Economic growth and environmental degradation: How to balance the interests of developed and developing countries

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Abstract

In this paper we present a pragmatic basis for a multilateral cooperation to deal with climate change problem after accounting for the interests of both developed and developing economies. We develop our argument for such a cooperation based on the principle of affordability of developed countries and accessibility of developing countries. Towards this, we have estimated a panel Autoregressive Distributed Lag (ARDL) model using data pertaining to groups of countries classified based on region and income from 1960 to 2014. Results show that countries with high Gross Domestic Product (GDP) percapita emit more volume of hazardous Greenhouse Gases (GHG) than their developing counterparts and more importantly, the coefficient of elasticity of emission to the growth rate of GDP is substantially lower for high-income countries. Therefore, we argue that developed countries may lead the world in the climate change mitigation efforts through emission reduction and promotion of efficient use of energy resources.

Keywords: climate change, greenhouse gas, CO_2, panel ARDL

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1. Introduction

Climate change as a result of enhanced Greenhouse Gas (GHG) emission, primarily CO_2 by burning fossil fuels, albeit with some skepticism, has been accepted as a major challenge faced by the humanity today (Stern, 2007; Helm, 2008; Saunders, 2008 and Belaid and Youssef, 2017). For example, Oppenheimer and Attila-Hughes (2016) have observed that the emission of CO_2 has increased by more than 40 percent from pre-industrial level because of the anthropogenic activities like mining, fossil fuel burning etc. At the same time, increased emission was followed by

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higher economic growth and improvement in the standard of living in many parts of the world (Ellis, 2009). But costs are enormous compared to the benefits, especially in the long-run. See, for example, Zhuang (2009), IPCC (2015), Levy and Patz (2015), WMO (2016), FAO (2016), WHO (2016), Stemberg et al. (2016), Ali and Erenstein (2017), Roajs-Downing et al. (2017), Veliz et al. (2017), Yang et al. (2017), and Chaabouni and Saidi (2017) for evidences on a variety of impacts of the climate change on human civilization. Further, literature mostly from emerging economies reveals that an increase in the growth of the economy coupled with increase in energy resources especially non-renewable energy resources has resulted in environmental degradation (see, for example, Adjeye (2000), Zhang and Cheng (2009), Alam et al. (2012), Alkhathlan and Javid (2013), Asici (2013), Omri (2013), Saidi and Hammami (2015), Belaid and Youssef (2017), Damania et al. (2017), and Gaspar et al. (2017)). Given this background, it is high time that world is united as a whole to save the planet from further destruction and erosion (IPCC, 2014; Adenle et al., 2017). However, climate change mitigation efforts at the global level has been riddled with difference of opinion between developed and developing countries as to who should lead the mitigation efforts and how it should be rolled out? (Muller, 2002).

Developed countries (Annex- I countries[1]) argue that developing countries like China and India emit an enormous amount of GHGs and therefore, emission cut should be based on current emission (Brown et al., 2006). In other words, emission reduction by developed countries alone will not be either sufficient or useful or highly expensive in the absence of commensurate emission reduction by emerging economies like China and India (Clarke et al., 2009).

At the same time, developing countries (Non-annex I countries) argue that climate change is a consequence of the historical emission by developed countries through industrialization and emission by developing countries is to achieve a higher growth rate in the GDP to alleviate poverty and improve economic opportunities. Accordingly, emission by developing countries is for the survival, whereas emission in developed countries is mostly associated with a lifestyle based on energy-intensive production and consumption. Hence, developed countries have to cut more GHGs relative to developing countries (Padukone, 2010 and O'Hara and Abelson, 2011). Moreover, Less Developed Countries (LDCs) are most affected by consequences of climate change without adequate resources to deal with it (Shue, 1999; Perkins, 2008 and Levy and Patz, 2015). A related argument is that sooner developed countries plunge to cut emission, better the planet would be as it would considerably affect distribution over future climate change, whether developing countries initiate mitigation efforts in the near future or not (Waldhoff and Fawcett, 2011).

Admittedly, the world had struck a conciliatory note in recent past in dealing with climate change mitigation. For example, world leaders made commitments at the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 in Paris to reduce GHG emission and thereby ward off climate change. Overwhelming sense of unity displayed by countries at Paris was unequivocally

[1] United Nations Framework Convention on Climate Change (UNFCCC) has divided parties to the convention into three categories viz: annexure-I, annexure-II and Non-annexure I in which annexure-I parties consists mostly of developed industrial countries.

driven by the actual as well as potential consequences of climate change (Raman, 2016). Ideas such as Common but Differentiated Responsibilities (CBDR) and Nationally Determined Contributions (NDCs) to mitigation efforts enshrined in the Article (2) and (3) respectively and stipulation of the Article (4.4) that developed countries must lead the mitigation efforts while developing countries would follow enhanced mitigation efforts were essentially aimed at resolving the question of 'who will bell the cat?' But the move of the United States (US) to withdraw from the Paris Climate Agreement 2015[2] and commitment of the US administration to deregulate extraction and use of polluting energy resources are a major setback to the global effort to deal with climate change. It also fails to recognise the scientific reality that climate change is real which ought to be dealt with concerted global mitigation efforts. Climate as a global public good and the related problem of free-riding is one of the major sources of this laxity on the part of countries. As Nordhaus (1994) observed, the cost of emissions from one country is distributed globally and inadequate efforts by some countries relative to others may, therefore, incentivize non-compliant countries to exploit uneven emission controls to gain a comparative advantage.

