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Md. Al Mamun
Kazi Sohag
Md. Abdul Hannan Mia
Gazi Salah Uddin
Ilhan Ozturk

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IPAG Business School
184, Boulevard Saint-Germain
75006 Paris
France

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Md. Al Mamun
Department of Business Administration,
East West University, Dhaka-1212, Bangladesh.
Email: mamunacademic@gmail.com; alm@ewubd.edu

Kazi Sohag
Institute of Climate Change (IKP),
National University of Malaysia, Malaysia.
Email: sohagkaziewu@gmail.com

Md. Abdul Hannan Mia
Professor of MIS, University of Dhaka, Bangladesh.
Email: hannan@du.ac.bd

Gazi Salah Uddin
Linköping University, Sweden & IPAG Business School, France
Email: gazi.salah.uddin@liu.se

Ilhan Ozturk
Faculty of Economics and Administrative Sciences,
Cag University, Turkey
Email: ilhanozturk@cag.edu.tr

1.

Abstract

Environmental degradation measured by CO_2 emissions is a significant challenge to sustainable economic development. Owing to significant differences in the empirical relationship between the economic growth and CO_2 emissions and policies adopted by different countries to overcome the challenge are not decisive. This study aims to generalize our knowledge about the relationship between CO_2 emissions and economic growth across the world for 1980-2009 period. Besides, it explores whether the transformation of different economies (e.g. agrarian to industrial and industrial to sophisticated service economy) over the past few decades yielded any significant positive impact towards sustainable economic development by reducing the level of CO_2 emission. Empirical results suggest (i) except for high-income-countries, Environmental Kuznets Curve (EKC) is a general phenomenon across the world, and (ii) the transformation of different economies towards a service economy has produced more pollution in high income countries and less pollution in low and middle income countries.

Keywords: CO_2 emissions, Environmental Kuznets Curve, Sectoral output.
JEL Classification: C23, Q20, Q40, Q43, Q56.

1. Introduction

Over the last two and half decades, there is an increasing threat of global warming caused by increased greenhouse gas emission. CO_2 emissions alone account for 58.8% of the greenhouse gas emission in the world (Zhenling, 2013). Azomahou et al. (2006) argue that the existing global energy system and the economic development across the world are directly responsible for such a result.

Given this reality, a study on the regional differences in the dynamic linkage between CO_2 emissions, sectoral output and economic growth is important at least for three reasons: First, various empirical studies investigating the economic growth and CO_2 emissions nexus provide inconclusive, inconsistent and partial understanding of this issue. However, a comprehensive and conclusive understanding in this regard is a must as we aim at developing an efficient and effective global framework to counter the problem of greenhouse gas and focus more on sustainable development rather than the economic growth itself.

Second, given the global thrive for perpetual economic growth; question has been raised if economic growth and ecological harmony is a non-existent public good? Such question streams from the inconclusive findings of the existence of environment Kuznets curve (EKC) in various economics around the world. Although, from the time Grossman and Krueger

(1991) first test the EKC by focusing on the level of urban air pollution, till today, a significant number of studies (e.g. Panayotou, 1993; Robers and Grimes, 1997; Shafik, 1994, Akbostanci et al., 2009; Jaunky 2010; Choi et al., 2010; Narayan and Popp 2012; Baek et al., 2013) have examined the environmental consequences of economic growth by incorporating different catalysts like trade liberalization, foreign direct investment, urbanization, size of the population, etc. Each of these empirical studies has its own dimension and has contributed to our greater understanding of the economic growth and natural ecological balance paradox. However, existing empirical evidences regarding the presence of EKC across various countries are inconclusive, and the findings are sensitive to the study period chosen, the methodology used, the country or region selected and the lack of uniformity in the selection of other intervening variables. Such inconclusive result has clouded the effort to develop a global consensus on policy initiatives to augment a harmonious coexistence between economic development and environmental preservation.

Third, economic growth achieved and persuaded still by various countries significantly differs in their structure. Some countries historically inherit agriculture sector as the primary engine of economic growth, while others rely on industrial or service sectors. Due to the increasing importance of the knowledge economy in global GDP, a large number of countries today are shifting from traditional agriculture and industrial sectors toward a more sophisticated service sector. World Bank (2010) suggest that, in post industrialized period, there is a tremendous growth of service sector output with the agriculture sector contributing only 2%, while service sector contributing 66% of high-income countries share of GDP. Therefore, the potential for these sectors generating a different level of economic growth vis-à-vis different level of CO_2 emission cannot be ruled out. However, empirical investigations about the relative contribution of sector-wise output on CO_2 emissions across regions are non-existent. This is important because, there is a possibility that different sectors might contribute differently in the overall level of CO2 emissions and knowledge about the sector contribution will help us to develop an environmentally harmonious pro-growth strategy.

Therefore, the aim of this study is to provide concrete policy recommendations by providing a specific answer to some key questions so as to deal with the problem of CO_2 emissions. The questions include: i) whether the economic growth and CO_2 emission nexus can be generalized across the world with different economic regions showing significant differences in the level of economic growth and output structure; ii) whether a focus on sectoral output and CO_2 emission can uncover the most environmentally desirable growth sector to pursue; and iii) whether some countries should produce less and allow others to produce more if output produced by the former countries generates relatively more CO_2 emission and if the former countries receives appropriate financial compensation from the latter countries to enable overall reduction of CO_2 emission of the world?

The rest of paper is as follows: In section 2 review of the recent literature is provided whereas section 3 describes the data and outlines the methodology of the analysis. In section 4, results and discussion are presented and finally section 5 concludes the paper.

2. Literature Review

The vast majority of the existing literatures have either focused on a specific country or (e.g. Dean, 2002; Dean and Lovely, 2008; Shen, 2008; Weber et al., 2008; Yan and Yang, 2010 ; Bloch et al., 2012; Choi et al., 2010; and Wang, 2011 focuses on China; Alam et al., 2012 focused on Bangladesh; Soytas et al., 2009 and Ozturk and Acaravci, 2010 on Turkey; Baek et al., 2013; Kim, 2010 on South Korea; Tiwari, 2011; and Ozturk and Uddin, 2012 on India;

Essien, 2011 on Nigeria; Menyah, 2010 on USA; Saboori et al., 2012 on Malaysia, etc.) or specific geographic or economic regions (e.g. Pao (2010) on BRIC countries; Acaravci and Ozturk (2010) on EU countries; Arouri (2012) on MENA countries; Borhan (2013) on eight Asian countries; Moomaw & Unruh (1997) and Piaggio et al., (2012) on OECD countries; Coondoo et al. (2008) on Africa, America, Asia and European countries; Hossain (2011) on industrialized countries; while Friedl et al. (2003) on small economies, Al-Mulali et al. (2013) on Latin America and Caribbean etc. Evidently, literatures focusing on specific economic regions have imparted more generalized insight while literatures focusing on a specific country have imparted more specific insight.

Although the majority of the empirics have primarily concluded different magnitudes of positive relationships between CO_2 emission and economic growth, others have documented quite different results, as well. For instance, Selden and Song (1994) and Galeotti and Lanza (2005) reaffirm the EKC hypothesis; Holtz-Eakin and Selden (1995) find a monotonic rising curve; Shafik and Bandyopadhyay (1992), De Bruyn (1998), Roca et al. (2001), and Lantz and Feng (2006) etc. find a non-monotonic relationship; Shafik (1994), Grossman and Krueger (1995), and Friedl and Getzner (2003), etc. find an N-shape relationship; Robers and Grimes (1997), Cole et al., (1997), Schmalensee et al., (1998), Galeotti and Lanza (2006), Apergis and Payne (2009), and Lean and Smyth (2010) report an inverted U-shape relationships in CO_2 emission and economic growth nexus. Thus the findings have complicated our understanding about the relationship between CO_2 emission and economic growth and led to an inconclusive policy framework to deal with the ever increasing challenge of greenhouse gas.

