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2 October 2020

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Abstract: Several Asian countries are facing challenges regarding accomplishment of the objectives of Sustainable Development Goals (SDGs), and India is facing a similar situation. Following this, this study talks about designing an SDG framework for India, which can be used as a benchmark for the other Asian countries. In this pursuit, this study looks into whether per capita income, energy use, trade openness, and oil price have any impact on CO_2 emissions between 1980 and 2019. The nonlinear autoregressive distributed lag approach proves that the fluctuations in independent variables have an asymmetric long-term impact on CO_2 emissions. The results reveal that the prevailing economic growth pattern in India is environmentally unsustainable, because of its dependence on fossil fuel-based energy consumption and imported crude oil. Import substitution has been identified as one of the first stepping stones to address this issue, and accordingly, a multipronged SDG framework has been designed based on the direct and extended version of the study outcomes. While the Central policy framework shows a way to address SDG 7, SDG 8, SDG 12, and SDG 13, the Tangential policy framework shows the way to sustain the Central policy framework by addressing SDG 4.

Keywords: CO_2, Energy, India, NARDL, Oil Prices, SDG
JEL Classifications: P18, K32, O44, F63

I. Introduction

The latest Sustainable Development Goals (SDG) progress report (UNESCAP, 2019) on Asia and the Pacific countries shows the inefficiency of these nations in handling the issue of rising emissions. While the developed economies are making significant progress in achieving a secure energy future with betterment of environmental quality, these nations are experiencing the rise in emission levels, along with encountering the issue of energy security. Prevailing fossil fuel-based economic growth pattern in these nations has been considered as one of the major reasons behind these issues. This persistence in the reliance on fossil fuel solutions is forcing these nations to take a departure from attaining the objectives of SDG 13, i.e. climate action. As these nations are largely emerging in nature, hence attaining economic growth has been given a higher priority over sustaining the environmental quality. When the economic growth patterns of these nations are analyzed, then SDG progress report 2019 revealed that the countries pertaining to the South and South-West region are the laggards in achieving the objectives of SDG 13. While these nations have made an incremental progress in attaining the objectives of SDG 8, i.e. decent work and economic growth, this growth pattern has been speculated to be unsustainable in nature. This issue has been emphasized in the recent report on SDG achievement by United Nations (2019), while discussing about the inclination of these nations to invest on fossil fuels, rather than investing in climate activities.

As these nations are more inclined towards achieving economic growth even at the cost of environmental quality, it can be assumed that these nations will be inclined towards embarking on the fossil fuel solutions. In order to sustain the production process, these nations continue depleting the natural resources. Taking a cue from the "*Limits to Growth*" discourse, it can be assumed that the continued depletion of the natural resources might have a detrimental consequence on economic growth pattern (Meadows et al., 1972). This characteristic policy-level myopia prevailing in these nations might create a predicament in attaining the objectives of SDG 12, i.e. responsible consumption and production. Furthermore, when the industrial growth pattern exerts a pressure on the pool of natural resources, it becomes difficult for the nations to maintain intergenerational equity. This issue is reflected in terms of disparity in the distribution of wealth within the nation, and coexistence of skewed accumulation of wealth and fossil fuel consumption gradually brings forth decline in energy security. The recent energy security assessment report for the Asian countries by ADB (2019) points to these issues, while reflecting upon the instrumental role of natural resources in ensuring energy security. While discussing these issues, the role of alternate energy sources has been attributed as a viable replacement of the fossil fuel solutions, so as to lead these nations towards a sustainable energy future (ADB, 2019). Hence, the alternate energy sources could have been recognized as a policy instrument for making energy cost-effective and clean, and an instrument for ascertaining energy security. Any initiative on this front might help these nations to achieve the objectives of SDG 7, i.e. clean and affordable energy. By far, these nations have not made any significant progress in this front, and the SDG thinktanks have also identified this issue (IEA, 2019; IISD, 2019). Given this scenario, it is evident that a comprehensive SDG framework is essential for the Asia and Pacific countries, so that they can make a progression towards attaining the SDG objectives by 2030.

Saying this, it is important to mention that the policy framework should be designed in a way, so that SDG 13, SDG 7, SDG 12, and SDG 8 can be addressed. In so doing, natural resources, energy consumption, climatic shift, and economic growth pattern should be brought together under a single policy framework. Now, following UNESCAP (2019) and

ADB (2019), it is evident that India is encountering difficulties in attaining sustainable development through the prevailing economic and allied policies. Though the policymakers are putting an endeavor to ensure 100% rural electrification in India, energy poverty is still at large. A recent study by Bloomberg (Bello, 2019) has reflected that the rural electrification might not cater to the problem of failing energy security in India, as maintaining the alternate energy solutions might be difficult without the proper distribution channels and a sustained household income. In this regard, the SDG Index and Dashboard report for India by NITI Aayog (2019) stresses on the high dependence of Indian economy on crude oil, while describing the vulnerability of Indian economy to crude oil price volatility. This issue traces back to the dependence on fossil fuel solutions in India, and it suggests that the Indian economic growth pattern might have created a vicious circle of energy poverty. In such a scenario, in order to sustain the economic growth pattern, the policymakers are trying to bring amendments in the trade pattern, so that the dependence on imported natural resources can be reduced, while the domestic production can be given a boost to create employment. A recent report by World Bank (Artuc et al., 2019) states that India might set an example for the South Asian economies the envisaging import substitution policies as a mean to achieve sustainable development. Based on this discussion, India can be considered as a case study for the South Asian and Asia Pacific economies in their endeavors to achieve the SDG objectives, and the learnings for the Indian context can be utilized in these nations. However, a broad policy framework to achieve this objective is yet to be devised by the policymakers, and there comes the significance of the present study.

