Trade Openness-Carbon Emissions Nexus: The Importance of Turning Points of Trade Openness for Country Panels

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Abstract: This paper explores the relationship between trade openness and CO_2 emissions by incorporating economic growth as an additional and potential determinant of this relationship for three groups of 105 high, middle and low income countries. We apply the Pedroni (1999) and Westerlund (2007) panel cointegration tests and find that the three variables are cointegrated in the long run. Trade openness impedes environmental quality for the global, high income, middle and low income panels but the impact varies in these diverse groups of countries. The panel VECM causality results highlights a feedback effect between trade openness and carbon emissions at the global level and the middle income countries but trade openness Granger causes CO_2 emissions for the high income and low income countries. Policy implications are also provided.

JEL Classification: Q5
Keywords: Trade Openness, CO_2 Emissions, Causality

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I. Introduction

Over the last four decades, the world's economy has experienced enormous economic growth and this impressive growth is mainly associated with the process of globalization that started with the foundation of GATT[1] which was later upgraded to WTO[2]. Trade openness has helped both poor and rich economies to grow faster, and hence enhanced their trade volume and income. However, this growth trend has come along with environmental consequences. The huge expansion in the world merchandise trade gives rise to more production and more establishment of structures and industrial units. This wide expansion in world aggregate output necessitates greater energy resources, which is considered the potential source of carbon dioxide (CO_2) emissions. Then one may ask: is there a relationship between trade openness and the environment? Recently, this question has been the focus of global efforts to design a world trade policy (Taylor, 2004; Copeland and Taylor, 2005; Ahmed and Long, 2013). The literary work on the environmental repercussions of trade is recognized by Antweiler et al. (2001) but this recognition is not sufficient for a sound policy mapping. The lack of an adequate policy underpinning can also be observed from the consecutive failures of trade-climate talks. On the contrary, Stern (2009) argues that sustainable development is hard to achieve against rising temperature and climate change disasters. Therefore, global warming and poverty are considered as two shared challenges that need to be addressed simultaneously. The global investment in carbon-reduction practices and a fast dissemination of low carbon technology from high income to low income countries are only possible through trade openness (Ahmed et al. 2015). In reality, many of the economies of the world have yet not formalized their emission reduction strategies and the key reason for not reaching a policy consensus in the trade-climate talks is the complexity and contesting nature of achieving environmental consensus on trade openness (Kozul-Wright and Fortunato, 2011). There is still a need for both theoretical and quantitative analyses on the relationship between trade and its possible environmental concerns, as joint policy responses could be designed.

[1] General Agreement of Trade and Tariffs (GATT) came into force on January 1, 1948.
[2] World Trade Organization (WTO) commenced on January 1, 1995 under the Marrakesh Agreement and replaced GATT.

For over a decade, there has been a debate over the relationship between trade openness and environmental degradation. This debate is based on the idea that there is an underlying positive relationship between trade openness and economic growth. Several empirical studies have been conducted on this relationship (e.g., Cole and Elliott, 2003; Frankel and Rose, 2005; Managi et al. 2008). However, there are very few empirical studies on environmental degradation based on theoretical framework (e.g., Antweiler et al. 2001; Copeland and Taylor, 2004). Trade economists and environmentalists argue that the liberalization of trade through efficient use of resources and maintaining sustainable growth could make an essential contribution towards creating the necessary conditions for environmental improvements. They also argue that trade liberalization and environmental policies will generate benefits through improving the allocative efficiency, correcting market failures and strengthening the potential of the internalization of environmental instruments. In fact, the wealth created by trade liberalization will also improve the quality of life and help eliminate poverty, which has been considered as an underlying cause of environmental degradation in many developing countries. The evidence of trade openness on environmental degradation from individual countries varies according to their income levels, and this may be due to differences in policy, economic structure, level of economic openness and country-specific variables (Baek et al., 2009; Naranpanawa, 2011; Wiebe et al., 2012; Forslid and Okubo, 2014).

The most worrying thing at this stage is the conflicting situation between trade and climate economists. The policy deadlock between high and low income countries is widening as trade talks suffer more failures. It is projected that advanced countries will limit trade with lower income countries in order to control carbon leakages as a result of the widening deadlock. As discussed by Messerlin, (2010) and Ahmed and Long (2013), trade and climate change policies are interdependent and the trade-climate policies will either suffer from mutual destruction or mutual construction due to varying global externality effects. Consequently, unilateral measures towards trade restrictions from advanced economies to emerging economies would result in a division in the global economies where they will be cleaner and dirty production heavens and hells in these countries. The neoclassical model theoretically defines how trade liberalization expands cleaner and dirty productions due to income differences. The division implies that the environmental impacts of trade opening on high and low income countries are the opposite (for more details see Copeland and Tylor, 1995).

There is a series of literature available on the trade-emissions nexus based on a single country analysis, but to help in understanding the global surge towards a multilateral policy agreement on climate change requires a meta-analysis, using the world trading system. During the upcoming trade-climate negotiations, the trade agreements will acquire more importance if the negotiations involve regional countries of different income levels. Similarly, the adoption of a trade-environment policy will also be based on a group of countries not unilaterally between countries. Therefore, this notion suggests that there is a need for a panel data analysis on the relationship between trade and carbon emissions.

In doing so, this study contributes to the existing literature in four ways. (i) It utilizes panels of high, middle and low income countries to empirically examine the causal behavior of trade and emissions in the long-run. (ii) It uses the most appropriate and recent long-run panel techniques including the panel cointegration tests proposed by Pedroni, (1999) and Wisterlund (2007) which are also applied to test for robustness. (iii) It incorporates the techniques with the Granger causality approach of Engle and Granger (1987) to discern the causal relationship between trade and emissions for the underlined panels. (iv) It provides a comprehensive empirical analysis of the carbon-trade relationship by providing new turning points between trade openness and CO_2 emissions (i.e., carbon emissions rise with trade openness initially, and then the environmental quality starts to improve after the trade openness per capita reaches a threshold level at a later stage of economic development), using country-level and high, middle and low income country panel-level data sets. The findings of this paper are highly significant and possess deep policy implications for countries included in the panels, as well as for international trade and environmental agencies and regional economic blocks. It is also important for researchers 'work since it is expected to open future directions of this research.

The remainder of the paper is organized as follows: Section 2 presents a brief review of the related literature. Section 3 presents the methodological framework and Section 4 provides and discusses the results. Section 5 offers the conclusion and policy recommendations.

2. Review of the relevant literature

The literary work on the trade-environment nexus is started with the introduction of the environmental Kuznets curve (EKC) hypothesis which became popular in early 1990s. The EKC hypothesis is an inverted-U shaped relationship between income and environment. Grossman and Krueger (1991) examine the environmental consequences of NAFTA[3] and provide a baseline for further exploration of the EKC hypothesis. However, the literary work on growth and the environment picked up momentum after the Earth summit[4], which was held in Rio-de-Janeiro (Brazil) in 1992. It was helped by the important contribution of Shafik and Bandyopadhyay (1992) that served as a background study for the *World Development Repor*t (1992). This study states that an improvement in environmental quality is essential for sustainable development. Since then, there is a sufficient literature that explores the growth-environment nexus but the contradictory results of the various studies have kept this topic interesting and worthy of further investigation by many researchers. For example, the studies of Grossman and Krueger (1991), Shafik (1994), Soytas et al. (2007) and Ang (2007) using the EKC hypothesis, and of Copeland and Taylor, (2004) and Kearsley and Riddel (2010) using the pollution haven hypothesis, could not conclude whether trade openness has any environmental impacts. On the other hand, Frankle and Rose (2005) find a positive and statistically significant correlation between trade openness and measures of environmental degradation (such as NO_2 and SO_2). However, Kellenberg (2008) shows mixed evidence on the relationship between trade openness and four pollutants (NO_2, SO_2, CO_2 and VOCs[5]).

Antweiler et al. (2001) first highlight the three broad categories of trade impact on the environment which are the scale, technique and composition effects. The scale effects refer to increases in pollution and natural recourse depletion due to expanded economic activity and greater consumption (Grossman and Krueger, 1993; Lopez, 1994). The technique effect refers to the tendency of having a cleaner production process as income increases and trade expands due to better technologies and better environmental practices (Grossman and Krueger, 1996). The composition effect indicates how the environment is affected by the composition of output which is determined by the degree of openness as well as by the comparative advantage of the country.

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[3] North American Free Trade Agreement (NAFTA)

[4] Also known as the Rio-Summit which was organized by the United Nations in Rio-de-Janeiro (Brazil) from 3~14 June, 1992

[5] Volatile organic compounds (VOCs).

The net impact of the composition effect as a result of trade openness could be positive or negative, depending on the relative size of the capital-labor effect and the environmental regulation effect (Shafik and Bandyopadhyay, 1992; Selden and Song, 1994; Kahuthu, 2006). In a nut shell, as the EKC describes, the environmental repercussions of growth vary with changes in income levels. Therefore, the countries with different income levels and economic compositions attract different environmental consequence of trade liberalization.

