & Mandal, 2016, Deacon & Mueller, 2004; Welsch, 2004). By using polity, a variable that proxies for governance or political regime between countries, a study by McCarney and Adamowicz (2005) find that greater democracy is linked to decreased BOD emissions but may rather increase CO_2 emissions. They find this by interacting polity variable with per capita income and trade. They explained that this result may stem from the indirect impact of governance on environmental quality, whereby bad governance reduces welfare and prosperity and hence reducing the income levels and consequently emissions.

Table 2: Decomposition of Environmental Impact of trade: Previous results

Author	Methods	Pollutant	Overall effect	Scale-technique effect	Composition effect
Grossman and Krueger (1991)	Fixed effect	SO_2	Positive	-	-
Antweiler Copeland and Taylor (2001)	Fixed vs Random effect	SO_2	Positive	Negative	Positive
Elliot and Cole (2003)	Fixed vs Random effect	SO_2	Negative	Negative	Positive
		CO_2	Positive	Positive	Positive
		BOD	Negative	Negative	Negative
Managi, Hibiki, and Tsurumi (2009)	GMM (IV)	SO_2	Negative	Negative	Negative
		CO_2	Positive	Positive	Positive
		BOD	Negative	Negative	Negative

Overall, the results are best described as mixed. This is due to different environmental quality indicators such as SO_2, CO_2, BOD, SPM, NOx etc. There is also differences in functional forms and different econometric techniques employed. Results have also varied due to different framework analysis (panel data, cross-section, and time series regressions) and set of explanatory variables used such as regulations, land size, income (intensive vs non intensive), education, urbanization, role of government etc. Apart from specific case studies and pollutant, there is hardly enough empirical evidence and consensus that trade liberalization have a significant influence on the environment. However, there is evidence for EKC though the role trade openness play in that process is still unclear. Finally, there is still little and lagged empirical evidence for the decomposition of the effects of trade on environmental quality. An ideal empirical investigation should be able to identify and isolate the trade-induced effects while accounting for changes in the country's composition and comparative advantage. Without this, one cannot assess whether a country is made dirtier as a result of trade liberalization. Finally, the real net impact of trade on welfare cannot be empirically ascertained.

3. Empirical Approach

This section presents the empirical model, data and justification of variables and estimation strategy used to empirically examine the impact of trade of environmental quality.

3.1 The Empirical Model

As aforementioned, the econometric specification of the impact of trade on the environment has taken several forms (also, see appendix table A). Traditionally, studies examining the link between trade and environment adopt the basic EKC model and include trade openness and other control variables such as FDI, population, urban dummy and land size. Though this technique is simple and useful for measuring the direct impact of trade, it does not consider the complexities of trade-induced composition effect as well as the scale-technique effect. Thus, based on decomposition equation in (5) and the empirical specification by Managi, Hibiki, and Tsurumi (2009) this study specifies the environmental quality equation as:

$$\begin{aligned} Emission_{it} = {} & \lambda_1 + \alpha_0 Emission_{it-1} + \alpha_1 Y_{it} + \alpha_2 {Y_{it}}^2 + \alpha_3 \mathrm{K/L}_{it} + \alpha_4 {\mathrm{K/L}_{it}}^2 + \alpha_5 (\mathrm{K/L})_{it} Y_{it} \\ & + \alpha_6 TO_{it} + \alpha_7 RY_{it} TO_{it} + \alpha_8 ({RY_{it}}^2) TO_{it} + \alpha_9 R\mathrm{K/L}_{it} TO_{it} + \alpha_{10} (R{\mathrm{K/L}_{it}}^2) TO_{it} \\ & + \alpha_{11} (RY_{it})(R\mathrm{K/L}_{it}) TO_{it} + \alpha_{12} Polity + \alpha_{13} (Polity) Y_{it} \\ & + \varepsilon_{it} \qquad (6) \end{aligned}$$

The dynamic model[8] allows for the possibility that trade impact on emission in the previous period (t-1) affect emission in the current period (t). As argued by Lieb (2003), trade and income may not have an instantaneous but only a lagged effect on pollution. Thus, there is the need to account for the lag of emissions. We therefore expect some short-run and long run implications for the model

[8] Managi, Hibiki, and Tsurumi (2009) used similar model but three system of equations: emission equation, trade equation (from gravity model) and income equation (from endogenous growth model) for the dynamic adjustment process and also control for endogeneity. Due to data problems and the purpose of this study, we only consider the dynamic model of the emission equation for our analysis and assume the existence of endogeneity.

(Leib, 2003; Managi, Hibiki, & Tsurumi, 2009). Table 3 describes all the variables used and their respective expected signs suggested by theory.

Table 3: Description of Variables

Variable	Description	Expected Sign
$Emission_{it}$	Emitted pollutant (CO_2 or N_2O) for country i at time t, dependent variable. The lagged term is included to account for the dynamic process	α_0 (+ /-)
Y_{it}	Real GDP per capita of country i at time t. The quadratic term captures the **scale technique effect or EKC**	α_1 (+), α_2 (–)
K/L_{it}	Capital-labor ratio for country i in year t. This shows the factor endowment or otherwise the composition effect.	+ /-
TO_{it}	This represents the trade openness or omission measured as (export + import)/GDP	+ /-
RY_{it}	Country i's relative real income per capita (a county's real income per capita expressed relative to world average) for each year	+ /-
RK/L_{it}	Country i's relative capital-labor ratio (a country's K expressed relative to world average) for each year.	+ /-
$RY_{it}TO_{it}$	an interaction of trade openness with country i's relative real income per capita (**Pollution haven effect**)	$\alpha_7(+), \alpha_8(-)$
$RK/L_{it}TO_{it}$	an interaction of trade openness with country i's relative capital– labor ratio (**factor endowment effect**)	$\alpha_9(-), \alpha_{10}(+)$
$(RY_{it})(RK/L_{it})TO_{it}$	The interaction of trade openness, relative capital– labor ratio and real income per capita	+ /-
$Polity$	Measure of democracy in a political regime. The scores vary from -10 to 10. Negative scores represent autocratic political regime and positive scores denote democracy. The coefficient of the polity variable indicates the direct impact of governance on environmental quality.	+/-
$(Polity)Y_{it}$	Interaction capturing the specific effect of per capita income for different political regime. As income grows, a more democratic government will be more responsive to increased demand for environmental quality. **Indicates additional technique effect**	-
ε_{it}	Composite error term and consists u_i, the fixed effect reflecting the time-invariant country characteristics and v_{it} is the random noise	

Decomposition of the Empirical Model

Equation (6) can be decomposed into the following categories: (1) scale-technique effect and (2) trade induced composition effect. First, since this study makes the estimate for national pollution *emission* and real income per capita, we capture the scale-technique effect by using the GDP per capita. This is in sync with the study by Cole and Elliot (2003). Contrary to Managi, Hibiki, and Tsurumi (2009) this study however, specifies the scale-technique effect by controlling for the role of government. Following McCarney and Adamowicz (2005), the study argues that the scale-technique effect (STE) would be influenced by democratic governance. Thus, the STE is specified as:

$$STE_{it} = \alpha_1 Y_{it} + \alpha_2 {Y_{it}}^2 + \alpha_{13}(Polity)Y_{it} \tag{7}$$

From EKC, α_1 is excepted to be positive and α_2, negative. The interaction between per capita income (Y) and the polity variable gives additional technique effect. α_{13} is expected to be negative since democratic countries are responsive to high environmental quality as income grows.

The composition effect (COMP) is simply ascertained by ignoring the $Emission_{it-1}$, Y_{it}, ${Y_{it}}^2$ and the polity variables in equation (6). This gives us equation (8).

$$\begin{aligned} COMP_{it} = {} & \alpha_3 \mathrm{K/L}_{it} + \alpha_4 {\mathrm{K/L}_{it}}^2 + \alpha_5 (\mathrm{K/L})_{it} Y_{it} + \alpha_6 TO_{it} + \alpha_7 RY_{it} TO_{it} + \alpha_8 (R{Y_{it}}^2) TO_{it} \\ & + \alpha_9 R\mathrm{K/L}_{it} TO_{it} + \alpha_{10} (R{\mathrm{K/L}_{it}}^2) TO_{it} + \alpha_{11} (RY_{it})(R\mathrm{K/L}_{it}) TO_{it} \end{aligned} \tag{8}$$

In this study we are interested in trade-induced composition effect (TCOMP) which reflects the relative opposing magnitudes of factor endowment effect and pollution haven effect. The trade-induced composition effect [9]is formalized by Cole and Elliot (2003) as:

$$\begin{aligned} TCOMP_{it} = {} & \alpha_6 TO_{it} + \alpha_7 RY_{it} TO_{it} + \alpha_8 (R{Y_{it}}^2) TO_{it} + \alpha_9 R\mathrm{K/L}_{it} TO_{it} + \alpha_{10} (R{\mathrm{K/L}_{it}}^2) TO_{it} \\ & + \alpha_{11} (RY_{it})(R\mathrm{K/L}_{it}) TO_{it} \end{aligned} \tag{9}$$

[9] Managi, Hibiki, and Tsurumi (2009) termed $\alpha_3 \mathrm{K/L}_{it} + \alpha_4 {\mathrm{K/L}_{it}}^2 + \alpha_5 (\mathrm{K/L})_{it} Y_{it}$ part of equation (7) as indirect trade-induced composition effect. This is not considered in this study because the argument is to find the direct trade-induced relationships that capture the strength of pollution haven hypothesis vis-à-vis factor endowment hypothesis between countries.