Given this background, it can be anticipated that an inclusive policy framework is necessitated for the Asian economies, so that these economies can make progress towards accomplishing the SDG resolutions by 2030. In this quest, the present study focuses on evaluating the impact of economic growth and its drivers on carbon emissions in India over the period of 1980-2019. Through this exploration, the present research intends to suggest a comprehensive policy structure for realizing sustainable development, and successively attuning concomitant economic and developmental policies. As these nations are characterized as the laggards in realizing the SDGs, hence, devising policy outlines for these nations is anticipated to help other emerging economies to standardize their policies for ascertaining sustainable development. Consideration of economic growth, trade openness, energy consumption, crude oil price, and environmental degradation within a unified policy schema might succor in suggesting a broad policy framework for attaining SDG 13, SDG 7, SDG 12, and consequently SDG 8. Nonetheless, during the portrayal of the policy framework, a phased routine might be applied, as a robust policy needs to take account of the transactional spillovers and structural similarities among these nations, and therefore, a phased multipronged SDG framework can be endorsed. To the best of our understanding, this policy-level approach to encounter environmental degradation has not been implemented in the literature, and there lies the policy level contribution of the study.

Now, in order to achieve this policy-level objective, it is necessary to understand that the model parameters might not have same impacts on the target policy variable, whenever they will be encountering any external shock. On the other hand, it is possible that those shocks will appearing in certain time differentials. Hence, in order to design a robust policy framework, the methodological adaptation needs to be carried out in a way that these aspects of policy formulation can be complemented. In this pursuit, Nonlinear autoregressive distributed lag (NARDL) method by Shin et al. (2014) is employed in this study. This method is capable of capturing the differential impacts of model parameters on the target policy variable in incidents of the positive and negative shocks. Moreover, NARDL is capable of capturing the impacts appearing with time differentials. In view of this, this method is able to complement the policy-level contributions of the study, and thereby, indicating the analytical contribution of the study.

The remaining paper is organized as follows: Section-II reviews the extant literature. Section-III presents the modeling framework and detailed data description. Section-IV includes the derived results and section-V concludes the paper.

II. Literature review

Domestic production (Panayotou, 1997; Ang, 2007), energy consumption (Soytas et al. 2007; Destek and Sinha, 2020), population growth rate (Coondoo and Dinda, 2002), foreign direct investment (FDI) inflows (Sharma et al., 2018), and international trade (Sinha et al., 2019) are some of the well-recognized drivers of environmental pollution. At different levels of income, energy consumption, and population growth rate, the level of environmental pollution may vary significantly as well (Shahbaz et al., 2018b; Shahbaz and Sinha, 2019). Even across regions and times, their association with environmental pollution may be significantly different. As a result, studies include either a linear or nonlinear approach to determine the level of pollution in a country or region. There also exists a segregation of the literature into region-specific (i.e., a group of countries) and country-specific studies. We divide the literature similarly, where both linear and nonlinear associations have been tested. The latter studies are depicted in Table-1, whereas the former literature is mentioned here as under.

In their studies, Holtz-Eakin and Selden (1995) and Tucker (1995) examined a sample of 130 and 131 countries, respectively, to confirm the presence of the environmental Kuznets curve (EKC). That is, at different levels of income, the level of CO_2 emissions varies significantly in both studies. Therefore, scholars recommend adopting environmentally friendly production techniques over time. Similarly, Stern et al. (1996) contend the level of sulphur dioxide (SO_2) tends to increase significantly in the beginning because of increased domestic production. However, this direct association between environmental degradation and domestic production may weaken and become negative with time. In succession, the additional economic cost led by SO_2 emissions may start decreasing. Using a sample of 88 countries, Coondoo and Dinda (2002) explored the possible causation between GDP growth and environmental quality. To obtain a comprehensive picture, they divided countries into different groups. Their results show that, in the developing countries group, per capita income is significantly driven by CO_2 emissions. Conversely, in Central and South America, Oceania, and Japan, CO_2 is Granger-caused by per capita income. In Asia and Africa, both variables are bi-directionally associated during the examined period. Similarly, Azomahou et al. (2006) confirm a positive association between environmental pollution and per capita income for the 1960–1996 period. However, in the long range, the non-parametric approach accepts the monotonous functional relationship between both variables.

Using a panel of Middle East and North African (MENA) countries, Shahbaz et al. (2019) determined whether the association between annual domestic production and CO_2 is nonlinear over time. The authors established an N-type association between both variables—That is, initially, national income increase may lead to a carbon upsurge in the region. However, after achieving a level of income, it may turn negative, as technological advancement would reduce the marginal consumption of energy, further improving environmental quality. Finally, excessive production activities, once again, would intensify environmental pollution. While examining the association between energy-CO_2, Poumanyvong and Kaneko (2010) in their panel data study examined whether the level of

CO_2 emissions is substantially driven by energy usage and urbanization in 99 countries. By segregating the sampled countries into three groups, the study proves a long-run direct association between urbanization and CO_2 emissions across the groups. However, the magnitude of the association between both variables is only marginally different across the groups. Similarly, using GDP, trade expansion, and energy usage as CO_2 determinants, Atici (2009) found that Central and Eastern European countries followed the EKC hypothesis for the 1980–2002 period. Atici (2009) further reveals that, after achieving a level of per capita GDP, the intensity of pollution emissions begins to decrease. Thus, compared with other determinants, energy consumption causes more pollution, possibly owing to the intensive use of high-carbon driven technology in the region. However, the impact of increased trade expansion on environmental pollution is insignificant in the examined countries.

There has also been a global upsurge in the use of electricity consumption as a major energy source (IEA, 2017). Given this trend, Lean and Smyth (2010) used both GDP growth and electricity consumption as determinants of environmental pollution. Based on a sample of Association of Southeast Asian Nations (ASEAN) countries, they confirm a direct association between electricity usage and environmental pollution, whereas the GDP's influence on environmental pollution was found to be nonlinear. This type of association reveals the possibility of the EKC proposition in the region. Similarly, using a panel data set of five South Asian countries, Vidyarhthi (2014) confirmed a long-term association between CO_2 emissions and its determinants. Moreover, there exists a bidirectional causality between per capita output and energy usage. However, the association between CO_2 and per capita output was found to be unidirectional, where CO_2 drives per capita output over time. In contrast, using the dynamic threshold approach, Aye and Edoja (2017) examined 31 developing countries across 1971 to 2013. They observed a U-shaped association between CO_2 emissions and domestic production, indicating the absence of EKC in the region. To reduce the pollution level, the authors suggest intensifying the use of less carbon-intensive machinery in the region, or alternatively, ensuring extensive use of renewable energy resources.