The study of Frankel (2008) has very similar results as those of Grossman and Krueger (1993) and Selden and Song (1993) because those authors use the same income level sample to test the impact of (SO_2) emissions on the environment. Similarly, changes in the terms of trade of countries change the composition of trade, and thereby it has an opposite environmental consequence on trading partners if they belong to different income levels. For example: the trade between a developing and an industrially advanced countries renders a comparative advantage to developing country with less restrictions on carbon intensity. However, later if the industry in the advanced country transfers its production to the developing country, it would increase the environmental hazards in the low income country and simultaneously reduce the emissions intensity in the advanced country. The study of Cole (2004) examines the trade-environment impact of OECD and non-OECD countries and validates the 'pollution haven' hypotheses. Managi et al. (2009) re-examine the trade-environment nexus for the OECD and non-OECD countries with a different estimation technique using two pollutants (SO_2 and CO_2) and find similar results to those of Cole, (2004). The change in the EKC's of countries with changing trade patterns is more recently studied by Suri and Chapman (1998), Antweiler et al. (2001), and Cole and Elliot (2003), Cole (2004), Managi and Jena (2008) and Ahmed and Long (2013).

The economies with technological change (technique effect) receive a positive impact on the environmental quality as technological improvements contribute to cleaner production (Kozul-Wright and Fortunato, 2011). After attaining the threshold income level, those economies attract efficient capital allocation to the production process. This movement enhances the technical competitiveness in the market and the overall industries to undergo a technological change. This process converts the degrading environmental circumstances to an environment quality improvement. However, the research on development economies finds that if a country's growth is mainly contributed by trade liberalization, the level of emissions rises with growth (Lopez, 1994; Copeland and Taylor, 2001; Chaudhuri and Pfaff, 2002; Ozturk and Acaravci, 2010; Nasir and Rehman, 2011; Shahbaz et al., 2013) and with the passage of time, this scale effect is counter-balanced by the technical change as individual preferences change (Kozul-Wright and Fortunato, 2011; Weibe et al., 2012; Ahmed and Long, 2014; Ahmed and Qazi, 2014).

The empirical findings that address the trade-environment nexus are thus quite contrasting, depending on the methodology and the nature of data. For example: Antweiler et al. (2001) estimate the time series data for 41 countries and conclude that the technique effect over shadows the scale effect but later the studies of Cole and Elliot (2003), Copeland and Taylor (2005) and Cole (2006) validate Antweiler et al. (2001)' results for SO_2 but still find different results for the CO_2 and NO_2 pollutants. Similarly, the studies based on the country specific-analysis (i.e. Ang, 2008; Jalil and Mahmud, 2009; Menyahand Wold-Rufael, 2010; Nasir and Rehman, 2011; Shahbaz et al., 2013; Ahmed and Long, 2014) and those based on panel investigation (i.e. Huang et al., 2008; Narayan and Smyth, 2009; Narayan and Narayan, 2010; Hossain, 2011; Wang et al.,2011) have varied results. Frankel and Romer (1999) argue that it is hard to find a causal relationship between trade and the environment if trade openness is taken as an exogenous variable. However, Copeland and Taylor (2005) suggest that it is necessary to use trade as an exogenous variable, while testing the income effect of the environment.

This literature on the trade and environment nexus leaves room for undertaking a more multi-country analysis based on countries with different income levels. The new literature utilizes similar empirical techniques and renders unbiased results for policy-making. Therefore, the current study uses the panel data analysis for105 three (low, medium and high) income level country groups to analyze the causal relationship between trade and the environment. It uses the Pedroni and Westerlund panel cointegration tests and Granger causality tests applied to those low, middle and high income panels to examine the cointegration and direction of causality for these panels. This study offers relevant policy implications for all income level country-groups and opens directions for future research on trade opening and environment nexus.

3. Econometric methodology and data collection

3.1 *Cross sectional dependence tests*

Since trade openness implies a strong and increasing interdependence between countries, it is necessary to consider the impact of cross-sectional dependence in cross-country panels. De Hoyos and Sarafidis (2006) note that the presence of cross-sectional dependence in cross country panels may be due to unobserved common shocks that become part of the error terms. For this reason, if cross-sectional dependence is present in the data but is not taken into account in the analysis, it would lead to inconsistent standard errors of the estimated parameters (Driscoll and Krray, 1998). We test the cross sectional dependence by applying one semi parametric test designed by Friedman (1937), and one parametric test developed by Pesaran, (2007). The statistics of these two tests are the following:

The Freidman statistic computes:

$$R = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{r}_{ij} \qquad (1)$$

where $\hat{r}$ is the spearman's rank correlation coefficient between i and j expressed as:

$$r_{ij} = r_{ji} = \frac{\sum_{t=1}^{T} \left(r_{it} - (T+1/2)\right)\left(r_{jt} - (T+1/2)\right)}{\sum_{t=1}^{T} \left(r_{it} - (T+1/2)\right)^2}$$ of the residuals.

The Pesaran statistic computes:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right) \qquad (2)$$

where $\hat{\rho}_{ij}$ is the estimate of

$$\rho_{ij} = \rho_{ji} = \frac{\sum_{t=1}^{T} \varepsilon_{it} \varepsilon_{jt}}{\left(\sum_{t=1}^{T} \varepsilon_{it}^2 \right)^{1/2} \left(\sum_{t=1}^{T} \varepsilon_{jt}^2 \right)^{1/2}} \qquad (3)$$

The null hypothesis to be tested is: $\rho_{ij} = \rho_{ji} = corr(\varepsilon_{it}, \varepsilon_{jt}) = 0$ for $i \neq j$ and the alternative hypothesis to be tested is $\rho_{ij} = \rho_{ji} \neq 0$ for some $i \neq j$.

3.2Panel unit root tests

Due to the problem of cross-sectional dependence in our panel dataset, we only apply those panel unit root tests that allow us to treat this effect. Two alternative unit root tests, namely the LLC statistic of Levin et al. (2002) and the CADF statistic of Pesaran (2007) are employed. The LLC test evaluates the null hypothesis that each cross-section in the panel contains a unit root against the alternative hypothesis that all cross-sections are stationary. This test produces efficient results for a panel of moderate size and is generalized to allow for "fixed effects, individual deterministic trends and heterogeneous serially correlated errors" (Baltagi, 2009). In the presence of cross-sectional dependence, Levin et al. (2002) allow for a limited degree of cross-sectional dependence by subtracting the cross-sectional averages from the data. In order to mitigate the impact of cross-sectional dependence, we demean the data when implementing the LLC test. Pesaran, (2007) provides the cross-sectional augmented Dickey-Fuller (CADF) test statistic in heterogeneous panels with cross-sectional dependence. The test augments the standard ADF regressions with the cross-sectional averages and their first differences to eliminate the impact of cross-sectional dependence. The null hypothesis assumes that all the series are non-stationary versus the alternative hypothesis that only a fraction of the series is stationary. The asymptotic distribution of CADF is non-standard and the asymptotic critical values are provided for different values of both N and T.

3.3Panel cointegration tests

Similar to the panel unit root tests, the extension of time-series cointegration to panel data is also recent. The panel cointegration tests that have been proposed so far can be divided into two groups: the first group is based on the null hypothesis of the presence of cointegration (McCoskey and Kao, 1998; Westerlund, 2007), while the second group assumes no cointegration as the null hypothesis (Pedroni, 1999; Kao, 1999; Larsson et al., 2001, Groen and Kleibergen, 2003). For the current analysis, two different panel cointegration techniques, the Pedroni (1999) and Westerlund (2007), are applied. Pedroni, (1999, 2004) propose seven different statistics to test for the cointegration relationship in a heterogeneous panel. These tests are corrected for the bias introduced by potentially endogenous regressors. The seven test statistics of Pedroni are classified into the "within dimension" and "between dimension" statistics. The within dimension statistics are referred to as the panel cointegration statistics, while the between dimension statistics are called the group mean panel cointegration statistics. These cointegration test statistics are based on the extension of the two step residual-based strategy of Engle and Granger (1987). The procedure involved in the estimation of the seven test statistics requires in the first step to estimate the following panel cointegration regression and store the residuals:

$$x_{i,t} = \alpha_{0i} + \rho_i t + \beta_{1i} Z_{1i,t} + ... + \beta_{mi} Z_{mi,t} + \mu_{it} \tag{4}$$

In the second step, the test requires taking the first difference of the original data series of each country and computes the residual of the differenced regression:

$$\Delta x_{i,t} = \theta_{1i} \Delta Z_{1i,t} + ... + \theta_{mi} \Delta Z_{mi,t} + \eta_{it} \tag{5}$$

In the third step, the test calls for estimating the long-run variance ($\hat{\kappa}^2_{11,i}$) from the residuals ($\hat{\eta}_{it}$) of the differenced regression. In the fourth step, using the residual ($\hat{\mu}_{it}$) of the original co integrating equation, the test estimates the appropriate autoregressive model. Following these steps, the seven panel statistics are then computed with the appropriate mean and variance adjustment terms as described by Pedroni, (1999) as follows.