The conclusion about economic growth and CO_2 emission becomes even more clouded when empirical results argue the presence of contrasting causality in respect to the direction to the relationship, as well. For example, Masih and Masih (1998), Stern (2000) and Shiu and Lam (2004) find a unidirectional causality from energy consumption and CO_2 emission to aggregate output; while Masih and Masih (1997), Asafu-Adjaye (2000), Soytas and Sari (2003), Oh and Lee (2004), Yoo (2005), Wolde-Rufael (2006) etc. find bi-direction causality in growth and CO_2 emission nexus; and others like Agras and Chapman (1999), Friedl and Getzner (2003), Martinez-Zarzoso and Bengochea-Morancho (2004), Richmond and Kaufman (2006), Dinda and Coondoo (2006), Managi and Jena (2008), Jalil and Mahmud (2009) reveal no significant relationship between economic growth and environmental pollutants i.e. higher national income does not necessarily mean higher amount of emissions of pollutants.

Many studies also find different results using a variety of empirical models such Ganger causality (Knapp and Mookerjee, 1995; Stern, 1993; Aqeel and Butt, 2001; Yuan et al., 2007; and Ghosh, 2010 etc); dynamic causality test (Pao et al., 2010; Sharif M. Hossain, 2011), time series techniques (Akbostanci et al., 2009; Choi et al., 2010; Jaunky, 2011), ordinary least square method (Lise, 2006); star model (Kim et al., 2010); the short and long-run elasticity (Narayan and Popp, 2012); vector error correction model based bounds testing approach (Saboori et al., 2012), and panel autoregressive methodologies (Wang, 2012; Arouri et al., 2012; Baek et al. 2013).

Knapp and Mookerjee (1995) using Granger causality test document statistically significant relationship between human activities, i.e. population growth and CO_2 emissions. Their findings created a new avenue for augmenting CO_2 emission and economic growth nexus in the presence of additional exogenous. Recently, using time series model, Akbostanci et al.

(2009) conclude that CO_2 emissions and income tend to have a monotonically increasing relationship in the long run. Using the same method, Jaunky (2010) confirms EKC hypothesis for 36 high-income-countries to acknowledge the finding of Akbostanci et al. (2009) result. Choi et al. (2010) using time-series data from 1971 to 2006, investigate the existence of EKC in the presence of trade openness for one of the most thriving economies like China, a new industrialized economy like Korea and developed economy like Japan. The estimated EKC shows different temporal patterns across countries, highlighting differences in national characteristics. The result shows N-Shaped curve for China, U-shaped curve for Japan, inverted U-shaped curve for Korea and Japan and U-shape for China. Pao et al. (2010) examine a dynamic causal relationship between pollutant emissions, energy consumption and output for BRIC countries. The study documents a positive and statistically significant long-run equilibrium effect of energy consumption on emissions, while real output exhibits the inverted U-shape pattern with the threshold income. And in the short term, changes in emissions are driven mostly by in energy consumption. The study also documents a strong bi-directional causality between energy consumption and emissions, energy consumption and output in the long run; while strong unidirectional casualties from emissions and energy consumption to output in the short run. Sharif M. Hossain (2011) examines the dynamic causal relationships between CO_2 emissions, energy consumption, economic growth, trade openness and urbanization for newly industrialized countries. Using the time-series data, he concludes that long-run elasticity of CO_2 emissions with respect to energy consumption is twice the elasticity of short run. However, the study found no evidence of long-run causal relationship between emission and economic growth, except for unidirectional short-run causality from economic growth and trade openness to energy consumption, urbanization and CO_2 emissions. Narayan and Popp (2012) examine the EKC hypothesis based upon the short and long-run income elasticity in respect to CO_2 emission and find that some countries should play a greater role in reducing CO_2 emissions.

Using OLS method, Lise (2006) concludes that CO_2 emissions and income exhibit a linear relationship rather than an EKC path for Turkey. Say and Yucel (2006), however, refute such result as spurious since, under OLS process, the problem of stationarity exists in data set. Controlling for gross fixed capital investment and labor by employing Toda and Yamamoto (TY hereafter) (1995) procedure under Granger causality in a multivariate framework, Soytas et al. (2009) came up with one of the most interesting findings for Turkey. The study finds that CO_2 emission Granger causes energy consumption while the vice-versa is not. Furthermore, lack of a long-run causal links between income and CO_2 emissions signifies that a reduction in CO_2 emission does not necessarily mean a compromise with economic growth for Turkey. Using the star model with Korean data, Kim et al. (2010) argue that there is interdependence between CO_2 emissions and economic growth. Such interdependence shows a significant nonlinear dynamics due to the asymmetric mean-reverting property in the autoregressive process. Baek et al. (2013) examine the existence of the EKC in Korea using the autoregressive distributed lag (ARDL) approach. The study finds evidence supporting the existence of EKC hypothesis for Korea for over the past four decades. Furthermore, nuclear energy (rather than electricity from fossil fuels) and energy consumption exhibits a far more beneficial effect on environmental quality both in short and in long-run.

Wang et al. (2011) using panel co-integration tests for 28 Chinese provincial data find an inverted U-shaped relation between CO_2 emission with energy consumption and economic growth. The study also finds that the per-capita CO_2 emission in China is much higher relative to other emerging economies in the world. The reasons behind such findings are due to the uneven economic development, excessive use of energy, variation in the level of economic growth among the provinces. More recently, employing bounds testing approach for Malaysian data, Saboori et al. (2012) document a long-run causal relationship between economic growth and CO_2 emissions represented in an inverted-U shape curve. However, there is a lack of causalities between CO_2 and income in the short-run and unidirectional causality from income to CO_2 emissions in the long-run. Using various panel methodologies for 12 MENA countries data, Arouri et al. (2012) suggest a significant positive impact of energy consumption on CO_2 emissions in the long-run, while a quadratic relationship between real GDP and CO_2 emissions to confirm the EKC hypothesis. While Wang (2012), also confirms negative economic growth and CO_2 emission nexus in low growth, positive nexus in the medium growth and insignificant nexus in high-growth countries. In terms of the number of countries covered (i.e. 98 countries), Wang (2012) produces the most comprehensive study to examine the non-linear relationship between CO_2 emissions from oil and GDP in the presence of population growth. The study finds a threshold effect in the relation, and it concludes a different degree of impact of oil CO_2 emissions on the different level of economic growth.

3. Data and Methodology

3.1 Data

The study uses World Development Indicators (WDI) dataset from 1980 to 2009. Due to the insufficient number of observation of dependent variable, a total of 136 countries have been selected for the study. These countries are divided into five major group: lower income countries (LIC), lower middle-income countries (LMIC), upper middle-income countries (UMIC), high-income OECD countries (HIOECD) and finally high-income non-OECD countries (HINOECD). The dependent variable in this study is CO_2 emission per capita metric tons, which include CO_2 produced during consumption of solid, liquid, gas fuels and gas flaring. Additional variables include GDP growth rate (GDPG) as the proxy for economic growth, trade openness (TO) to account for the effect of economic liberalization, agriculture value added (AVA), industry value added (IVA), and service value added (SVA) to account for the comparative effect of sectoral output on CO_2 emissions. The inclusion of sectoral output is indeed one of the unique features of this study. Finally, log of the total population (lnPo) rather than urbanization is used since urbanization is a linear proportion to the size of the total population in most countries.