Given such a context described above, we argue that developed countries have to lead the world in its effort to combat climate change as originally laid down by UNFCCC and help developing/poor countries to adapt to eco-friendly practices over time through transfer of funds and technology. We build this argument based on the principles of affordability and accessibility. First, affordability principle drawn based on the insights of Environmental Kuznet Curve (EKC) which implies that developed countries can afford economically to lead the world in climate change mitigation efforts. EKC suggests that the relationship between environmental quality and development of a country is of an inverted U shape indicating that environmental quality decreases with development up to a certain income level and then begins to improve. Thus, a developed country can afford to contribute more to the climate change mitigation than a developing/poor country. Empirical evidences in the existing literature on EKC like Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992), Panayotou (1993), Suri and Chapman (1998), Dinda (2004), Soumyananda (2004), Iwata et al. (2010), He and Richard (2010), Fosten et al. (2012), Zanin and Marra (2012), Giovanis (2013), Saboori and Sulaiman (2013), Shahbaz et al. (2014), Ahmed et al. (2016), Apergis (2016), Al-mulai and Ozturk (2016), Jebli et al. (2016), Khan et al. (2016), Rafindadi (2016), Chiu (2017), Apergis et al. (2017), Atasoy (2017), Moutinho et al. (2017), and Sahabhaz et al. (2017) from industrialized rich countries corroborate EKC. Specifically, Narayan and Narayan (2010) and Narayan et al. (2016) have found that subsequent to income increases, carbon emission decreases in most of the countries. In a similar vein, Stern (2007) observed that in developed countries, progress on adaptation is still at an early stage, even though market structures are well developed and the capacity to adapt is relatively high.

Of course, there are difference of opinion among researchers regarding the shape of EKC and causes behind it. Grossman and Krueger (1996), pioneers of the EKC, emphasized that "there is nothing inevitable about the relationship between growth and environment that has been observed in the past". Subsequent studies have either

[2] United States administration under President Donad Trump on August 4 2017 issued first written notification that US intends to withdraw from the 2015 Paris climate agreement.

repudiated the existence of EKC or found EKC of N-shape (see, Pearson (1994), Arrow et al. (1995), Stern et al. (1994, 1996), Ekins (1997), Moomaw and Unruh (1997), Roberts and Grimes (1997), Vincent (1997), Rothman (1998), List and Gallet (1999), Dasgupta et al. (2002), Harbaugh et al. (2002), Friedl and Getzner (2003), Perman and Stern (2003), Stern (2004a, 2004b), Poudel et al. (2009), Lee et al. (2009) and Alvarez-Herranz and Balsalobre-Lorente (2015, 2016)). However, it is also acknowledged that EKC is sensitive to functional forms, additional variables such as trade or energy consumption, and to changes in countries, cities, and years (Harbaugh et al., 2002 and Allard et al., 2018). EKC is centred on three aspects viz: increase in the scale of production, changes in the product mix and production technique. With improvement in technology and resultant increasing returns to scale, EKC will be U-shaped (Andreoni and Levinson, 2001 and Stokey, 1998). Evidences show that decoupling of economic growth takes place at faster rate in developed countries than the developing countries (Jebli et al., 2016; Shahbaz et al., 2017 and Wu et al., 2018) which, in turn, is expected to enable developed countries to take a leading role in dealing with environmental challenges.

In order to strengthen the validity of the affordability principle further, we conduct an empirical investigation to measure the sensitivity of carbon emission to the growth of GDP of all countries. Results indicate that emission of developed countries is less sensitive to the growth of GDP and therefore, developed countries can reduce emission without having to reduce GDP. This implies that emission reduction measures adopted by industrially developed countries will not only help the world to reduce the level of GHGs but also it can be achieved without sacrificing developmental goals of the world at large. Further, emission by low-income countries is more sensitive to the GDP and these countries lack both technological and financial wherewithal to invest in low emission intensive technologies. If developed countries transfer emission mitigation technologies as well as financial assistance to low-income countries, it will greatly help these countries to reduce emission (Ikeme, 2003). Our empirical results are consistent with the finding of Rong (2010) that developing countries will be in a better position to adopt effective mitigation policies with the enhancement of their respective mitigation capabilities coupled with the intensive emission reduction and transfer of technology by developed countries.

Second, accessibility implies that poor people without access to basic necessities of life like food, education and healthcare hail mostly from either developing or poor countries. For example, a sizeable portion of India's population is below the poverty line and still does not have access to electricity with associated socio-economic consequences (see, for example, Acharya and Sadath, 2017 and Sadath and Acharya, 2017). Hence, use of energy resource like coal to produce electricity can go a long way in enabling India to deal with its income and energy poverty. This sort of reasoning makes more compelling in the light of United Nations Development Programme's (UNDP) Sustainable development goals (SDGs) which envisages to end extreme poverty in all forms by 2030 (UNDP, 2017 and European Commission, 2016). Of late, according to the World Hunger Index 2017 (WHI, 2017), 800 million people in the world face starvation with most of them in poor or developing regions of the world such as South Asia and Africa.

This paper adds to the existing literature by presenting a basis to hinge global cooperation to deal with climate change problem, particularly in the context of the

US withdrawal from Paris agreement, by integrating the affordability of developed countries in the light of revelations of EKC and compulsions of developing/poor countries in the light of issues of enormous poverty and hunger, to strike a balanced and conciliatory approach between developed and developing countries to tackle climate change. For example, as Perkins (2008) observed, in the absence of a truly multilateral solution and consensus as witnessed in the UN climate summit 2019 (COP 25) at Madrid, it is perhaps likely that individual countries should be unwilling to take action on account of apprehension of other countries resorting to free-riding. Additionally, the existing advocacy that rich countries should lead climate change mitigation is not built on the credible empirical basis and the paper fills the gap by providing empirical evidence and argues that the issue must be dealt with justice guided by the need and merit (Brown et al., 2006). Finally, the success of Nationally Determined Contributions (NDCs) or Nationally Appropriate Mitigation Actions (NAMA) to emission reduction will be conditional upon a global understanding between developed and developing countries to address climate change as their shared responsibility based on certain mutually acceptable principles (Adenle et al., 2017).