The panel v-statistic is:

$$Z_v \equiv T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1}. \tag{6}$$

The panel ρ–statistic is:

$$Z_p \equiv T\sqrt{N} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \left(\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i \right). \tag{7}$$

The panel t-statistic (non-parametric) is:

$$Z_t \equiv \left(\tilde{\sigma}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \left(\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i \right). \tag{8}$$

The panel t-statistic (parametric) is:

$$Z^*_t \equiv \left(\tilde{s}^{*2}_{N,T} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^*_{it-1} \Delta \hat{\mu}^*_{it}. \tag{9}$$

The group ρ-statistic is:

$$\tilde{Z}_p \equiv TN^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{\mu}_{it-1}^2\right)^{-1}\sum_{t=1}^{T}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right). \quad (10)$$

The group t-statistic (non-parametric) is:

$$\tilde{Z}_t \equiv N^{-1/2}\sum_{i=1}^{N}\left(\hat{\sigma}_i^2\sum_{t=1}^{T}\hat{\mu}_{it-1}^2\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right). \quad (11)$$

The group t-statistic (parametric) is:

$$\tilde{Z}_t^* \equiv N^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\tilde{s}^{*2}\hat{\mu}_{it-1}^{2*}\right)^{-1/2}\sum_{t=1}^{N}\hat{\mu}_{it-1}^*\Delta\hat{\mu}_{it}^*, \quad (12)$$

where $\hat{\lambda}_i = \frac{1}{2}(\hat{\sigma}_i^2 - \hat{s}_i^2)$ and $\tilde{s}_{N,T}^{*2} = \frac{1}{N}\sum_{i=1}^{N}\hat{s}^{*2}$ (13)

After the calculation of the panel cointegration test statistics, the appropriate mean and variance adjustment terms are applied, so that the test statistics are asymptotically standard normally distributed as:

$$\frac{X_{N,T}-\mu\sqrt{N}}{\sqrt{V}} \Rightarrow N(0,1) \quad (14)$$

where $X_{N,T}$ is the standardized form of the test statistics with respect *N* and *T*. The functions u and v are the functions of the moment of the underlying Brownian motion function. All statistics test the null hypothesis of no cointegration as:

$$H_0: \rho_i = 1 \quad for\ all\ i = 1,2,........,N \quad (15)$$

The alternative hypothesis for the between dimension and the within dimension for the panel cointegration is different. The alternative hypothesis for the between dimension statistics is as following:

$$H_0: \rho_i < 1 \quad for\ all\ i = 1,2,........,N \quad (16)$$

where a common value for $\rho_i = \rho$ is not required. The alternative hypothesis for the within dimension-based statistics is given below:

$$H_0 : \rho_i = \rho < 1 \quad for\, all\, i = 1, 2, ..., N. \tag{17}$$

Assume a common value for $\rho_i = \rho$. Under the alternative hypothesis, all the panel test statistics diverge to negative infinity. Thus, the left tail of the standard normal distribution is required to reject the null hypothesis.

Four error correction-based panel cointegration tests developed by Westerlund (2007) are employed in the present study. These tests are based on structural dynamics rather than residuals dynamics, so that they do not impose any common factor restrictions. The null hypothesis of no cointegration is tested by assuming whether the error-correction term in a conditional error model is equal to zero. If the null of no error correction is rejected, then the null hypothesis of no cointegration is also rejected. The error-correction model based on the assumption that all the variables are integrated of order 1 is following:

$$\Delta z_{it} = \delta_i' d_t + \theta_i (z_{i(t-1)} - \beta_i' y_{i(t-1)}) + \sum_{j=1}^{m_i} \theta_{ij} \Delta z_{i(t-j)} + \sum_{j=0}^{mi} \phi_{ij} \Delta y_{i(t-j)} + \omega_{it} \tag{18}$$

where $d_t = (1-t)'$ holds the deterministic components and $\delta_i' = (\delta_{1i}, \delta_{2i})'$ is being the associated vector of the parameters. In order to allow for the estimation of the error-correction parameter θ_i by the least square, Equation (18) can be rewritten as:

$$\Delta z_{it} = \delta_i' d_t + \theta_i z_{i(t-1)} + \pi_i' y_{i(t-1)} + \sum_{j=1}^{m_i} \theta_{ij} \Delta z_{i(t-j)} + \sum_{j=0}^{mi} \phi_{ij} \Delta y_{i(t-j)} + \omega_{it} \tag{19}$$

Here, θ_i is the adjustment term that determines the speed at which the system corrects back to the equilibrium relationship. The parameterization of the model makes the parameter θ_i remain unaffected by imposing an arbitrary β_i. Now, it is possible to construct a valid test of the null hypothesis versus the alternative hypothesis that is asymptotically similar and whose distribution is free of nuisance parameters. In a nutshell, Westerlund (2007) developed four tests that are based on the least squares estimates of θ_i and its t-ratio for each cross-sectional *i*. Two of them are called the group mean statistics and can be presented as:

$$G_\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\theta}_i}{S.E.(\hat{\theta}_i)} \qquad (20)$$

and

$$G_\alpha = \frac{1}{N}\sum_{i=1}^{N}\frac{T\theta_i'}{\theta_i'(1)} \qquad (21)$$

G_τ and G_α test the null hypothesis of $H_0:\theta_i=0$ for all *i* versus the alternative hypothesis of $H_0:\theta_i<0$ for at least one i. It means that the rejection of the null hypothesis indicates the presence of cointegration for at least one cross-sectional unit in the panel. The other two tests are panel statistics and can be presented as:

$$P_\tau = \frac{\hat{\theta}_i}{S.E.(\hat{\theta}_i)} \qquad (22)$$

$$P_\alpha = T\hat{\theta} \qquad (23)$$

P_τ and P_α test the null hypothesis of $H_0:\theta_i=0$ for all i versus the alternative hypothesis of $H_0:\theta_i<0$ for all i. The rejection of the null hypothesis means the rejection of no cointegration for the panel as a whole.

3.4Panel cointegration estimates

When all the variables are cointegrated, the next step is to estimate the associated long-run cointegration parameters. The fixed effects, random effects and GMM methods could lead to inconsistent and misleading coefficients when applied to the cointegrated panel data. For this reason, we estimate the long-run models using the FMOLS (fully modified OLS) methods.

Following Pedroni (2001), the FMOLS technique generates consistent estimates in small samples and does not suffer from large size distortions in the presence of endogeneity and heterogeneous dynamics. The panel FMOLS estimator for the coefficient β is defined as:

$$\hat{\beta} = N^{-1}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(y_{it}-\overline{y})^{2}\right)^{-1}\left(\sum_{t=1}^{T}(y_{it}-\overline{y})\right)z_{it}^{*}-T\hat{\eta}_{i} \quad (24)$$

where $z_{it}^{*}=(z_{it}-\overline{z})-\frac{\hat{L}_{21i}}{\hat{L}_{22i}}\Delta y_{it}$, $\hat{\eta}_{i}\equiv\hat{\Gamma}_{21i}+\hat{\Omega}_{21i}^{0}-\frac{\hat{L}_{21i}}{\hat{L}_{22i}}(\hat{\Gamma}_{22i}+\hat{\Omega}_{22i}^{0})$ and $\hat{L}_{i}$ is a lower triangular decomposition of $\hat{\Omega}_{i}$. The associated t-statistic gives:

$$t_{\hat{\beta}^{*}} = N^{-1/2}\sum_{i=1}^{N}t_{\hat{\beta}^{*},i} \text{ where } t_{\hat{\beta}^{*},i}=\left(\hat{\beta}_{i}^{*}-\beta_{0}\right)\left[\hat{\Omega}_{11i}^{-1}\sum_{t=1}^{T}(y_{it}-\overline{y})^{2}\right]^{1/2}. \quad (25)$$

3.5Panel causality test

Following the work of Engle and Granger, (1987), we specify the VECM panel model to examine the Granger causality relationship between trade openness and CO_2 emissions. After estimating Equation (24) and identifying the long-run relationships, we estimate the panel VECM model of the form:

$$\Delta\ln C_{it}=\theta_{1i}+\sum_{j=1}^{m}\theta_{11ij}\Delta\ln C_{i,t-j}+\sum_{j=1}^{m}\theta_{12ij}\Delta\ln Y_{i,t-j}+\sum_{j=1}^{m}\theta_{13ij}\Delta\ln TR_{i,t-j}+\lambda_{1i}e_{i,t-1}+\varepsilon_{it} \quad (26)$$

where λ_{1i} are the adjustment coefficients weighting the cointegrating vectors e_{it-1} while θ_{12ij} are the short-run coefficients weighting the lagged growth rates of the dependent variables. A similar expression can be written for other variables. A multivariate Granger causality with a lag length m (SIC=2) is estimated to examine the direction of the causality between the variables in both the short-run and the long-run. The short-run causality is tested by means of the Wald tests (F tests) of the null hypotheses $H_0:\theta_{12ij}=0$ (i.e. the independent variables do not cause the dependent variable in the model) for all i and j in Equation (26). To examine the long-run causality between the independent and dependent variables, we test the null hypothesis $H_0:\lambda_{1i}=0$ for all i and j in Equation (26). To test the Granger causality, it is also desirable to check whether the two sources of causations are jointly significant. This can be done by testing the joint hypothesis of the short-run and the long-run causality. The joint causality test indicates whether the variables bear the burden of short-run adjustment to re-establish the long-run equilibrium, following a shock to the system.