In a panel data study of African countries, Ogundipe et al. (2014) found that their combined sample of 53 countries could not establish the EKC supposition, as these countries, at the time, had not achieved the desired level of per capita income. While assessing the impact of renewable energy usage on environmental pollution, Paramati et al. (2017) found that the excessive use of renewable energy resources leads to higher environmental pollution in developing economies. They recommend exploring less carbon-intensive alternative energy resources by expediting research and development (R&D) in this sector. Based on a sample of G7 countries, Shahbaz et al. (2018a) reveal that the intensity of CO_2 emissions increases with the use of biomass energy. In these countries, trade expansion contributes to improving long-term environmental quality. Similarly, Liang et al. (2019) used the entropy method to determine whether urban expansion has intensified the pollution level in the Jing–Jin–Ji region of China. They found that pollution intensity is significantly controlled by the environmental policy of the government. Further, the impact of urbanization on pollution emissions remains nonlinear or inconsistent during the examined period. Finally, using a sample of South Asian countries, Sharma et al. (2020) established that the level of CO_2 emissions varies significantly at different levels of income and FDI inflows. They found that the existing energy basket in the region is a significant driver of carbon emissions. Therefore, they recommend exploring alternative energy resources that are less carbon-intensive. Because we choose a country-specific approach, it is critical to examine related literature comprehensively. Table-1 provides the details of past studies (in chronological order).

Table-1: Related literature review

S.N.	Author(s)	Country	Study period	Method	Variables	EKC exists	Causality
1	Lindmark (2002)	Sweden	1870-1997	OLS	CO_2, GDP	Yes	GDP → CO_2
2	Ang (2007)	France	1960-2000	ARDL, VECM, GC	CO_2, GDP, E	Yes	GDP→ CO_2
3	Managi and Jena (2008)	India	1991-2003	Productivity measurement technique	SO_2, NO_2, GDP	Yes	GDP → SO_2 and NO_2
4	Zhang and Cheng (2009)	China	1960-2007	VAR, ECM	CO_2, GDP, E, CAP, URB	No	E →CO_2
5	Ghosh (2010)	India	1971-2006	ARDL	CO_2, GDP, E, CAP, EMP	No	N.A. in the long run
6	Ahmed and Long (2012)	Pakistan	1971-2008	ARDL	CO_2, GDP, TOP, E, POP	Yes	GDP→ CO_2 POP→ CO_2 TOP→CO_2
7	Kanjilal and Ghosh (2013)	India	1971-2008	ARDL	CO_2, GDP, E, TOP	Yes	GDP→ CO_2 E →CO_2
8	Shahbaz et al. (2013)	Indonesia	1975q_1-2011q_4	ARDL, VECM	CO_2, GDP, E, TOP, FD	N.A.	GDP↔CO_2 FD → CO_2
9	Shahbaz et al. (2014)	UAE	1975-2011	ARDL, VECM	CO_2, GDP, U, EL	Yes	EL↔CO_2 GDP→ CO_2 U→CO_2
10	Lacheheb et al. (2015)	Algeria	1971-2009	ARDL	CO_2, GDP, CAP, TOP, EL, POP	No	GDP→ CO_2 POP→ CO_2
11	Shahbaz et al. (2015)	India	1970-2012	ARDL	CO_2, GDP, E, TOP, FD	Yes	CO_2→E GDP↔FD
12	Gul et al. (2015)	Malaysia	1975-2013	Meboot	CO_2, E, BM, POP	N.A.	E→CO_2
13	Bouznit and Pablo-Romero (2016)	Algeria	1970-2010	ARDL	CO_2, GDP, E, EL, TOP, FD	Yes	E→CO_2
14	Magazzino (2016)	Italy	1970-2006	VECM	CO_2, GDP, E	N.A.	GDP↔CO_2 E↔CO_2
15	Gökmenoğlu and Taspinar (2016)	Turkey	1974-2010	Todo-Yamamoto	CO_2, GDP, E, FDI	Yes	FDI↔CO_2 E↔CO_2
16	Mohiuddin et al. (2016)	Pakistan	1971-2013	VECM	CO_2, GDP, E EO, EG		E→CO_2
17	Nain et al. (2017)	India	1971-2011	Todo-Yamamoto	CO_2, GDP, EL	N.A.	EL→GDP EL→CO_2
18	Mikayilov et al. (2018)	Azerbaijan	1992-2013	ARDL, FMOLS, DOLS	CO_2, GDP	No	N.A.
19	Sulaiman and Abdul-Rahim (2018)	Nigeria	1971-2000, 1971-2005, 1971-2010	ARDL	CO_2, GDP, E, POP	N.A.	GDP→ CO_2
20	Wang and Li, (2019)	China	1990-2014	NE grey Verhulst	CO_2, GDP	Yes	N.A.

Notes:
The symbol → indicates the unidirectional causality, which goes from the left-hand to right-hand side variable, whereas symbol ↔ indicates the bidirectional causality, which runs in both directions.