2. Global Response to Climate Change and Environmental Degradation

The realisation at the global level that economic advancement of modern human civilisation since industrial revolution with a focus on production and consumption of goods and services has caused serious damage to the planet was first reflected in the UN conference on Human Environment at Stockholm, Sweden in 1972. In this conference, the United Nations Environment Programme (UNEP) was founded to provide leadership to the world in the promotion of environment friendly economic practices. Subsequently, first World Climate Conference (WCC) was held in Geneva in 1979 under the aegis of World Meteorological Organisation (WMO) in collaboration with agencies like UNEP. WCC called upon countries to make full use of existing climate knowledge, improve it, foresee, and prevent potential man-made changes in the climate with serious potential impact on the wellbeing of the humanity.

However, after almost ten years of establishment of the UNEP, environmental challenges faced by the planet were growing as a result of inadequacy of remedial measures. This led to the establishment of World Commission on Environment and Development (WCED) in 1983 under the auspices of the UN to suggest measures to ensure that development is sustainable with cooperation of all countries involved. The commission, also known as Brundtland commission named after its chairperson Gro Harlem Brundtland, submitted its report titled 'Our Common Future' in 1987 in which the famous concept of sustainable development was defined as "development which meets the needs of current generation without compromising the ability of future generations to meet their own needs". Brundtland report, while emphasising the importance of socio-economic development to deal with broader developmental challenges of the world, also emphasised in no less terms, the importance of protecting the planet from evils of development. Specifically, the report reiterated the importance of cooperation between developed and developing countries while dealing with a global common good such as environment and climate with transfer of capital and technology from rich to the poor countries.

In 1988, the UNEP along with the WMO set up the Intergovernmental Panel on Climate Change (IPCC) as a scientific body to make assessments on all aspects of climate change and formulate realistic response strategies. IPCC brought out its first assessment report in 1990 in which climate change was flagged as a major global challenge and hence called for international cooperation to deal with it. IPCC played a key role in the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in the Earth summit at Rio in 1992. Rio conference reiterated the urgency for re-examining developmental pursuits all over the world causing irreparable damage to environment and called for behavioural and attitudinal transformation to tackle the problem of climate change and global warming. Thus, a blueprint for sustainable development namely 'Agenda 21' was adopted which identified challenges such as poverty, conservation, management of natural resources, etc. faced by the humanity along with the aim of preparing the world to address those challenges.

The UNFCCC came into force in 1994 with an objective of stabilisation of GHG concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with climate system. Since its ratification, the UNFCCC has acted as the global platform of conference of parties (COP) in the fight against environmental destruction. Also, it has successfully resolved obvious conflicts of interests between developed and developing countries in the global efforts to tackle climate change. For example, concepts like CBDR with implications for climate change mitigation efforts at regional level and commitment by developed countries not only to assist developing/poor countries in their effort of climate change mitigation, but also leading the global mitigation efforts are achievements of the UNFCCC.

As part of intensifying global efforts to mitigate climate change, COP in its third meeting in 1997 at Kyoto, Japan adopted drastic measures, namely 'Kyoto Protocol' with provisions such as developed countries are bound to reduce GHGs emission during the first commitment period, 2008-2012 based on the justification that they are mainly responsible for emitting major chunk of existing GHGs since industrial revolution. As a part of such a provision, Kyoto Protocol proposed the Clean Development Mechanism (CDM) under which developed countries can obtain tradable emission permits in accordance with their support to developing countries to promote sustainable development practices and investments. Thus, the UNFCCC proposed to resort to market mechanism through marketable emission permits to reduce greenhouse gas emission and incentivise developed countries to undertake binding emission reduction in a cost-effective manner. After a prolonged ratification exercise by countries except the US, the Kyoto protocol came into force in 2005.

Meanwhile, in 2001, IPCC came out with its third assessment report with strong scientific evidence of dangerous anthropogenic interference with climate system and explicitly observed that climate change issue is a part of larger challenge of sustainable development and therefore, called for sustainable development approach so that climate policies would be more effective at national and regional level. Subsequently, IPCC, in its fourth assessment report in 2007, reiterated that global warming is unequivocal and unabated emission would pose greater risks in the future than observed in the past.

However, in the meantime, the ambitious Kyoto Protocol, was faltering on account of opposition from rich industrial countries and therefore, the COP met at Bali, Indonesia in 2007 and charted a new and comprehensive course for negotiation process known as the 'Bali Road Map' to enable effective and sustainable implementation of the UN convention through long-term cooperation of parties with the aim of completing by 2009. Thus, intense negotiations launched as part of the Bali Road Map culminated in Copenhagen Conference in 2009 where all major countries made non-binding pledges to cut carbon emission and unanimously agreed to define maximum acceptable increase in the global temperature as 2^0C above pre-industrial level. Copenhagen summit also proposed to mobilise $100 billion annually to assist developing countries and establish a new green fund which were accepted in the subsequent summit at Cancun, Mexico in 2010. The Cancun agreement also witnessed most comprehensive and far reaching response to climate change through various programmes such as promotion of innovation of eco-friendly technology and transfer of technology to developing countries.

Finally, the COP 21st meeting at Paris in 2015, known as the Paris climate agreement, charted another new course in the global fight against climate change and succeeded in bringing all countries together in the global effort to tackle climate change. One of the major contributions of the Paris agreement is the concept of Nationally Determined Contribution (NDC) which envisages all parties to do their best to cut emission given their individual domestic compulsions and report regularly on their mitigation efforts. The Paris agreement came into force in 2016 and 183 countries and the European Union have ratified the agreement so far.

