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Effects of Urbanization, Industrialization, Economic Growth, Energy Consumption and Financial Development on Carbon Emissions: An Extended STIRPAT Model for Heterogeneous Income Groups

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Abstract

This study examines the effects of urbanization and industrialization on carbon emissions for a panel of 156 countries and various income groups over the period 1990-2014 employing the first and second-generation tests. To address the issues of heterogeneity, endogeneity, and cross-sectional dependence, dynamic generalization method of moments (GMM), common correlated effects mean group (CCEMG) and dynamic CCEMG estimation procedures are applied. Carbon emissions, urbanization, industrialization, economic growth, financial development, and energy consumption are integrated of order one. The results show that urbanization and industrialization have statistically positive and significant effects on carbon emissions across all panel groups. Whereas economic growth exerts heterogeneous effects on environmental pollution, validating the implications of "environmental Kuznets curve". Similarly, financial development raises pollution in all income groups except high-income countries. The findings did not confirm "theory of ecological urbanization" while the evidence on "ecological modernization theory" is inconclusive. Overall findings imply that the global challenge of environmental pollution is mainly aggravated by rapid urbanization and industrialization whereas economic growth, financial development, and energy consumption have heterogeneous effects depending upon the development stage of countries. This study recommends that sustainable urbanization and industrialization need to be promoted using green finance and clean energy sources.

Keywords: environment, climate change, greenhouse gases, industrial growth, urbanization, CO_2 emissions, energy consumption, financial development, GDP.

1. Introduction

From the past few decades, climate change and global heating have emerged as global challenges, widely attributed to greenhouse gas (GHG) emissions which trap heat into the earth surface. The blanket of trapped heat increases frequency and intensity of storms and droughts including melting of glaciers and rising sea levels. The CO_2 emissions constitute 73% of GHG emissions, produced by fossil fuels combustion owing to various anthropogenic activities (European Commission, 2017). Accordingly, environmental degradation has become a severe threat to natural habitat of humans and other species on the earth (Majeed & Mumtaz, 2017).

Among GHG emissions, CO_2 is considered as dangerous and prevalent emissions in the atmosphere as its concentration has risen about 43% since the start of industrialization. The World Bank (2020) statistics show that the global rise in carbon emissions (metric tons per capita) are recorded from 4.19 in 1990 to 4.98 in 2014. However, for high-income countries (HICs) carbon emission increased from 11.41 to 10.92 over the same period. For upper-middle-income countries (UMICs) and lower-middle-income countries (LMICs), the emissions also increased from 3.42 to 6.52 and 0.97 to 1.46, respectively, over the years 1990-2014. This significant rise in CO_2 emissions has become a concern of researchers and policy makers all over the world.

Urbanization and industrialization are widely viewed as the primary sources of growth performance and climate change. The World Bank (2020) estimates suggest that global urbanization has increased from 43.03 percent in 1990 to 53.46 percent in 2014. However, the extent of this increase varies for different income groups over the same period. For example, urbanization in HICs countries rose from 74.26 to 80.62 percent. For UMICs and LMICs, it increased from 43.04 and 29.79 to 62.94 and 38.66, respectively. In the 1990s, LICs had 23.26 urban population, which later has increased to 30.88 in 2014. Thus, urban population growth varies considerably across the development stage of countries.

According to the World Bank (2020) global industrialization trend shows that world industrialization has increased rapidly from 11 billion (constant 2010 US$) in 1994 to 204 billion in 2014. Similarly, for HICs industrialization has grown from 92 billion in 1997 to 113 billion in 2014. In the case of UMICs, industrialization increased from 241 billion to 725 billion and 60 billion to 169 billion for LMICs over the same time. For LICs, industrialization increased from 63 million to 1 billion. These trends indicate that industrial growth has been an increasing phenomenon since the end of 20^{th} century.

The empirical literature suggests that urbanization and industrialization are the key determinants of CO_2 emissions. Wang et al. (2018) explored the impact of urbanization along with growth and energy use for a panel of 170 economies and for various income groups. The study, however, did not account the role of industrialization. Further, the study did not consider second generation tests and estimators. Bekhet & Othman (2017) analyzed the relationship of urbanization with CO_2 emissions for Malaysia using conventional time series analysis. Lin et al. (2009), Wang et al. (2011) and Wu et al. (2016) examined the impact of urbanization on CO_2 emissions for China. Zhou et al.

(2013) and Liu & Bae (2018) explored the effects of urbanization and industrialization on CO_2 emissions for China using conventional time series estimation techniques.

The use of conventional estimation methods in analyzing the role of urbanization and industrialization together and the failure to consider the dissimilarities in countries on the bases of their income levels motivate our study analysis. The objective of this study is to investigate the impact of urbanization and industrialization on CO_2 emissions for a panel of 156 countries considering the differences in their income levels. The theory of 'urban environmental transition' and the theory of 'urbanization and ecological environment' form the basis of urbanization, industrialization, and environment association. The urban environmental transition theory suggests that several environmental challenges appear as cities evolve. The metropolisation and industrialization evolution shifts environmental issues from brown, to grey, to green locally and across borders. Resultantly, the natural ecosystem gets threatened and disturbed. However, ecological urbanization theory suggests that urbanization does not result in environmental degradation rather it helps to sustain the environment by increasing income and environmental awareness, encouraging people to adopt eco-friendly lifestyles. Ecological modernization theory suggests that in the initial stages of modernization, the environment deteriorates but improves at later stages when green technologies are introduced.

This study contributes to the existing literature in the following ways. First, to the best of our knowledge this is the first study that explores the impact of urbanization and industrialization together on CO_2 emissions for a global panel of countries and for four different income groups. Second, we improve the methodological part of the existing studies by employing first as well as second generation estimation procedures for overcoming the complex econometric problems such as heterogeneity, endogeneity and cross-sectional dependence. Furthermore, fully modified ordinary least squares (FMOLS), dynamic OLS and dynamic GMM are employed for the detailed analysis. Third, parameter estimates are also obtained by employing CCEMG and DCCEMG methods, which allow slope heterogeneity and cross-sectional dependence. Fourth, it investigates urbanization and industrialization role in a comparative analysis among different income groups. Fifth, we have used economic growth, financial development, and energy consumption in a global framework, which is an emerging research area. Sixth, the implications and usefulness of this study are pluralistic and have wider scope as urbanization is a standard control variable not only in environmental and energy literature but also serves as control variable in all other macroeconomic empirical models.

The remaining study is arranged as follows: Section 2 reviews the existing literature. Section 3 explains the data and methodology. Section 4 consists of results and discussion. Section 5 presents conclusion with some policy suggestions.

2. Literature Review

The literature on the relationship of the environment with anthropogenic activities has produced various hypothesis and theories. Some important among them are: i) environmental Kuznets Curve (EKC), which explores the nonlinear association between economic growth and environmental quality, ii) pollution haven hypothesis (PHH), which explores the relationship between foreign trade/ FDI inflows and environmental quality, iii) the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model, which explores the links of population, technology and economic growth, including other variables, with the environmental degradation.

The EKC hypothesis suggests that as the economy grows, environmental degradation increases but with higher economic growth (when the economy becomes richer) environmental quality improves. The PHH predicts that opening of developing countries for trade and FDI inflows increase emissions because of environmental regulations. Within the STIRPAT framework, many studies have explored the effects of population growth (urbanization), affluence (economic growth), and technology (industrialization) on environmental degradation. The STIRPAT model considers anthropogenic activities as the driving forces of climate change. This study examines the effects of urbanization, industrialization, and economic growth including energy consumption and financial development in STIRPAT framework. Further discussion is provided into the following sub-sections.