List of abbreviations
GDP: real gross domestic production
CO2: Carbon dioxide
E: Energy consumption
EL: Electricity consumption
EO: Oil-based energy
EG: Gas-based energy
SO2: Sulphur dioxide

NO2: Nitrogen dioxide
POP: Population
TOP: Trade openness
FDI: Foreign dirct investment
BM: Broad money
FD: Financialdevelopment
CAP: Capital formation
U: Urbanization
EMP: Employment
ARDL: Autoregressive Distributed Lag
FMOLS: Fully Modified Ordinary Least Square
DOLS: Dynamic Ordinary Least Square
VAR: Vector Autoregression
VECM: Vector Error Correction Model
GC: Granger Causality

The country-specific literature review shows that domestic production, alternative energy resources, population growth, trade openness, capital formation, financial sector development, and urbanization can be possible drivers of environmental quality. As far as methodology is concerned, autoregressive distributed lag (ARDL) and vector error correction model (VECM) approaches are frequently employed. However, none of the past studies considers the separate impacts of favorable and unfavorable variations. A closer examination of the literature suggests that the insertion of dummy variables for the possible series break is also ignored when determining the magnitude of environmental pollution. Considering the ongoing structural changes and increasing environmental pollution in India, it is necessary to understand whether the fluctuations in the selected variables significantly drive CO_2 emissions in both periods. Undeniably, if the impacts of the movements of both sides in carbon emissions' determinants are different and significant, then an appropriate long-term policy formulation is needed. Therefore, the existing scenario motivates the use of the NARDL approach in the presence of an unidentified series breakdown.

III. Data and Estimation Approach

Given the economic growth pattern in majority of the Asian countries, and specifically in India, the economic growth is enabled by fossil fuel-based energy consumption. In view of the rising economic growth in these nations, it might not be possible for these nations to depend on the pool of endogenous natural resources for energy generation, and therefore, in order cater to the rising demand for energy, these nations will need to depend on imported crude oil. In view of this, the fluctuations in the oil price will be reflected in the fluctuations in energy production, and consequently in the CO_2 emissions. Along side this, the pattern of international trade will also have an impact on the CO_2 emissions pattern, by means of the imposition of the import substitution policy. Following this discussion, the baseline empirical model of the study can be devised as per the following:

$$CO_{2t} = f(GDP_t, E_t, OP_t, TOP_t) \quad (1)$$

Here, CO_2 is the per capita carbon dioxide emissions, GDP is the per capita gross domestic product, OP is the crude oil price, TOP is the per capita trade openness, and t is the years of observation. Except for oil price, the other data series are retrieved from the World Development Indicators. The oil price series is acquired from the Energy Information Administration data repository. Initially, the series of CO_2 emissions, GDP, oil prices, energy, and TOP (proportion of the addition of exports and imports to gross domestic product) are collected in metric tons, constant US dollars (2010), US dollar/barrel, kt of oil equivalent, and constant US dollars (2010), respectively. Except for oil prices, all other series are converted into per capita form by dividing the population. Thereafter, all the series are changed into natural logarithm values, as this approach would control for data sharpness. Owing to the length of the examined period (1980–2019), we explore the possibility of series discontinuity, and validate the results using the Wald test. To determine the pollution function in India, we employ the NARDL approach (Shin et al., 2014). Following Ang (2007, 2008), Soytas et al. (2007), and Shahbaz et al. (2017), the behavioral equation for CO_2 emissions function is mentioned as under, which considers the favorable and unfavorable changes separately:

$$\Delta CO2_t = \beta_0 + \alpha_1 CO2_{t-1} + \alpha_{2(+)} GDP_{t-1(+)} + \alpha_{3(-)} GDP_{t-1(-)} + \alpha_{4(+)} OILP_{t-1(+)} + \alpha_{5(-)} OILP_{t-1(-)} + \alpha_{6(+)} ENERGY_{t-1(+)} + \alpha_{7(-)} ENERGY_{t-1(-)} + \alpha_{8(+)} TOP_{t-1(+)} + \alpha_{9(-)} TOP_{t-1(-)} + \sum_{i=1}^{p} \beta_1 \Delta\, CO2_{t-i} + \sum_{i=0}^{r} \beta_2 \Delta\, GDP_{t-i(+)} + \sum_{i=0}^{r} \beta_3 \Delta\, GDP_{t-i(-)} + \sum_{i=0}^{r} \beta_4 \Delta\, OILP_{t-i(+)} + \sum_{i=0}^{r} \beta_5 \Delta\, OILP_{t-i(-)} + \sum_{i=0}^{r} \beta_6 \Delta\, ENERGY_{t-i(+)} + \sum_{i=0}^{r} \beta_7 \Delta\, ENERGY_{t-i(-)} + \sum_{i=0}^{r} \beta_8 \Delta\, TOP_{t-i(+)} + \sum_{i=0}^{r} \beta_9 \Delta\, TOP_{t-i(-)} + Dummy_t + \mu_t \quad (2)$$

Equation-2 carries the short-run and long-run favorable (+) and unfavorable (-) changes, which are represented by the coefficients β_i and α_i, respectively. The NARDL approach captures the impact of the CO_2 determinants in both periods separately. In the case of CO_2 emissions, separate examination of both periods becomes more crucial, as its level of emissions may vary significantly across periods. We expect the association of CO_2 emissions with per capita domestic production and energy usage to be direct, whereas its association with oil price and trade openness needs to be established; depending on oil availability and trade policy, the influence of both variables may differ across countries. Using the Wald test, the NARDL approach enables us to validate whether the short-run ($\beta = \beta_+ = \beta_-$) and long-run ($\alpha = \alpha_+ = \alpha_-$) asymmetries are significant for estimations. Further, the unit-root test with series discontinuity examines the prospect of an unknown break in the system (Kim and Parron, 2009), which is confirmed by the Wald test and denoted as $Dummy_t$ in equation-2. To establish the lag criteria for dependent (p) and independent (r) variables, the Akaike information criteria are considered. The favorable and unfavorable changes in independent variables are estimated using equation-2, where the partial sums of both types of variations are calculated separately.

$$ge_{t(+)} = \sum_{k=1}^{t} \Delta\, ge_{k(+)} = \sum_{k=1}^{t} max\,(\Delta\, ge_{k,} 0)\ and\ ge_{t(-)} = \sum_{k=1}^{t} \Delta\, ge_{k(-)} = \sum_{k=1}^{t} min\,(\Delta\, ge_{k,} 0) \quad (3)$$