3. Data and Methodology

Data for the study is collected from the World Bank website. It includes country-wise CO_2 emission in Kilotons, GDP at market prices in current U.S. dollars, CO_2 emission per GDP based on 2011 Purchasing Power Parity (PPP) dollars, percapita emission and Research and Development (R&D) expenditure as a percent of GDP. GDP in dollar figures are converted from the domestic currency using the official exchange rates. Alternative conversion factors are used for few countries due to the fact that official exchange rates did not reflect the rates applied for foreign exchange transactions. Study period extends from 1960 to 2014; however, the data on R&D expenditure as a percent of GDP is available only from 1996. The study covers 217 countries[3] organised into seven region-based groups and four income-based groups. The region-based groups are East Asia and Pacific, Europe and Central Asia, Latin America and Caribbean, Middle East and North Africa, North America, South Asia, and Sub-Saharan Africa. High income, low income, lower middle income, and upper middle income are income-based groups. The study organises data into panels based on both region and income for the purpose of analysis. After accounting for the missing observations, there are 7904 observations of region-wise countries and 7895 observations of income-wise countries.

CO_2 emission and GDP at market prices may not be stationary in the level from. Therefore, to test for the stationarity of the variables, we use Levin, Lin and Chu *t* test

[3] Total number of countries is more than the number of United Nations (UN) member countries. This is due to treating special administrative regions, overseas territories, etc. as separate entities.

and Im, Pesaran and Shin W-statistic. CO_2 emissions of a few country groups and GDP at market prices of all country groups are not stationary in the level form[4]. First differencing the non-stationary variables makes them stationary and therefore, the variables are integrated of the order one, I (1). If a liner combination of I (1) variables result in I (0) residuals, the variables are said to be cointegrated. Therefore, there is a possibility of long-run relationship among the variables considered in the study.

We use Pooled Mean Group (PMG) approach in panel Autoregressive Distributed Lag (ARDL) framework popularized by Pesaran et al. (1999). This model is particularly useful in handling large T and small N. It is also helpful when variables are integrated of different order as well. The cointegrating form of simple ARDL is adapted in the panel framework where intercept, short-run coefficients and cointegrating terms are allowed to differ across cross-sections. We specify the general form of PMG model as follows:

$$CO2_{it} = \beta_0 + \sum_{l=1}^{L} \beta_1 CO2_{it-l} + \sum_{r=0}^{R} \beta_2 GDP_{it-r} + \mu_{it} \quad (1)$$

$CO2_{it}$ is CO2 emission of country *i* at time *t* and GDP_{it} is GDP of the country *i* at time *t*. If the variables used in the equation are an I (1) process and cointegrated, the residuals will be I (0). The cointegrating from of the equation is specified as follows:

$$\Delta CO2_{it} = \phi_i CO2_{it-j} + \theta_i GDP_{it-j} + \sum_{l=1}^{L} \gamma_i \Delta CO2_{it-l} + \sum_{r=0}^{R} \delta_i \Delta GDP_{it-r} + \varepsilon_{it} \quad (2)$$

The error correction parameter ϕ_i shows the speed of adjustment which is expected to be negative and statistically significant indicating convergence to long-run. All variables are in natural logarithms.

4. Results

Empirical results of the study are presented in this section. Summary statistics of the variables viz. CO_2 emission and GDP of group of countries based on region and income are shown in Table 1. Panel 1 shows the mean and standard deviations for group of countries based on region and panel 2 for the income-based group. Regions like Sub-Saharan Africa, Latin America and Caribbean have much smaller mean values of CO_2 emission as well as GDP, whereas North America has substantially large CO_2 emission and GDP. South Asia's emission level is comparable to Europe and Central Asia, but with substantially lower GDP, thus, clearly show that as level of income increases, emission also increases and vice versa.

Figure 1 presents the current level of CO_2 emission and GDP across different regions. As shown in the figure, East Asia and Pacific, Europe and Central Asia and North America have larger amount of CO_2 emission as well as GDP. Rest of the

[4] A detailed note on the unit root tests used and the results are presented in the empirical results section.

regions have substantially lower levels of both CO_2 emission and GDP, Sub-Saharan Africa being the lowest and followed by the South Asia. Figure 2 presents the same for countries classified under different income-groups. Upper-middle income group has highest CO_2 emission followed by high-income group. Low income group has lowest emission followed by lower-middle income group.

Table 2 presents region-wise CO_2 emission per current GDP in US $, per GDP based on 2011 PPP $ and percapita emission in panel 1, panel 2 and panel 3 respectively. During the first decade of the study period 1960-69, Sub-Saharan Africa had lowest emission per GDP followed by South Asia, whereas Europe and Central Asia had highest emission per GDP followed by the Middle East and North Africa. In the decade of 1970-79, Europe and Central Asia reduced the emission per GDP substantially and stood at the third place behind Sub-Saharan Africa and South Asia. Almost all geographic regions have recorded reduction in emission per GDP. During the period from 2010 to 2014, North America has lowest emission per GDP, whereas Middle East and North Africa have emitted highest. CO_2 emission per GDP based on 2011 PPP$ presents a slightly different picture. Sub-Saharan Africa and South Asia have lowest emission followed by Latin America and Caribbean, whereas other geographic regions have comparable higher levels of emission. Finally, CO_2 emission percapita is presented in panel 3. Almost all geographic regions show an increasing trend in the percapita emission except Europe and Central Asia who have reduced the percapita emission since 1980s. Middle East and North Africa and North America have shown a decline in the emission during the last five years of the study. In terms of absolute size of percapita emission, Sub-Saharan Africa and South Asia have lowest emission percapita, whereas North America has the highest.

CO_2 emission per current GDP in US$, per GDP based on 2011 PPP$ and percapita emission based on income groups are presented in panel 1, panel 2 and panel 3 respectively in Table 3. CO2 emission per GDP has shown a consistent declining trend across all income groups during the study period. High-income group has shown substantial decline followed by the upper middle-income group, whereas lowest absolute decline is observed in the case of low-income group. In terms of the size, low income group has lowest CO_2 emission per GDP throughout the study period followed by high-income group. Based on CO_2 emission per GDP based on 2011 PPP$, low-income group has substantially smaller emission compared to other income groups. Highest emission is recorded in the case of upper-middle income group and high-income group. CO2 emission percapita in panel 3 shows that high income group has highest emission, whereas low income group has lowest.