2.1 Economic Growth and CO_2 Emissions

The EKC has been extensively explored and many empirical studies have been tested it. Generally, panel data empirical studies use a quadratic equation to estimate EKC and generalize the findings for heterogeneous income groups. The literature on EKC, however, is not yet conclusive (Majeed & Mazhar, 2020). The studies such as Grossman & Krueger (1995), Majeed (2018), Majeed & Luni (2019) confirm the validity of EKC. However, the studies such as Harbaugh & Levinson (2002) and Mills & Waite (2009) did not support EKC concerning the role of affluence and population on the environment.

The basic philosophy of the EKC is rooted in the economic strength of an economy. That is, the rich economies are likely to exhibit favorable impact of economic growth on the environment while the poor countries show unfavorable effects. The prominent reasons for such heterogeneous effects are (i) the poor countries rely on traditional pollution intensive technology and compromise the environment to achieve higher economic growth, while the rich countries value the environment and adopt green and eco-friendly technologies and (ii) the poor countries use traditional sources of energy such as coal, fossil fuels and natural gas, whereas the rich countries use clean energy sources such as renewable and nuclear energy. In this study, we examine the impact of economic growth to validate EKC implications in heterogeneous income groups.

2.2 Urbanization and CO_2 Emissions

Theoretical underpinnings of urbanization and environmental quality can be traced from following theories. First, urban environmental transition theory suggests that cities endure various environmental issues during industrialization and development stages. Their environmental issues experience a transition from brown (water related issues) to grey (auto and industrial pollution) to green (anthropogenic gasses) agenda. Second, the theory of ecological urbanization postulates that urbanization provides a way forward for achieving sustainability through following ways: i) it increases the overall income level which encourages individuals to use eco-friendly services, ii) it improves environmental awareness by providing interactive and social services, and iii) it promotes eco-friendly research and development (R&D) activities and innovations, thus preserving environmental quality. Third, the compact city theory implies that "higher urbanization improves the environmental quality by increasing the productivity, efficiency and economies of scale in public infrastructure" Majeed & Mazhar, 2019b).

Theoretical literature also suggests several channels through which urbanization influences the environment. First, increasing urbanization raises the demand for basic infrastructure, which increases deforestation and environmental degradation (Sadorsky, 2013). Second, urbanization increases transportation, fuel consumption and other anthropogenic activities, creating air pollution (Liu & Bae, 2018; Li et al., 2019). Third, it increases industrial production (scale effect), increasing air pollutants in the atmosphere (Kalhor & Mahdisoltani, 2015; Guo et al., 2016; Zhou & Wang, 2018; Liu & Bae, 2018; Samreen & Majeed, 2020). Fourth, it distorts equilibrium of natural habitats as cites create new habitats for some species (pigeons, sparrows, flies) and eradiate for others (native species) (Uttara et al., 2012). Fifth, it triggers other eco-environmental challenges such as traffic congestion, industrial dumps, contamination dispersal, municipal wastes, and development of slums.

On the other hand, the literature also considers favorable effects of urbanization on environment. Urbanization develops such urban cultures, which support optimal utilization of energy sources (Parik & Shukla, 1995; Alam et al., 2007). Second, urbanization enhances productivity by producing the same output using fewer resources owing to positive externalities and economies of scale. Third, it promotes the services sector, which pollutes less than other sectors such as manufacturing and transport sectors. Fourth, innovations such as green technologies also help to conserve the environment. Fifth, it also promotes energy efficiency and clean energies. The use of renewable energy resources (solar, wind, geothermal, hydroelectric and biomass) also lowers environmental pressures (European Environment Agency, 2008; Majeed & Luni, 2019). Sixth, as cities are more economically developed, they increase production efficiency, abating pollution discharge (Tao et al., 2016).

The empirical literature can be grouped as follows: The first strand of the literature advocates the environmental deteriorating effect of urbanization. Studies such as Parikh & Shukla (1995), York et al. (2003), Al-Mulali & Ozturk (2015) and Bekhet & Othman (2017) reported the positive impact of urbanization on CO_2 emissions. Parikh & Shukla (1995) for Sub-Saharan economies, York et al. (2003) for global panel, Al-Mulali & Ozturk (2015) for MENA countries, and Bekhet & Othman (2017) for Malaysian economy concluded that urbanization increases carbon emissions.

The second strand of the literature suggests environment conserving effects of urbanization. Barala et al. (2011) concluded a negative linear relationship between urbanization and carbon emissions, as urbanization helps to achieve economies of scale for public infrastructure. Martinez et al. (2018) noted that urbanization enhances environmental awareness. They found favorable effects of urbanization on the environment for Colombia.

Another strand of the literature proposed an inverted U-shaped effect of urbanization on CO_2 emissions. The studies such as Xu et al. (2016) and Xu & Lin (2017) for China and Abdouli et al. (2018) for BRICS countries proved the existence of Kuznets Curve in urbanization environment linkage. Likewise, using a panel data model, Abdouli et al. (2018) concluded that initially urbanization deteriorates the environment. However, after reaching a certain threshold it improves the environment.

2.3 Industrialization and CO_2 Emissions

The ecological modernization theory advocates that industrialization is non-linearly related with environmental quality. In the initial stages of modernization, there is less industrial development which contributes to the environmental issues. However, these issues tend to reduce in the longer term with the introduction of alternative eco-friendly modern technologies and with the greater public awareness about the environmental quality (Majeed & Mazhar (2019a). Moreover, willingness to pay for the cleaner environment also increases.

The empirical literature on industrialization and the environment nexus can be grouped as follows. The first strand of literature suggests the environmental damaging impact of industrialization. This is supported by the studies such as Wang et al. (2011), Al-Mulali & Ozturk (2015), Hong et al. (2019), Li et al. (2019) and Samreen & Majeed (2020). Wang et al. (2011) found that the heavy industry of China significantly contributed to carbon emissions. Al-Mulali & Ozturk (2015) provided similar results for MENA countries. Similar results are also proved by Liu & Bae (2018) for China, by Pata (2018) for Turkey, Hong et al. (2019) for South Korea and Samreen & Majeed (2020) for a panel of 89 countries.

The second strand of literature reports favorable effects of industrialization on CO_2 emissions. Zhou et al. (2013) reported the environmental conservation impact of industrialization for Chinese economy owing to upgrading and optimization of industrial structure. Congregado et al. (2016) concluded favorable environmental effects of industrialization for the USA because of replacing fossil fuels consumption by renewable energy sources.

The third strand supports the environment conserving impact of industrialization using EKC argument. Economies tend to converge as they develop because countries use more advanced and eco-friendly technologies in their production system. The studies such as Xu & Lin (2015) have identified favorable impacts of industrialization on CO_2 emissions. These studies suggest that industrialization increases domestic production enhances. This rise in production, lowers return on capital and rises attempts to cleaner environment ultimately inverted U-shaped relationship is observed.

2.4 Financial Development and CO_2 Emissions

Financial development is an important determinant of environmental quality. The literature suggests both positive and negative effects of financial development on carbon emissions (Majeed & Mazhar (2019b). On the one hand, the financial sector finances production activities, which create pollution if production relies on conventional energy sources and pollution-intensive technologies. Similarly, credit facilities for unnecessary consumption put pressure on the ecosystem. Financial development attracts foreign direct investment, which also harms the environment when environmental regulations are weak. These augments are verified by many studies such as Zhang (2011), Boutabba (2014) and Majeed et al. (2020). On the other hand, the financial sector also contributes to a clean environment by providing finance for clean and eco-friendly technologies. Studies such as Tamazian et al. (2009), Islam et al. (2013), and Saidi & Mbarek (2017) also evident that financial development reduces CO_2 emissions.