In this model (equation 9), Antweiler, Copeland and Taylor (2001) theory predicts α_6 to be zero. We have also seen that the comparative advantage is reduced for a country with more stringent environmental policies due to competition losses. Since developed countries with high income have more strict regulations than developing countries with low income, it is expected that free trade will cause a damaging impact on environmental quality for countries with low per capita income but improve the environment of countries with high per capita incomes. This is because first, dirtier industries will relocate to low income countries that also have comparative advantage in the pollution intensive production processes. This impact (pollution haven hypothesis) is captured by the interaction of relative real GDP per capita and trade openness (i.e. RY*TO). The quadratic term is included to account for differences in RK/L and RY (Cole, 2003). We therefore, expect α_7 to be positive and α_8 to be negative.

Likewise, our theoretical discussion on factor endowment hypothesis predicts that countries with low capital-labor ratio will have a comparative disadvantage in pollution-intensive industry and hence pollution will be low. However, countries with high capital-labor ratio tend to have comparative advantage in dirty industry and hence pollution might increase. This argument is captured by the interaction of relative capital-labor ratio and trade openness (i.e. RK/L*TO) and its quadratic term. Per the hypothesis α_9 and α_{10} are therefore expected to be negative and positive respectively. Finally, α_{11} can be either positive or negative

3.2 Data and Justification of Variables

The data for this study is obtained from different sources. The CO_2 and N_2O emissions data[10] are obtained from Carbon Dioxide Information Analysis Center (CDIAC) and World Development Indicators (WDI) respectively. CO_2 emissions (a global pollutant) are those emanating from the burning of fossil fuels. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring (IEA, 2017). N_2O emissions (a local pollutant) on the other hand are emissions mostly from agricultural activities; fertilizer use and agricultural soils. N_2O emissions have been neglected in previous studies and policy debate even though they have been increasing

[10] Data on emissions are estimated using engineering functions. While data for CO_2 emissions are measured in metric tons per capita, N_2O emissions are measured in thousand metric tons of CO_2 equivalent.

at an alarming rate in recent time (IEA, 2017). The concern is that they signify an overwhelming decrease in the nitrogen available to crops (Clayton et al., 1997; IEA, 2017) and their contribution to global warming and the damage to the ozone layer cannot be overemphasized (IPCC, 2013).

This study has a narrow focus. It concentrates on the link between trade and greenhouse gases (CO_2 and N_2O) and not all the indicators on environmental quality or pollution. It is extremely difficult to have a perfect indicator describing the environment because there are several parts of the ecosystem that we care about (air, land, water). It is noted that studies on this topic have produced different results for different pollutant and the intensity of pollution (emissions versus concentration). However according to Antweiler, Copeland and Taylor (2001), environmental quality can be measured by pollutants that have the following characteristics: (1) It should be a by-product from production of goods; (2) the pollutant should be emitted in large quantities per unit output in some industries than others; (3) have a strong local effect; (4) subject to some regulations; (5) have a well-known abatement technologies; (6) have readily available data. CO_2 and N_2O emissions share many of these properties[11], thus the motivation for choosing them. We do not consider pollutants such as SO_2 *concentrations* and BOD which have local and transboundary impact (Managi, Hibiki, & Tsurumi, 2009) because this study does not examine such broader question as whether trade impact on economic efficiency transcends beyond country boarders. The interest is to know how trade affects greenhouse gases and CO_2 and N_2O fall within that spectrum. The study utilizes data of 100 countries of which 27 OECD countries and 33 SSA countries are used for the comparative analysis. Countries with too many missing values or no data are not included. The data span the period 1983 to 2008 which is extensive and much updated compared to previous studies (Managi, Hibiki, & Tsurumi, 2009; Antweiler, Copeland & Taylor, 2001; Elliot & Cole. 2003). Table 4 provides descriptive statistics of our sample.

The data on trade openness and GDP per capita is sourced from WDI. Trade openness is measured as a ratio of the sum of exports and import to GDP. As argued by Squalli and Wilson (2011, p.1748) the term openness seems to connote deliberate policy decisions such as removal of tariffs

[11] See IEA's latest report on Carbon emission for fuel combustion (2017) and IPCC fifth assessment report on climate change (2014).

and other trade restrictions. And clearly, using trade/GDP will mean that large countries like USA, Germany, China, Japan, and Sweden are going to be ranked low on the list of “opened countries”. However, Frankel (2009) explain that Trade/GDP is negatively related to country size, suggesting that small income countries are more dependent on trade and hence the need to open up their economies. Also, trade/GDP is dependent on many other factors such as geography or deliberate free-trade policy. In our analysis, the ‘source’ does not matter and hence trade/GDP serves as a good proxy for trade openness. Consistent with the argument by Frankel (2009), the descriptive statistics reveal a mean value of 69.196 of trade openness for OECD countries, while SSA countries registered 73.569. The study also uses GDP per capita measured in real dollars (2010 constant US$). The differences in real per capita income between serves as proxies for differences in growth between countries. Hence, this variable is used to infer the inverted-U shaped relationship between growth and pollution (see e.g. Grossman & Krueger, 1993).

The composition effect is ascertained by the relative capital abundance to labor in a country. The capital-labor ratio is taken from the Extended Penn World Table 4.0. In the estimation model the square term is included. This polynomial is theoretically appealing because of the marginal diminishing effect of capital accumulation (Antweiler, Copeland & Taylor, 2001). To capture the comparative advantage, the capital-labor ratio and real income per capita relative to world average per year is used. This idea of the share of factors and income per world average is suggested in the trade literature by Vanek (1968) in his reformulation of the factor proportion theory. Previous studies that decompose trade’s impact on the environment have used same in their measurement of comparative advantage via factors and differences in environmental regulations. It is revealing in table 5 that the sample mean of relative income and relative capital-labor ratio for OECD are greater than SSA countries. Thus, suggesting that OECD countries have comparative advantage in capital-intensive production and enact stiffer environmental polices whiles SSA countries have comparative advantage in labor-intensive production with laxer environmental policies.

Table 4: Descriptive statistics

Variable	Region	Obs	Mean	Std. Dev.	Min	Max
CO_2 emission per capita	OECD	694	9.2840	4.7880	1.7653	27.4314
	SSA	851	0.8300	1.7690	0.0107	9.8542
	All Countries	2585	3.9971	4.9280	0.0107	34.7330
Nitrous Oxide	OECD	702	33574.51	63765.06	348.48	370816
	SSA	858	8046.97	14661.25	15.46	149775
	All Countries	2600	23415.31	57982.41	15.46	502550
GDP per capita	OECD	702	34697.54	18533.78	4507.43	111968.00
	SSA	855	1754.05	2536.18	115.79	20333.90
	All Countries	2596	11998.05	17409.86	115.79	111968.00
Trade Openness	OECD	702	69.196	43.183	16.012	343.562
	SSA	842	73.569	51.805	11.086	531.737
	All Countries	2576	72.591	52.284	0.021	531.737
Capital-labor ratio	OECD	702	87979.11	32401.05	14519.10	178839.00
	SSA	858	8525.63	14094.12	323.90	82261.60
	All Countries	2600	37767.96	40645.33	323.90	194172.00
polity	OECD	702	8.5612	4.1818	-10	10
	SSA	858	-1.1946	6.0494	-10	10
	All Countries	2600	2.9071	7.0421	-10	10
Relative income per capita	OECD	702	4.4930	2.2700	0.7221	11.8420
	SSA	855	0.2280	0.3210	0.0156	2.1380
	All Countries	2596	1.5539	2.2125	0.0156	11.8420
Relative capital-labour ratio	OECD	702	0.0162	0.0053	0.0030	0.0283
	SSA	858	0.0021	0.0030	0.0001	0.0171
	All Countries	2600	0.0067	0.0071	0.0001	0.0320

Finally, the polity variable, taken from Center for Systemic Peace (CSP) is coded by polity IV index as -10 to 10. This measures regime type of a country. Negative scores denote autocracy and positive values denote democracy. The polity variable indicates the direct impact of governance on environmental quality. In our full sample, the average country is more democratic. The sub-sample however shows that OECD countries are more democratic compared to SSA countries. It is expected that a more democratic country has a reduced trade-led pollution compared to the autocratic government (McCartney and Adamowicz, 2005, p.10). This is because in a democratic country, the demand for greener environment would lead to stiffer environmental regulations.