The 105 countries are selected for the estimation of the causality between CO_2 emissions and trade openness on the basis of data availability. The study covers the period 1980-2014, which includes the data available for all the countries at the time when we embark on this project. The data on the CO_2 emissions (metric tons), real exports (US$), real imports (US$) and real GDP (US$) are obtained from the *World development Indicators* (CD- ROM, 2015). We have employed the population series to transform the series into per capita units. CO_2 emissions per capita (metric tons) is used to measure environmental pollution. Trade openness is measured by the real export (US$) per capita plus the real imports (US$) per capita. Real GDP per capita is used to measure economic growth. All the variables are used in the natural logarithmic form.

4. Results and their discussion

Table1 displays the results of the Friedman and Pesaran cross-sectional independence tests which are applied to the variables trade openness, economic growth and CO_2 emissions. The null hypothesis of the cross-sectional independence is rejected for each selected variable. Prior to formal econometric modelling, it is necessary to have an understating of the integrating properties of the data. For this purpose, the LLC panel unit root test is initially applied for each series. The results of this test reported in Tables 2 to 5 indicate that trade openness, CO_2 emissions and GDP per capita are non-stationary in the level form with an intercept and a trend for the global, high income, middle income and low income countries. Similarly, the results of the CADF tests indicate that all the series are non-stationary in the level form with an intercept, and with both an intercept and a trend in each panel. However, in the first difference, the series of $\ln C_{it}$ and $\ln Y_{it}$ are integrated of I(1). It implies that trade openness, economic growth and CO_2 emissions have a unique order of integration for each panel.

Table 1: The Cross-sectional Independence Tests

Test Statistics	Friedman	Pesaran
Global Panel		

$\ln C_{it}$	379.12 [0.000]*	42.104 [0.000]*
$\ln TR_{it}$	2565.5 [0.000]*	330.48 [0.000]*
$\ln Y_{it}$	1515.72[0.000]*	194.96[0.000]*
High Income Panel		
$\ln C_{it}$	130.114 [0.000]*	11.609 [0.000]*
$\ln TR_{it}$	1023.30 [0.000]*	117.087 [0.000]*
$\ln Y_{it}$	797.23 [0.000]*	96.948 [0.000]*
Middle Income Panel		
$\ln C_{it}$	406.134 [0.000]*	46.242 [0.000]*
$\ln TR_{it}$	1321.17 [0.000]*	172.813 [0.000]*
$\ln Y_{it}$	505.31 [0.000]*	45.33 [0.000]*
Low Income Panel		
$\ln C_{it}$	44.369 [0.000]*	2.230 [0.025]*
$\ln TR_{it}$	309.64 [0.000]*	44.657 [0.000]*
$\ln Y_{it}$	107.66 [0.000]*	13.082 [0.000]*
Note: The p-values are in parentheses and reject the independence null hypothesis. * shows significance at the 1% level of significance.		

Table-2: The Panel Unit Root Analysis for the Global Panel

Variables	In level				In1st Difference			
	Constant	P-value	Constant and Trend	P-value	Constant	P-value	Constant and Trend	P-value
The LLC Unit Root Test on the Demeaned Series								
$\ln C_{it}$	1.834	0.966	7.605	1.000	-7.984*	0.000	-3.919*	0.000
$\ln TR_{it}$	4.841	1.000	6.456	1.000	-1.824**	0.034	-6.669*	0.000
$\ln Y_{it}$	-0.477	0.316	1.453	0.927	-5.197*	0.000	-3.706*	0.000
The CADF Unit Root Test								
$\ln C_{it}$	-1.528	0.997	-1.541	1.000	-2.861*	0.000	-3.214*	0.000
$\ln TR_{it}$	-1.385	1.000	-2.064	0.999	-2.975*	0.000	-3.071*	0.000
$\ln Y_{it}$	-1.657	0.910	-2.062	0.999	-2.471*	0.000	-2.836*	0.000
Note: * and ** show significance at 1% and 5% levels of significance respectively.								

Table3: The Panel Unit Root Analysis for the High Income Panel

Variables	In level				In1st Difference			
	Constant	P-value	Constant and Trend	P-value	Constant	P-value	Constant and Trend	P-value
LLC Unit Root Test on Demeaned Series								

$\ln C_{it}$	2.185	0.985	4.695	1.000	3.509*	0.000	-1.612**	0.053
$\ln TR_{it}$	9.079	1.000	4.134	1.000	-7.305*	0.000	-4.871*	0.000
$\ln Y_{it}$	-0.809	0.209	0.884	0.811	-3.766*	0.000	-8.513*	0.000
The CADF Unit Root Test								
$\ln C_{it}$	-1.344	0.996	-1.820	1.000	-2.707*	0.000	-3.055*	0.000
$\ln TR_{it}$	-0.843	1.000	-2.325	0.539	-2.876*	0.000	-3.045*	0.000
$\ln Y_{it}$	-1.843	0.322	-2.358	0.451	-2.417*	0.000	-3.343*	0.000
Note: * and ** show significance at 1% and 5% levels of significance respectively.								

Table-4: The Panel Unit Root Analysis for the Middle Income Panel

Variables	In level				In1st Difference			
	Constant	P-value	Constant and Trend	P-value	Constant	P-value	Constant and Trend	P-value
The LLC Unit Root Test on the Demeaned Series								
$\ln C_{it}$	-1.172	0.120	3.456	0.999	-5.103*	0.000	-6.820*	0.000
$\ln TR_{it}$	0.198	0.578	-0.066	0.473	-5.222*	0.000	-4.638*	0.000
$\ln Y_{it}$	-0.241	0.405	0.964	0.832	-5.841*	0.000	-3.373*	0.000
The CADF Unit Root Test								
$\ln C_{it}$	-1.615	0.887	-1.710	1.000	-2.887*	0.000	-3.072*	0.000
$\ln TR_{it}$	-1.661	0.803	-2.112	0.965	-2.888*	0.000	-2.982*	0.000
$\ln Y_{it}$	-1.776	0.481	-2.378	0.348	-2.896*	0.000	-2.942*	0.000
Note: * shows significance at 1% level of significance.								

Table5: The Panel Unit Root Analysis for the Low Income Panel

Variables	In level				In 1st Difference			
	Constant	P-value	Constant and Trend	P-value	Constant	P-value	Constant and Trend	P-value
The LLC Unit Root Test on the Demeaned Series								
$\ln C_{it}$	-0.500	0.308	0.206	0.581	-5.407*	0.000	-3.080*	0.000
$\ln TR_{it}$	-0.891	0.186	1.932	0.973	-3.825*	0.000	-4.445*	0.000
$\ln Y_{it}$	-1.261	0.103	0.231	0.591	-7.802*	0.000	-6.842*	0.000
The CADF Unit Root Test								
$\ln C_{it}$	-1.545	0.838	-1.765	0.996	-2.321*	0.008	-3.472*	0.000
$\ln TR_{it}$	-1.285	0.983	-2.378	0.430	-2.569*	0.000	-3.296*	0.000
$\ln Y_{it}$	-0.738	1.000	-2.383	0.421	-2.944*	0.000	-3.060*	0.000
Note: * shows significance at the 1% level of significance.								

The unique order of integration of the variables helps us apply the panel cointegration approach to examine the long-run relationship between the variables in each panel. The results of the Pedroni (1999, 2004) panel cointegration tests are reported in Table 6. Pedroni uses four within dimension (panel) test statistics and three between dimension (group) statistics to check whether the selected panel data are cointegrated. The "within dimension" statistics contain the estimated values of the test statistics based on the estimators that pooled the autoregressive coefficients across the different cross-sections for the unit root test on the estimated residuals. The "between dimension" statistics, on the other hand, report the estimated values of the test statistics based on the estimators that average the individually estimated coefficients for each cross-section. The results of the within dimension tests and the between dimension test suggest that there is strong evidence to reject the null hypothesis of no cointegration in each panel. Therefore, trade openness, economic growth and CO_2 emissions are cointegrated in the selected panels of the high, low and middle income countries as well as the global panel. Table 7 reports the results of the Westerlund panel cointegration tests. The empirical evidence indicates that the null hypothesis of no cointegration can be rejected in most cases. Therefore, we say that there is an additional support for the presence of cointegrating relationship between trade openness, economic growth and CO_2 emissions.