2.5 Energy Consumption and CO_2 Emissions

Energy consumption is another key determinant of environmental quality. Energy consumption deteriorates the environment because conventional energy sources emit GHGs in the atmosphere. However, if a major share of energy consumption comprises renewable and nuclear energy, environmental quality improves (Majeed & Luni, 2019).

The above literature review suggests that urbanization and industrialization are the key determinants of environmental degradation. The existing studies are generally based on country-specific or regional experiences, which cannot be generalized for other groups of countries. Moreover, studies either analyze urbanization or industrialization. Further, these studies used conventional estimation techniques. To the best of our knowledge, an analysis based on global panel and heterogeneous income groups, including both urbanization and industrialization in the model is missing in the existing literature.

3. Data and Methodology

3.1 Data

This study used panel data of 156 countries from 1990 to 2014. The selected time span is subject to the data availability. The data for industrialization is unavailable before the 1990s for many of the sample countries while the data for CO_2 is not available after 2014. For a disaggregated analysis, countries are grouped into four classifications according to income levels following the World Bank (2020). Countries having income \$1005 and below fall in the category of LICs. Similarly, countries with income \$1006 to \$3955 and \$3956 to \$12,235 are labelled as LMICs and UMICs, respectively. Lastly, economies possessing \$12,236 and above are categorized as HICs. This study includes 34 LICs, 48 LMICs, 55 UMICs and 80 HICs. The data for all variables is extracted from the World Bank (2020). Table A1 provides the description of variables (see appendix for Tables A1-A9).

3.2 Econometric Model

This study follows the IPAT model, developed by Ehrlich & Holdren (1971), to represent the idea that "environmental impact (I) is the product of three factors: population (P), Affluence (A) and technology (T)." The IPAT identity is written as:

$$\mathrm{I = P\ x\ A\ x\ T} \dots\dots\dots\dots\dots (1)$$

Since IPAT model simply represents accounting identity, it cannot be used for hypothesis testing. We adopted a modification and a stochastic version of IPAT modelling that is "Stochastic Impacts by Regression on Population, Affluence and Technology

(STIRPAT)" developed by Dietz & Rosa (1997). The STIRPAT model adds elasticity to population, affluence and technology while calculating error term. The model is written as:

$$I_{it} = \alpha_i \, P_{it}^{\beta} \, A_{it}^{\gamma} \, T_{it}^{\delta} \varepsilon_{it} \ldots \ldots \ldots (2)$$

Where, α is a constant term, P: population, A: affluence, T: technology, β, γ, δ are parameters, ε is the error term and i represents the cross-sections (1,…..N) and t is the time period. To eliminate possible heteroscedasticity in panel estimation, we have applied natural logarithm on both sides of equation 2 and equation 3 can be written as follows:

$$InI_{it} = \alpha_i + \beta InP_{it} + \gamma InA_{it} + \delta InT_{it} + \omega_i + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (3)$$

Where, the term P denotes population represented by urbanization, the notation A denotes affluence measured by GDP, T is technology proxied by industrialization and t indicates the year. Further, α_i and ε_{it} represent country-specific effects. To investigate the impacts of these determinants on CO_2 emissions, we can rewrite the equation (3) as follows:

$$InCO_{2it} = \alpha_i + \gamma InGDP_{it} + \beta InUR_{it} + +\delta InIND_{it} + \omega_i + \varepsilon_{it} \ldots \ldots (4)$$

Many studies have used different control variables in determining changes in CO_2 emissions. To control the effects of other variables on carbon emissions in the STIRPAT model, we have used financial development and energy consumption. The equation 4 is extended as follows:

$$InCO_{2it} = \alpha_i + \gamma InGDP_{it} + \beta InUR_{it} + \delta InIND_{it} + \lambda InFD_{it} + \varphi InEC_{it} + \omega_i + \varepsilon_{it} \ldots (5)$$

Where, CO_2 is carbon emissions (kt), GDP denotes GDP per capita constant 2010US$, UR represents urbanization (% of total population), IND is industrialization as industry value added (constant 2010 US$), FD represents financial development proxied by the "domestic credit to private sector as % of GDP", EC shows energy consumption measured in "kg of oil equivalent per capita" and finally ε is the error term.

Theory such as EKC opposes IPAT modelling (Dietz et al., 2007). This contradiction arises on the environmental effects of population and affluence. The IPAT model postulates that environmental impacts increase linearly with population and affluence. Whereas the EKC assumes that a curvilinear association exists between environmental impacts and its determinants (Dietz et al., 2007). The EKC is often linked with 'ecological modernization theory' suggesting that there is a non-linear relationship among a country's environmental impact and raising levels of economic development. This nonlinear relationship is attributed to the fact that as economy the grows environmental degradation increases but after reaching a certain point environmental quality begins to improve (York et al., 2003). This theory is also supported by Maslow's hierarchy of needs since when a country meets a specific level of economic need, it starts assessing other needs like ecological sustainability. However, the EKC does not consider the environmental impact of outside borders since the environment cannot be isolated. Studies such as Mills & Waite (2009) did not support EKC the role of affluence and population on the environment.

The IPAT model also assumes that environmental impacts increase linearly with technology. Whereas pollution haven hypothesis (PPH) does not assume the role of technological growth. According to PPH developing countries are becoming pollution haven due to migration of dirty industries from advanced economies. The theory predicts that the environmental disaster in developing countries can occur as they specialize and export polluted goods due to comparatively weak environmental restrictions. Further, PPH assumes that the stringent environmental regulations of a country have no impact on trade of pollution intensive commodities. PPH ignores the role of technological advancement. The stringent environmental restrictions in a country induce clean and efficient technologies usage and, therefore, produce less pollution-intensive tradable goods and diminish environmental impact (Porter & Van der Linde, 1995). Studies such as Jaffe et al. (1995) did not support PHH on trade of pollution-intensive products.

3.3 Econometric Methodology

For a comprehensive analysis, we employed both first- and second-generation tests and estimation techniques. To test for the integrating order of the variables, panel URTs developed by Levin et al. (2002), Im et al. (2003), Breitung (2005) and Pesaran (2007) are employed. The reason to employ these several tests is to report both individual and common stationarity processes with (without) cross sectional dependence (CSD). For instance, the Levin et al. (2002), Im et al. (2003), Breitung (2005) being traditional methods do not account for CSD. Therefore, to induce CSD second generation URTs have been applied following Pesaran (2007).

To test for cointegrating relationships between the variables different tests are applied. Pedroni (1999) test provides both panel and group estimates. The panel tests are tested for the alternative hypothesis of presence of cointegrating relationship for the whole panel whereas, the group tests assume that at least one unit is cointegrated. Further, Pedroni (1999) also demonstrates varying multiple cointegrating regressors since it incorporates the effects of country size and heterogeneity within and between dimensions. On the other hand, Kao (1999) provides homogenous cointegrating vectors. Westerlund (2007) is a second-generation error correction based cointegration test incorporating unit-specific trend and short run dynamics and slope parameters. It also assumes cross-sectional dependence. For first generation analysis, DOLS introduced by Stock & Watsom (1993) and FMOLS developed by Pedroni (2000) are employed. The DOLS model is specified as follows:

$$\begin{aligned} CO2_{i,t} = {} & \alpha_o + \alpha_1 GDP_{i,t} + \alpha_2 UR_{i,t} + \alpha_3 IND_{i,t} + \alpha_4 FD_{i,t} + \alpha_5 EC_{i,t} + \sum_{i=-l}^{i=l} \psi_i \Delta GDP_{i,t} \\ & + \sum_{i=-m}^{i=m} \beta_i \Delta UR_{i,t} + \sum_{i=-n}^{i=n} \varphi_i \Delta IND_{i,t} + \sum_{i=-o}^{i=o} \psi_i \Delta FD_{i,t} + \sum_{i=-p}^{i=p} \varphi_i \Delta EC_{i,t} \\ & + \varepsilon_{i,t} \dots \dots (2) \end{aligned}$$