4. Econometric Issues

Prior to estimating the empirical model, the study first find the possible cointegration between emission, trade and income which is strongly suggested by theory but previous studies hardly consider (see e.g. Antweiler, Copeland & Taylor, 2001; Cole & Elliot, 2003; de Alvis, 2015). A possible explanation for this is that cointegration is more of a time series issue and hence requires a panel with large T (time series dimension) at least. However, most traditional panel data used contains very small time dimensions compared to the cross-section (i.e. micro-panel data). In addition appropriate panel cointegration technique has been quite rare. It is even difficult to find a good technique in the EKC literature because of its model specification. For example, Wagner (2015) surveys papers in the EKC literature that have used panel cointegration techniques and concludes that most of these papers ignores the crucial difference between "powers of integrated process" and "integrated process". He argues that assuming the two processes as equal and regressing emission on the nonlinear explanatory variables is not a standard cointegrating regression but rather a *cointegrating polynomial regression* (CPR). Failure to recognize the difference may lead to spurious regression. This is because the assumption of cross-sectional independence becomes unrealistic. Thus, the standard panel cointegration techniques such as Philip and Moon (1999), Pedroni (2004) and Kao (1999) may fail. To overcome this problem, Wagner & Grabarczyk (2016) proposed the use of what they term "seemingly unrelated cointegrating polynomial regression" (SURCPR) for the polynomial specification. However, this approach is only useful for panels with smaller N and larger T, which does not fit our data.

The study rather employs Westerlund (2007) cointegration test which sits well with the data. Though this approach does not address many of the concern by Wagner (2015), the test is credited to produce high power compared to other techniques[12]. This test improves on the previous residual-based cointegration tests (e.g. Engle-Granger test) which require a common factor restriction[13] (Persyn & Westerlund, 2008). Westerlund test contains individual specific short run effect, individual specific intercept slope parameters, and individual specific intercept and trend terms

[12] After performing a Monte Carlo Simulation (Westerlund, 2007 p.9)

[13] This means that the shortrun parameters for the variables in their differences should be equal to long run-parameters in their levels. This causes a loss of power for the cointegration test (Westerlund, 2005).

even though it does not require corrections for temporal tendencies in data (Westerlund, 2007). For robustness, Pedroni and Kao tests are also utilized.

4.1 Unit roots and Cointegration test

As a diagnostic test, the unit root test on emissions, trade openness, income and its square are conducted. The study also test the stationarity of the dynamic process which is represented as the lag of emissions. By employing the Im-Pesaran-Shin and Fisher type unit root test based on Augmented Dickey Fuller (Choi, 2001) we confirm the notion of stationarity. The results (see appendix table C) show that at all levels, CO_2, N_2O, income per capita and trade openness are insignificant, hence we fail to reject the null hypothesis of unit root. Therefore, emissions, trade and income are nonstationary at levels. However, all panels are stationary at all levels of significance after first difference. Thus, it can be concluded that the series are I(1). This findings hold for both full sample and sub-samples. We then proceed to test whether emission, trade and income are cointegrated. The Westerlund-based panel cointegration test is adopted. In all test, trend and constant are not included. It can be seen in table 5 that the statistic for Pt and Pa[14] indicate that the null of cointegration be rejected, confirming that these variables are cointegrated. See results for Pedroni and Kao in appendix table D, which also confirm same. Therefore, it can be concluded that a regression between emission, trade and income is not spurious, as there exist some long run relationship between these variables.

Table 5 : Westerlund-based Cointegration test Results

	CO_2 emission, Trade, Income			N_2O Emission, Trade, Income		
	Value	Z-value	P-value	Value	Z-value	P-value
Gt	-1.548	-1.589	0.056	-1.705	3.579	1.000
Ga	-3.688	3.905	1.000	-7.716	2.245	0.988
Pt	-13.359	-3.002	0.001	-26.633	-9.202	0.000
Pa	-3.492	-2.027	0.021	-10.072	-7.524	0.000

Note: Ho: No cointegration. xtwest is used with a single lag as lead and head based on the minimum AIC

14 We focus on these statistics because the Monte-Carlo simulation gives them higher power over Gt and Ga. (see Westerlund, 2007 p.18).

4.2 Estimation

As discussed, the estimation strategy for this study is based on a dynamic panel data model. That is the model of interest has a lagged value of the dependent variable as one of the independent variable. The model of estimation is :

$$
\begin{aligned}
Emission_{it} = {} & \lambda_1 + \alpha_0 Emission_{it-1} + \alpha_1 Y_{it} + \alpha_2 {Y_{it}}^2 + \alpha_3 \mathrm{K/L}_{it} + \alpha_4 {\mathrm{K/L}_{it}}^2 + \alpha_5 (\mathrm{K/L})_{it} Y_{it} \\
& + \alpha_6 TO_{it} + \alpha_7 RY_{it} TO_{it} + \alpha_8 (R{Y_{it}}^2) TO_{it} + \alpha_9 R\mathrm{K/L}_{it} TO_{it} + \alpha_{10} (R{\mathrm{K/L}_{it}}^2) TO_{it} \\
& + \alpha_{11} (RY_{it})(R\mathrm{K/L}_{it}) TO_{it} + \alpha_{12} Polity + \alpha_{13} (Polity) Y_{it} + \varepsilon_{it} \qquad (6)
\end{aligned}
$$

Where $\varepsilon_{it} = u_i + v_{it}$. u_i is the fixed effect reflecting the time-invariant country characteristics and v_{it} is the random noise or idiosyncratic shock. All variables except the polity dummy are in natural logs. The basic assumptions of this model is that v_{it} ~ iid (0, σ_v^2), $E(v_{it}|\ Emission_{it-1})$ = 0 and $\alpha_0 < 1$. How do we consistently estimate for $\alpha_i^{\prime s}$?

The major problem in estimating this model is that the fixed effect treatment leads to what is called "Nickell bias" or within estimator which is inconsistent and bias due to the presence of autocorrelation induced by the lagged dependent variable and the error term (Nickel, 1981; Hsiao, 2003; Gujarati, 2003). This makes the OLS estimation technique asymptotically inefficient in the presence of autocorrelation. Also, the fixed effects (within) estimator becomes inconsistent in the panels with large number of individuals (N = countries) and small time dimension (T = years).

The available solution to this problem is to take the first difference of the equation (see e.g. Anderson & Hsiao 1982; Holtz-Eakin, Newey & Rosen 1988; Arellano & Bover, 1990; Arellano & Bond, 1991). This removes the fixed effect (u_i) or the country-specific heterogeneity is differenced out. However, the econometric problem of autocorrelation between differenced random noise (Δv_{it}) and the lagged-emission variable ($\Delta Emission_{it-1}$) may still exist (Jafari et al, 2017). In addition, we cannot treat trade and income as strictly exogenous variables. This is because causality runs in both directions and hence the explanatory variables may be correlated with the error term (Franel & Rose, 2005). Therefore OLS and FE parameters will no longer be unbiased and consistent (Jafari et al, 2017; Pesaran et al., 1999).

To effectively deal with these problems, econometricians (see e.g. Anderson & Hsiao, 1982, Arellano & Bover, 1990; Arellano & Bond, 1991, Blundell & Bond, 1998) recommend the use 2SLS IV approach, GMM-type moment conditions methods of Arellano and Bond (1991) and system-GMM estimators proposed by Blundell and Bond (1998) and pooled mean group estimation (Pesaran et al, 1999). With regards to the 2SLS IV approach, Anderson & Hsiao, (1982) suggests that if the model is correctly specified, then there exist a natural instrument for the dynamic model. To be precise, if the $Emission_{it}$ is affected by $\Delta Emission_{it-1}$ only contemporaneously, then $\Delta Emission_{it-2}$ and ΔX_{it-1}(first order lag of the change in explanatory variables) can serve as valid instruments. The problem with this approach however is that should v_{it} be serially correlated, then the lag values will not be valid instruments and the model would be inconsistently estimated. Moreover, moment conditions cannot hold perfectly in finite samples if the numbers of instruments are more than regressors (Roodman, 2009, p.2).