Table 6: The Pedroni Panel Cointegration Test Results

Models	Statistics	P-value	Statistics	P-value
	Global Panel		*High Income Panel*	
Panel υ-statistic	0.029	0.488	2.724*	0.003
Panel σ-statistic	-4.228*	0.000	-2.455*	0.007
Panel ρρ-statistic	-9.391*	0.000	-4.127*	0.000
Panel adf-statistic	-3.742*	0.000	-3.207*	0.000
Group σ-statistic	0.181	0.572	-0.697	0.243
Group ρρ-statistic	-8.686*	0.000	-3.993*	0.000
Group adf-statistic	-4.326*	0.000	-2.484*	0.006
Models	Statistics	P-value	Statistics	P-value
	Middle Income Panel		*Low Income Panel*	
Panel υ-statistic	4.040*	0.000	0.374	0.354
Panel σ-statistic	-6.709*	0.000	-1.392*	0.003

Panel ρρ-statistic	-9.318*	0.000	-3.815*	0.000
Panel adf-statistic	-6.256*	0.000	-2.995*	0.001
Group σ-statistic	-2.133**	0.016	-0.970	0.166
Group ρρ-statistic	-6.143*	0.000	-4.497*	0.000
Group adf-statistic	-2.946*	0.001	-3.150*	0.000
Note: * and ** show significance at the 1% and 5% levels of significance, respectively.				

Table 7: The Panel Cointegration Test Results

Statistics	Value	P-Value	Value	P-Value
	Global Panel		*High Income Panel*	
G_τ	-2.465*	0.000	-2.312**	0.036
G_α	-9.685	0.181	-6.892	0.984
P_τ	-20.64*	0.001	-12.04**	0.044
P_α	-8.735*	0.000	-9.295*	0.000
Statistics	Value	P-Value	Value	P-Value
	Middle Income Panel		*Low Income Panel*	
G_τ	-2.670*	0.000	-2.517**	0.015
G_α	-11.35*	0.006	-9.176	0.487
P_τ	-14.15**	0.031	-9.013**	0.030
P_α	-7.748*	0.008	-10.95*	0.000
Note: * and ** show significance at the 1% and 5% levels of significance, respectively.				

Table 8: The FMOLS Country Specific Results

$\ln C_{it}$:Dependent Variable					
High Income Countries					
Country/ Variables	Coefficient	P-value	Country/ Variables	Coefficient	P-value
Australia			*Austria*		
$\ln TR_{it}$	0.084	0.320	$\ln TR_{it}$	0.042	0.519
$\ln Y_{it}$	0.444	0.113	$\ln Y_{it}$	0.175	0.449
Constant	-0.985	0.639	Constant	-0.185	0.916
Barbados			*Belgium*		
$\ln TR_{it}$	0.051	0.624	$\ln TR_{it}$	0.016	0.737
$\ln Y_{it}$	1.755*	0.000	$\ln Y_{it}$	-0.141	0.892
Constant	15.62*	0.000	Constant	3.666	0.247
Brunei Darussalam			*Canada*		
$\ln TR_{it}$	-0.158	0.113	$\ln TR_{it}$	-0.017	0.879
$\ln Y_{it}$	-3.255*	0.000	$\ln Y_{it}$	0.098	0.836

Constant	39.98*	0.000	Constant	2.190	0.305
Cyprus			*Denmark*		
$\ln TR_{it}$	0.459	0.007	$\ln TR_{it}$	-0.046***	0.089
$\ln Y_{it}$	-0.464	0.281	$\ln Y_{it}$	-0.235	0.277
Constant	-3.568*	0.002	Constant	5.969*	0.002
Finland			*France*		
$\ln TR_{it}$	0.086	0.285	$\ln TR_{it}$	-0.181	0.126
$\ln Y_{it}$	0.159	0.506	$\ln Y_{it}$	-1.394*	0.003
Constant	-1.365	0.140	Constant	11.43*	0.000
Hong Kong SAR, China			*Hungary*		
$\ln TR_{it}$	-0.155*	0.000	$\ln TR_{it}$	-0.017**	0.026
$\ln Y_{it}$	1.017*	0.000	$\ln Y_{it}$	-0.574*	0.000
Constant	-4.386*	0.000	Constant	7.055*	0.000
Iceland			*Ireland*		
$\ln TR_{it}$	-0.057*	0.000	$\ln TR_{it}$	0.043	0.745
$\ln Y_{it}$	0.304**	0.013	$\ln Y_{it}$	0.354	0.283
Constant	0.012	0.991	Constant	-0.389	0.448
Israel			*Italy*		
$\ln TR_{it}$	-0.309*	0.000	$\ln TR_{it}$	-0.245	0.140
$\ln Y_{it}$	2.832*	0.000	$\ln Y_{it}$	1.383**	0.037
Constant	17.92*	0.000	Constant	-5.706**	0.029
Japan			*Korea Rep.*		
$\ln TR_{it}$	-0.031*	0.000	$\ln TR_{it}$	0.134**	0.014
$\ln Y_{it}$	0.616*	0.000	$\ln Y_{it}$	-0.822**	0.021
Constant	-3.278*	0.000	Constant	6.089**	0.014
Kuwait			*Luxembourg*		
$\ln TR_{it}$	0.544*	0.000	$\ln TR_{it}$	-0.054	0.813
$\ln Y_{it}$	1.724*	0.000	$\ln Y_{it}$	-0.018	0.978
Constant	-28.52*	0.000	Constant	4.614**	0.039
Malta			*Netherlands*		
$\ln TR_{it}$	0.899*	0.000	$\ln TR_{it}$	0.258*	0.007
$\ln Y_{it}$	-1.369*	0.009	$\ln Y_{it}$	-0.722**	0.015
Constant	-4.885*	0.000	Constant	3.152*	0.001
New Zealand			*Norway*		
$\ln TR_{it}$	0.069	0.517	$\ln TR_{it}$	0.095	0.012
$\ln Y_{it}$	0.240	0.632	$\ln Y_{it}$	0.084	0.696
Constant	-2.119	0.455	Constant	-1.156	0.498
Oman			*Portugal*		
$\ln TR_{it}$	0.664*	0.000	$\ln TR_{it}$	-0.144	0.409

$\ln Y_{it}$	0.431*	0.004	$\ln Y_{it}$	1.675*	0.006
Constant	-13.87*	0.000	Constant	-11.13*	0.000
Saudi Arabia			*Spain*		
$\ln TR_{it}$	0.050	0.225	$\ln TR_{it}$	-0.595**	0.023
$\ln Y_{it}$	0.263	0.320	$\ln Y_{it}$	2.734*	0.006
Constant	-1.085	0.593	Constant	-20.13*	0.007
Sweden			*Switzerland*		
$\ln TR_{it}$	0.031	0.315	$\ln TR_{it}$	-0.144**	0.014
$\ln Y_{it}$	-0.618*	0.008	$\ln Y_{it}$	0.357	0.376
Constant	7.494*	0.000	Constant	1.552	0.602
Trinidad and Tobago			*United Kingdom*		
$\ln TR_{it}$	0.215*	0.000	$\ln TR_{it}$	0.292*	0.000
$\ln Y_{it}$	0.122	0.179	$\ln Y_{it}$	-0.857*	0.000
Constant	-3.006*	0.000	Constant	3.533*	0.000
United Arab Emirates			*United States*		
$\ln TR_{it}$	-0.038	0.406	$\ln TR_{it}$	-0.197*	0.009
$\ln Y_{it}$	0.396***	0.099	$\ln Y_{it}$	0.630**	0.019
Constant	0.047	0.989	Constant	0.715**	0.087
Uruguay			*Chili*		
$\ln TR_{it}$	0.021	0.925	$\ln TR_{it}$	-0.013	0.203
$\ln Y_{it}$	0.850	0.236	$\ln Y_{it}$	0.858*	0.000
Constant	-6.886	0.118	Constant	-6.171*	0.000
Note: *, ** and *** show significance at the 1%, 5% and 10% levels of significance, respectively.					

The country-wise impacts of trade openness and economic growth on CO_2 emissions are reported in Table 9 (high income countries). Trade openness increases CO_2 emissions significantly in Cyprus (at 1%), Korea Rep. (at 5%), Kuwait (at 1%), Malta (at 1%), Netherlands (at 1%), New Zealand (at 1%), Norway (at 5%), Oman (at 1%), Trinidad and Tobago (at 1%) and United States (at 1%). Trade openness reduces CO_2 emissions significantly in Denmark (at 10%), Hong Kong SAR, China (at1%), Hungary (at 5%), Iceland (at 1%), Israel (at 1%), Japan (at 1%), Spain (at 5%), Switzerland (at 5%) and United States (at 1%). Similarly, economic growth increases CO_2 emissions significantly in Barbados (at 1%), Hong Kong SAR, China(at1%), Iceland (at 5%), Israel (at 1%), Italy (at 5%), Japan (at 1%), Kuwait (at 1%), Oman (at 1%), Portugal (at 1%), Spain (at1%), United Arab Emirates (at 10%), United States (at 5%) and Chili (at1%). However, it decreases CO_2 emissions significantly in Brunei Darussalam (at

1%), France (at 1%), Hungary (at 1%), Korea Republic (at 5%), Malta (at 1%), Netherlands (at 5%), Sweden (at 1%) and United Kingdom (at 1%).