Where, α is cointegrating vector, l, m, n, o, p are leads and lags length of the regressors. To account for cross-sectional heterogeneity and cater serial correlation and endogeneity issues FMOLS is used. The FMOLS estimates long run parameters using the following equation:

$$\hat{a}_{NT^*} - a = \left(\sum_{i=1}^{N} \hat{L}_{22i}^{-2} \sum_{t=1}^{T} (x_{it} - \bar{x})^2\right)^{-1} \sum_{i=1}^{N} \hat{L}_{11i}^{-1}\ \hat{L}_{22i}^{-2} \left(\sum_{t=1}^{T} (x_{i,t} - \bar{x})\ \varepsilon_{i,t}^{*}\ - T\hat{\gamma}_i\right) \ldots\ldots (3)$$

Where, $\varepsilon^{*}_{it} = \varepsilon_{it} - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \Delta x_{it}$; $\hat{\gamma}_i = \hat{\Gamma}_{21i} + \hat{\Omega}^{\circ}{}_{22i} - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} \left(\hat{\Gamma}_{22i} + \hat{\Omega}^{\circ}{}_{22i}\right)$

x_{it} represents all independent variables and $\bar{x}$ shows mean values (individual-specific). Furthermore, the t-statistics is calculated using the following equation:

$$t_{\hat{\alpha}_{NT^*}} = (\hat{\alpha}\ N^*T\ - \alpha) \left(\sum_{i=1}^{N} \hat{L}_{22i}^{-2} T \sum_{t=1}^{T} (x_{it} - \bar{x})^2\right)^{1/2} \rightarrow N(0,1) \ldots\ldots\ldots\ldots (4)$$

To complement the above stated static model specifications, this study also employed dynamic modelling methods that is dynamic system generalization method of moment (GMM). This additional specification enables us to estimate our analysis in dynamic framework, overcoming the issue of autocorrelation by using additional lagged dependent variables. Moreover, endogeneity is also controlled by dynamic GMM. The validity of the GMM estimators and presence of first and second order autocorrelation is checked from Sargan test and Arellano and Bond test, respectively. The dynamic model is specified as follows:

$$CO2_{i,t} - CO2_{i,t-1} = (1-\lambda)CO2_{i,t-1} + \alpha_1 GDP_{i,t} + \alpha_2 ENC_{i,t} + \alpha_3 FDE_{i,t} + \eta_i + \varepsilon_{i,t} \ldots\ldots (5)$$

Since ignoring CSD in panel data modelling leads to distorted and biased estimated parameter Pesaran (2007), we also employed common correlated coefficient (CCE) introduced by Pesaran (2007) and dynamic common correlated coefficient (DCCE) developed by Chudik and Pesaran (2015) to solve the problem of CSD. The CCE estimator can reliably estimate the heterogeneous coefficients around the cross sectional mean with an unobserved common factor and a heterogeneous factor loading. Following Chudik and Pesaran (2015) parameters are estimated as:

$$y_{i,t} = \beta_i + \alpha_i x_{i,t} + \delta_i \bar{y}_{i,t} + \eta_i \bar{x}_{i,t} + \varepsilon_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where, $y_{i,t}$ presents CO_2 emissions and $x_{i,t}$ are the selected regressors ($GDP_{i,t}$, $UR_{i,t}$, $IND_{i,t}$, $FD_{i,t}$, $EC_{i,t}$) δ_i corresponds to elasticity of $\bar{y}_{i,t}$ with respect to the cross-sectional average of CO_2 emissions and represents elasticity of $\bar{x}_{i,t}$ corresponding to the observed regressors. However, in the presence of dynamic specification, the CCE estimates become inconsistent owing to the inclusion of lagged dependent variable. Therefore, DCCE estimates are appropriate and consistent. It allows slope coefficients to be heterogeneous. The DCCE is efficient for balance and unbalance panel and even for small sample time series data. Moreover, it is based on autoregressive distributed lagged (ARDL) model with cross-sectionally augmented unit-specification, specified as follows:

$$y_{i,t} = \beta_i + \phi_i y_{i,t-1} + \alpha_{0i} x_{i,t} + \alpha_{1i} x_{i,t-1} + \sum_{1=0}^{P_T} \delta^{`}_{i,1}\, \bar{z}_{t-1} + \varepsilon_{i,t} \ldots\ldots\ldots\ldots\ldots (7)$$

Where, $\bar{z}_t = \frac{1}{N}\sum_{i=1}^{N} z_{it} = (\bar{y}_t, \bar{x}_t, \bar{g}_t)$, $y_{i,t-1}$ = CO_2 emissions , $x_{i,t}$= regressors, g= covariates.

4. Results and Discussion

This section presents results and discussion based on econometric findings, obtained using Eviews 9 and Stata 15.

4.1. Descriptive Statistics and Correlation Analysis

Table A2 presents summary statistics. The result signifies that the highest mean value of carbon emissions (289598.6) belongs to UMICs and the lowest (29317.35) is associated with LICs. The mean values of urbanization and industrialization correspond to development levels. That is, urbanization and industrialization increase with the development stage of the countries. Table A3 reports correlation statistics. The results reveal that there is a positive and significant correlation between urbanization and CO_2 emissions for HICs and LICs while negative and significant for UMICs and LMICs. The carbon emissions have the highest correlation with industrialization and comparatively the lowest correlation with economic growth for all panels.

4.2. The Cross-Section Dependence Test (CSDTs)

Table A4 reports the results obtained using various CSDTs. Countries depend on each other because of unobserved characteristics and other factors. The results confirm the presence of CSD among all variables as the null hypothesis of no cross-sectional dependence fails to accept for all panel groups.

4.3. Panel Unit Root Tests (URTs)

This study employs both first and second generation URTs. Levin et al. (2002) and Im et al. (2003) are most employed URTs for checking the stationarity of a variable. The results reported in Table A5 suggest that almost all the series are non-stationary at level as p-values are > 0.1. Table A6 illustrates the findings of URTs at first difference. All coefficients fail to accept the null hypothesis (presence of a unit root) because the probability values are statistically significant (P<0.1). Therefore, both first- and second-generation URTs indicate that all panels are stationary at first difference and hence are integrated of order one.

4.4. Panel Cointegration Tests

Table A7 illustrates panel cointegration estimates using Pedroni and Kao cointegration tests. The null hypothesis of no cointegration is not accepted for all income groups as coefficients (bold values) indicate the presence of long-run association between the variables. Moreover, this study also employed Westerlund (2007) error-correction based cointegration test. The findings reported in Table A8 confirm the presence of cointegrating relationship among the variables for AICs, UMICs, LMICs and LICs. Table 9A provides the list of sample countries.

4.5. The Long Run Estimates

Tables 1 presents long run estimates based on FMOLS approach. The coefficients on economic growth suggest that a one percent increase in economic growth reduces carbon emissions by 0.667, 0.320, 0.397 percent in HICs, UMICs and LMICs, respectively. In contrast, LICs experience 0.549 percent rise in carbon emissions with a one percent rise in economic growth. As LICs countries have poor technological leapfrogging conditions (see Majeed & Ayub, 2018), the redundant technology consumes energy inefficiently and increases emissions. Whereas, developed countries invest in new, advanced, and eco-friendly technologies, which reduce CO_2 emissions in the atmosphere. Such heterogeneous environmental effects of economic growth are supported by the implications of EKC theory. These findings are consistent with studies such as Majeed (2018), Majeed & Mazhar (2020), and Chen et al. (2016).