To improve the efficiency of estimating the dynamic model, this study employs the Arellano-Bond (1991) GMM estimating technique. This estimator exploits all available instruments for each $\Delta Emission_{it-k}$ for $k \geq 1$ variables until orthogonality is reached. Hence it is naturally suited to correct the problem of endogeneity and autocorrelation which might be present in the model. Given that the model is generally overidentified with T > 3, it is required that E $(\Delta v_{it}, \Delta v_{it-2}) = 0$ holds. That is, the error term is uncorrelated in the second order moving average. To check whether Δv_{it} are serially uncorrelated, Arellano-Bond (1991) proposed a second order autocorrelation test, AR (2). There is no serial correlation if the null is not rejected. In addition, the Sargan (1958) or Hansen (1982) test is utilized for testing the validity of over-identifying restrictions or the validity of the instruments used. The null hypothesis is that the instruments employed in the regression are not correlated with the error terms and hence failing to reject the null means the instruments as a group is exogenous. Also, the difference in Sargan/Hansen test is used to confirm the assumption that x_{it} is strictly exogenous or unrelated to the individual effects and can be used as viable instruments. If the model passes these test, then Arellano-Bond estimator is asymptotically efficient.

The argument against Arellano-Bond estimator is that it is less powerful if the dynamic process is a near random walk (α_0 approaching unity). In this case, the difference levels of the dependent variable become weak instruments. This is because the past levels of emission do not convey a lot of information about future changes (Roodman, 2009, p.129). In addition, the variance of the fixed effect relative to the idiosyncratic error tends to shoot up. Since the unit root test results also show that the dynamic process in not a near a random walk process, the Arellano-Bond model is appropriate.

5. Results and Discussions

Table 6 and 7 present the results of the Arellano-Bond GMM estimates[15] using our full dataset for CO_2 emissions and N_2O emissions respectively. First of all, the econometric technique passes the Hansen test of valid overidentifying restrictions. Also, the AR(2) test shows that there is no serial correlation between the error term and the second lag of emissions and thereafter. This means that the instruments are exogenous and results are valid and reliable. The significance of the lagged emission shows that the dynamic panel model is appropriate. This suggests that there is emission inertia, and changes in the independent variables in the current period will affect the emissions in the next period. Hence, trade's impact on emission has short and long-term implications.

In table 6 and 7, four different specification of the models are explored to capture clearly each component of the full model specification. Model 1 presents the basic EKC model with income and its square term. In table 7, it can be seen that the expected signs of EKC are met and are statistically significant (except model 4 where the square term of the income is statistically insignificant). This indicate a possible inverted u-shaped relationship between income and CO_2 emissions, which is consistent with other studies (Grossman & Krueger 1993; Tsurumi & Managi, 2010; Cole, 2003; Cole & Elliot, 2003; Managi, Hibiki, & Tsurumi, 2009; Jafari et al., 2017).

Model 2 includes the political variables to capture the role of governance in the model. The result validates the significance of governance in determining CO_2 emission. It is notable that the signs

[15] The two step variant of the GMM is used with Windmeijer (2005) corrected standard errors. For robustness, other dynamic estimation technique such as Arellano-Bover/Blundell-Bond is employed. However, there was a zero gain in its use. The regression results are similar for many variables and instruments are valid, but instruments used in the level equation are quite weak. The fixed effect and random effect are also utilized but are plagued by several econometric problems such as heteroscedasticity and serial correlation (See appendix table D). All computations are done in Stata 14.

of polity are sensitive to each model specification. In this model, it is unclear how to interpret the positive coefficient. Although McCartney and Adamowicz (2005) find same, it is quite counterintuitive to claim that promoting autocratic governance will result in a lower emission of CO_2 compared to democratic governance

Table 6: Dynamic GMM Estimation Results for CO_2 Emissions

Variables	Model 1	Model 2	Model 3	Model 4
E_{t-1}	0.6141***	0.5229***	0.6583***	0.5380***
	(0.1024)	(0.0981)	(0.1367)	(0.1015)
Y	1.3434***	1.333***	1.2601**	0.1156**
	(0.3748)	(0.3784)	(0.4978)	(0.0614)
Y^2	-0.0629***	-0.0576***	-0.0761***	-0.0274
	(0.0177)	(0.0203)	(0.0270)	(0.0929)
Polity		0.4462***	-0.0864*	0.3335**
		(0.0520)	(0.0655)	(0.1795)
Polity*Y		-0.0541*	-0.0243*	-0.0356*
		(0.0358)	(0.0157)	(0.0204)
Capital abundance (K/L)			0.3351	0.0684
			(0.2088)	(0.0478)
K/L^2			-0.0218*	-0.0148***
			(0.0130)	(0.0005)
Trade openness (TO)				0.2907***
				(0.0165)
Relative Y*TO				0.1248***
				(0.0018)
Relative Y^2*TO				-0.0202*
				(0.0118)
Relative K/L *TO				-0.0189***
				(0.0005)
Relative K/L^2*TO				0.0675***
				(0.0243)
Relative Y*Relative K/L*TO				0.0380**
				(0.0202)
Observations	2561	2561	2372	2268
number of countries	100	100	100	100
Hansen Test	43.91	43.39	39.67	90.52
AR(1)	-7.18***	-6.71***	-5.84***	-6.81***
AR(2)	0.77	0.45	0.98	0.26
Difference in Hansen	0.54	1.75	0.58	-2.42

Notes: *,**,***denotes significant at the 10% , 5% and 1% level respectively. The standard errors in four decimal places are presented in parentheses. All variables are in their natural logs except polity. The Hansen test show that instruments explored by Arellano-Bond are valid and robust. The difference in Hansen test shows exogeneity of IV subset which is not treated as endogenous in the Arellano-Bond estimation.

Model 3 basically includes the capital-labor ratio, which explains the composition effect. The interaction of income and capital-labor ratio is however dropped due to collinearity issues. The study find significant support for the theory that capital accumulation will have a diminishing marginal effect for CO_2 emissions. This is captured by the capital-labor ratio and its square term. Also noteworthy is that the polity variable in Model 3 produces the expected negative sign, indicating that democratic government can influence the reduction of pollution relative to autocratic government. This is intuitive because such governments are more responsive to public demands for higher environmental quality. In addition, the interaction of polity and income confirms the argument espoused by McCartney and Adamowicz (2005). The result indicates that democratic countries are 0.0541% more responsive to demands to curbing pollution as per capita income grows by 1% compared to autocratic countries. This indicate a high technique effect from trade in democratic countries.

Lastly, the full model is specified as model 4. This specification adds trade variables and its interactions. First, it can be seen that trade is significant and positively related to CO_2 emission. Specifically a 1% increase in trade intensity results in 0.2907% increase in CO_2 emission. It is quite intriguing that trade openness is also positive for both OECD and SSA countries, though the magnitude for the latter is larger (see Appendix table E). This suggest that the pollution haven and factor endowment hypothesis are at play. Looking at the interaction of the relative income and trade openness as well as its square term, we see that the pollution haven hypothesis is evident and significant. This suggests that through trade, rich countries are able to relocate their jurisdiction of tighter environmental regulations to a less stringent jurisdiction (poor countries). Hence developed world experience lower emissions compared to developing countries. It is interesting that the results also show significant evidence for factor endowment hypothesis which basically makes developed countries dirtier. Thus, the total effect of trade-induced composition effect will depend on the relative magnitude of pollution haven effect and factor endowment effect as well as the final interaction between relative income, relative capital-labor ratio and trade openness. Previous studies have reported similar statistical significant evidence for pollution haven effect and factor endowment effect for CO_2 emissions (see e.g. Cole & Elliot, 2003; Managi, Hibiki, & Tsurumi, 2009). However, works by Tobey (1990), Grossman and Krueger (1993), and Jaffe et al.

(1995) find little evidence for pollution haven. Surprisingly, polity enters this model in a theoretically counterintuitive manner. However, the responsiveness of democratic government to reducing CO_2 emissions as income grows by 1% is 0.0356% higher than autocratic government.