Panel unit root test statistics of CO_2 emission is presented in Table 4 in which panel 1 represents region-based classification and panel 2 represents income-based classification. We present Levin, Lin & Chu *t* statistic and Im, Pesaran and Shin W statistic along with their probabilities. If any one test confirms non-stationarity at the level form, we go for testing the same at first difference. As per the Levin, Lin and Chu test, South Asia, Sub-Saharan Africa and low-income groups are non-stationary at level and become stationary at first difference, while other groups are stationary at level. Im, Pesaran & Shin test mostly confirms this result with the exception of Middle East and North Africa and North America which are non-stationary at level and stationary at first-difference. Table 5 presents the same panel unit root test statistics for current GDP US $ for region-based classification in panel 1 and income-based classification in panel 2. Both tests confirm that GDP of all country groups are non-stationary at level with the exception of South Asia and they become stationary at first-difference. Only South Asia is stationary at the level form.

We present the panel ARDL model results in Table 6 for group of countries based on region. Panel 1 presents the short-run coefficients and *t* statistics, whereas panel 2 presents the same for long-run. All country groups with the exception of North America have negative cointegrating coefficient which is statistically significant. First lag of the CO_2 emission variable is negative and significant only in the case of Latin America and Caribbean. In the case of other country groups, either the coefficient is not statistically significant or the model has not chosen the lag of the CO_2 emission variable. Current GDP in US $ has a positive relationship with current level of CO_2 emission across all regions. However, the coefficient is not statistically significant in the case of East Asia and Pacific and South Asia. Since the variables are in natural logarithms, the coefficients can be interpreted as elasticity. For example, a percent increase in GDP leads to an increase of 0.435 percent CO_2 emission in the case of North America, which is highest and followed by Europe and Central Asia at 0.159 percent. As shown in panel 2, the GDP has positive relationship with CO_2 emission and the results are statically significant with the exception of North America. South Asia has numerically largest coefficient; one percent increase in GDP leads to an increase of 0.789 percent in CO_2 emission. It is followed by Sub Saharan Africa and Middle East and North Africa where a percent increase in GDP lead to an increase of about 0.4 percent in CO_2 emission. Lowest elasticity is recorded in the case of Europe and Central Asia at 0.053 percent.

To shed light on the relationship between current GDP US $ and CO_2 emission among countries based on income groups, we estimate the panel ARDL model for countries organised under different income groups. Results of the same is presented in Table 7 in which panel 1 presents short-run results and panel 2 presents long-run results. Cointegrating coefficient is negative and statically significant across all income groups. Lagged CO_2 emission is negatively related to the current level of emission and coefficients are mostly significant where model has chosen the lagged CO_2 emission variable. The short-run relationship between GDP and CO_2 emission is positive and statistically significant across all groups except countries of lower-middle income group. The long-run coefficients in panel 2 show that there is a positive and statistically significant relationship between GDP and CO_2 emission across all income groups. Low income group shows the strongest relationship; one percent increase in GDP leads to an increase of 0.707 percent in emission. As level of income increases, size of the coefficient is decreasing. However, high-income group has second largest elasticity coefficient at 0.441 percent.

Relationship between the current GDP US $ and CO_2 emission may be positive. However, if a country is inventing in emission reduction technologies, it may lead to a lower emission and as a result, the coefficient of GDP may be small for such countries. In order to shed light on this, we estimate equation (1) and equation (2) with R&D as a percent of GDP as a fixed regressor. The result of the model for region-based classification is presented in Table 8 and for income-based classification in Table 9. Main variables of interest here are the sign of the R&D as a percent of GDP and the size of the GDP variable in the long-run equation. The sign of the R&D as a percent of GDP variable is mostly negative which is as per the expectation. It indicates that the countries spending more on R&D as a percent of GDP emit less presumably as a result of improvement in technology. Further, the coefficient of the GDP variable remains more or less same and a marginal rise in the size of higher-income group is observed. However, introduction of R&D variable has not changed the overall trend in the original results reported in Table 6 and Table 7. Therefore, it calls for further investigation into this issue as the data used in this study is limited due to non-availability of R&D as a percent of GDP data for initial period of the study.

Overall, the results indicate that an increase in the GDP would inevitably lead to an increase in the CO_2 emission. However, the strength of relationship seems to be stronger in countries with low level of income and regions with greater presence of relatively poor countries. Historically, poor countries have lower emission per GDP with the exception of the last five years in the study period. CO_2 emission per GDP PPP $ shows that low-income countries have lowest emission and the gap with rich counterparts is quite substantial. Finally, as far percapita CO_2 emission is concerned, low-income countries have lowest percapita emission and there is a huge difference in comparison with high-income countries.

Empirical results show that it would not be reasonable to argue that all countries irrespective of their status in terms of economic development and carbon emission have to adopt same strategies in the same manner without differentiation. Instead, results show that developed countries can afford to contribute more to global climate change mitigation efforts in the form of further emission reduction without compromising their economic performance. As a result, developed countries will be in a better position to extend support to poor and developing countries and thereby help them to deal with their fundamental challenges like poverty. Thus, the Common but Differentiated Responsibilities and Respective Capabilities (CBDR- RC) of the UNFCCC is justified by the findings of the study. Further, it also provides justification for the demand made by the developing countries for technology transfer and monetary assistance in the Paris climate summit to implement policies to mitigate the climate change. Empirical results are also consistent with the proposition of the studies like Waldoff and Fawcett (2011) who argued that concerted efforts by developed countries to mitigate rise in temperature and climate change can go a long way in reducing climate change risks even in the face of delay on the part of developing countries to undertake mitigation initiatives.