Table 1: Results of FMOLS

Dependent Variable: LCO_2 Emissions (1990-2014)					
Variables	**AICs**	**HICs**	**UMICs**	**LMICs**	**LICs**
LGDP	-0.402***	-0.667***	-0.320***	-0.397**	0.549***
	(0.056)	(0.024)	(0.021)	(0.138)	(0.078)
LUR	0.958***	2.252***	1.089	0.516***	1.068***
	(0.093)	(0.077)	(0.016)	(0.185)	(0.131)
LIND	0.575***	0.610***	0.394***	0.703***	0.085*
	(0.037)	(0.018)	(0.015)	(0.072)	(0.049)
LFD	0.041***	-0.013***	0.021***	0.062**	0.191***
	(0.014)	(0.005)	(0.006)	(0.026)	(0.021)
LEC	0.748***	0.928***	0.611***	0.939***	1.085***
	(0.043)	(0.016)	(0.016)	(0.097)	(0.091)
Observation	2381	751	716	624	290
R-squared	0.993	0.996	0.995	0.991	0.984
Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)					

The coefficients on urbanization indicate that a one percent increase in urbanization increases emissions by 0.958, 2.252, 1.089, 0.516, 1.068 percent in AICs, HICs, UMICs, LMICs and LICs, respectively. This finding implies that urbanization degrades environmental quality by enhancing transportation and fuel usage activities. Further, environmentally irresponsible lifestyles in urban areas increase carbon footprint and degrades natural ecosystem. For instance, urban residents use non-essential broad range halocarbon household appliances which produce GHG. The positive impact of urbanization is consistent with Wang *et al.* (2011), Zhou *et al.* (2013), Al-Mulali & Ozturk (2015) and Bekhet & Othman (2017) who argued that urbanization increases emissions by enhancing energy consumption. Further, the demand for basic infrastructure converts forests into residual area, degrading the environment. Comparatively, environmental pollution effect of urbanization is higher in HICs. Since urbanization in HICs is high (0.75%), this finding suggests that relatively high urbanization can pollute the environment.

The coefficients on industrialization indicate that a one percent increase in industrialization enhances the emissions by 0.57, 0.610, 0.394, 0.703, and 0.085 percent in AICs, HICs, UMICs, LMICs and LICs, respectively. Industrialization raises CO_2 emissions owing to the extensive use of fossil fuel combustion for industrial production.

With industrial growth, the number of energy combustion plants increases at the cost of environmental quality. Further, heavy industries pollute the environment by emitting potential hazardous pollutants in the atmosphere. This finding is consistent with by Zhou *et al.* (2013), Al-Mulali & Ozturk (2015), Wang *et al.* (2018) and Liu *et al.* (2018).

Financial development is also positive and significant in all panels except in HICs. The effect of financial development on carbon emissions in the case of HICs is negatively significant implying that financial development improves environmental quality in HICs. Generally, HICs have well-developed industrialization with strict environmental regulations. Governments of HICs countries mostly support the development of green finance by preferring funding in environmental conserving projects. Similarly, investors focus on technological innovation rather than scale expansion. This negative impact of financial development channels through energy consumption and scale expansion. This finding is in line with the findings of the studies such as Zhang (2011), Boutabba (2014) and Majeed & Mazhar (2019b).

The positive impact of financial development is attributed to credit facilities for more industrial production (scale effect). Moreover, financial sector also provides credit facilities to consumers for purchase of more commodities, automobiles and other household appliances, increasing emissions. The environment deteriorating impact of financial development is ascribed to the removal of capital lending constraint for consumption and production purposes. Moreover, high financial development increases information symmetry, spreads out and strengthens financial linkages through better credit services. This finding is in accordance with Zhang (2011) and Majeed & Mazhar (2019b).

Finally, the coefficients of energy consumption indicate that a one percent increase in it the emissions raise by 0.761, 0.831, 0.565, 0.827 and 0.842 percent, respectively. These findings advocate that consumption of energy is drawn at the cost of rise in carbon emissions irrespective of income level. Table 2 reports the estimated coefficient obtained through DOLS. The results remain same as of FMOLS. The effect of financial development remains positive in all panels except for HICs where it is negatively associated.

Table 2: Results of DOLS

Dependent Variable: LCO$_2$ Emissions (1990-2014)					
Variables	**AICs**	**HICs**	**UMICs**	**LMICs**	**LICs**
LGDP	-0.289***	-0.514***	-0.417***	-0.219*	0.068*
	(0.079)	(0.077)	(0.103)	(0.127)	(0.221)
LUR	0.444***	1.964***	0.838***	0.635***	0.958***
	(0.121)	(0.251)	(0.197)	(0.166)	(0.321)
LIND	0.605***	0.502***	0.495***	0.616***	0.488***
	(0.050)	(0.057)	(0.067)	(0.067)	(0.129)
LFD	0.169***	-0.007	0.113***	0.038*	0.203***
	(0.023)	(0.017)	(0.033)	(0.024)	(0.054)
LEC	0.761***	0.831***	0.565***	0.827***	0.842***
	(0.068)	(0.050)	(0.092)	(0.088)	(0.211)
Observation	1751	881	590	689	290
R-squared	0.999	0.995	0.999	0.992	0.992
Ramsey RESET Test	1.704	1.380	0.939	1.224	0.862
P-value	0.1	0.167	0.347	0.221	0.389
Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)					

Table 3 illustrates the results employing non-static framework that is dynamic system GMM. The positive impacts of urbanization and industrialization remain consistent even after the inclusion of lag dependent variable. The effects are in line with results of Zhu et al. (2017), Pata (2018), Liu & Bae (2018), Khoshnevis & Shakouri (2018), Mahmood et al. (2020) and Sahoo & Sethi (2020). However, our results contradict with studies such as Li & Ma (2014), Xu et al. (2016) and Guo et al. (2016) who proposed inverted U-shaped relationship between urbanization and CO_2 emissions. Similarly, studies such as Zhou et al. (2013) reported opposite findings on industrialization and carbon emissions nexus. On the other hand, this finding is consistent with Wang et al. (2011). Moreover, the probabilities of second-order serial correlation signify that the problem of autocorrelation gets solved by employing two step GMM procedure.

Table 3: Results of Dynamic System GMM

Dependent Variable: LCO_2 Emissions (1990-2014)					
Variables	**AICs**	**HICs**	**UMICs**	**LMICs**	**LICs**
$LCO_{2\ t-1}$	0.267***	-0.009	0.702***	-0.291***	0.033
	(0.041)	(0.050)	(0.129)	(0.076)	(0.075)
LGDP	-0.498***	-0.804***	-0.595**	-0.595***	1.148***
	(0.075)	(0.109)	(0.266)	(0.179)	(0.144)
LUR	0.341*	0.672*	2.742***	1.750***	0.962***
	(0.181)	(0.368)	(0.881)	(0.575)	(0.238)
LIND	0.575***	0.760***	0.700***	0.955***	0.716***
	(0.049)	(0.071)	(0.102)	(0.055)	(0.089)
LFD	0.055*	0.337***	0.023	-0.021	0.198***
	(0.031)	(0.053)	(0.266)	(0.059)	(0.041)
LEC	0.528***	-0.152**	-1.677***	1.168***	1.170***
	(0.961)	(0.079)	(0.613)	(0.062)	(0.171)
Constant	-7.124	-2.647	-7.780	-18.736	-10.511
Sargan Test	1266.30	57.47	2.61	10.82	11.56
	(0.000)	(0.000)	(0.625)	(0.147)	(0.172)
First Order Serial Correlation	-4.17	-1.35	-4.06	-0.44	-1.46
	(0.000)	(0.178)	(0.000)	(0.660)	(0.144)
Second Order Serial Correlation	-1.60	-1.20	-0.24	-0.59	-1.08
	(0.125)	(0.230)	(0.811)	(0.553)	(0.279)
Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)					

This study also controls the issue of CSD through CCEMG and dynamic CCEMG estimation techniques. Table 4 shows that urbanization exerts positive and significant influence on carbon emissions in all panels. As urbanization increases, demand for energy, deforestation for urban buildings and waste generation increase, compromising environmental quality. This finding is in line with the studies of Wang et al. (2011), Al-Mulali & Ozturk (2015) and Bekhet & Othman (2017). Similarly, CCEMG estimates suggest that industrialization increases CO_2 emissions in UMICs and LMICs. According to CCEMG, industrialization also has CO_2 emissions enhancing impact for UMICs and LMICs. Similarly, the effect of financial development is statistically positive in LICs subgroup. Further, the effect of energy consumption is throughout positive and significant in all groups except LMICs.