These favorable and unfavorable variations in independent variables (i.e. per capita GDP, oil prices, energy, and trade openness) are represented by $ge_{t(+)}$ and $ge_{t(-)}$, respectively. Unless the bounds tests for the long-run cointegration are employed, the reliability of the outcomes cannot be confirmed. In this regard, the bounds tests proposed by Banerjee et al. (1998) and Pesaran et al. (2001) can assess whether a long-run cointegration exists with the comprised set of variables. The null hypothesis in Banerjee et al.'s (1998) test, which is t-statistics-based, assumes $\beta = 0$, whereas $\beta < 0$ confirms the rejection of the null hypothesis. The null hypothesis in Pesaran et al.'s test (2001), which is F-statistic based, assumes $\beta_{(+)} = \beta_{(-)} = \beta = 0$. In the present study, the acceptance of the alternative hypotheses for both tests validates long-run cointegration in the system. Further, the asymmetric coefficients for the long term are calculated using the long-run coefficients of favorable ($LA_i = \beta_{(+)} / \gamma$) and unfavorable

($LA_i = \beta_{(-)} / \gamma$) changes. The procedure for calculating the multiplier effects with dynamic asymmetry is described in equation-4.

$$AM_{l(+)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial GDP_{t(+)}}), AM_{l(-)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial GDP_{t(-)}}), AM_{l(+)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial OILP_{t(+)}}), AM_{l(-)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial OILP_{t(-)}}), AM_{l(+)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial ENERGY_{t(+)}}), AM_{l(-)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial ENERGY_{t(-)}}), AM_{l(+)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial TOP_{t(+)}}), AM_{l(-)} = \sum_{k=0}^{l}(\frac{\partial CO2_{t+k}}{\partial TOP_{t(-)}}) \quad (4)$$

In equation-4, l = 0, 1, 2, 3 … and if $l \rightarrow \infty$, then $AM_{l(+)} \rightarrow LA_{i(+)}$ and $AM_{l(-)} \rightarrow LA_{i(-)}$ are operative. Owing to the favorable and unfavorable variations in the selected determinants, the asymmetric deviations in CO_2 emissions allow us to capture the dynamic multipliers effect. As a result, these dynamic adjustments help achieve a new equilibrium, provided the variations are substantial.

IV. Results and Discussions

In the following, we consider the structural break, which provides the results of the augmented Dickey–Fuller (ADF) (Dickey and Fuller, 1979), and Phillips–Perron (Phillips and Perron, 1988) tests. These tests determine whether the data series are stable. Then, we discuss the outcomes of the NARDL estimation. Finally, we present the results of the variance decomposition. Applicability of the NARDL approach has been verified by the results of Brock-Dechert-Scheinkman test and the results of this test are reported in Appendix 1. The NARDL estimation can be conducted if the integration of the comprised variables is at the 0 or 1 order, as this property allows long-run cointegration in the system. Moreover, the NARDL estimation permits the combination of both orders, that is, 0 and 1. Thus, the employed unit root tests help in rejecting the existence of the *I*(2) order in the system. Table-2 shows that, at the level, all the series are unstable, whereas they are stable at the first difference. The outcomes of both tests were computed using the intercept and trend. However, in Table-2, the only unit root results with intercept are exhibited.

Table-2: Unit root tests

Variables	**ADF test (level)**		**ADF test (1st diff.)**		**PP test (level)**		**PP test (1st diff.)**	
	t-stat	p-value	t-stat	p-value	t-stat	p-value	t-stat	p-value
CO_2	-0.323	0.911	-6.062***	0.000	-0.326	0.910	-6.078***	0.000
GDP	-3.473	1.000	-4.278***	0.001	6.799	1.000	-4.242***	0.002
OILP	-1.275	0.627	-5.430***	0.000	-1.252	0.640	-5.430***	0.000
ENERGY	1.517	0.999	-4.962***	0.000	1.327	0.998	-5.141***	0.000
TOP	-0.490	0.881	-4.410***	0.001	-0.517	0.864	-4.451***	0.001

Notes: 1%, 5%, and 10% significance level are highlighted by (***), (**), and (*), sequentially. (Source: Authors' calculations)

If a data series possesses a significant structural discontinuity, then the possibility of misleading results using the common unit root tests cannot be denied, as these tests are weak in terms of the degree of distribution and explanation (Perron, 1989). To assess the data stationarity with structural discontinuity, an ADF test (Kim and Perron 2009) is also conducted. Unlike a traditional test, this test examines the stationarity in the data series with one unidentified series discontinuity. Table 3 displays the results of Kim and Perron's test. At the level with structural discontinuity, all the series are asymmetrical over time, whereas they are stable at the first differences. Structural breaks in CO_2, GDP, OILP, ENERGY, and TOP series are found in 2007, 2003, 2003, 2004, and 1992, respectively. Owing to the growth endeavors, in the last two-and-a-half decade, the country has witnessed numerous changes in all spheres. The globalization process initiated in the 1990s changed the magnitude of exports and imports significantly—For instance, in 1992, the trade openness series observed a structural break. Similarly, the structural breaks found in the oil price and energy series could be attributed to the deregulation of the *administrative pricing mechanism* initiated on April 1, 2002. Nevertheless, the government still controls cooking gas and kerosene market prices, as all income classes use these products (Shahbaz et al., 2017). The existence of stationarity with series discontinuity at the first difference allows us to employ the NARDL estimation.