3.2 Empirical methodologies

The dynamic relationships among CO_2 emissions, GDPG, IVA, SVA, AVA, TO, and populations have been examined by using a series of carefully designed testing procedures: First, the test of panel multicollinearity using Farrar-Glauber (1976) methods. The presence of multicollinearity among the regressors leading to model misspecification is a concern in the current study since the study includes a large number of variables. Assuming that x_i are normally and independently distributed, if the variables are orthogonal, there is no multicollinearity and vice-versa? Second, an examination of panel multicollinearity and panel unit roots test assuming cross sectional independence; third, the test of long run cointegrating relationship between the variables of interest using Westerlund (2007) method; Fourth, the examination of various dynamic panel methodologies are used to investigate the relationship between CO_2 and sectoral output in the presence of selected exogenous variables using Pesaran et al. (1999) for different regions.

3.2.1 Panel unit root test

Since the seminal paper by Nelson and Plosser (1982), the examination of unit root in macro time-series data become a convention (Al Mamun, et al. 2012). In recent year, various panel unit root test methodologies have grown. For example, the first-generation panel unit root tests methodologies (Maddala and Wu (1999), Levin et al. (2002) and Im et al. (2003)) based on the assumption of the cross-sectional independence across units; the second-generation unit root tests methodologies (Bai and Ng (2004), Smith et al. (2004), Moon and Perron (2004), Choi (2006) and Pesaran (2007)) with the assumption of cross-sectional dependence across units, and finally, panel unit root test methodologies those accounts for structural breaks in the panel.

This study employs several first-generation methodologies, including Im, Pesaran and Shin (2003) one, which are based on the well-known ADF procedure of Dickey and Fuller (1979). Im, Pesaran and Shin (IPS, 2003) propose one of the most efficient methodologies for investigating the presence of unit roots in panel data. It requires small time observations for the test to have power and the power of the test better fits to analyze long-run relationships in panel data (Al Mamun, 2013). IPS (2003) method works by specifying a separate ADF regression (see equation 01) for each cross-sectional unit with individual effects and no time trend.

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \quad \text{........................}(01)$$

Where, $i = 1...N$ and $t = 1...T$

After separate ADF regressions are estimated, the average of the t-statistics for ρ_i is calculated from the individual ADF regression using equation 02.

$$\bar{t}_{NT} = \frac{1}{N}\sum_{i=1}^{N} t_{iT}(p_i \beta_i) \quad \text{.................................}(02)$$

The *t*-bar is then standardized, which converges to the standard normal distribution as N and $T \rightarrow \infty$. IPS (2003) point that *t-bar* test better performs when N and T are small (though this is not the case here). The advantage of IPS (2003) methodology is its use of separate tests for the *N* cross-sectional units. However, IPS (2003) proposes a slightly different version of such test when the errors in different regressions contain a common time-specific component. The study also applies Levin–Lin–Chu (LLC, 2002) and Breitung (2000) panel unit root tests with common & individual unit root processes.

3.2.2 Panel cointegration test

Although the concept of cointegration was introduced by Ganger (1981) followed by a series of works in this field led by Engle and Granger (1987) and Phillips and Ouliaris (1990); however, Pedroni (1995, 1997) was the first to study the properties of spurious regression both in homogeneous and heterogeneous panels in testing the null of no cointegration. Eventually, the test of the null hypothesis of no cointegration becomes a branch of cointegration tests. McCoskey and Kao (1999) and Koa (1999) develop another branch of panel cointegration tests with the null hypothesis of cointegration in their studies.

Pedroni (1995, 1997) provides asymptotic distributions for test statistics for heterogeneous panel; those are appropriate for different types of dynamics such as endogenous regressors, fixed effects, individual specific effects, deterministic trends, etc. Pedroni (1997) tests permit the heterogeneity of the autoregressive root under an alternative hypothesis consistent with the idea of Im et al. (1997). Panel cointegration tests can also be undertaken under a homogeneity assumption for the cointegrating vectors among cross sectional units (Pedroni, 1995, 1997; and Kao, 1999). In addition to the heterogeneous case, Pedroni (1995, 1997) also studied properties for the especial case of homogeneous cointegrating vectors suggesting that residual-based tests for the null of no cointegration have asymptotically distributions equivalent to raw panel unit root tests when regressors are exogenous. However, panel cointegration tests with common-factor restriction cause a significant loss of power in residual-based methodologies (Banerjee et al., 1998; and Kremers et al., 1992). So, Westerlund (2007) develops four new panel cointegration tests against the null of no-cointegration. These tests are based on structural rather than residual dynamics; consequently they do not require common-factor restriction with optimum lag and lead lengths for each series chosen by using the Akaike Information criterion (AIC). Since the variables of interest are integrated at I(1), the study applies the Westerlund (2007) cointegration test for variables under first-difference with the null of no cointegration using equation 03.

$$\Delta CO_{2it} = \delta_i' d_t + \alpha_i (CO_{2i,t-1} - \beta_i' X_{i,t-1}) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta CO_{2i,t-1} + \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta X_{i,t-1} + \varepsilon_{it} \text{ ....}(03)$$

Where t = time and N is cross-sectional units. α_i are the speed adjustment to equilibrium relationship in $CO_{2i,t-1} - \beta_i' x_{i,t-1}$ after a sudden shock and d_t is a deterministic component. A negative and significant α_i suggests the presence of error correction, i.e. long run cointegration. The deterministic component could take one of three possibilities, i.e. 0, 1 or (1, t)′ referring both a constant and a time trend for considering independence between Δx_{it} and $\varepsilon_{it.}$ Furthermore, bootstrap method can be used with a simple modification of equation 03 assuming the independence of error across time and cross-sectional units.

Thus, the null hypothesis of no cointegration is $\alpha_i = 0$ for all i, while the alternative hypothesis depends on what is being assumed about the homogeneity of α_i. The group-mean tests do not require the α_i's to be equal, which means that H_0 is tested against H_1^g : αi < 0 for at least one i. While the panel tests assume that α_i are equal for all i and are, therefore, designed to test H_0 versus H_1^p : $\alpha_i = \alpha < 0$ for all i. The panel statistics denoted as P_τ and P_α , test the null hypothesis of no cointegration in the panel. Again, group mean statistics, G_τ and G_α , test the null hypothesis of no cointegration against the alternative that at least one cross-sectional unit in the panel is co-integrated.

3.2.3 The panel dynamic approaches

Johansen (1995), Philips & Hansen (1990) argue that long-run relationships exist if variables are integrated at same order. Pesaran et al. (1999) following maximum likelihood (MLE) based estimation, however, counter Johansen (1995) by presenting the mean group (MG) and the pooled mean group (PMG) estimators, estimators those work with better efficiency even if variables are integrated at mixed order. Thus, the applications of MG or PMG estimates do not require cointegration tests, and analysis can be performed with unrestricted specification for the autoregressive distributed lag for time periods t = 1, 2, ….., T and groups i = 1, 2, …, N. Since the mixed integrated order amongst the variables does not affect the efficiency of the estimation; conventional stationarity check is no longer required, as well. Furthermore, this model is appropriate for the panels with large N and T dimensions.

Pesaran & Smith (1995) MG methodology estimates the long-run parameters by averaging the long-run coefficients of ARDL models for each cross-sectional unit. Therefore, the test of long-run relationship between CO_2 emission and economic growth along other x_i takes the following form.

$$CO_{2it} = \theta_0 + \gamma_{i1}CO_{2i,t\text{-}1} + \gamma_{i1}GDP_{it} + \gamma_{i2}GDP_{it}^2 + \gamma_{i3}IVA_{it} + \gamma_{i4}AVA_{it} + \gamma_{i5}SVA_{it} + \gamma_{i6}TO_{it} + \gamma_{i7}\ln P_{it} + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(04)$$

Where, the long run parameter θ_i for country *'i'* is $\theta_i = \beta_i / 1 - \gamma_i$; while MG estimator for panel is $\hat{\theta}_i = \frac{1}{N}\sum_{i=1}^{N}\theta_i$ and $\hat{\beta}_i = \frac{1}{N}\sum_{i=1}^{N}\beta_i$. So, MG model estimates separate regressions for each country and then calculates parameters as unweighted means of the estimated coefficients for the individual countries without imposing any restriction. Therefore, all coefficients are allowed to be heterogeneous both in the long-run and the short-run. Given the country-specific heterogeneous feature in the data set, MG estimator is a rational methodology to use. Furthermore, the study fits with the requirement of MG approach, as the necessary condition for the consistency and validity of MG approach requires a sufficiently large time-series and cross-country dimension.