Table 4: Estimates of CCEMG and Dynamic CCEMG

Dependent Variable: LCO_2 Emissions (1990-2014)					
Variables	**AICs**	**HICs**	**UMICs**	**LMICs**	**LICs**
CCEMG					
LGDP	0.218	0.221	-0.679**	0.051	0.635
	(0.273)	(0.181)	(0.342)	(0.434)	(0.614)
LUR	1.080*	-1.262	2.766*	0.501	-0.551
	(1.409)	(1.686)	(1.577)	(1.193)	(0.894)
LIND	0.194	-0.097	0.405*	0.330***	-0.127
	(1.124)	(0.102)	(0.237)	(1.156)	(0.354)
LFD	0.069	0.061	-0.045	-0.050	0.111**
	(0.048)	(0.046)	(0.043)	(0.048)	(0.057)
LEC	1.001***	1.149***	0.794***	0.783	1.432***
	(0.141)	(0.105)	(0.116)	(0.137)	(0.412)
Dynamic CCEMG					
LGDP	0.645	-0.001	-0.722	-0.112	0.278
	(0.412)	(0.437)	(0.465)	(0.573)	(0.601)
LUR	11.548***	0.763	7.850	1.371	-3.493
	(6.470)	(4.440)	(7.832)	(1.739)	(2.904)
LIND	0.398	-0.094	0.644**	-0.043	0.132
	(0.685)	(0.254)	(0.328)	(0.186)	(0.379)
LFD	-0.049	0.105	-0.040	0.006	0.121
	(0.086)	(0.067)	(0.053)	(0.044)	(0.100)
LEC	1.046**	1.109***	0.777***	1.441***	2.894***
	(0.522)	(0.113)	(0.085)	(0.374)	(1.183)
$CO_{2\ t-1}$	1.563***	0.921***	-0.877***	-0.975***	-0.935***
	(0.503)	(0.037)	(0.062)	(0.043)	(0.119)
Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)					

5. Conclusion and Policy Implications

This study analyzed the effects of urbanization and industrialization on CO_2 emissions including economic growth, financial development and energy consumption for a global panel of 156 counties over the period 1990-2014. Moreover, the analysis is disaggregated for four different income groups according to income levels. The empirical analysis is conducted using both first and second-generation tests. The long run estimates are obtained using FMOLS, DOLS, dynamic system GMM, CCEMG and DCCEMG econometric techniques.

The main findings suggest that urbanization and industrialization elevate CO_2 emissions consistently irrespective of development stage of countries. The results validate the existence of urban environmental transition theory for all panels. However, the theory of ecological urbanization and ecological modernization are invalidated in UMICs and HMICs as these countries are also experiencing carbon emissions as eco-friendly urbanization is not substantiated despite high income levels.

Among control variables, the impact of energy consumption is also significantly positive in all models. However, the impacts of financial development and economic growth are both positive and negative depending on development categorization of the countries. For HICs the effect of financial development is negatively significant indicating that financial sector helps to adopt advance and cleaner technology to protect the environment. Similarly, the impact of economic growth is also negative and significant for global panel and other sub-panels except LICs where scale effect is dominant. This positive impact of economic growth in LICs and negative in relatively all other groups validate EKC theory.

5.1 Contribution of the Study

There has been extensive research in the last few decades on urbanization and industrialization, however, most of the studies overlooked the fact that industrialization and urbanization both matter for environmental quality. There are few studies that have analyzed urbanization and industrialization side by side, but they are either longitudinal studies or generalized global panel studies. These drawbacks produce mixed, biased and misleading conclusions.

This study contributes to the existing literature in number of ways. First, this study addresses the relationship of three major global issues namely urbanization, industrialization, and environment nexus in a single study using global perspectives. Second, to the best of our knowledge this is the first study that explores the impact of urbanization and industrialization together on CO_2 emissions unlike previous studies, which ignore one of them and suffer from omitted variables bias. Third, this study improves methodological part of paper by applying second generation tests. Fourth, this study also exploits the dynamic heterogeneous nature of relationships by using CCEMG and dynamic CCEMG estimation procedures which allow slope heterogeneity and cross-sectional dependence. Fifth, this study also analyses heterogeneous evaluation of urbanization and industrialization in a comparative setting according to income levels.

5.2 Theoretical and Practical Contribution

The empirical findings of the study suggest environment deteriorating effects of urbanization and industrialization on CO_2 emissions in global and all income groups implying that all world economies are doing unordered and blind urbanization and industrialization which are increasing population and technology's environmental impacts. These findings suggest that green and sustainable urbanization and industrialization policies need to be adopted by all countries irrespective of their income levels to conserve the global environment. This can be done by diverting internal migration away from huge cities to small and medium cities by providing planned and control resources. Further, balance development in both urban and rural area may be done in attempt to further decrease the pressure of urbanization. For UMICs and HICs, the theory of ecological urbanization is invalid. Ecological modernization theory is valid in HICs in the case of economic growth and financial development while it is not supported in the case of urbanization and industrialization. The industrial growth needs to be decoupled from carbon growth by promoting green industrial reforms.

Economic growth increases pollution in LICs while decreases it in other groups. LICs needs to focus on growth as well as on its decoupling from the environment (Khan &

Majeed, 2020). Further, our empirical findings suggest the environmentally favorable effect of financial development for HICs while unfavorable for all other income groups implying that 'scale effect' dominates in HICs and 'technique effect' dominates in other groups. HICs need to focus extensively on R&D for green and efficient technological innovations while other countries need to deploy clean and eco-friendly technologies through financial sector development. To control the negative environmental effects of energy, the share of renewable energy needs to be increased by investing infrastructure development required for renewable energy production.

5.3 Limitations / Future Research Directions

This study has some research limitations which can be addressed by future research. First, sample size and time span need to be extended. Second, this study incorporates domestic credit to private sector as a measure of financial development ignoring other measures such as financial access, depth, efficiency, and stability. Third, this study does not disaggregate energy consumption into renewable and non-renewable energy sources.