In the middle income countries (Table 9), we find that trade openness impacts positively and significantly the CO_2 emissions in Angola (at 1%), Brazil (at 1%), China (at 1%), Venezuela RB (at 1%), Cuba (at 1%), Ecuador (at 5%), Egypt (at 5%), Guyana (at 1%), Honduras (at 1%),Indonesia (at 1%), Malaysia (at 5%), Morocco (at 1%), Nicaragua (at 1%), Nigeria (at 5%), Panama (at 1%), Sri Lanka (at 5%)and Vietnam (at1%). The effect of economic growth on CO_2 emissions is found positive and significant in Bolivia (at 5%), Botswana (at 1%), Cameroon (at 10%), Bulgaria (at 1%), Congo Republic (at 5%), Albania (at 1%), Costa Rica (at 1%), Côte d'Ivoire (at 1%), Dominican Republic (at 1%), Egypt (at 1%), Fiji (at 1%), Gabon (at 1%), Guyana(at 1%), India (at 1%), Indonesia (at 1%), Iran (at 1%), Nigeria (at 5%), Pakistan (at 1%), Paraguay (at 5%), Peru (at 1%), South Africa (at 1%), Sudan (at 1%), Syria (at 1%), Thailand (at 1%), Tunisia (at 1%), Turkey (at 1%) and Zambia (at 1%).

In the low income countries (Table 10), trade openness increases CO_2 emissions in Bangladesh (at 1%), Benin (at 10%), Burkina Faso (at 1%), Congo Republic (at 1%), Ethiopia (at 1%), Kenya (at 1%) and Mozambique (at 5%). Trade openness improves environmental quality through lowering CO_2 emissions in Mali (at 1%), Rwanda (at 1%) and Zimbabwe (at1%). Furthermore, we have investigated the impact of trade openness and economic growth on CO_2 emissions using the global, high income, middle income and low income countries. The results reported in Table 11show that trade openness and economic growth reduce the environmental quality through increasing CO_2 emissions in all panels.

Table-9: The FMOLS Country Specific Results

$\ln C_{it}$: Dependent Variable					
Middle Income Countries					
Country/ Variables	Coefficient	P-value	Country/ Variables	Coefficient	P-value
Algeria			*Angola*		
$\ln TR_{it}$	-0.094	0.454	$\ln TR_{it}$	0.199*	0.000
$\ln Y_{it}$	0.603	0.444	$\ln Y_{it}$	-0.245	0.227
Constant	-2.886	0.590	Constant	-0.125	0.924
Argentina			*Bolivia*		

$\ln TR_{it}$	0.022	0.525	$\ln TR_{it}$	-0.039	0.793
$\ln Y_{it}$	0.343	0.123	$\ln Y_{it}$	1.772**	0.017
Constant	-1.764***	0.058	Constant	-11.89*	0.005
Botswana			*Cameroon*		
$\ln TR_{it}$	-0.183*	0.006	$\ln TR_{it}$	0.042	0.230
$\ln Y_{it}$	1.370*	0.000	$\ln Y_{it}$	0.977**	0.053
Constant	-9.254*	0.000	Constant	-8.258**	0.020
Brazil			*Bulgaria*		
$\ln TR_{it}$	0.245*	0.008	$\ln TR_{it}$	0.059	0.750
$\ln Y_{it}$	-0.132	0.789	$\ln Y_{it}$	2.864*	0.000
Constant	0.006	0.999	Constant	-15.28*	0.000
China			*Colombia*		
$\ln TR_{it}$	0.215*	0.000	$\ln TR_{it}$	0.018	0.210
$\ln Y_{it}$	0.072	0.417	$\ln Y_{it}$	-0.401	0.158
Constant	-0.710***	0.064	Constant	3.544	0.108
Venezuela, RB			*Congo Rep.*		
$\ln TR_{it}$	0.132*	0.000	$\ln TR_{it}$	-0.011	0.721
$\ln Y_{it}$	-0.263	0.164	$\ln Y_{it}$	1.765**	0.021
Constant	3.061**	0.045	Constant	-13.84*	0.009
Albania			*Costa Rica*		
$\ln TR_{it}$	-0.373*	0.000	$\ln TR_{it}$	-0.084*	0.000
$\ln Y_{it}$	2.581*	0.000	$\ln Y_{it}$	1.708*	0.000
Constant	-16.80*	0.000	Constant	-13.13*	0.000
Côte d'Ivoire			*Cuba*		
$\ln TR_{it}$	-0.054*	0.007	$\ln TR_{it}$	0.736*	0.000
$\ln Y_{it}$	1.450*	0.000	$\ln Y_{it}$	-0.903*	0.001
Constant	-10.52*	0.000	Constant	3.122**	0.018
Dominican Republic			*Ecuador*		
$\ln TR_{it}$	-0.090	0.224	$\ln TR_{it}$	0.313*	0.044
$\ln Y_{it}$	1.317*	0.000	$\ln Y_{it}$	-1.399	0.125
Constant	-9.844*	0.000	Constant	9.609	0.123
Egypt, Arab Rep.			*El Salvador*		
$\ln TR_{it}$	0.052***	0.095	$\ln TR_{it}$	0.507	0.146
$\ln Y_{it}$	0.932*	0.000	$\ln Y_{it}$	-0.114	0.925
Constant	-6.281*	0.000	Constant	-2.931	0.678
Fiji			*Gabon*		
$\ln TR_{it}$	-0.543***	0.073	$\ln TR_{it}$	-0.960***	0.099
$\ln Y_{it}$	3.473*	0.002	$\ln Y_{it}$	8.931*	0.000
Constant	-23.51*	0.001	Constant	-69.82*	0.002

Ghana			*Guatemala*		
$\ln TR_{it}$	0.088	0.252	$\ln TR_{it}$	0.153	0.494
$\ln Y_{it}$	0.210	0.570	$\ln Y_{it}$	1.071	0.445
Constant	-2.955	0.123	Constant	-9.552	0.302
Guyana			*Honduras*		
$\ln TR_{it}$	-0.224*	0.005	$\ln TR_{it}$	0.523*	0.000
$\ln Y_{it}$	1.110*	0.000	$\ln Y_{it}$	-0.475	0.461
Constant	-5.340*	0.001	Constant	-0.521	0.893
India			*Indonesia*		
$\ln TR_{it}$	-0.458*	0.000	$\ln TR_{it}$	0.141*	0.008
$\ln Y_{it}$	2.022*	0.000	$\ln Y_{it}$	0.833*	0.000
Constant	-10.48*	0.000	Constant	-6.531*	0.000
Iran			*Jamaica*		
$\ln TR_{it}$	-0.307*	0.022	$\ln TR_{it}$	0.048	0.678
$\ln Y_{it}$	2.114*	0.000	$\ln Y_{it}$	0.067	0.814
Constant	-12.65*	0.000	Constant	0.271	0.864
Jordan			*Malaysia*		
$\ln TR_{it}$	0.048	0.678	$\ln TR_{it}$	0.474**	0.034
$\ln Y_{it}$	0.067	0.814	$\ln Y_{it}$	0.329	0.481
Constant	0.271	0.846	Constant	-5.359**	0.013
Mauritania			*Mexico*		
$\ln TR_{it}$	1.109	0.180	$\ln TR_{it}$	-0.061	0.111
$\ln Y_{it}$	-6.937***	0.093	$\ln Y_{it}$	-0.100	0.760
Constant	37.88***	0.086	Constant	2.787	0.300
Morocco			*Nicaragua*		
$\ln TR_{it}$	0.394*	0.001	$\ln TR_{it}$	0.227*	0.000
$\ln Y_{it}$	-0.098	0.765	$\ln Y_{it}$	-0.071	0.674
Constant	-1.787	0.312	Constant	-1.335	0.228
Nigeria			*Pakistan*		
$\ln TR_{it}$	0.452**	0.019	$\ln TR_{it}$	-2.299*	0.000
$\ln Y_{it}$	1.320**	0.038	$\ln Y_{it}$	5.256*	0.000
Constant	-6.558**	0.044	Constant	-29.10*	0.000
Panama			*Paraguay*		
$\ln TR_{it}$	0.434*	0.001	$\ln TR_{it}$	-0.046	0.774
$\ln Y_{it}$	0.144	0.518	$\ln Y_{it}$	2.755**	0.022
Constant	-4.366*	0.000	Constant	-20.24*	0.009
Peru			*Philippines*		
$\ln TR_{it}$	0.012	0.722	$\ln TR_{it}$	-0.074	0.307
$\ln Y_{it}$	1.122*	0.000	$\ln Y_{it}$	-0.331	0.308