The PMG estimator allows short-run coefficients, including the intercepts and the adjustment speed to the long-run equilibrium to be heterogeneous among countries. However, it restricts the long-run slope coefficients to be homogeneous across countries. This implies that $\theta_i = 0$ for all *i's*. In order to estimate short-run and the long-run coefficients, Pesaran et al. (1999) adopt the pooled maximum likelihood estimation (MLE) approach by assuming that the disturbances ε_{it} are normally distributed. The PMG is estimated according to the equation 05.

$$\ln CO_{2,it} = \mu_i + \sum_{j=1}^{p}\lambda_{ij}\ln CO_{2,it\text{-}j} + \sum_{j=0}^{q}\delta_{ij}^{/}X_{it-j} + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(05)$$

Where, i = 1, 2,….., N represents cross-sectional unit, and t = 1, 2, 3, …..,T represents time; j is the optimum time lag, X'_{it} = independent variables like $GDPG_{it}$, IVA_{it}, SVA_{it}, AVA_{it}, TO_{it}, $\ln Po_{it}$ etc. and μ_i is the fixed effect. By re-parameterization, equation 05 can be written as:

$$\Delta\ln CO_{2,it} = \mu_i + \varphi_i \ln CO_{2,it-1} + \beta_i' X_{it} + \sum_{j=1}^{p-1}\lambda_{ij^*}\Delta\ln CO_{2,it-j} + \sum_{j=0}^{q-1}\delta_{ij}'^{*}\Delta X_{it-j} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(06)$$

$$\text{Where, } \varphi_i = -1\left(1 - \sum\nolimits_{j=1}^{p}\lambda_{ij}\right), \beta_i = \sum\nolimits_{j=0}^{p}\delta_{ij},$$

$$\lambda_{ij^*} = -\sum_{m=j+1}^{p}\lambda_{im},\ j = 1,2,,\ldots\ldots\ldots, p-1, \text{ and}$$

$$\delta_{ij^*} = -\sum_{m=j+1}^{p}\delta_{im},\ j = 1,2,,\ldots\ldots\ldots, q-1.$$

And by grouping the variables in levels, the error correction equation is rewritten as:

$$\Delta\ln CO_{2it} = \mu_i + \varphi_i\left(\ln CO_{2,it-1} - \theta_i' X_{it}\right) + \sum_{j=1}^{p-1}\lambda_{ij^*}\Delta\ln CO_{2,it-j} + \sum_{j=0}^{q-1}\delta_{ij}^{*\prime}\Delta X_{it-j} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(07)$$

Where θ_i =-(β_i/ϕ_i) defines the long-run equilibrium relationship among y_{it} and x_{it}, while λ_{ij^*} and $\delta_{ij}^{*\prime}$ are short-run coefficients relating to CO_2 to its past values and other determinants such as x_{it}. The error-correction coefficient ϕ_i, measures the speed of adjustment of $CO_{2,it}$ toward its long-run equilibrium following a change in x_{it}. $\phi_i < 0$ ensures that there exists a long-run relationship. Therefore, a significant and negative value for ϕ_i is an evidence of cointegration between y_{it} and x_{it}. Finally, the average long run estimates are measured by the following:

$$\hat{\theta}_{PMG} = \frac{\sum_{i=1}^{N}\tilde{\theta}_i}{N}, \hat{\beta}_{PMG} = \frac{\sum_{i=1}^{N}\tilde{\beta}_i}{N};\ \hat{\lambda}_{jPMG} = \frac{\sum_{i=1}^{N}\tilde{\lambda}_i}{N}, \text{and } \hat{\gamma}_{jPMG} = \frac{\sum_{i=1}^{N}\hat{\gamma}_i}{N}$$

$$\text{Where, } j = 0, \ldots\ldots\ldots q-1, \quad \hat{\theta}_{PMG} = \tilde{\theta}$$

The following four models have been developed based upon the methodology presented in equation 07.

$$\begin{aligned}\Delta \ln CO_{2i,t} &= \mu_i + \varphi_i(\ln CO_{2i,t-1} - \lambda_1 GDPG_{i,t-1} - \lambda_2 TO_{i,t-1} - \lambda_3 \ln Pop_{i,t-1}) \\ &+ \sum_{j-1}^{p-1}\gamma_j^i \Delta(\ln CO_{2i})_{t-j} + \sum_{j=0}^{q-1}\delta_{1j}^{\ i}\Delta GDPG_{i,t-j} + \sum_{j=0}^{q-1}\delta_{2j}^{\ i}\Delta TO_{i,t-j} \\ &+ \sum_{j=0}^{q-1}\delta_{3j}^{\ i}\Delta \ln Pop_{i,t-j} + \delta_{i,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(08.1)\end{aligned}$$

$$\begin{aligned}\Delta \ln CO_{2i,t} &= \mu_i + \varphi_i(\ln CO_{2i,t-1} - \lambda_1 GDPG_{i,t-1} - \lambda_2 GDP_{i.t-1}^2 - \lambda_3 TO_{i,t-1} - \lambda_4 \ln Pop_{i,t-1}) \\ &+ \sum_{j-1}^{p-1}\gamma_j^i \Delta(\ln CO_{2i})_{t-j} + \sum_{j=0}^{q-1}\delta_{1j}^{\ i}\Delta GDPG_{i,t-j} + \sum_{j=0}^{q-1}\delta_{2j}^{\ i}\Delta GDPG_{i,t-j}^2 \\ &+ \sum_{j=0}^{q-1}\delta_{3j}^{\ i}\Delta TO_{i,t-j} + \sum_{j=0}^{q-1}\delta_{4j}^{\ i}\Delta \ln Pop_{i,t-j} + \delta_{i,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 08.2)\end{aligned}$$

$$\begin{aligned}\Delta \ln CO_{2i,t} &= \mu_i + \varphi_i(\ln CO_{2i,t-1} - \lambda_1 \ln IVA_{i,t-1} - \lambda_2 \ln AVA_{i,t-1} - \lambda_3 \ln SVA_{i,t-1} - \lambda_4 TO_{i,t-1} - \lambda_5 \ln Pop_{i,t-1}) \\ &+ \sum_{j-1}^{p-1}\gamma_j^i \Delta(\ln CO_{2i})_{t-j} + + \sum_{j=0}^{q-1}\delta_{1j}^{\ i}\Delta \ln IVA_{i,t-j} + \sum_{j=0}^{q-1}\delta_{2j}^{\ i}\Delta p\ln SVA_{i,t-j} + \sum_{j=0}^{q-1}\delta_{3j}^{\ i}\Delta \ln AVA_{i,t-j} \\ &+ \sum_{j=0}^{q-1}\delta_{4j}^{\ i}\Delta T0_{i,t-j} + \sum_{j=0}^{q-1}\delta_{5j}^{\ i}\Delta \ln Pop_{i,t-j} + \delta_{i,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(08.3)\end{aligned}$$

Where i = 1,…, 136 cross sectional units; t = 1,…30 time periods; λ_i are parameters to be estimated and Δ is the differenced operator and *ln* is the logarithmic expression. If the variables are I(1) and cointegrated, then the error term is an I(0) process for all *i*. A principal feature of cointegrated variables is their responsiveness to any deviation from long-run equilibrium. This feature implies an error correction model in which the short-run dynamics of the variables in the system are influenced by the deviation from equilibrium. The parameter φ_i is the error-correction coefficient or the speed of adjustment term. If $\varphi_i = 0$, then there would be no evidence for a long-run relationship. This parameter is expected to be significantly negative under the prior assumption that the variables show a return to a long-run equilibrium.