Table 7: Dynamic GMM Estimation Results for N_2O Emissions

Variables	Model 1	Model 2	Model 3	Model 4
InEt-1	0.5642***	0.5161***	0.2891***	0.2283***
	(0.0667)	(0.0675)	(0.0751)	(0.0671)
Y	0.5362**	0.5341**	0.4175*	2.2061
	(0.2485)	(0.2568)	(0.2448)	(1.3994)
Y^2	-0.0255*	-0.0351**	-0.0701*	-0.0783
	(0.0135)	(0.0154)	(0.0423)	(0.0832)
Polity		-1.4239*	0.9822*	-1.216*
		(0.7525)	(0.5219)	(0.7070)
Polity*Y		0.2143**	-0.1303**	0.1864*
		(0.1055)	(0.0698)	(0.1022)
Capital abundance (K/L)			4.0075***	1.5571***
			(0.6622)	(0.0450)
K/L^2			-0.2356***	-0.0949**
			(0.0397)	(0.0450)
Trade openness (TO)				0.9516**
				(0.2516)
Relative Y*TO				-0.2016
				(0.1546)
Relative Y^2*TO				0.0410
				(0.0301)
Relative K/L *TO				0.1136***
				(0.0396)
Relative K/L^2*TO				0.0241
				(0.0192)
Relative Y*Relative K/L*TO				0.0056***
				(0.0011)
Observations	2096	2096	2072	2064
number of countries	100	100	100	100
Hansen Test	43.24	42.31	46.39	90.08
AR(1)	-7.18***	-2.85***	-2.49***	-2.83***
AR(2)	0.77	1.04	0.90	1.10
Difference in Hansen	0.54	0.89	2.55	-0.63

Note: *,**,***denotes significant at the 10% , 5% and 1% level respectively. The standard errors in four decimal places are presented in parentheses. All variables are logged except polity. The Hansen test show that instruments used by Arellano-Bond are valid and robust. The difference in Hansen test shows exogeneity of IV subset which is not treated as endogenous in the Arellano-Bond estimation.

With regards to N_2O emissions, model 1, 2 and 3 find statistical significant results for the expected signs of EKC. However, model 4 finds insignificant evidence of EKC. The political variables once again shows a significant impact on pollution. Though the study obtains positive coefficient in model 3, the results in model 2 and 4 show that in a democratic government, N_2O emissions is marginally reduced by 1.4239% compared to autocratic government. This indicates that improved government has a beneficial impact on N_2O emissions and the environment.

Unlike CO_2 emissions, the study could not find evidence for pollution haven hypothesis on N_2O emissions. The interactions of trade and income are signed in a theoretically counterintuitive way. The results show that as income increases with trade, pollution eventually increases. This suggests that developed countries with higher income and stringent environmental regulations are still made dirtier as they could not use trade to transfer pollution to developing countries with laxer regulatory environment. The situation is worsen by the positive factor endowment effect captured by the interaction of the relative capital-labor ratio and its square term. It shows that more of the output produced in capital abundant countries (developed countries) are pollution-intensive goods. It is therefore not shocking to obtain a positive trade-induced composition effect for N_2O emissions.

Table 8 presents the decomposition of the overall trade impact into scale-technique and trade-induced composition elasticities of CO_2 and N_2O emissions. The elasticities are estimated at the sample means. This means that we assume an "average" country as a representative of the world. The results show that elasticities are significantly different from zero. Contrary to previous studies, the elasticities are quite large. This is possibly due to differences in sample and the use of log-log transformation[16] of the model. It is evident from the results that scale-technique effect is negative for CO_2 emissions but positive for N_2O emissions. The study finds that on average, 1% trade-induced increase in income in a democratic country will generate a 0.0532% reduction in CO_2 emission. This suggests that for CO_2 emissions, the role government play in reducing pollution via abatement technologies outweigh the increased pollution caused by a rising economic activities. This result is contrary to the findings by Cole and Elliot (2003) and Managi, Hibiki, and Tsurumi (2009). As far as N_2O emissions is concern, it appears there is less emphasis and support by government in reducing its volume. The results indicate that a 1% increase in economic activities in an average democratic country leads to 1.932% increase in N_2O emissions.

[16] For example Managi, Hibiki, and Tsurumi (2009) adopts the log-level transformation.

Table 8: Decomposition of Effects

Elasticity	CO_2	N_2O
Scale-Technique	-0.532**	1.932*
Trade-Induced Composition	7.833*	3.531**
Trade Openness	6.802***	3.899***

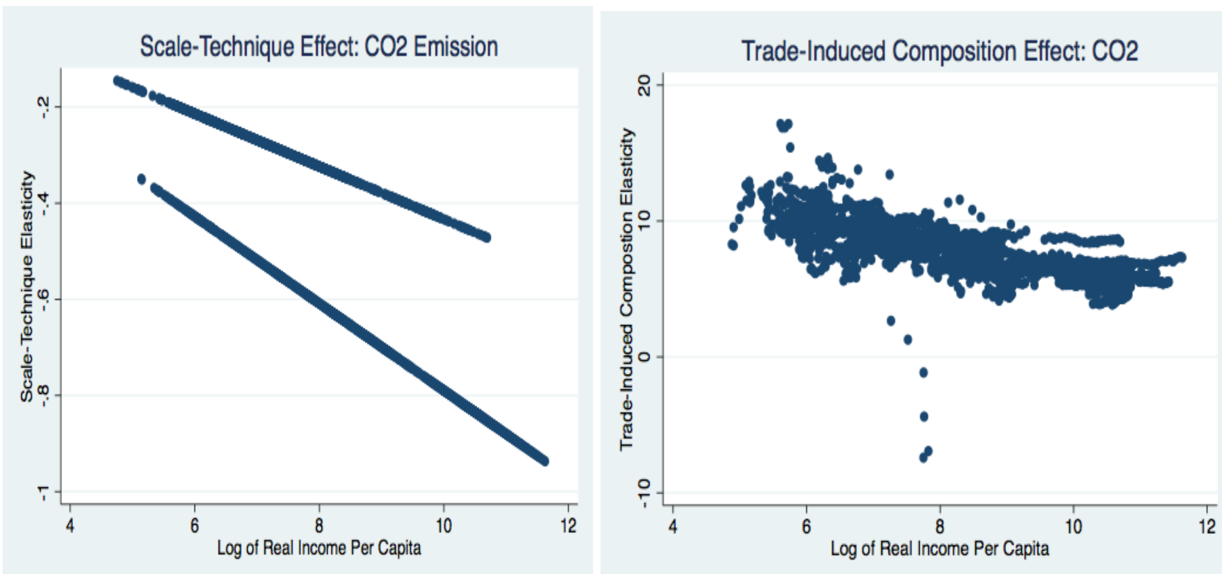
Note: The elasticities of scale-technique and trade-induced composition are estimated at their sample means using the Delta approach. *,**,***denotes significant at the 10% , 5% and 1% level respectively.

The trade-induced composition effect basically finds the relative strength of the pollution haven hypothesis and the factor endowment hypothesis. A positive result means that the pollution caused by capital-labor ratio is greater than the pollution resulting from differences in environmental policies. For CO_2 emission, it can be seen that on the net, a 1% increase in trade induced by composition effect increases CO_2 emission by 7.833%. Thus, countries are made dirtier by the trade-induced composition effect. This is because environmental policies and pollution abatement technologies used are not huge enough to counter the increasing growth of pollution-intensive goods caused by comparative advantage arising from factor endowment. This is consistent with Cole and Elliot (2003) and Managi, Hibiki, and Tsurumi (2009). With regards to the N_2O emission, the "pollution haven" effect reinforces the factor endowment effect resulting in a positive trade-induced composition elasticity of 3.531. This means that a 1% increase in trade induced by both capital-labor ratio and differences in environmental regulations will generate a 3.351% increase in N_2O emissions. This is not surprising because in the N_2O model, the study finds no evidence for pollution haven hypothesis. In sum, the study finds a general significant increase in CO_2 and N_2O emissions from the trade openness elasticity of 6.802 and 3.899 respectively.

To map and analyze the effects in a greater detail, figure 1 zooms into the scale-technique and trade-induced composition effects by looking at their respective impacts across different income levels. The figure tries to investigate how an extra increase in real income changes the scale-technique and trade-induced composition effect. The elasticity for each observation are plotted against real income per capita. The results provide some interesting insights. Firstly, for the scale-technique effect, the results naturally split into two, each trend indicating the income group of our full sample.

In panel a, the trend line on top shows the scale-technique for low income countries or developing countries. Though the scale-technique effect becomes more negative as income increases for developing countries, the impact is lower than developed countries at all levels of income.

a.



b.