At the same time, the above argument does not mean that developing countries can free-ride at the cost of developed countries. Instead, the approach should be flexible enough, on the one hand, to provide a leeway to developing/poor countries like the CBDR so that they need not compromise on their developmental challenges like poverty eradication with the support of developed countries and on the other hand, nudges the industrialised countries to do everything possible to cut emission (Perkins, 2008).

Table 1 – Summary Statistics of Emission and Current Gross Domestic Product (GDP) US $ for Region/Income Group Classification

Country Group	CO_2 emissions kt		GDP current US $ (Million)	
	Mean	Std. Dev.	Mean	Std. Dev.
Panel 1 Region Based Classification				
East Asia & Pacific	160410.08	107338.65	178421.83	168883.04
Europe & Central Asia	116110.19	20503.47	175261.34	122649.79
Latin America & Caribbean	27081.87	12030.37	47435.87	49516.02
Middle East & North Africa	49207.68	33823.33	44482.28	48194.12
North America	1716510.34	296765.90	2370640.05	2111335.62
South Asia	103524.20	79762.29	75524.43	82604.50
Sub-Saharan Africa	9625.71	4015.40	8863.82	9540.61
Panel 2 Income Based Classification				
High income	170229.39	29673.54	292917.95	229920.28
Low income	2115.97	1487.59	3422.12	3193.57
Lower middle income	33089.84	23356.82	27009.83	29013.32
Upper middle income	121266.94	81663.23	83425.90	102782.47

Table 2 – CO_2 Emission based on Regions

Year	East Asia & Pacific	Europe & Central Asia	Latin America & Caribbean	Middle East & North Africa	North America	South Asia	Sub-Saharan Africa
Panel 1 CO_2 Emission per Current GDP US $							
1960-69	3.24	4.16	2.79	4.11	3.60	1.93	1.45
1970-79	3.21	2.17	2.46	3.26	2.22	1.26	1.26
1980-89	1.27	1.15	1.10	1.43	0.93	0.80	0.76
1990-99	1.10	2.09	0.92	1.63	0.56	0.97	0.66
2000-09	0.82	1.25	0.66	1.10	0.37	0.73	0.55
2010-14	0.48	0.50	0.41	0.63	0.25	0.53	0.33
Panel 2 CO_2 Emission per GDP Based on 2011 PPP							
1990-99	0.318	0.510	0.260	0.322	0.397	0.177	0.164
2000-09	0.299	0.389	0.254	0.321	0.329	0.164	0.164
2010-14	0.298	0.303	0.245	0.312	0.292	0.179	0.160
Panel 3 CO_2 Emission Mertic Ton Percapita							
1960-69	2.100	6.434	1.543	7.495	11.221	.211	.333
1970-79	5.281	8.524	3.169	11.235	15.234	.172	.650
1980-89	4.361	8.193	2.729	8.597	14.919	.267	.709
1990-99	4.437	7.446	3.392	9.795	14.684	.465	.666
2000-09	4.354	7.237	4.172	10.465	15.093	.715	.910
2010-14	4.867	6.741	5.033	9.887	13.272	1.012	.905

Table 3 – CO_2 Emission based on Income Group

Year	High income	Low income	Lower middle income	Upper middle income
Panel 1 **CO_2 Emission per Current GDP US $**				
1960-69	3.96	0.83	1.82	3.53
1970-79	3.18	0.83	1.53	2.56
1980-89	1.02	0.52	1.00	1.49
1990-99	0.87	0.52	1.50	1.83
2000-09	0.56	0.42	1.12	1.17
2010-14	.34	.31	.55	.55
Panel 2 **CO_2 Emission per 2011 PPP GDP**				
1990-99	.349	.127	.288	.390
2000-09	.303	.117	.263	.351
2010-14	.273	.135	.239	.305
Panel 3 **CO_2 Emission Mertic Ton Percapita**				
1960-69	7.388	0.121	0.394	1.602
1970-79	11.884	0.204	0.569	2.682
1980-89	9.622	0.188	0.718	3.014
1990-99	10.296	0.180	1.010	3.301
2000-09	10.960	0.250	1.117	3.792
2010-14	10.521	0.256	1.313	4.160

Table 4 – Panel Unit Root Test Statistics of CO_2 Emission

	Level				First Difference			
Country Group	Levin, Lin & Chu t	Prob	Im, Pesaran& Shin W-stat	Prob	Levin, Lin & Chu t	Prob	Im, Pesaran& Shin W-stat	Prob
Panel 1 **Region-wise Classification**								
East Asia & Pacific	-5.397	0	-2.281	0.011				
Europe & Central Asia	-5.855	0	-3.250	0.001				
Latin America & Caribbean	-3.995	0	-2.611	0.005				
Middle East & North Africa	-2.065	0.020	-0.439	0.330	-18.480	0	-19.594	0
North America	-2.784	0.003	-0.564	0.286	-6.160	0	-6.207	0
South Asia	-0.089	0.465	0.089	0.535	-7.632	0	-10.543	0
Sub-Saharan Africa	1.705	0.956	-1.170	0.121	-12.803	0	-26.515	0
Panel 2 **Income-wise Classification**								
High income	-6.439	0	-2.296	0.011				
Low income	0.803	0.789	0.010	0.504	-9.577	0	-19.833	0
Lower middle income	-3.978	0	-3.027	0.001				
Upper middle income	-11.158	0	-7.101	0				