4. Results and Discussions

We begin with the investigation of multicollinearity following Farrar-Glauber (1976) methodology. The result (table 1) shows that for all variables except for GDPG in lower income countries, the F-test statistics has P-values less than 10%. This provides early evidence that there is no panel multicollinearity i.e. the problem of model misspecification does not exist.

Inset table 1 here

Then we move to test the first generation unit root test under different methodologies. Under IPS (2003) methodology, all the variables are integrated at I(1) considering both common and individual unit root process under individual intercept and no trend (table 2). The test results also suggest that GDPG is showing integration at I(1), while GDPG^2 is showing mixed order of integration only under IPS (2003) methodology. Under Levin, Lin & Chu (2002) methodology, AVA is showing mixed order of integration and IVA is showing no integrated order at level and in first differences. TO is also showing mixed order of integration under Fisher (1988) methodology. Since there exists mixed order of integration among the variables, Pesaran et al. (1999) methodology is the clearly favored estimator for the study. Moreover, the result of panel unit root test also argues for the superiority Pesaran et al. (1999) over other error correction models.

Inset table 2 here

Next we move to Westerlund (2007) cointegration test to get an early indication about the possible cointegrating relationship in the panel data. Table 3 summarizes the result of Westerlund (2007) cointegration tests. The result of the long-run cointegrating relationship between CO_2 emissions and various sectoral outputs suggests that the group mean statistics does reject the null hypothesis of no-cointegration at various significance levels for every single region. So, the result provides a mixed outlook about the possible long run cointegrating relationship between CO_2 emissions and sectoral output in low-income countries.

Inset table 3 here

At first we determine the nature and magnitude of the long-run elasticities and the short-run dynamics between CO_2 emissions and economic growth. The result has been estimated under MG, PMG and DFE alternatives following by Pesaran et al. (1999). However, the findings of Hausman (1978) test confirms that in most of the cases the PMG alternative provides more consistent, efficient and statistically significant estimators over MG and DFE estimates for all regions (table 4 to 6). Therefore, rest of the discussions is based on the findings of PMG estimates.

The existence of statistically significant long run dynamic relationship requires that the error correction coefficient be negative and statistically significant. Empirical results (tables 4 to 6) clearly confirm the existence of long-run elasticities and short run dynamic between economic growth and CO_2 emissions for all the regions. For example, table 4 suggests that error correction estimates ranges from -0.501 to -0.089 with an average of -0.306 for all different economic regions. Thus, it takes approximately 3.16 years to readjust the temporal shocks in the long-run equilibrium relationship between CO_2 emissions and the regressors i.e. GDPG, TO and lnP. However, the readjustment of the temporal shocks in the dynamic linkage is much faster (average of -.371) under equation 08.3 that includes sectoral output along with TO and lnP in the model. Furthermore, the adjustment is much quicker low income and HIOECD countries compared to HINOECD and all middle income countries.

Inset table 4, 5, 6 here

Both table 4 and 5 reports that CO_2 emission is a positive function of economic growth and population size in the long-run. This finding is broadly consistent with the findings of the majority of the earlier studies (see Moomaw and Unruh, 1997; Galeotti and Lanza, 2003; Apergis and Payne, 2009; Lean and Smyth, 2010; and Jaunky, 2010). One would generally perceive that the rate of CO_2 emission due to GDPG or sectoral output will be much higher in case of low-income countries with miserable and unsophisticated primitive productive technology, pitiable knowledge about the negative effect of environmental degradation, low environmental regulations and standards, poor and lack of transparent environmental watchdog, etc. However, a first hand peep on the results (table 4 to 5) shows an interesting pattern about such dynamic linkage. Though, GDPG exerts a statistically significant positive impact on CO_2 emission across different economic regions, interestingly; the long-run elasticity of GDPG is much higher in upper middle income and high-income countries compared to low-income countries. Why such unexpected, but immensely robust findings do we confront? Can we, therefore, argue that, compared to high-income countries, low income have achieved far more environmentally efficient economic growth over the years? Indeed, the most scientific answer to this compelling question needs a bunch of future research in this direction. However, the general economic rationalism suggests that high-income countries mostly rely on the industrial and service sectors in augmenting their economic growth. Evidently, these sectors do consume more energy either directly or indirectly, which generates higher CO_2 emission. Furthermore, energy consumption level is disproportionate between high income and low-income countries with high-income countries consuming lion share of the energy of the world.

Trade openness generally exhibits negative impact on CO_2 emission in most of the regions; however, the result is statistically significant in low income and high income OECD countries. Moreover, such impact is slightly higher in low income countries compared to high income countries. Thus, international trade has not only brought economic development to the world, but also resulted in a more environment friendly economic growth. This is because international trade requires the trading nations, especially low income countries, to abide by some very rigorous and standardized environmental practices in the manufacturing process to qualify for export to high-income countries. Finally, the impact of population on CO_2 emission is quite inconsistent across regions under different models. Initially under Eq. 8.01 population generally shows a statistically significant positive impact on CO_2 emission across regions. However, such impact is relatively higher in case of upper middle and high income non-OECD countries compared to low income and high income OECD countries. However, once we include $GDPG^2$ in the model, this parameter becomes negative and statistically significant for all middle income countries. Furthermore, incorporation of sectoral output variables in the model changes the sign for the parameters of population size in high income countries, as well.

After generalizing the result of the impact of GDPG on CO_2 emission across regions, now we answer if increasing economic growth is an endless motivation to strive. The results (table 5) clearly suggest the existence of EKC with a coefficient of $GDPG^2$ being negative and significant while the coefficient of GDPG is positive and statistically significant across regions except for HIOECD countries. The presence of EKC could not be conclusively supported for HIOECD countries because the coefficient of GGDG though is positive and statistically significant; however, the estimated parameter of $GDPG^2$ is negative but statistically insignificant. This is a robust finding and is in contrast to many empirical findings including (Han & Lee, 2013), which report a significant decline in the dependence of economic growth on pollution. This result concludes that in general a harmonious coexistence of economic growth and environmental conservation is possible for countries around the world.

Finally, we focus on the key research gap addressed in this paper i.e. understanding the regional differences on the relative contribution of different sector's outputs on CO_2 emission. The PMG result (table 6) shows that the industrial sector output, as expected, has a statistically significant positively influences the level of CO_2 emission in all different regions. So, the general idea about the negative environmental effect of industrialization is unequivocally confirmed across regions. Besides, higher industrialization has led to relatively higher level of CO_2 emission in high-income non-OECD and upper middle income countries compared to high income OECD, lower middle income, and low income countries. Interestingly, the coefficient of industrial output is relatively much higher in case of high income non-OECD countries compared to OECD countries. This clearly indicates the differences between these regions in term of the quality of economic output produced.