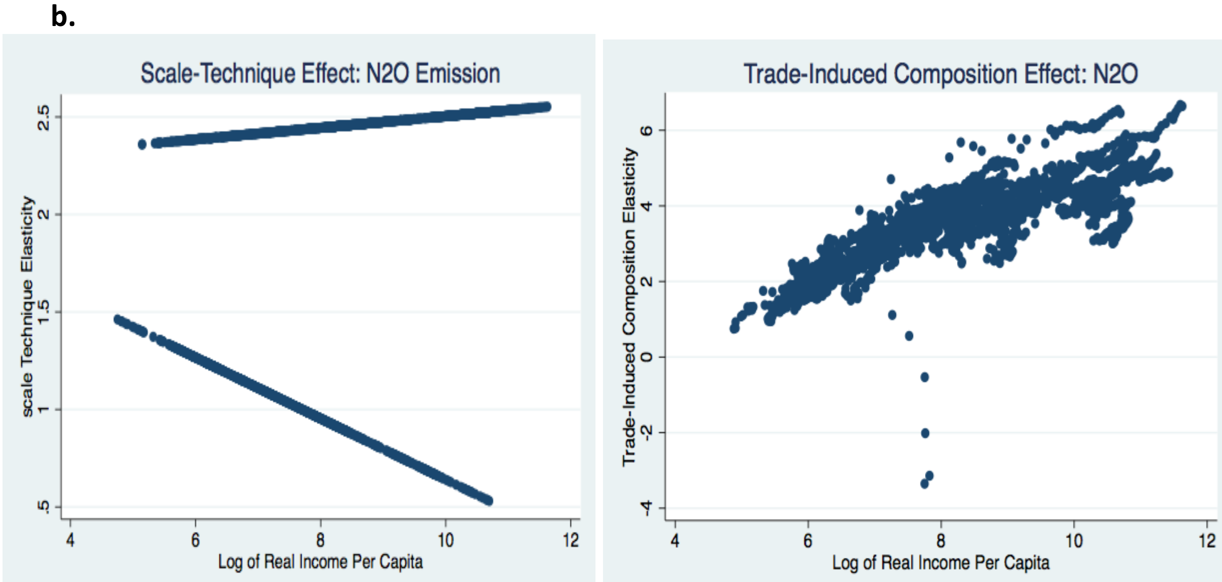


Fig. 1a-b *showing the decomposition of impact of trade on pollution with respect to income levels. Panel a. depict the effect for CO_2 emissions and Panel b., N_2O emissions.*

This means that the favorable technique effect outweighing the scale effect is more apparent in developed countries than developing countries. Since CO_2 is a global pollutant and essentially a by-product from industrial processes or activities, it is expected that developed countries experience high positive scale effect (increased in pollution). However, the negative technique effect via the role of government in enacting stiffer environmental policies to curb increasing pollution seems to have a greater influence. Specifically, the many of the environmental treaties on greenhouse gases such as the Oslo Protocol (1994), the Kyoto Protocol (1997), and more recently the Paris Agreement (2016), rectified by relatively many developed countries seems to be a great step in the right direction to improve environmental quality (i.e. reduction in CO_2).

In panel b however, we see a complete divergence in the scale-technique effect. This is because the elasticity is positive for all country types. This seems to confirm that N_2O emissions have been neglected in the policy debate. While developed countries show a relative concern by reducing N_2O emissions as economic activities increase, the story is completely different in the case of developing countries. This can be explained from the point that N_2O emissions are not majorly by-products of industrial activities. It also emanates from the use of fertilizers and general agricultural activities. Since developing countries are more agrarian, it is possible that their economic activities lead to increase in N_2O emissions.

The trade-induced composition effect on the other hand shows no clear cut relationship between the marginal elasticity and income. This basically depicts the complex nature of trade on the environment. There are many intervening forces at play. With regards to CO_2, we see generally positive results but with a downward trend. This shows that the pollution haven effect is weak compared to the capital-labor ratio effect. However, the difference falls as income increases. For N_2O emission, the pollution haven effect reinforces the positive factor endowment hypothesis and hence causing an overall upward trend. The magnitude increases as income rises. Since it is very difficult to see the trade-induced composition effect results for developed and developing countries, the study conducts a comparative analysis for OECD countries and SSA countries.

In table 9, the study compares the scale-technique and trade-induced effect for OECD member countries and SSA countries. This gives us an idea of how each income group is contributing to pollution. The elasticities of these effects are estimated at the sample means of OECD and SSA countries respectively.

Table 9: Decomposition: OECD vs SSA countries

	CO_2		N_2O	
Elasticity	OECD	SSA	OECD	SSA
Scale-Technique	-3.7914***	0.35109**	4.9591**	5.6678**
Trade-Induce Composition	7.1801	3.1753	6.9793*	-8.4332
Trade Openness	0.4631**	1.5382	5.1353	-1.0211***

Note: The elasticities of scale-technique and trade-induced composition are estimated at their sample means using the Delta approach. *,**,***denotes significant at 10% , 5% and 1% respectively.

The results reveal a negative scale-technique effect for CO_2 emissions but positive effect for N_2O emissions for OECD countries. This confirms the results discussed above. Specifically, for our mean OECD country, trade-induced increase in income in a democratic regime of 1% will lead to a fall in CO_2 by 3.3714% but an increased in N_2O by 4.9591%. The situation is worse in SSA case. CO_2 emissions shows positive scale-technique, suggesting that they are not beneficiaries of the general negative scale-technique effect for developing countries discussed above. For N_2O emissions, the effect is even larger, signifying that the role of government in enacting stiffer regulations and using pollution abating technologies is gravely lacking in SSA countries.

Turning to trade-induced composition effect, the results show positive effect for both pollutants in OECD countries while SSA countries experienced huge negative effect for N_2O. This implies that the comparative advantage gained via factor endowment in SSA countries do not make them dirtier. This is simply because SSA countries are labor abundant countries and hence do not produce pollution intensive goods. Besides, as noted, the pollution haven hypothesis does not hold in N_2O case. [17] These impacts therefore reinforces each other to cause a fall in N_2O emissions. However, the trade openness elasticities suggest that the environmental impact of trade is generally bad.

[17] For estimated results of OECD and SSA countries, see appendix table E

Table 10: Summary of Results

	CO_2 emissions			N_2O emissions		
Elasticity	All countries	OECD	SSA	All countries	OECD	SSA
Scale-Technique	Negative	Negative	Positive	Positive	Positive	Positive
Composition	Positive	Positive	Positive	Positive	Positive	Negative
Overall	***Positive***	***Positive***	***Positive***	***Positive***	***Positive***	***Negative***

6. Conclusion

This study has examined the empirical evidence of the link between trade and environment while paying key attention to the role of government. It decomposes the impact into scale-technique and trade-induced composition effect. The analysis is conducted over an updated sample of 100 selected countries and 27 OECD and 33 SSA countries. The Arellano-Bond GMM estimation technique is used mainly to correct for endogeneity issues between trade and income and serial correlation problems in the dynamic panel model. It is noted that the issue of heteroscedasticity, autocorrelation and simultaneity bias can lead to imprecise results and hence inferences may be wrong. Interestingly, the study find different parameter estimates from the study by Managi, Hibiki, and Tsurumi (2009), Antweiler, Copeland and Taylor (2001) and Cole and Elliot (2003). Thus, differences in methods and data are extremely crucial in determining the trade-induced impact on the environment.

The results provide a number of conclusions. First the study finds a strong link between trade and environmental quality. There is evidence for EKC hypothesis in all specified models. This means that an increase in growth results in an initial increase in emission and subsequent fall in pollution with further growth. However, the falling part of the curve has not been so apparent in this study (see appendix for plot of GDP against emissions). The results also render support for factor endowment hypothesis and pollution haven hypothesis (except for N_2O case) and the role of government. The study shows that generally, trade is detrimental to the environment (taking the two greenhouse gases into consideration). Thus, the results support the alarmists claim that trade can harm the natural habitat. In addition, the decomposition shows that scale-technique effect largely depends on role of government and pollutant. While the study finds a fall in CO_2 emissions via this effect, N_2O tends to increase. Interestingly, the analysis provides a conclusion that as income increases, the scale-technique effect falls by a greater magnitude for high income countries compared to low income countries. This is due to the increasing role of government in developed countries using environmental policies to subvert the rising emissions due to economic activities. However for trade-induced composition effect, the relationship is more inextricable. There is no clear pattern between low income group and high income group, supporting the theory of Antweiler, Copeland and Taylor (2001). The comparative analysis also offers claim that the impact of trade depends on pollutant and country types. Trade leads to increase in CO_2 emissions for both OECD and SSA countries, though the impact is relatively smaller for the former. However, trade generates a reduction in N_2O emissions for SSA countries whiles OECD countries yet again experience increasing N_2O emissions.

Though the dynamic model shows that trade's impact on the environment is not automatic, but there are some short-run and long run implications, the micro-panel type of the data could not allow for rigorous investigation. Therefore, future research can scrutinize the topic in this direction. A much richer and updated data and the use of Panel Vector Error Correction Model (VECM) approach on panel-time series can yield interesting findings. This data type can also allow for the use of the seemingly unrelated panel cointegration regression suggested by Wagner (2015). In addition, results for specific country analysis instead of our average country analysis will be meaningful. Finally, since there are many dimensions of environmental quality, other insightful environmental indicators can be looked at.