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Appendix

Table 1: Variable Description, Definition and Data Sources

Variables	Construction	Definition of Variables
CO_2	CO_2 emissions (kt)	*"Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring."*
UP	Urban population (% of total population)	*"It refers to people residing in urban regions as defined by national statistical offices"*
IND	Industry, value added (constant 2010 US$)	*"It comprises value added in mining, manufacturing, construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources."*
GDP	GDP per capita constant 2010 US dollars	*"Sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources."*
FD	Domestic credit to private sector (% of GDP)	*"Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, that establish a claim for repayment. The financial corporations include monetary authorities and deposit money banks, as well as other financial corporations where data are available."*
EC	Energy consumption (kg of oil equivalent per capita)	*"It refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport."*

Table A2: Descriptive Statistics

Variables		**AlCs**	**HICs**	**UMICs**	**LMICs**	**LICs**
CO_2	**Mean**	197145.2	259382.2	289598.6	88894.06	29317.35
	Maximum	10291927	5789727	10291927	2238377	242821.4
	Minimum	47.671	106.343	58.672	47.671	62.339
	Std. dev	754656.7	793718.5	1064665	254772.7	54801.69
GDP	**Mean**	12493.55	30310.93	5480.34	2050.858	3541.441
	Maximum	111968.3	111968.3	18243.24	9163.633	52727.52
	Minimum	164.336	1051.362	354.257	200.297	164.336
	Std. dev	17823.06	21157.16	2912.615	1504.351	10100.37
UR	**Mean**	57.796	75.850	60.142	41.585	37.318
	Maximum	100.000	100.000	90.000	68.968	94.072
	Minimum	8.854	28.002	8.854	16.208	12.621
	Std. dev	21.616	14.301	17.135	15.031	15.745
IND	**Mean**	111229	204752	112414	31629	22998
	Maximum	3937310	31895000	3937310	611834	178256
	Minimum	24	41	33	24	63
	Std. dev	341110	477715	340904	79743	42674
FD	**Mean**	49.327	82.703	38.969	29.718	25.780
	Maximum	308.986	308.986	166.504	114.723	158.505
	Minimum	0.186	0.186	1.166	1.385	0.491
	Std. dev	44.698	51.387	32.545	20.595	35.481
EC	**Mean**	2005.252	4126.695	1359.466	638.278	734.303
	Maximum	18178.14	18178.14	5167.012	4209.622	5085.886
	Minimum	9.548	481.701	266.601	9.548	43.360
	Std. dev	2312.190	2840.725	905.535	524.609	1025.088

CO_2= carbon dioxide, GDP= gross domestic product, UR=urbanization, IN= industrialization, FD=financial development, EC= energy consumption

Table A3: Correlation Analysis

Variables	CO_2	GDP	UR	IND	FD	EC
AICs						
CO_2	1.000					
GDP	0.105	1.000				
UR	0.066***	0.586***	1.000			
IND	0.896***	0.268***	0.192***	1.000		
FD	0.312***	0.633***	0.453***	0.427***	1.000	
EC	0.158	0.704***	0.572***	0.242***	0.461***	1.000
HICs						
CO_2	1.000					
GDP	0.139***	1.000				
UR	0.085***	0.348***	1.000			
IND	0.937***	0.214***	0.121***	1.000		
FD	0.348***	0.504***	0.251***	0.435***	1.000	
EC	0.168***	0.441***	0.270***	0.146***	0.137***	1.000
UMICs						
CO_2	1.000					
GDP	-0.018***	1.000				
UR	-0.100***	0.596***	1.000			
IND	0.963***	0.102***	0.003***	1.000		
FD	0.400***	-0.056***	-0.148***	0.355***	1.000	
EC	0.180***	0.473***	0.321***	0.168***	0.115***	1.000
LMICs						
CO_2	1.000					
GDP	-0.093***	1.000				
UR	-0.061***	0.460***	1.000			
IND	0.902***	-0.049***	-0.071***	1.000		
FD	0.121***	0.547***	0.266***	0.131***	1.000	
EC	0.159***	0.422***	0.535***	0.023***	0.261***	1.000
LICs						
CO_2	1.000					
GDP	0.700***	1.000				
UR	0.781***	0.751***	1.000			
IND	0.938***	0.795***	0.758***	1.000		
FD	0.824***	0.668***	0.786***	0.718***	1.000	
EC	0.878***	0.927***	0.815***	0.887***	0.845***	1.000

Table A4: Results of Cross-sectional Dependence Tests

Dependent Variable: LCO_2 Emissions (1990-2014)					
Tests Statistics	**AICs**	**HICs**	**UMICs**	**LMICs**	**LICs**
Breusch-Pagan LM	12635.96***	865.882***	1883.259***	1126.417***	112.098***
Pesaran Scaled LM	198.926***	51.471***	97.883***	63.931***	12.976***
Pesaran CD	40.357***	2.865***	33.058***	29.997***	2.419***
(* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)					

Table A5: Unit Root Tests at Level

Variables	**Levin, Lin & Chu**		**Breitung**		**Im, Pesaran and Shin W-Stat**		**Pesaran**	
	Statistics	**Probability**	**Statistics**	**Probability**	**Statistics**	**Probability**	**Statistics**	**Probability**
	Null: Unit root (suppose common unit root process)				**Null: Unit root (suppose individual unit root process)**			
				AICs				
CO_2	4.186	1.000	8.4E-12	0.500	10.159	1.000	-0.291	0.385
GDP	28.236	1.000	25.162	1.000	5.138	1.000	7.991	1.000
UR	24.246	1.000	76.970	1.000	15.292	1.000	3.562	1.000
IND	23.519	1.000	20.129	1.000	5.496	1.000	-6.195	0.000
FD	0.288	0.613	9.715	1.000	1.570	0.941	0.429	0.666
EC	-11.765	0.000	7.0E-11	0.500	-0.554	0.289	2.449	0.993
				HICs				
CO_2	-0.455	0.324	5.509	1.000	1.358	0.912	2.877	0.998
GDP	3.953	1.000	7.676	1.000	6.665	1.000	2.965	0.998
UR	22.687	1.000	23.045	1.000	2.736	0.996	0.527	0.701
IND	1.136	0.872	7.915	1.000	4.164	1.000	3.597	1.000
FD	0.512	0.695	5.179	1.000	3.486	0.999	-0.655	0.256
EC	-0.190	0.424	5.828	1.000	3.006	0.998	1.252	0.895
				UMICs				
CO_2	0.402	0.656	2.916	0.998	3.605	0.999	-1.088	0.138
UR	4.448	1.000	-0.889	0.186	-0.582	0.280	2.830	0.998
GDP	12.403	1.000	11.167	1.000	8.654	1.000	1.970	0.976
IND	10.028	1.000	8.201	1.000	0.207	0.582	-0.033	0.487
FD	0.967	0.833	3.082	0.999	2.311	0.989	0.350	0.637
EC	-4.204	0.000	3.545	0.999	-6.378	0.000	2.377	0.991
				LMICs				
CO_2	4.661	1.000	5.221	1.000	3.294	0.999	0.429	0.666
GDP	12.391	1.000	6.923	1.000	1.212	0.887	-0.047	0.481
UR	-5.329	0.000	0.567	0.714	1.408	0.921	1.633	0.949
IND	-1.125	0.130	5.010	1.000	1.028	0.848	0.533	0.703
FD	3.431	0.999	2.741	0.996	-1.218	0.111	0.880	0.810
EC	4.629	1.000	4.097	1.000	-0.029	0.488	1.377	0.916
				LICs				
CO_2	6.649	1.000	7.202	1.000	3.491	0.999	3.159	0.999
GDP	2.833	0.997	2.387	0.991	3.967	1.000	-1.552	0.060
UR	6.692	1.000	15.305	1.000	11.369	1.000	-4.466	0.000
IND	5.256	1.000	7.445	1.000	2.638	0.995	-6.339	0.000
FD	-0.805	0.210	3.923	1.000	0.835	0.798	0.365	0.643
EC	2.071	0.981	1.070	0.857	-0.269	0.393	-1.284	0.100