Table 5 – Panel Unit Root Test Statistics of Current GDP in US $

Country Group	Level				First Difference			
	Levin, Lin & Chu t	Prob	Im, Pesaran& Shin W-stat	Prob	Levin, Lin & Chu t	Prob	Im, Pesaran& Shin W-stat	Prob
Panel 1 Region-wise Classification								
East Asia & Pacific	1.999	0.977	3.755	1.000	-23.060	0	-16.450	0
Europe & Central Asia	1.403	0.920	5.044	1	-23.542	0	-16.587	0
Latin America & Caribbean	3.064	0.999	4.113	1	-24.483	0	-25.480	0
Middle East & North Africa	-1.352	0.088	0.880	0.811	-6.725	0	-8.815	0
North America	2.353	0.991	4.282	1	-3.785	0	-4.343	0
South Asia	-2.354	0.009	-2.361	0.009				
Sub-Saharan Africa	0.627	0.735	2.247	0.988	-20.277	0	-19.062	0
Panel 2 Income-wise Classification								
High income	5.883	1	9.886	1	-31.405	0	-24.590	0
Low income	0.652	0.743	1.364	0.914	-14.016	0	-15.850	0
Lower middle income	1.097	0.864	3.262	0.999	-29.887	0	-25.823	0
Upper middle income	0.483	0.686	2.948	0.998	-29.144	0	-23.198	0

Table 6 – Panel ARDL Results for the Regions

Variables	East Asia & Pacific	Europe & Central Asia	Latin America & Caribbean	Middle East & North Africa	North America	South Asia	Sub Saharan Africa
Panel 1 Short Run Equation							
COINTEQ01	-0.188 (-5.24)*	-0.193 (-5.13)*	-0.114 (-7.15)*	-0.188 (-5.9)*	0.001 (9.54)*	-0.125 (-2.92)*	-0.163 (-8.8)*
CO2EMISSION (-1)	-0.022 (-0.54)		-0.136 (-3.87)*		-0.040 (-0.24)		-0.009 (-0.27)
CO2EMISSION (-2)			-0.036 (-0.95)				
GDPCURRENTUS$	0.069 (1.29)	0.159 (7.14)*	0.100 (2.43)*	0.094 (2.5)*	0.435 (2.76)*	0.005 (0.06)	0.075 (2.18)*
GDPCURRENTUS$ (-1)	0.051 (1.21)	-0.024 (-0.89)			-0.155 (-0.95)		
GDPCURRENTUS$ (-2)					-0.145 (-1.1)		
C	-0.085 (-0.79)	1.520 (5.68)*	0.337 (8.57)*	0.091 (1.55)	0.386 (6.12)*	-1.162 (-2.65*)	-0.258 (-5.43)
Panel 2 Long Run Equation							
GDPCURRENTUS$	0.332 (15486)*	0.053 (5.65)*	0.236 (9.42)*	0.393 (18.54)*	29.702 (0.01)	0.789 (24.49)*	0.412 (22.92)*

Note: *t* statistic is presented in the bracket, * indicates statistical significance at 5% level of significance.

Table 7 – Panel ARDL Results for the Income Based Groups

Variables	High Income	Low Income	Lower Middle Income	Upper Middle Income
Panel 1 Short Run Equation				
COINTEQ01	-0.069 (-3.78)*	-0.149 (-5.86)*	-0.211 (-5.88)*	-0.162 (-3.75)*
CO2EMISSION (-1)	-0.119 (3.76)*	-0.009 (-0.22)	-0.076 (-2.02)*	-0.060 (-2)*
CO2EMISSION (-2)			-0.060 (-1.8)**	
GDPCURRENTUS$	0.137 (5.44)*	0.070 (2.03)*	0.049 (1.24)	0.107 (3.85)*
GDPCURRENTUS$ (-1)				-0.027 (-1.06)
C	-0.112 (-2.49)*	-1.211 (-5.95)*	-0.231 (-2.96)*	0.083 (0.92)
Panel 2 Long Run Equation				
GDPCURRENTUS$	0.441 (27.66)*	0.707 (20)*	0.400 (23.07)*	0.332 (22537)*

Note: *t* statistic is presented in the bracket, * and **indicates statistical significance at 5% and 10% level of significance respectively.

Table 8 – Panel ARDL Results for the Regions with R&D Expenditure

Variables	East Asia & Pacific	Europe & Central Asia	Latin America & Caribbean	Middle East & North Africa	North America	South Asia	Sub Saharan Africa
Panel 1- Short Run Equation							
COINTEQ01	-0.251 (-1.523)	-0.266 (-5.069)*	-0.427 (-3.199)*	-0.393 (-2.077)*	0.130 (1.534)	-0.455 (-5.042)*	-0.253 (-1.919)**
CO_2 EMISSION (-1)	-0.062 (-0.383)			-0.063 (-0.397)	-0.267 (-5.590)*	-0.099 (0.631)	
GDP CURRENTUS$	-0.064 (-0.438)	0.144 (5.406)*	-0.018 (-0.162)	0.280 (0.156)	2.297 (1.466)	0.055 (0.373)	0.233 (0.223)
GDP CURRENTUS$ (-1)			-0.027 (-0.170)		-1.502 (-1.077)		
R&D AS A % GDP	-0.066 (-0.805)	-0.065 (-1.702)	-0.099 (-1.047)	-0.095 (-1.261)	-0.125 (-0.612)	0.255 (1.285)	0.178 (0.773)
C	2.605 (1.596)	0.825 (5.232)*	-2.223 (-2.893)*	-1.623 (-2.138)*	1.352 (1.415)	-0.672 (-1.136)	-1.169 (-2.408)*
Panel 2- Long Run Equation							
GDP CURRENTUS$	0.067 (5.493)*	0.186 (24.789)*	0.589 (24.202)*	0.599 (24.691)*	0.870 (3.784)*	0.446 (10.394)*	0.521 (10.404)*

Note: *t* statistic is presented in the bracket, * and **indicates statistical significance at 5% and 10% level of significance respectively.