Further investigation about the contribution of different sectors in CO_2 emission (table 6) reveals some robust conclusions. The long-run impact of the service sector output on CO_2 emission across regions generally confirms that the shift from the industrial economy to service economy over the years is not a welcoming aspect of economic transformation in the high income countries. However, such transformation has led to a lower level of CO_2 emission in middle and low income countries. This is a significant finding. Service sector output exhibits a statistically significant positive coefficient of 0.021 and 0.008 for HINOECD countries and HIOECD countries respectively while statistically negative coefficient of -.002 and -.004 for low income and lower middle income countries respectively. Finally, the contribution of the agriculture output in CO_2 emission is not conclusive across all regions. However, the contribution of the agriculture output in CO_2 emission is positive and statistically significant for low income (0.002), lower middle income (0.001) and high income OECD (0.001) countries. The result probably signifies that, in high-income OECD and lower middle income countries usually use more technologies, toxic, and insecticides in the production of agriculture output which increases CO_2 emission per unit of agriculture output. Interestingly, though the low income countries still depend heavily on primitive agriculture technologies and logistics which reduce the level of CO_2 emission; however, in recent years there is significant increase in the use of pesticides in these countries as well. A comparative analysis of the overall result reveals that service output parameters for high income countries are much higher compared to industrial and agriculture output parameters. Therefore, the increasing contribution of service output in these countries economic growth is emitting more CO_2 compared to industrial and agriculture output. This finding is consistent with the findings of World Bank (2010). Additionally, Alcántara and Padilla (2009) argue that various parts of service sectors are increasingly emitting more CO_2 compared to other sectors of the economy. In fact, transportation sector, one of the major sub-sectors of the service sector, is responsible for a large degree of CO_2 emission. Due to the strong pull effect of service activities on other activities of the economy, the direct and indirect effect of service output in CO_2 emission is highly increasing.

With regard to the short run marginal effect, there is a significant variation across regions in the estimated coefficients under various models without any general pattern except in few instances (table 4 to 6). Results of PMG estimates (table 4) suggest that the impact of GDPG is generally negative for most of the regions except for HINOECD courtiers. However, the results are statistically significant for middle income (-0.001) and HINOECD (0.001) countries. This indicates that GDP growth rate significantly reduces the CO_2 emission in middle income countries, while increases emission in the HINOECD countries in the long run. Table 4 also shows that TO increases the level of CO_2 emission for low income and lower middle income countries, while reduces the emission in HINOECD countries even in the short-run contracting the findings for long-run. The result possibly indicates that TO exert its immediate positive effect on output growth by opening up the avenues of international market opportunities for low income countries, and this has lead to increase in CO_2 emission the short-run. However, adoption of better technologies or stringent guidelines on environmental standard in the long-run may wind out such effect in the long-run. Moreover, size of the population does not exert any statistically significant influence on CO_2 emission in the short-run. Finally, the results of short-run impact of sectoral output (table 6) suggest that except the short run significant impact of the industrial output on CO_2 emission in HIOECD countries, the overall short-run coefficients of sectoral outputs are statistically insignificant for all other regions. Therefore, it can be concluded that, sectoral outputs do not have any short term impact on CO_2 emission across the world.

5. Conclusion and Policy Implications

The aim of this paper is to examine the relationship between CO_2 emissions and economic growth across the world for 1980-2009 period. The current study has highlighted several interesting findings. First, in contrast to existing public perception, high-income countries are emitting more CO_2 per 1% increase in output. Second, industrial output increases the level of CO_2 emission across the world. While, service output increases more CO_2 emission compared to industrial and agriculture output in high income countries in the long-run. Therefore, there is a major anomaly in the way the transformation in high income countries towards service oriented economy has been worked out. However, service output reduces the level of CO_2 emission for low income and lower middle income countries indicating that such transformation has benefited these countries. Fourth, there is a clear presence of EKC across regions except for high-income OECD countries. Finally, economic liberalization has generally reduced the level of CO_2 emission, while size of the population increased the level of CO_2 emission across regions in the long-run.

The overall findings of the study offer some serious policy implications in reducing CO_2 emission across the world. Since high-income countries generate more CO_2 emission per 1% growth in GDP, the current levels of environmental conservatism efforts by these countries are clearly not sufficient. In fact, given their economic size and level of their prosperity, these countries should channel more resources and logistics to minimize CO_2 emission in augmenting their output growth. The idea of putting higher green tax on output in these countries can be one of the appropriate mechanisms to reduce the overall CO_2 emission across the world. Furthermore, in strict environmental conservation sense, these countries should reduce their output if they continue to fail in reducing the level of CO_2 emission intensity since there are other countries producing similar output with less CO_2 emission.

Since service sector emits the highest level of CO_2 in high income countries, strategy to reduce CO_2 must consider a wider understanding of the service sector, an understanding that consider wholesale and retail trade, transportation, real estate, hotels and restaurants, the tourism industry and other service sub-sectors. Alcántara and Padilla, (2009) argue that these service sub-sectors are notably responsible for a significant increase in emissions experienced during recent years. O'Mahony et al. (2012) also argue that an increase in the intensity of the transport sector contributes to a significant increase in emissions. But these services received very little attention during the design of policies aimed at reducing emissions.

Despite the presence of EKC for LIC, LMIC, UMIC, and HINOECD countries, since, the parameter of GDPG is much higher than the parameters of $GDPG^2$, an increase in GDPG will have very slow impact on the reduction of CO_2 emission in the long run. Therefore, the ongoing effort to reduce CO_2 emission is not going to be very effective given the level of the challenge. The recent study of Intergovernmental Panel on Climate Change (2013) has clearly highlighted the intensity of the concern. Thus we need an intense and swift global effort to augment technological breakthrough for achieving environmental friendly and economically efficient output in the future. Muradov and Veziroglu (2008) argue that to satisfy the world's growing appetite for energy and keep our planet healthy; at least 10 TW (or terawatt) of carbon-free power has to be produced by mid-century. However, the level of technological breakthrough achieved so far to this end has not been so successful yet. So, carbon-negative system for production of synthetic fuels with sequestration of solid carbon can be an important alternative to clean up billion tons of CO_2 from the Earth's atmosphere. Living in this age of a hydrocarbon economy, the development and implementation of new CO_2-free routes to hydrogen production from NG and other hydrocarbons with recovery of solid carbon product may present an environmentally safe alternative to CO_2 sequestration. Furthermore, any technology that can recycle the billions of tons of CO_2 into renewable energy will be an important breakthrough to this end. The global community should put serious effort in augmenting a break-through technology, a technology that proves the idea of growth and environmental balance a very much realizable public good.

Since the size of the population is one of the most important variables contributing to CO_2 emission across regions; therefore, population control can be considered an effective mechanism to deal with the increasing problem of CO_2 emission. However, such solution is pretty shallow considering empirical findings (Simon, 1981; D.Gale Johnson, 1999; Fumitaka Furuoka, 2009; Dyson, 2010; Fumitaka Furuoka and Qaiser Munir, 2011, Minh Quang Dao, 2012; etc.) about the positive and significant effect of population size on economic growth in countries like China, India, Indonesia, Turkey, and Brazil, etc. Therefore, increasing the knowledge base of economic agents about saving energy and negative effect of greenhouse gas, practicing more energy-efficient living can also play a crucial role in minimizing CO_2 emissions. Recent studies by Lopes et al. (2012), Mikko et al. (2012), Nicola et al. (2012), Bradford et al. (2012), Anas et al. (2012), Ting et al. (2013), Chris et al. (2013), Dirk et al. (2013), Jillian et al. (2013), etc. are encouraging effort in crafting a comprehensive policy to achieve more energy efficiency leading to low carbon economies. Finally, as trade openness minimizes CO_2 emission, focus on incorporating rigorous environmental standard in the bilateral and multilateral trade and investment agreement should be duly prioritized.

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Appendix: List of countries included.