That notwithstanding, the current study is relevant with a number of policy implications**.** From the results on CO_2 emissions (which have global externality), it stands to reason that OECD countries benefit more from trade policies or are able to transport pollution-intensive production processes to developing countries of which SSA countries are also made dirtier. In addition, it seems N_2O emissions has been missing in policy talks and as such there has been less concern by governments to reduce its volume. Therefore, it is crucial that policy makers in both developed and developing countries set broader trade policies to encapsulate these environmental concerns. This can especially change the narrative of developing countries having a laxer regulatory environment and hence, pollution haven effect may break down completely.

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Appendix

Table A: Summary of the Literature

Study	Methodology	Data	Pollutant	Result(s)
Grossman and Krueger (1991)	Panel regression (Fixed and random effect) *Cubic Specification*	panel data of some selected countries	SO2** (42 counties) SPM (29 countries) Dark matter (19 countries)	Inverted U shaped EKC and trade have negative impact on the environment in the short run
Panayotou (1997)	Panel regression *Quadratic and Cubic Specification (in levels and logs)*	Panel data (1982-194 for 30 countries)	SO_2*	Positive scale effect, technique effect turn to decrease concertation at an increasing rate.
Antweiler, Copeland and Taylor (1998, 2001)	Panel analysis (Fixed effect and random effect) *Quadratic specification*	Panel data (1971-1996) For 109 cities	SO_2**	Positive scale effect, negative technique effect, negative composition effect. Overall, trade is good for the environment
Cole (2003)	Panel analysis (Fixed effect and Random effect) *Quadratic and Cubic Specification based on ACT model*	Panel data (1970-1995) 32 developed and developing countries.	CO_2* SO_2* NOx* BOD*	little evidence in support of trade being a significant determinant of the inverted-U shape EKC.
Cole and Elliot (2003)	Panel regression (fixed and random effect) *Quadratic and Cubic Specification based on ACT model*	Panel data (1975-1990) 26 developed and developing countries	CO_2,* SO_2* NOx* BOD*	Positive scale-technique effect, Positive composition effect. Overall, trade increases CO_2 emissions.
Frankel and Rose (2005)	Panel Regression *Quadratic Specification*	Panel data (1990-1996)	SO_2** NO_2** PM**	Little evidence that trade has a detrimental effect on the environment
McCarney, and Adamowicz (2005)	Panel regression *Quadratic and Cubic Specification*	Panel data (1970 -2000)	CO_2** BOD*	Democratic governments can induce significant reductions in BOD emissions but CO_2 turn to increase

Managi, Hibiki, and Tsurumi (2009)	Panel Regression Differenced GMM *Quadratic Specification based on ACT model*	Panel data (88 countries covering the period 1973 to 2000)	CO_2* SO_2* NOx* BOD*	Trade benefit the environment for OECD countries but damaging for the environment of non-OECD countries
Tsurumi and Managi (2010)	Panel analysis (Semiparametric method) *Quadratic Specification*	Panel data (1963-2000)	CO_2* SO2*	Technique effect is likely to reduce SO2*but was unlikely to reduce CO2*
Jafari et al. (2017)	dynamic panel estimation (Arellano-Bond's (GMM)). *Quadratic Specification*	Panel data1980–2009 (166 countries)	CO_2*	Trade and FDI has no significant impact but role of government does have a significant negative impact in developing countries.

Note: ACT means Antweiler, Copeland and Taylor (2001). *denotes emissions ** denotes concentration

Table B: List of Selected Countries

Algeria	Cote d'Ivoire[b]	India	Mexico[a]	Singapore
Argentina	Cuba	Indonesia	Mongolia	South Africa[b]
Australia[a]	Cyprus	Iran Islamic Rep	Morocco	Spain[a]
Austria[a]	Denmark[a]	Iraq	Mozambique[b]	Sri Lanka
Bangladesh	Dominican Republic	Ireland[a]	Namibia[b]	Sudan[b]
Belgium	Ecuador	Israel[a]	Nepal	Swaziland[b]
Benin[b]	Egypt, Arab Rep	Italy[a]	Netherlands[a]	Sweden[a]
Botswana[b]	El Salvador	Jamaica	New Zealand[a]	Switzerland[a]
Brazil	Equatorial Guinea[b]	Japan[a]	Nicaragua	Thailand
Bulgaria	Finland[a]	Jordan	Nigeria[b]	Togo[b]
Burundi[b]	France[a]	Kenya[b]	Norway[a]	Trinidad and Tobago
Cameroon[b]	Gabon[b]	Korea Rep[a]	Oman	Tunisia
Canada[a]	Gambia[b]	Liberia[b]	Pakistan	Turkey[a]
Chad[a]	Germany[a]	Luxembourg[a]	Panama	Uganda[b]
Chile[a]	Ghana[b]	Madagascar[b]	Peru	United Kingdom[a]
China	Greece[a]	Malaysia	Philippines	United States[a]
Colombia	Guatemala	Mali[b]	Portugal[a]	Uruguay
Congo, Dem. Rep[b]	Guinea[b]	Malawi[b]	Rwanda[b]	Venezuela,
Congo, Rep[b]	Guinea-Bissau[b]	Mauritania[b]	Senegal[b]	RB Vietnam
Costa Rica	Honduras	Mauritius[b]	Sierra Leone[b]	Zimbabwe[b]

Note: a, b denotes OECD member country and SSA countries respectively

Table C: Unit Root Test Results

	Im-Pesaran-Shin and Fisher-Type based Augmented Dickey Fuller test			
	Ho: All panels contain unit root			
	Levels		First difference	
Panel	IPS statistic	FT (Inverse normal Z) statistic	IPS statistic	FT (Inverse normal Z) statistic
CO_2	0.3863	-0.5534	-26.9517 ***	-44.7456***
Lagged CO_2	1.5648	1.7146	-24.4182 ***	-26.9838***
N_2O	1.3759	0.1249	-27.6964 ***	-46.8901 ***
Lagged N_2O	3.5382	3.0708	-25.5912 ***	-28.0395 ***
Income per capita	22.9618	13.6805	-16.2708 ***	-22.7786 ***
Squared income per capita	29.8665	14.7517	-13.7858 ***	-19.2039***
Trade Openness	4.6035	3.0413	-23.7471 ***	-36.5373 ***

*Note:**** significant at 1% level of significance. Out of the many statistics, the inverse normal Z statistics of Fisher type unit root test are reported. Choi (2001) recommends the inverse normal (Z) because it offers the best trade-off between size and power.

Table D: Panel Cointegration Test

	CO_2 emission, Trade, Income		N_2O emission, Trade, Income	
	Pedroni	Kao	Pedroni	Kao
Rho statistics	-1.596***		-9.3***	
PP statistics	-4.558***		-22.494***	
ADF Statistics	-2.68***	6.167***	-16.67***	7.904***

Note: Ho: No cointegration. *** indicate significant at 1% level of significance.

Table D: Robustness Check using Different Estimation Techniques

Variables	Arellano-Bover/Blundell-Bond		Fixed Effect		Random Effect	
	CO_2	N_2O	CO_2	N_2O	CO_2	N_2O
InEt-1	0.6117*** (0.0779)	0.9230*** (0.0037)				
Y	0.2025 (0.0715)	0.53802*** (0.0947)	1.8751*** (0.5482)	2.008*** (0.5024)	1.9138*** (0.3397)	2.3557*** (0.3167)
Y^2	0.0101 (0.0714)	-0.06118* (0.0579)	-0.0601*** (0.0212)	-0.1141*** (0.0194)	-0.0628*** (0.0209)	-0.1088*** (0.0045)
K/L	0.7099*** (0.0347)	0.5439*** (0.0751)	0.0011 (0.0404)	0.3849* (0.2205)	-0.0108 (0.2392)	0.3958* (0.2234)
K/L^2	0.0816*** (0.0052)	-0.0413*** (0.0036)	0.0014 (0.0121)	-0.0382*** (0.0112)	0.0036 (0.0121)	-0.0396*** (0.0113)
TO	1.7538*** (0.4189)	0.2847 (0.4772)	0.1361 (0.1809)	-0.7485*** (0.1658)	0.2156 (0.1667)	-0.7106*** (0.1647)
RY*TO	0.2152*** (0.0760)	-0.3473*** (0.0991)	0.0355** (0.0142)	-0.0258 (0.0314)	0.0435 (0.0335)	-0.0364 (0.0316)
$(RY)^2$*TO	-0.0561 * (0.0206)	0.0388** (0.0222)	-0.0104* (0.0058)	0 .0316*** (0.0072)	-0.0113** (-0.0055)	0.0307*** (0.0072)
RK*TO	0.00465 (0.0241)	0.1432*** (0.027)	0.0421*** (0.0137)	0.0263** (0.0125)	0.044*** (0.0129)	0.0321*** (0.0125)
$(RK)^2$*TO	0.08195*** (0.0212)	0.0029 (0.0236)	0.0009 (0.0071)	0.0381*** (0.0065)	-0.0021 (0.0066)	0.0369*** (0.0064)
RY*RK*TO	0.0337** (0.01436)	0.0085 (0.0149)	0.0015** (0.0061)	0.0065 (0.0057)	0.0160*** (0.0061)	0.0067 (0.0057)
Polity	0.2472*** (0.0189)	0.09462* (0.0756)	-0.2041* (0.1157)	0.1612 (0.1062)	-0.2177* (0.1125)	0.1473 (0.1069)
Polity*Y	-0.0235*** (0.00588)	-0.0883* (0.0683)	0.0343** (0.0163)	-0.0213 (0.0149)	0.0365** (0.0158)	-0.0190 (0.0151)
Observations	2561	2167	2561	2576	2561	2576
number of countries	100	100	100	100	100	100
Hansen Test	90.10	93.91				
AR(1)	-8.81**	-2.83**				
AR(2)	0.55	1.08				
Difference-in-Hansen	13.54*	7.56				
R-Squared			0.8567	0.0436	0.8576	0.0562
Wald-test			2.2e+05***	2.0e+05***		
Wooldridge test			17.622***	3.722*		