Table-3: Kim and Parron's unit root test (one structural break)

Variables	**(level)**			**(First difference)**		
	Break date	t-stat	p-value	Break date	t-stat	p-value
CO_2	2007	-3.464	0.406	2002	-6.487***	<0.01
GDP	2003	-0.012	0.999	2002	-6.251***	<0.01
OILP	2003	-3.731	0.266	2014	-6.094***	<0.01
ENERGY	2004	-1.751	0.999	2003	-6.262***	<0.01
TOP	1992	-2.616	0.863	2013	-5.513***	<0.01

Notes: 1%, 5%, and 10% significance level are highlighted by (***), (**), and (*), sequentially. (Source: Authors' calculations)

The NARDL bounds estimation results are shown in Table-4, where the R^2 value indicates that the 92.6% deviation in CO_2 emissions arises due to the chosen variables. The outcomes of the Breusch–Pagan (χ^2_{HET} = 0.902) and Jarque–Bera (χ^2_{NOR} = 0.934) tests confirm the absence of heteroskedasticity and abnormality, respectively. Likewise, the null hypothesis of the absence of serial correlation cannot be dismissed, as the *p*-value of the serial correlation test (χ^2_{SEC} = 0.617) is insignificant. The appropriateness of the functional association is confirmed by the Ramsey test (F = 0.624). In other words, for the examined period of 1980–2019, the comprised independent variables are appropriate for determining the level of CO_2 emissions. As far as asymmetric examination is concerned, the outcomes of the Wald tests validate that the segregation of chosen variables into favorable and unfavorable changes is significant and meaningful. Except for per capita GDP (0.198), the Wald test values for the positive variations in the oil price (0.007), energy (0.001), trade expansion (0.001), and dummy variable (0.002) are found in favor of asymmetric examination. Notably, both types of variations have significantly driven CO_2 emissions in both periods. The outcomes of *t*-statistics (T_{BAN} = -6.739) confirm that, at the 1% level, the series of CO_2, per capita GDP, OILP, ENERGY, and TOP are cointegrated over time. Further, F-statistic (F_{BT} = 12.493)[1] conceptualized by Shin et al. (2014) reveals that the series are cointegrated and possess a long-run nonlinear association despite the asymmetric approach.

Table-4: The nonlinear autoregressive distributed lag bounds test results

Variable to be explained: CO_2			
Variable	**Coefficient**	**t-statistics**	**Prob.**
Constant	-1.360***	-6.72	0.003
CO_{2t-1}	-1.634***	6.74	0.003
GDP^+_{t-1}	1.475**	4.35	0.012
GDP^-_{t-1}	-3.310	1.08	0.341

[1] The terms in parentheses carry *p*-values.

$OILP^{+}_{t-1}$	-0.726***	8.740	0.001
$OILP^{-}_{t-1}$	-0.227**	-3.540	0.024
$ENERGY^{+}_{t-1}$	0.485***	7.07	0.002
$ENERGY^{-}_{t-1}$	-0.087***	-6.320	0.003
TOP^{+}_{t-1}	-0.527***	-5.91	0.004
TOP^{-}_{t-1}	0.301***	6.06	0.003
$Dummy_{2004}$	-0.287***	7.190	0.002
ΔCO_{2t-1}	-0.032	-0.240	0.826
ΔGDP^{+}	-0.765**	-3.61	0.023
ΔGDP^{+}_{t-1}	-0.855**	-4.230	0.013
ΔGDP^{-}	-0.432	-0.270	0.800
ΔGDP^{-}_{t-1}	-2.464	-1.340	0.250
$\Delta OILP^{+}_{t-1}$	0.288***	4.790	0.009
$\Delta OILP^{-}_{t-1}$	0.066	2.020	0.113
$\Delta ENERGY^{+}$	1.610***	6.660	0.003
$\Delta ENERGY^{-}$	-3.860***	-4.790	0.009
ΔTOP^{+}	-0.438***	-6.490	0.003
ΔTOP^{-}	0.896***	7.520	0.002
R^2	0.926	-	-
Durbin-Watson	2.230	-	-
Diagnostic Tests	Stat	p-value	-
χ^2_{SEC}	12.81	0.617	-
χ^2_{HET}	0.015	0.902	-
χ^2_{NOR}	0.135	0.934	-
Ramsey RESET (F)	0.927	0.624	-
Cointegration Tests			
F_{BT}	12.493***	-	-
T_{BAN}	-6.739***	-	-
Asymmetry Statistics	**Long Run Effect (+)**		
Exog. Variable	Coefficients	F-stat	p>F
GDP^{+}	0.903**	19.280	0.012
$OILP^{+}$	-0.444***	116.600	0.000
$ENERGY^{+}$	2.971***	139.800	0.000
TOP^{+}	-0.323***	34.850	0.004
Dummy	0.176***	55.870	0.002
$Wald_{LR(GDP)}$	-	2.310	0.198
$Wald_{LR(OILP)}$	-	26.820	0.007
$Wald_{LR(ENERGY)}$	-	40.50	0.001
$Wald_{LR(TOP)}$	-	96.240	0.001
$Dummy_{2004}$	-	55.870	0.002
Asymmetry Statistics	**Long Run Effect (-)**		
GDP^{-}	2.026	1.197	0.335
$OILP^{-}$	0.139	23.560***	0.008
$ENERGY^{-}$	53.484	37.470***	0.004
TOP^{-}	-1.845	81.340***	0.001
$Wald_{SR(GDP)}$	-	0.3540	0.583
$Wald_{SR(OILP)}$		16.720**	0.015
$Wald_{SR(ENERGY)}$	-	11.850**	0.026
$Wald_{SR(TOP)}$	-	0.129	0.737
$Dummy_{2004}$		0.032	0.866

Notes: 1%, 5%, and 10% significance level are highlighted by (***), (**), and (*), sequentially. The positive and negative subscripts are used for positive and negative shocks, respectively. χ^2_{SEC}, χ^2_{HET}, and χ^2_{NOR}, exhibit the results of serial correlation, White's heteroscedasticity, and normality, respectively. The subscripts ($_{LR}$) and ($_{SR}$) are used to show the long run and short run outcomes of the Wald test, respectively. $Dummy_{2004}$ is carried for a structural break, where value one is taken from 2004-2019, and zero for the preceding period. F_{BT} = F statistics and T_{BAN} = t statistics. While displaying the short-run impact of independent variables, only significant values are kept in Table 4. However, the results can be retrieved on request. (Source: Authors' calculations)