Table A6: Unit Root Tests at 1st Difference

Variables	Levin, Lin & Chu		Breitung		Im, Pesaran and Shin W-Stat		Pesaran	
	Statistics	Probability	Statistics	Probability	Statistics	Probability	Statistics	Probability
	Null: Unit root (suppose common unit root process)				Null: Unit root (suppose individual unit root process)			
AICs								
CO_2	-54.194	0.000	-20.143	0.000	-53.407	0.000	-8.936	0.000
GDP	-33.253	0.000	-20.338	0.000	-27.121	0.000	-4.325	0.000
UR	-4.552	0.000	-3.255	0.000	-23.696	0.000	-1.586	0.056
IND	-31.529	0.000	20.048	0.000	-18.608	0.000	-17.096	0.000
FD	-35.371	0.000	-3.989	0.000	-8.278	0.000	-6.393	0.000
EC	-41.975	0.000	-2.752	0.003	-38.640	0.000	-9.820	0.000
HICs								
CO_2	-32.001	0.000	-14.159	0.000	-29.379	0.000	-11.121	0.000
GDP	-17.599	0.000	-11.141	0.000	-13.119	0.000	-3.507	0.000
UR	-7.141	0.000	-4.656	0.000	-23.145	0.000	0.749	0.773
IND	-19.805	0.000	-13.917	0.000	-9.391	0.000	-2.470	0.007
FD	-19.484	0.000	-7.811	0.000	-11.961	0.000	-2.998	0.001
EC	-3.051	0.001	-3.008	0.001	-6.116	0.000	-4.311	0.000
UMICs								
CO_2	-29.482	0.000	-10.915	0.000	-29.904	0.000	-11.272	0.000
GDP	-18.209	0.000	-9.931	0.000	-10.865	0.000	-1.779	0.038
UR	-29.750	0.000	-8.496	0.000	-11.187	0.000	-2.704	0.003
IND	-19.016	0.000	-9.968	0.000	-14.023	0.000	-3.740	0.000
FD	-19.512	0.000	-10.480	0.000	-14.596	0.000	-1.899	0.029
EC	-71.100	0.000	-9.628	0.000	-21.049	0.000	-4.033	0.000
LMICs								
CO_2	-8.939	0.000	-2.335	0.009	-9.186	0.000	-10.239	0.000
GDP	-4.521	0.000	-4.061	0.000	-7.751	0.000	-2.207	0.014
UR	-3.333	0.000	-3.917	0.000	-2.026	0.021	-2.226	0.013
IND	-6.964	0.000	-4.923	0.000	-3.825	0.000	-1.413	0.079

FD	-19.659	0.000	-5.261	0.000	-9.136	0.000	-3.098	0.001
EC	-14.546	0.000	-4.447	0.000	-8.184	0.000	-6.023	0.000
LICs								
CO_2	-7.318	0.000	-1.515	0.064	-9.054	0.000	-3.940	0.000
GDP	-10.783	0.000	-2.787	0.002	-8.834	0.000	-3.042	0.000
UR	-131.68	0.000	-3.123	0.000	-2.939	0.001	-3.440	0.000
IND	-5.954	0.000	-3.402	0.000	-7.400	0.000	-10.847	0.000
FD	-7.713	0.000	-5.915	0.000	-5.112	0.000	-6.076	0.000
EC	-11.-49	0.000	-2.021	0.021	-8.780	0.000	-5.496	0.000

Table A7: Results of Panel Cointegration Tests

Dependent Variable: LCO_2 Emissions (1990-2014)					
Tests	AICs	HICs	UMICs	LMICs	LICs
Pedroni Test for Cointegration					
Alternative Hypothesis: Common AR coefficients (within-dimension)					
Panel v-statistic	-8.452	-4.594	-5.652	-4.355	-3.842
Panel rho-statistic	3.581	3.708	2.185	3.988	2.981
Panel PP-statistics	-12.515***	-12.864***	19.200***	-9.879***	-4.341***
Panel ADF-statistics	-6.573***	-9.561***	-7.340***	-4.806***	-3.967***
Alternative Hypothesis: Individual AR coefficients (between-dimension)					
Group rho-statistic	7.127	6.855	5.162	5.106	3.839
Group PP-statistic	-20.299***	-21.685***	-23.339***	-17.939***	-6.124***
Group ADF-statistic	-8.537***	-13.432***	-4.922***	-4.308***	-4.515***
Kao Cointegration Test					
ADF	-3.723***	2.303**	-2.614**	-5.255***	-2.084**
(* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)					

Table 8: Results of Westerlund (2007) Panel Cointegration Test

Test	**Value**	**Asymptotic p-value**	**Bootstrap p-value**
AICs			
Group-r	-2.506	0.318	0.090*
Group-α	-3.313	1.000	0.183
Panel- r	-18.815	0.000	0.010**
Panel-α	-6.715	0.995	0.030**
HICs			
Group-r	-1.988	0.968	0.555
Group-α	-2.940	1.000	0.510
Panel- r	-9.963	0.065	0.100
Panel-α	-4.871	0.988	0.403
UMICs			
Group-r	-2.651	0.180	0.108
Group-α	-2.819	1.000	0.520
Panel- r	-10.554	0.092	0.030**
Panel-α	-6.970	0.904	0.037**
LMICs			
Group-r	-3.289	0.000	0.028**
Group-α	-4.208	1.000	0.020**
Panel- r	-11.617	0.003	0.028**
Panel-α	-8.486	0.667	0.088*
LICs			
Group-r	-1.449	0.997	0.665
Group-α	-3.334	1.000	0.068**
Panel- r	-4.729	0.811	0.175
Panel-α	-4.588	0.950	0.155
The tests are applied taking lags (1 1), leads (0 1), bootstrap (400) replications. (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)			

Table A9: List of Countries

HICs		UMICs		LMICs		LICs
Antigua & Barbuda	Korea, Rep.	Albania	Thailand	Bolivia	Tunisia	Benin
Argentina	Kuwait	Algeria	Turkmenist an	Cabo Verde	Ukraine	Comoros
Australia	Latvia	Azerbaijan	Venezuela, RB	Cambodia	Lao PDR	Congo,Dem.R ep
Austria	Liechtenstei n	Belarus	Iran, Islamic Rep.	Cameroon	Lesotho	Ethiopia
Bahamas	Lithuania	Belize	Iraq	Congo, Rep.	Libya	Gambia
Bahrain	Luxembour g	Paraguay	Jamaica	Cote d'Ivoire	Moldova	Guinea -Bissau
Barbados	Mongolia	Botswana	Jordan	Egypt, Arab Rep.	Monaco	Haiti
Belgium	New Zealand	Brazil	Kazakhstan	Eswatini	Timor-Leste	Malaysia
Brunei Darussalam	Nicaragua	Bulgaria	Lebanon	Georgia	Solomon Islands	Malta
Canada	Norway	China	Madagascar	Ghana		Myanmar
Chile	Oman	Colombia	Maldives	Honduras		Netherlands
Croatia	Panama	Costa Rica	Mali	India		Nigeria
Cyprus	Poland	Dominica	Morocco	Indonesia		Senegal
Czech Republic	Saudi Arabia	Dominican Republic	Mexico	Kenya		South Sudan
Darussalam	Seychelles	Ecuador	Micronesia, Fed. Sts.	Kiribati		Tajikistan
Denmark	Singapore	Equatorial Guinea	Mauritania	Mozambique		Tanzania
Estonia	Slovak Republic	Fiji	Nauru	Uzbekistan		Togo
Finland	Slovenia	Gabon	Suriname	Vanuatu		Yemen, Rep
France	Spain	Grenada		Vietnam		Zimbabwe
Germany	St. Kitts &Nevis	Guatemala		Zambia		
Greece	Sweden	Bosnia & Herzegovina		Namibia		
Hong Kong	Switzerland	American Samoa		Niger		
Hungary	Trinidad &Tobago	Romania		North Macedonia		
Iceland	UAE	Samoa Russian Federation		Pakistan		
Ireland	UK	Serbia		Papua New Guinea		
Italy	USA	Nepal		Sao Tome & Principe		
Japan	Uruguay	St. Lucia		Sri Lanka		