Table 9 – Panel ARDL Results for the Income Based Groups with R&D Expenditure

Variables	High Income	Low Income	Lower Middle Income	Upper Middle Income
Panel 1 **Short Run Equation**				
COINTEQ01	-0.193 (-4.491)*	-0.513 (-1.359)	-0.215 (-3.068)*	-0.345 (-3.847)*
CO2 EMISSION (-1)		0.434 (3.967)*		
GDP CURRENTUS$	0.088 (1.030)	0.151 (1.624)	-0.065 (-0.720)	-0.024 (-0.302)
GDP CURRENTUS$ (-1)		0.193 (0.964)		
R&D AS A % GDP	-0.127 (-3.876) *	-0.108 (-1.838)**	0.008 (0.208)	-0.045 (-0.697)
C	-0.144 (-1.472)	1.956 (1.294)	-0.400 (-2.637)*	1.170 (3.694)*
Panel 2 **Long Run Equation**				
GDPCURRENTUS$	0.435 (667.979)*	0.644 (2.468)*	0.504 (18.305)*	0.303 (32.349)*

Note: *t* statistic is presented in the bracket, * and **indicates statistical significance at 5% and 10% level of significance respectively.

Figure 1 – Region-wise CO_2 Emission and Current GDP Levels

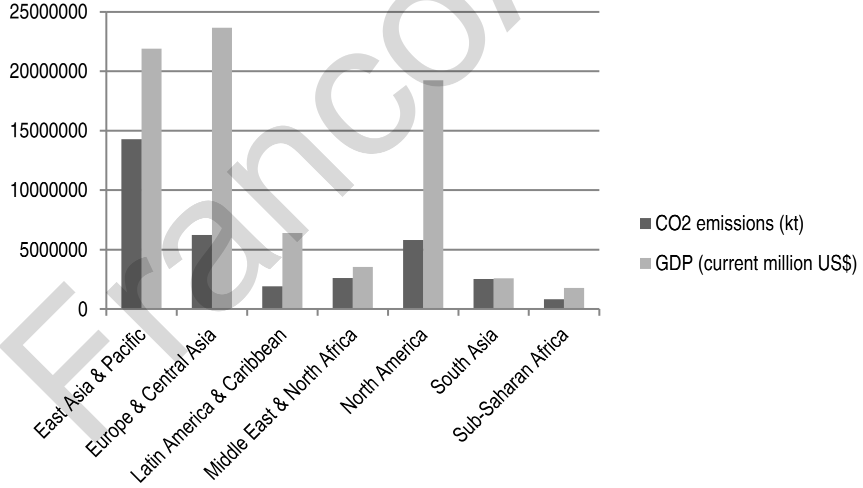
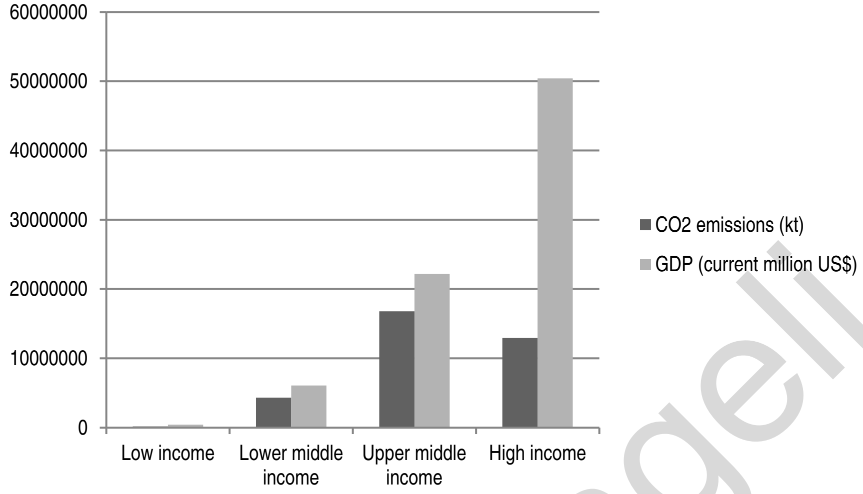


Figure 2 – Income Group-wiseCO_2 Emission and Current GDP Levels



5. Conclusion

Climate change due to anthropogenic intervention in the environment is a reality. Therefore, there is almost near unanimity globally about the urgency of climate change mitigation. However, there exists a difference of opinion between developed and developing countries as to who should embark first on mitigation path. Withdrawal of the US from Paris agreement is a manifestation of the divide which is driven by likely developmental implications of mitigation efforts. In this paper, therefore, we seek to find a way out of these conflicting interests by suggesting a pragmatic basis for a multilateral solution to the climate change mitigation efforts led by industrialised countries. Towards this end, we examined how far carbon emission in various groups of countries is sensitive to their GDP. This approach is adopted on the presumption that degree of the sensitivity or elasticity of emission to GDP can be equated with the developmental apprehension of countries. For instance, a country with highly elastic carbon emission to GDP will have to sacrifice growth to cut emission.

Thus, empirical results show that high-income countries emit greater amount of percapita GHGs compared to poor and developing countries. Further, emission in high-income countries is less elastic to changes in the GDP compared to poor and developing countries with higher elasticity coefficient. Results also indicate that emission in low-income and developing countries is mostly driven by the essential economic activities represented by GDP growth rate.

In the light of the insights from both theoretical literature as well as empirical results, we argue that developed countries can afford to shoulder more responsibility to deal with climate change compared to poor/developing countries. Therefore, it will be in the interest of the entire planet if developed countries adopt measures like drastic cut in the use of polluting fossil fuels and thereby facilitate global emission balancing as poor and developing countries have no immediate option to cut their emission, promote innovation and use of energy efficient technology. Further, access to capital and technology by poor and developing countries is essential to cope up with the urgency of climate change and thereby placing them on a low carbon development path with strong institutional frameworks in conjunction with developed countries as ultimate solution to the problem of human induced climate change.

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