IV.I. Long-run results

Table-4 shows that the favorable variations in per capita gross domestic production have a direct influence on carbon discharges in the country. In other words, a 1% upturn in per capita GDP increases CO_2 emissions by 1.475%. However, GDP's insignificant coefficient for unfavorable changes reveals that, with time, the level of CO_2 emissions does not decrease substantially if per capita GDP experiences a downturn. The nonlinear association between CO_2 and GDP indicates that, for pursuing long-term economic goals, India may have compromised on the concerns of environmental protection. This observation traces back to the classic issue of the growth-development tradeoff, which has been reflected in the report of NITI Aayog (2019) and UNESCAP (2019). Prevailing pro-growth agenda in the Asian economies is reflected in case of India also, and this issue can be attributed to the fossil fuel-driven growth pattern of Indian economy. While studies by Wang et al. (2017) and Shahbaz et al. (2019) ignore the differential impacts of upside and downside variations in GDP on CO_2 emissions, this segment of the results might bring forth serious policy implications regarding realignment of economic growth pattern in India. This environmental unsustainability of economic growth pattern has been experienced in Asian countries, as well (Parker and Bhatti, 2020). As per Gupta and Goyal (2015), reduction in the national output might lead to a betterment of the environmental quality, but this solution is not practicable, as the policy intervention should be able to internalize the negative environmental externalities through the economic growth pattern. In view of this result, this situation might create a concern for attaining the objectives of SDG 13, as this persisting economic growth pattern might create a predicament on the way of achieving the objective of climate action. This argument becomes clearer, when the impacts of other drivers of economic growth are analyzed in parallel with this result. The outcomes suggest that increased oil prices have contributed to decreasing the level of CO_2 emissions in India, which is revealed by the negative coefficient of oil price (-0.726). This segment of the results complements the impact of GDP on CO_2 emissions by divulging the dependence of Indian economy on crude oil. Because of this persisting dependence, rise in the oil price might have a negative impact on the manufacturing activities and electricity generation, and thereby, resulting in lowered CO_2 emissions. On the other hand, the reduction in the oil price is having less impact on the CO_2 emissions, and thereby, demonstrating a low oil price elasticity of carbon emissions, in the face of a falling crude oil price scenario. A situation of similar nature is also prevalent in case of Belt and Road initiative countries (Hu et al., 2020). From this piece of evidence manifests the unsustainable economic growth pattern of India, and it also shows the importance of alternate and clean energy solutions not only for the betterment of environmental quality, but also for ensuring energy security. This might create a concern for attaining the objectives of SDG 7, as continued dependence of crude oil might create a predicament on the way of achieving the objective of clean and affordable energy.

While talking about the concern for India in achieving the objectives of SDG 7, the impacts of the directional shocks of energy consumption on CO_2 emissions need to be analyzed. Long-run coefficients of energy consumption reveal that CO_2 emissions increase by 0.485% if energy consumption improves by 1%. That is, favorable energy consumption variations are significant in raising the level of CO_2 emissions. The intensified use of electricity has enlarged the scope for coal and crude oil consumption, which results in higher carbon discharge (IEA, 2019). In addition, in the post-liberalization period, owing to the rapid growth in manufacturing, industrialization, and transportation systems, energy use in India has widened substantially, and this energy-led economic growth has gradually exerted negative environmental externality in terms of rising CO_2 emissions. Regarding the impact of unfavorable variations, the negative and significant coefficient of energy consumption (-0.087) suggests that, owing to the decreased energy use, the level of CO_2 emissions decreases with time. This segment of the results suggests the unsustainability of the energy-led economic growth pattern of India, and it complements the impacts of crude oil price movement on CO_2 emissions. This experience reflects the scenario prevailing in the other Asian countries (Apergis and Ozturk, 2015; Ahmed et al., 2017). Apart from the academic literature, the recent report by IRENA (2019) also discusses this issue for the Asian countries. Therefore, any policy intervention to internalize this intensifying negative environmental externality in Indian economy can be considered as a benchmark for the other Asian countries. While bringing forth the policy intervention, it should be remembered that this energy consumption is also driven by the incessant consumption of natural resources, which might create a major predicament on the way of attaining the objectives of SDG 12, i.e. moving towards responsible consumption.

Now, the discussion on energy-led growth of India necessitates the cross-border movement of resources, which also has an impact on the economic growth, as well as CO_2 emissions pattern, via the energy consumption channel. This movement of resources is majorly governed by trade openness, and therefore, it can be assumed that it will have certain impact on CO_2 emissions. Notably, the positive variations in the volume of trade openness have helped in controlling CO_2 emissions in India, as the coefficient for the upside variations (TOP^{+}_{t-1} = -0.527) is found to be negative and significant. In contrast, the coefficient of downside variations (TOP^{-}_{t-1} = 0.301) indicates that, with time, the level of CO_2 discharges increases significantly, which may be because of the decrease in the volume of trade openness. This segment of the results suggests that international trade in India is following an environmentally sustainable pattern, and this has been possible through the gradual import substitution by the policymakers. As Indian import portfolio was majorly dependent of crude oil, therefore the import substitution policies in India has been able to reduce the import of crude oil and other petroleum products, and consequently, the level of CO_2 emissions. A recent report by World Bank (Artuc et al., 2019) has reflected this achievement by Indian government, and they have stressed on replicating this practice for the other Asian countries as a first stepping stone towards achieving the SDGs by 2030. On this ground, Ali and Abdullah (2015) found that trade intensification causes rise in the level of CO_2 emissions in Malaysia, whereas Hossain (2011) found the similar impact for Thailand, and Shahzad et al. (2017) found the same for Pakistan. This gives a rationale for considering the Indian example for the other Asian countries on the ground of designing policy framework for attaining the SDGs.