High Income Non OECD	**High Income OECD**	**Upper Middle Income**	**Lower Middle Income**	**Low Income Countries**
Bahamas	Australia	Algeria	Albania	Bangladesh
Bahrain	Austria	Angola	Belize	Benin
Barbados	Belgium	Antigua and Barbuda	Bhutan	Burkina Faso
Brunei Darussalam	Denmark	Argentina	Bolivia	Burundi
Cyprus	Finland	Botswana	Cameroon	Central African Rep.
Equatorial Guinea	France	Brazil	Cape Verde	Comoros
Kuwait	Hungary	Bulgaria	Congo, Rep.	Congo, Dem. Rep.
Malta	Ireland	Chile	Cote d'Ivoire	Ethiopia
Oman	Italy	China	Djibouti	Gambia
Saudi Arabia	Japan	Colombia	Egypt, Arab Rep.	Gambia
Singapore	Korea, Rep.	Costa Rica	El Salvador	Guinea
St. Kitts and Nevis	Luxembourg	Cuba	Fiji	Guinea-Bissau
Trinidad and Tobago	Netherlands	Dominica	Ghana	Kenya
United Arab Emirates	New Zealand	Dominican Republic	Guyana	Liberia
	Norway	Gabon	Honduras	Madagascar
	Poland	Grenada	India	Malawi
	Portugal	Iran, Islamic Rep.	Indonesia	Mauritania
	Spain	Jamaica	Kiribati	Mozambique
	Sweden	Jordan	Lao PDR	Nepal
	Switzerland	Lebanon	Mongolia	Niger
	United Kingdom	Malaysia	Morocco	Rwanda
	United States	Maldives	Nicaragua	Sierra Leone
		Mauritius	Pakistan	Tanzania
		Mexico	Papua New Guinea	Togo
		Palau	Paraguay	Uganda
		Panama	Philippines	Zimbabwe
		Peru	Senegal	
		Romania	Sri Lanka	
		Seychelles	Sudan	
		South Africa	Swaziland	
		St. Lucia	Syrian Arab Republic	
		St. Vincent and the Grenadines	Tonga	
		Suriname	Vanuatu	

		Thailand	Vietnam	
		Tunisia	Zambia	
		Turkey		
		Uruguay		
		Venezuela, RB		

Table 1: Farrar Glauber (1976) Multicollinearity Test

	LIC		LMIC		UMIC		HINOECD		HIOECD	
	F-Test	P-Value	F-Test	P-Value	F-Test	P-Value	F-Test	P-Value	F-Test	P-Value
GDPG	3.055	0.140	5.026	0.061	4.097	0.087	5.365	0.055	8.765	0.022
ln(IVA)	31.120	0.002	259.165	0.000	1265.473	0.000	262.786	0.000	692.603	0.000
ln(AVA)	84.970	0.000	89.503	0.000	63.352	0.000	31.405	0.002	47.388	0.001
ln(SVA)	37.812	0.001	268.630	0.000	1338.431	0.000	259.135	0.000	769.764	0.000
TO	47.422	0.002	261.421	0.000	1263.262	0.000	268.524	0.000	679.465	0.000
lnP	25.997	0.003	45.033	0.001	99.239	0.000	12.877	0.011	12.886	0.011

Table 2: Result from panel unit root test with level and no trend$^{\times}$ and individual intercept and no trend under 1st difference$^{\times\times}$.

Variables	Common unit root process		Individual unit root process					
	Levin, Lin & Chu t		Im, Pesaran and Shin W-stat		ADF - Fisher Chi-square		PP-Fisher Chi-square	
	At Level×	1st Diff. ××	At Level	1st Diff.	At Level	1st Diff.	At Level	1st Diff.
GDPG	5.69	-33.51***	7.73	-48.05***	0.25	2341.13***	0.13	333.97***
GDPG^2	-0.64	-64.54***	-2.11*	-53.05***	26.16**	3384.97**	58.12*	1846.33**
ln(IVA)	-1.05	-0.09	-1.04	-19.52***	291.71	883.18***	11.54	2370.84***
ln(SVA)	32.61	-3.31*	3.78	-19.15***	242.64	897.95***	296.04	2484.29***
ln(AVA)	-1.58*	-3.58***	0.85	-14.84***	14.32	695.18***	15.17	2251.47***
TO	-1.03	-7.97***	-1.18	-19.90***	290.65	905.08***	332.81*	2298.46***
lnP	14.44	-3.69***	3.51	-11.80***	72.29	337.20***	49.16	332.34***

***, **, * refers significance at 1%, 5% and 10% respectively.

Table 3: Results from Westerlund (2007) panel cointegration test

	High Income OECD		High Income Non OECD		Upper Middle Income		Lower middle income		Low income countries	
Statistic	Value	Z-stat	Value	Z-stat	Value	Z-stat	Value	Z-stat	Value	Z-stat
$G\tau$	-2.549***	-4.016	-2.797***	-3.974	-2.238***	-3.180	-2.783***	-4.123	-2.413***	-3.737
$G\alpha$	-9.745*	-1.517	-7.984	-0.104	-6.060	1.728	-7.602	-0.754	-7.298	0.410
$P\tau$	-10.931***	-3.418	-12.29***	-5.800	-12.253***	-3.155	-11.343***	-3.265	-17.020***	-7.963
$P\alpha$	-7.850**	-2.777	-12.417***	-4.859	-6.181**	-1.865	-7.261**	-2.181	-14.672**	-8.236

Note: $G\tau$ & $G\alpha$ are group mean statistics that test the null hypothesis of no cointegration against the alternative hypothesis of cointegration among some of the selected countries. $P\tau$ & $P\alpha$ are the panel statistics that test the null of no cointegration against the alternative hypothesis of cointegration among all of the selected countries.

$$\Delta \mathrm{lnCO}_{2i,t} = \mu_i + \varphi_i(\mathrm{lnCO}_{2i,t\text{-}1} - \lambda_1 \mathrm{GDPG}_{i,t-1} - \lambda_2 \mathrm{TO}_{i,t-1} - \lambda_3 \mathrm{lnPop}_{i,t-1}) + \sum\nolimits_{j-1}^{p-1} \gamma_j^i \Delta(\mathrm{lnCO}_{2i})_{t-j}$$
$$+ \sum\nolimits_{j=0}^{q-1} \delta_{1j}^{\,i} \Delta \mathrm{GDPG}_{i,t-j} + \sum\nolimits_{j=0}^{q-1} \delta_{2j}^{\,i} \Delta \mathrm{TO}_{i,t-j} + \sum\nolimits_{j=0}^{q-1} \delta_{3j}^{\,i} \Delta \mathrm{lnPop}_{i,t-j} + \delta_{i,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(08.1)$$

Table 4: The nature of regional differences on the dynamic impact of GDPG, TO, lnP on CO_2 emission.

	LIC			LMIC			UMIC			HINOECD			HIOECD		
CO_2	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Long run															
GDPG	.005***	.001***	.002*	.010*	.009***	.030***	.002	.019***	.036***	.013	.002*	.007*	.016	.007***	.023***
TO	-.001	-.001**	.001	.002*	-.0001	.0004	.000	-.000	.001	-.003**	-.000	-.001	-.002	-.001***	-.001*
lnP	.037	.025***	.009	.076	-.039	.175	1.523	1.272***	.399*	.930**	.345***	.247***	.885	.080***	.353***
Short run															
ECM	-.501***	-.268***	.407***	-.465***	-.252***	-.114***	-.464***	-.181***	-.089***	-.498***	-.249***	-.196***	-.484***	-.309***	-.115***
ΔGDPG	-.001*	-.001	-.001*	-.001	-.001**	-.001	-.001**	-.001*	-.000	.000	.0009**	.001	-001**	-.000	-.000
ΔTO	-.000	.001*	-.001	.000	.001**	.0001	-.000	-.000	-.000	.000	-.001*	-.001*	.0004*	.000	-.000
ΔlnP	-3.341	-1.646	.269	.987	-.824	-.356*	1.541	1.123	-1.066**	2.471**	-.353	.401**	.336	-.461	-.224
α	-.123	.006	-.007	-.997	.329***	-.249	-5.267**	3. 283***	-.428	-3.346**	-.905***	-.446	-1.322	-.056***	-.554**
Hausman test (DFE, PMG)		2.34			18.44***			20.76***			8.28*			22.23**	