Note: *,**,***denotes significant at the 10% , 5% and 1% level respectively. The standard errors are presented in parentheses. Using the same specification, CO_2 emissions could not pass the difference in Hansen test in the level equation of the Arellano-Bover/Blundell-Bond. Also the Fixed effect suffered from heteroscedasticity and serial correlation judged by the Wald-test and Wooldridge test respectively (to conserve space the constants are not reported). All econometric techniques show consistent results for EKC. Also trade is positively related to CO_2 but negatively related to N_2O emissions. The pollution haven effect is however not consistent over methods and pollutants.

Table E: Estimation Results for OECD and SSA Countries

Variables	OECD Member countries		SSA Countries	
	CO_2 Emission	N_2O Emission	CO_2 Emission	N_2O Emission
InEt-1	0.3446***	0.5559***	0.1182***	-0.0359*
	(0.1157)	(0.0918)	(0.0038)	(0.0152)
Y	0.035907	7.5623*	1.3996	5.6577***
	(1.25314)	(4.3860)	(2.9957)	(4.6549)
Y^2	-0.0344*	-0.3623*	-0.1596	-0.7341***
	(0.0098)	(0.2031)	(0.2020)	(0.2225)
Polity	-1.0968***	-4.4184	-2.8773***	-0.1922
	(0.3358)	(4.1040)	(1.4593)	(1.0695)
Polity*Y	-0.46289	0.4987	0.4645**	0.0314
	(0.3792)	(0.3668)	(0.2294)	(0.1688)
Capital abundance (K/L)	4.1077***	-6.9775	-0.2116	-4.5063**
	(2.8239)	(4.8592)	(1.6703)	(1.5910)
K/L^2	-0.1419	0.2737**	0.1034	0.2284***
	(0.2088)	(0.0837)	(0.0913)	(0.0007)
Trade openness (TO)	3.591***	1.3880**	3.1875 ***	-4.9332**
	(0.9515)	(0.0602)	(1.0063)	(1.0963)
Relative Y*TO	-0.6604*	-1.5720***	0.7036***	-0.8373***
	(0.4007)	(0.3911)	(0.1793)	(0.1740)
Relative Y^2*TO	-0.0752	0.1678***	0.0642	0.3446***
	(0.0645)	(0.0588)	(0.0801)	(0.0889)
Relative K/L *TO	0.1605*	0.4705***	-0.0326	-0.4723***
	(0.0876)	(0.0896)	(0.1414)	(0.1522)
Relative K/L^2*TO	-0.1226***	0.0469	-0.1365***	0.1283***
	(0.0395)	(0.0466)	(0.0352)	(0.0380)
Relative Y*Relative K/L*TO	-0.1033**	-0.2202***	0.0156	-0.2528
	(0.0542)	(0.0531)	(0.0565)	(0.0619)
Observations	640	640	803	776
number of countries	27	27	33	33
Hansen Test	19.95	18.66	19.75	25.75
AR(1)	-4.56**	-5.83***	-5.29**	-4.42***
AR(2)	0.76	-0.26	-3.03*	-1.27
Difference in Hansen	1.39	-2.05	-0.44	1.11

Note: *,**,***denotes significant at the 10% , 5% and 1% level respectively. The standard errors are presented in parentheses. The estimate for CO_2 emissions for SSA countries could not pass the AR test. Although this shows that instruments used in this sub-sample are not robust, the Arellano-Bond is not weakened by the many instruments. The Difference in Hansen shows exogeneity of variables that are not considered as endogenous variables in the model.

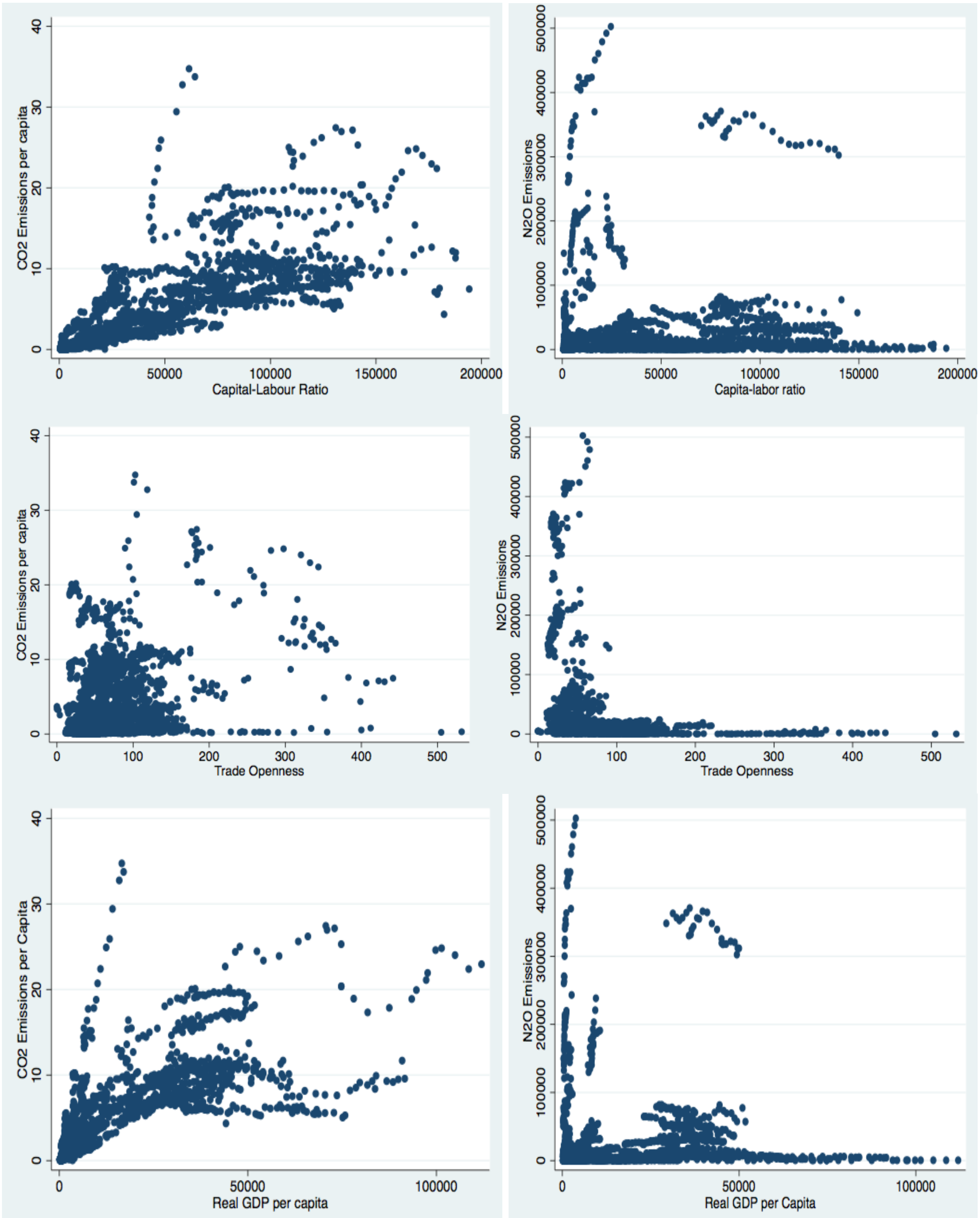

Fig. A: Simple Scatter plots of data.