Constant	-8.662*	0.000	Constant	2.862	0.147
Senegal			*South Africa*		
$\ln TR_{it}$	0.146	0.292	$\ln TR_{it}$	-0.091***	0.086
$\ln Y_{it}$	0.621	0.287	$\ln Y_{it}$	0.879*	0.002
Constant	-5.775***	0.075	Constant	-4.580**	0.023
Sri Lanka			*Sudan*		
$\ln TR_{it}$	0.618**	0.035	$\ln TR_{it}$	-0.380*	0.004
$\ln Y_{it}$	-0.028	0.957	$\ln Y_{it}$	2.045*	0.000
Constant	-4.676**	0.017	Constant	-12.15*	0.000
Syrian Arab Rep.			*Thailand*		
$\ln TR_{it}$	-0.470*	0.000	$\ln TR_{it}$	-0.842*	0.000
$\ln Y_{it}$	1.565*	0.000	$\ln Y_{it}$	3.669*	0.000
Constant	-7.025*	0.000	Constant	-19.53*	0.000
Tunisia			*Turkey*		
$\ln TR_{it}$	-0.024	0.656	$\ln TR_{it}$	-0.212**	0.053
$\ln Y_{it}$	0.679*	0.000	$\ln Y_{it}$	1.814*	0.000
Constant	-4.490*	0.000	Constant	-13.07*	0.000
Vietnam			*Zambia*		
$\ln TR_{it}$	0.695*	0.000	$\ln TR_{it}$	-0.616*	0.000
$\ln Y_{it}$	-0.424	0.196	$\ln Y_{it}$	3.534*	0.000
Constant	-1.860	0.157	Constant	-20.68*	0.000
Note: *, ** and *** show significance at the 1%, 5% and 10% levels of significance, respectively.					

Table10: FMOLS Country Specific Results

$\ln C_{it}$: Dependent Variable					
Low Income Countries					
Country/ Variables	Coefficient	P-value	Country/ Variables	Coefficient	P-value
Bangladesh			*Benin*		
$\ln TR_{it}$	0.470*	0.009	$\ln TR_{it}$	0.486***	0.080
$\ln Y_{it}$	0.358	0.450	$\ln Y_{it}$	4.441*	0.000
Constant	-5.933*	0.005	Constant	-31.57*	0.000
Burkina Faso			*Chad*		
$\ln TR_{it}$	0.554*	0.000	$\ln TR_{it}$	0.134	0.712
$\ln Y_{it}$	-0.307	0.218	$\ln Y_{it}$	0.380	0.775
Constant	-3.454*	0.003	Constant	-6.763	0.296
Congo, Dem. Rep.			*Ethiopia*		
$\ln TR_{it}$	0.059*	0.000	$\ln TR_{it}$	0.868*	0.001

$\ln Y_{it}$	1.123	0.135	$\ln Y_{it}$	-1.799*	0.000
Constant	-9.575*	0.000	Constant	2.841***	0.079
Kenya			*Liberia*		
$\ln TR_{it}$	0.466*	0.000	$\ln TR_{it}$	0.156	0.136
$\ln Y_{it}$	-2.251**	0.018	$\ln Y_{it}$	0.380*	0.000
Constant	10.23***	0.059	Constant	-4.447*	0.000
Madagascar			*Malawi*		
$\ln TR_{it}$	-0.078	0.545	$\ln TR_{it}$	-0.076	0.375
$\ln Y_{it}$	-0.670	0.273	$\ln Y_{it}$	0.964*	0.005
Constant	2.039	0.592	Constant	-7.371*	0.000
Mali			*Mozambique*		
$\ln TR_{it}$	-0.208*	0.003	$\ln TR_{it}$	1.018**	0.021
$\ln Y_{it}$	0.424*	0.008	$\ln Y_{it}$	-1.711***	0.059
Constant	-4.459*	0.000	Constant	2.026	0.471
Nepal			*Rwanda*		
$\ln TR_{it}$	0.235	0.579	$\ln TR_{it}$	-0.454*	0.001
$\ln Y_{it}$	1.795	0.118	$\ln Y_{it}$	0.253	0.318
Constant	-13.68*	0.004	Constant	1.073	0.311
Sierra Leone			*Togo*		
$\ln TR_{it}$	-0.824	0.671	$\ln TR_{it}$	0.119	0.143
$\ln Y_{it}$	-0.072	0.504	$\ln Y_{it}$	-0.233	0.484
Constant	-0.129	0.714	Constant	-0.785	0.690
Zimbabwe					
$\ln TR_{it}$	-0.355*	0.008			
$\ln Y_{it}$	1.260*	0.000			
Constant	-5.752*	0.000			
Note: *, ** and *** show significance at the 1%, 5% and 10% levels of significance, respectively.					

Table11: The FMOLS Panel Results

lnC_{it}: Dependent Variable				
Variables	Coefficient	P-value	Coefficient	P-value
	Global Panel		*High Income Panel*	
$\ln TR_{it}$	0.018*	0.000	0.025*	0.000
$\ln Y_{it}$	0.772*	0.000	0.110*	0.002
Variables	*Middle Income Panel*		*Low Income Panel*	
$\ln TR_{it}$	0.016*	0.000	0.042**	0.041

$\ln Y_{it}$	0.178**	0.025	0.631*	0.000
Note: *and ** show significance at the 1% and 5% levels of significance, respectively.				

Our results confirm the presence of an inverted U-shaped relationship between trade openness and carbon emissions for the high income panel. This result means that initially the CO_2 emissions increase, then start to decrease after a threshold level of trade openness is reached. The results support the existence of an environmental Kuznets curve (EKC) relationship between trade openness and carbon emissions with a turning point of trade openness. These thresholds are for example US$15,498.28for Australia, US$88,076.84 for Iceland, US$15,401.83 for Netherlands, US$23,216.80for Switzerland, and US$15,157.68 for the United States (we have not reported results for the rest of the countries in this income panel but available upon request from the authors)[6]. In the case of the middle income countries, the threshold point between trade openness and CO_2 emissions is for example US$2,835.85,US$3,938.66, and US$1,176.27 and US$2,969.82, for China, Costa Rica, El Salvador and Jordan (we have not also reported results for rest of the countries in this income panel but available upon request from the authors)[7].

Table 12: The Panel Results of EKC

lnC_{it}: Dependent Variable				
Variables	Coefficient	P-value	Coefficient	P-value
	Global Panel		*High Income Panel*	
$\ln TR_{it}$	0.045*	0.000	0.123*	0.000
$\ln TR_{it}^2$	-0.002*	0.000	-0.053*	0.000
$\ln Y_{it}$	0.736*	0.000	-0.005	0.948
Turning Point	$7,879.92		$21,9695.98	
Variables	*Middle Income Panel*		*Low Income Panel*	
$\ln TR_{it}$	0.369*	0.000	0.164*	0.000
$\ln TR_{it}^2$	-0.025*	0.000	-0.012*	0.000

[6] The threshold point in the rest of the high income countries is: US$ 22,810.24for Belgium, US$ 36,463.89for Cyprus, US$ 25,810.49for Hong Kong SAR China,US$ 75,458.89 for Ireland, US$ 17,682.01for Israel, 15,637.99US$for Malta,US$ 40,430.10for New Zealand, US$7,044.48for Portugal,US$ 3,869.45for Trinidad and Tobago and US$ 24,490.99for Chile.

[7]The threshold point in the rest of the middle income countries is US$ 16,85.85, US$ 34,01.77, US$2,465.44, US$1,738.64, US$1,564.19, US$1,021.47, US$ 21,237.88, US$3,503.84, US$ 2,068.57, US$2,210.68, US$1,694.79, US$ 5,178.17 and US$2,366.65 for Bolivia, Colombia, Dominican Republic, Guatemala, Honduras, Jamaica, Jordan, Malaysia, Mexico, Morocco, Paraguay, Senegal, Sri Lanka and Sudan.

$\ln Y_{it}$	0.186*	0.018	0.595*	0.000
Turning Point	$1,603.59		$928.28	
Note: *shows significance at the 1% level of significance.				

In the low income countries, an inverted U-shaped relationship between trade openness and carbon emissions also exists with a threshold point of trade openness with CO_2 emissions (we have not reported results for the rest of the countries in this income panel but available upon request from the authors). For example, the thresholds areUS$1,8751 (Bangladesh), US$477.57 (Kenya), US$483.07 (Madagascar) and US$239.48 (Nepal). Furthermore, the inverted U-shaped relationship between trade openness and carbon emissions using the global, high, middle and low income countries panels are estimated (see Table 12). The inverted U-shaped relationship between trade openness and carbon emissions is supported for all the four panels. However, the panel turning points of trade at which the emissions start to decline are found within the sample size for the global, high, middle and low income panels. The causal relationship between trade openness and CO_2 emissions is investigated by applying the panel VECM Granger causality test and the results are reported in Table13. In the global panel, a feedback effect is found between trade openness and CO_2 emissions, which implies that the relationship between trade openness and CO_2 emissions is bidirectional in the long-run. The bidirectional causal association is noted between economic growth and carbon emissions in the long-run, but in the short-run economic growth is caused by CO_2 emissions. Furthermore, trade openness and economic growth Granger cause CO_2 emissions in the long-run, but in the short run trade openness Granger causes CO_2 emissions in the high income countries. In the middle income countries, the relationship between trade openness and CO_2 emissions is bidirectional in the long run, which means that the feedback effect exists between economic growth and CO_2 emissions in the long run for this group. Trade openness and economic growth Granger cause CO_2 emissions in the long run for the low income countries. The joint causality analysis confirms the long run and the short run causality findings.