Note: LIC = Lower income countries; LMIC = Lower middle income countries; UMIC = Upper middle income countries; HINOECD = High income non-OECD countries; HIOECD = High income OECD countries
The dependent variable is CO_2 emission. Parameters significance at 1%, 5% and 10% levels have been represented by ***, **, and * respectively.

$$\Delta \mathrm{lnCO}_{2i,t} = \mu_i + \varphi_i(\mathrm{lnCO}_{2i,t\text{-}1} - \lambda_1 \mathrm{GDPG}_{i,t-1} - \lambda_2 \mathrm{GDP}^2_{i.t-1} - \lambda_3 \mathrm{TO}_{i,t-1} - \lambda_4 \mathrm{lnPop}_{i,t-1}) + \sum\nolimits_{j-1}^{p-1} \gamma_j^i \Delta(\mathrm{lnCO}_{2i})_{t-j}$$
$$+ \sum\nolimits_{j=0}^{q-1} \delta_{1j}^{\,i} \Delta \mathrm{GDPG}_{i,t-j} + \sum\nolimits_{j=0}^{q-1} \delta_{2j}^{\,i} \Delta \mathrm{GDPG}^2_{i,t-j} + \sum\nolimits_{j=0}^{q-1} \delta_{3j}^{\,i} \Delta \mathrm{TO}_{i,t-j} + \sum\nolimits_{j=0}^{q-1} \delta_{4j}^{\,i} \Delta \mathrm{lnPop}_{i,t-j} + \delta_{i,t} \quad \ldots\ldots\ldots(08.2)$$

Table 5: The nature of regional differences on the dynamic impact of GDPG, TO, lnP on CO_2 emission.

	LIC			LMIC			UMIC			HINOECD			HIOECD		
CO_2	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Long run															
GDPG	-.000	.001***	.002**	.015*	.010***	.036***	.002	.021***	.040***	.001	.009***	.007	.008	.006***	.023***
$GDPG^2$	.001	-.0001*	-.000	-.000	-.0003*	-.001***	-.001	-.001***	-.000	.000	-.001***	.000	.001	-.0002	-.0003
TO	-.001	-.0004***	.000	.002*	.000	.001	.005	-.001	.002	-.003**	-.000	-.001	-.002	-.001***	-.0001*
LnP	.042	.026***	-.007	-.070	-.053*	.124	-.149	-1.245**	.372	1.386**	.239***	.248**	.940	.094***	.350**
Short run															
ECM	-.507***	-.268***	-.408***	-.450***	-.251***	-.114***	-.474***	-.181***	-.089***	-.481***	-.224***	-.197***	-.493***	-.315***	-.119***
ΔGDPG	-.001	-.000	-.001*	-.001	-.001	-.001*	-.001	.000	-.001	-.001	-.001	.001	.000	.001*	.000
$\Delta GDPG^2$	-.000	-.000	.000	.000	.000	.001	-.000	-.000	.000	-.000	.001	.000	-.000	-.0004***	-.000
ΔTO	-.000	-.000	.000	.000	.0004**	.000	-.000	-.000	.-000	.000	-.001**	-.001*	.000	.000	-.000
ΔlnP	-2.889	-1.550	.240	-.015	-.832	.304	1.978	1.347	-1.062**	3.555*	.096	.398**	.317	-.491	-.221
α	-.129	.004	.011	-.759	.372***	-.159	-5.735**	3.224	-.394*	-3.562*	-.663**	-.447	-1.374	-.123***	-.564**
Hausman test (DFE, PMG)		7.26			20.73***			23.15***			48.01**			22.54***	

Note: LIC = Lower income countries; LMIC = Lower middle income countries; UMIC = Upper middle income countries; HINOECD = High income non-OECD countries; HIOECD = High income OECD countries
The dependent variable is CO_2 emission. Parameters significance at 1%, 5% and 10% levels have been represented by ***, **, and * respectively.

$$\Delta \ln CO_{2\,i,t} = \mu_i + \varphi_i (\ln CO_{2\,i,t-1} - \lambda_1 \ln IVA_{i,t-1} - \lambda_2 \ln AVA_{i,t-1} - \lambda_3 \ln SVA_{i,t-1} - \lambda_4 TO_{i,t-1} - \lambda_5 \ln Pop_{i,t-1}) + \sum_{j-1}^{p-1} \gamma_j^i \Delta(\ln CO_{2\,i})_{t-j} + + \sum_{j=0}^{q-1} \delta_{1\,j}^{\;i} \Delta \ln IVA_{i,t-j} + \sum_{j=0}^{q-1} \delta_{2\,j}^{\;i} \Delta p \ln SVA_{i,t-j} + \sum_{j=0}^{q-1} \delta_{3\,j}^{\;i} \Delta \ln AVA_{i,t-j} + \sum_{j=0}^{q-1} \delta_{4\,j}^{\;i} \Delta T0_{i,t-j} + \sum_{j=0}^{q-1} \delta_{5\,j}^{\;i} \Delta \ln Pop_{i,t-j} + \delta_{i,t} \quad \text{.......................}(08.3)$$

Table 6: The nature of regional differences on the dynamic impact of IVA, SVA, AGV, TO, lnP on CO_2 emission.

	LIC			LMIC			UMIC			HINOECD			HIOECD		
CO_2	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE	MG	PMG	DFE
Long run															
ln(IVA)	0.003	0.004***	0.002	-0.000	0.009***	0.015***	-.002	.009***	.037***	-.045	0.019***	0.016***	0.013	0.004**	0.012***
ln(SVA)	0.011	-0.002***	0.000	-0.000	-0.004***	0.013***	-.030	-.000	.019**	-.056*	0.021***	0.012**	0.013*	0.008***	0.008**
ln(AVA)	0.009	0.002*	-0.001	-0.002	0.001***	0.001	-.017*	.000	-.001	.017	-0.001	0.001	-0.008	0.001***	0.001
TO	0.000	0.001***	0.000	0.001	-0.0003**	0.000	-.001	.000*	.001	-.001	-0.000	-0.001**	-0.000	-0.002***	-0.001*
lnP	0.066	0.058***	0.008	0.606	-0.096***	0.093	1.860*	.782***	.222	.194	-.055*	.094	.003	-.176***	.312***
Short run															
ECM	-0.795***	-0.317***	-0.439***	-.706***	-0.293***	-0.165***	-.775***	-.303***	-.112***	-.632***	-0.322***	-0.306***	-0.659***	-0.272***	-0.143***
Δln(IVA)	0.005	-0.001	-0.001	0.002	-0.001	0.001	-.001	.004	-.001	.033*	0.012	-0.001	0.000	0.002*	0.001
Δln(SVA)	-0.010	0.000	-0.001	0.006	0.000	-0.001	.002	-.000	-.000	.036*	0.009	-0.003*	-0.000	-0.000	-0.000
Δln(AVA)	-0.005	0.000	0.001	0.004	-0.002	-0.000	.005*	.003	-.001	-.001	0.006	0.000	0.000	-0.001	0.000
ΔTO	-0.0003*	-0.000	0.000	-0.000	0.000	0.000	.000	-.000	-.000	-.001	-0.001	-0.000	0.0005**	0.000	0.001
ΔlnP	-4.838	-.787	.612***	7.311	-.144	.043	6.389**	.613	-.794	-.027	-1.906*	-.562***	1.798**	-.361	-.141
α	-2.288	-0.241***	0.008	-9. 971	0.482***	-0.317	-17.71**	-3.259***	-.494	1.141	.016	-.430	-.890	.910***	-.718**
Hausman test (DFE, PMG)	15.89***			27.44***			18.45**			29.25**			26.97***		

Note: LIC = Lower income countries; LMIC = Lower middle income countries; UMIC = Upper middle income countries; HINOECD = High income non-OECD countries; HIOECD = High income OECD countries
The dependent variable is CO_2 emission. Parameters significance at 1%, 5% and 10% levels have been represented by ***, **, and * respectively.