Table 13: The Panel VECM Granger Causality Analysis

Dependent Variables	Source of Causation (Independent variables)						
	ΔlnC_{it}	$\Delta lnTR_{it}$	ΔlnY_{it}	ECT_{-1}	ΔlnC_{it}, ECT_{-1}	$\Delta lnTR_{it}$, ECT_{-1}	ΔlnY_{it}, ECT_{-1}
	Short-Run			Long-run	Joint Causality		
Global Level							
ΔlnC_{it}	-	0.142 (0.867)	9.388* (0.000)	-0.180* (0.000)	-	97.51* (0.000)	55.96* (0.000)
$\Delta lnTR_{it}$	0.647* (0.523)	-	12.14* (0.000)	-0.084* (0.030)	3.499* (0.014)	-	12.88 (0.000)
ΔlnY_{it}	19.91* (0.000)	9.173* (0.000)	-	-0.002*** (0.089)	14.47* (0.000)	6.260* (0.000)	-
High Income Countries							
ΔlnC_{it}	-	2.801*** (0.094)	1.268 (0.281)	-0.106* (0.000)	-	16.80* (0.000)	17.67* (0.000)
$\Delta lnTR_{it}$	0.156 (0.855)	-	4.215** (0.015)	-0.070 (0.237)	0.562 (0.640)	-	3.411** (0.017)
ΔlnY_{it}	0.873 (0.481)	4.251** (0.014)	-	-0.009*** (0.089)	1.470 (0.221)	3.526** (0.014)	
Middle Income Countries							
ΔlnC_{it}	-	1.299 (0.273)	0.745 (0.475)	-0.179* (0.000)	-	48.07* (0.000)	47.87* (0.000)
$\Delta lnTR_{it}$	4.081** (0.017)	-	10.37* (0.000)	-0.040** (0.018)	4.154** (0.015)	-	8.539* (0.000)
ΔlnY_{it}	1.097 (0.334)	5.129* (0.006)	-	-0.007** (0.039)	3.385** (0.017)	4.324** (0.005)	-
Low Income Countries							
ΔlnC_{it}	-	0.159 (0.852)	2.040 (0.131)	-0.157* (0.000)	-	14.77* (0.000)	17.15* (0.000)
$\Delta lnTR_{it}$	2.898*** (0.056)	-	2.496*** (0.083)	-0.048 (0.257)	1.987 (0.115)	-	2.454*** (0.062)
ΔlnY_{it}	4.386** (0.013)	2.924*** (0.054)	-	-0.010 (0.269)	3.840* (0.009)	1.990 (0.114)	-

Note: The Wald F-statistics are reported with respect to the short-run changes in the independent variables. ECT represents the coefficient of the error correction term. The values in ( ) are the p-values.Note: *, ** and *** show significance at the 1%, 5% and 10% levels of significance, respectively.

5. Concluding remarks and policy implications

This study investigates and tests the relationship between trade openness and environmental pollutants (CO_2 emissions) while incorporating economic growth, by using a panel dataset for 105 heterogeneous (high, middle and low) countries categorized into four country panels. The study covers the period 1980-2014 which was the most recently available for us at the time when we embarked on this study. For the empirical analysis, we have employed the latest panel estimation techniques that are robust to both cointegration and cross-sectional dependence.

The results of the panel unit root and cross-sectional dependence tests indicate that all the variables are integrated of I(1) and are cross-sectionally dependent. The Pedroni and Westerlund cointegration tests confirm the presence of panel cointegration relationships between trade openness, economic growth and CO_2 emissions in the selected panels. The country-specific estimates of the FMOLS procedure suggests that trade openness reduces carbon emissions in most of the countries. Similar inference is drawn for the global, high, middle and low income panels. The causality analysis confirms the existence of a feedback effect between trade openness andCO_2 emissions for the global panel as well as for the middle income country panel in the long-run. Trade openness Granger causes CO_2 emissions for the high income and low income countries in the long-run.

The policy backlash between trade openness and environment regimes can clearly be observed in the multilateral climate change negotiations among member countries. The recent Doha climate change conference adds another failure, and now environmental policymakers and researchers have started to see it with a different angle. For example, Campbell, (2013) says the negotiations to-date grant industrialized countries a permission to emit more rather than a binding agreement would give them. In the wake of this conflict, the empirical results of this investigation provide a vibrant policy option for the countries of all income levels. The overall findings validate the various past outcomes of Grossman and Krueger (1991, 1995), Antweiler et al. (1998), Copeland and Taylor (2003) and Frankel and Rose (2005). However, this meta-analysis brings forth environmental implications of trade liberalization in the low, middle and high income panels. The validation of the inverted-U shaped relationship suggests that trade increase environmental degradation at initial stage but then it starts to improve environmental quality after a certain threshold level of trade openness. That threshold level is represented by a turning point in the results.

The results of the panel cointegration suggest that trade openness contribute to emissions in all income levels but with varying turning points for different panels. For example, the turning point in the case of the high income level is almost the same. However, the deteriorating phase of negative environmental repercussions is smaller than in the middle and low income panels. The middle income countries though have the highest environmental deterioration but require less time to improve environmental quality than the low income panels. The low income panel requires the longest time frame to reach the turning point but its environmental deterioration is larger than in the high income panels but smaller than the middle income panels. This further enumerates that the countries of the small income panel receive the highest negative environmental impacts of trade openness though they contribute less to degradation than the middle panel but more than the high income panels. The middle income panel induces the highest emissions, thereby it attracts higher environmental consequences than the high income panel but less than the small income panel. Similarly, the high income panel contributes least and also attracts the least environmental degradation. Moreover, due to the externality effect, emissions in the atmosphere due to trade liberalization have an overall negative impact on the earth's health. However, this study also confirms the inverted-U shaped relationship between trade openness and CO_2 emissions for the global panel.

The results show that different income levels have different tendencies to affect the environment due to trade openness. However, the implications they give forth are also different. Hence, there is a need for different policy tools for achieving sustainable development. For example, the existing mechanisms (i.e. the Clean Development Mechanism (CDM) and the Joint implementation (JI) under the Kyoto Protocol) provide an emission-reduction strategy through an international technology diffusion from industrialized to industrializing countries (Youngman et al., 2007; Dechezleprêtre et al., 2008). The individual turning points help specific countries to shape their national environmental regulations for achieving sustainable development goals. The causality results find a feedback effect in the long-run only for the global and middle income countries panels. This shows that in the long-run, the global environment improves with the environmental improvement in the middle income countries. Therefore, the participations of the middle income countries are essential in mapping global environmental policies.

The existence of EKC in all four (small, middle, high and global) country panels assures the ultimate improvement in the environment along the trade liberalization path. However, in view of the cost and damage associated with environmental degradation, the turning points can be achieved in shorter times with multilateral agreements and policy dialogues. The contravening measures in advanced economies push the manufacturing sector towards industrializing the developing economies due to less stringent environmental regulations in this regard. This outward movement causes an environmental improvement in advanced countries but increases growth and deteriorates the environment in developing countries. Hence, the emissions flow in the opposite direction of goods (Suri and Chapman, 1998). Our results suggest that setting up minimum environmental standards will limit the emission intensity of the manufacturing sector in industrializing countries. The negative environmental consequence of the scale effect in developing economies can be reduced with enhanced technological inflows from developed economies. Therefore, the policies of individual economies play a vital role for having a quick offset. Unilateral agreements between trading partners seem feasible in this case.

Now as far as the small income economies are concerned, trade liberalization induces emissions and there is a unidirectional causality running from trade openness to CO_2 emissions. The results suggest that it may take a long time to reach the turning point in the case of the small income panel, but the low income countries are likely to attract a similar trading effect from industrializing economies in the long-run. However, the least developing countries contribute less to environmental deterioration than industrializing countries. But, due to a lack of proper living conditions, weak infrastructure and a disaster forecast and management system, the countries bear the largest environmental impacts. The low income economies which mainly depend on an agrarian economy should receive special attention and technological subsidies to enhance their infrastructure, adaptability to changing climate conditions, better disaster management, forecasting and a recovery system. The study further endorses the notion of Grossman and Krueger, (1991) that the environmental implications of trade also depend on the policy changes in the particular economy. Thus, a global multilateral agreement seems be helpful for global environmental management.

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