IV.II Short-run results

The negative and significant impact of favorable per capita GDP variations on CO_2 emissions indicates that short run rise in GDP might demonstrate the immediate impacts of rise in aggregate demand and rise in labor productivity. As the stock of capital remains constant during this phase, contribution to CO_2 emissions faces a decline. However, short run decline in GDP might demonstrate the immediate decline in aggregate demand, and therefore, contribution to CO_2 emissions faces a decline. Owing to the inelastic nature of the demand of capital stock during this phase, the impact of crude oil consumption on CO_2 emissions should be positive and inelastic. Therefore, the CO_2 emissions demonstrate the traits of inelasticity with respect to crude oil price movements. This aspect of inelasticity should be a concern for the policymakers, from the perspective of environmental sustainability of economic growth. On the other hand, low elasticity of manufacturing intensity with respect to energy consumption can be assumed, and a reflection of this phenomenon can be seen in terms of the negative environmental impact of energy consumption. With the rise in energy consumption, CO_2 emissions have seen to rise, whereas the decline in CO_2 emissions can be attributed to the fall in the energy consumption. This segment of the findings complements the impact of crude oil price movement, and thereby, demonstrating the unsustainability of economic growth pattern prevailing in India. Lastly, the immediate impact of import substitution can be seen in terms of the short-run impact of trade openness on CO_2 emissions. Considering *ceteris paribus*, the impact of the rise in trade openness shows a decline in CO_2 emissions, whereas the fall in trade openness shows a rise in CO_2 emissions. As the technological progression in the short run can be assumed to remain constant, the import substitution policies can have a direct impact on the manufacturing practices prevailing in India.

The outcomes of the dynamic asymmetric multiplier are shown in Figure-1, which reveals the dynamic adjustment process between the comprised variables. Considering the favorable and unfavorable variations in the presence of optimum lag length, the adjustment mechanism of CO_2 emissions with per capita GDP, OILP, ENERGY, and TOP are displayed in Figure 1a, 1b, 1c, and 1d, respectively. The strength and difference of asymmetric variations between favorable and unfavorable changes are represented by the red-dotted lines, indicating that the disentangling of the favorable and unfavorable variations is statistically significant. This way, we also add to the literature on environmental pollution. Similarly, the plain black and black dotted lines denote the favorable and unfavorable variations, respectively.

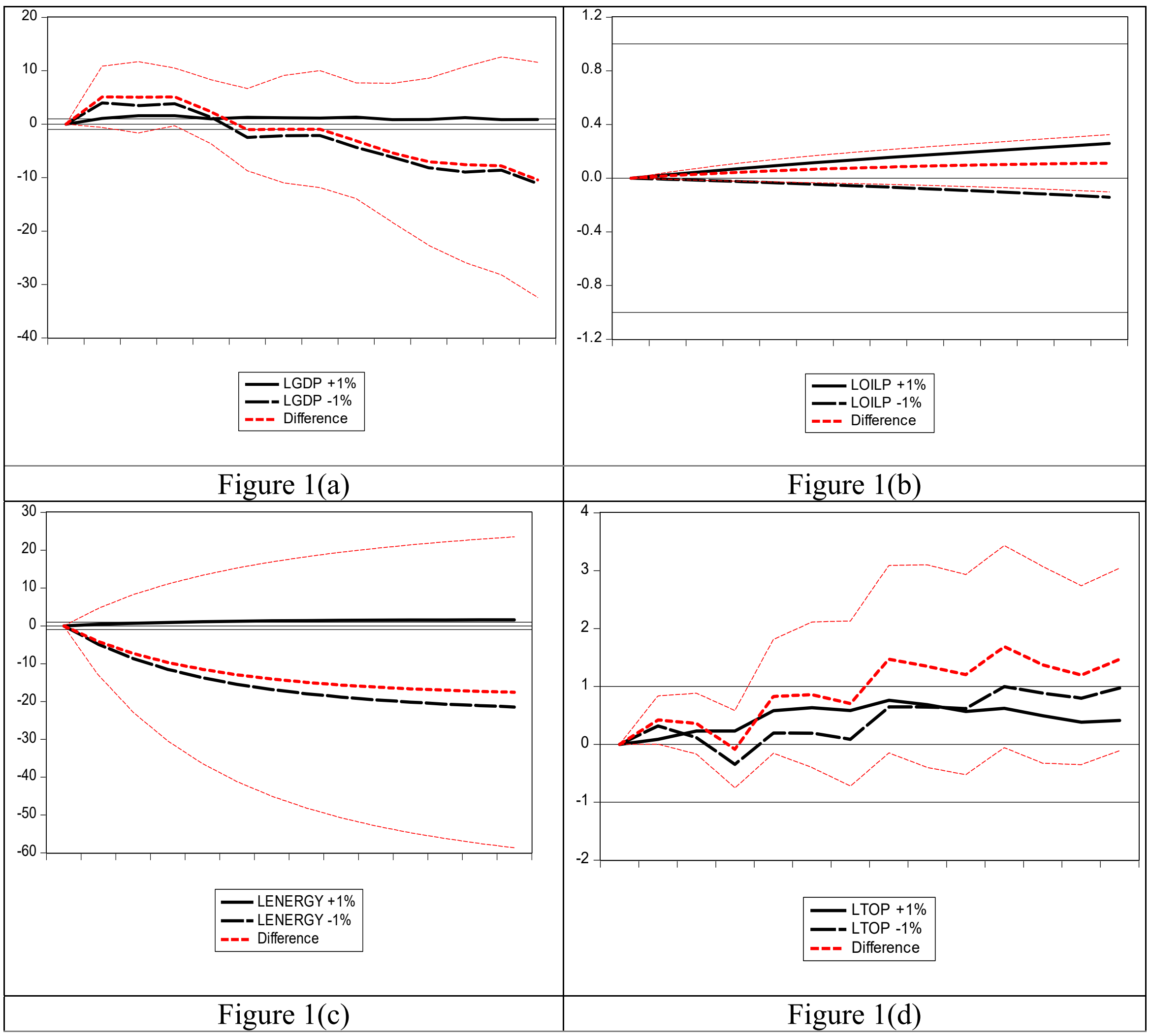

Figure-1. Dynamic asymmetric adjustment in CO_2 emissions with 1% favorable and unfavorable variations in the independent variables

In Figure-1, the time horizon and favorable–unfavorable variations are denoted on the horizontal and vertical axes, respectively. In Figure-1(a), compared with the negative variations in GDP, the positive variations are more noticeable over time. Conversely, Figure-1(b) reveals that both favorable and unfavorable variations in the oil price are noticeable. However, compared with the unfavorable variations, the favorable variations are stronger. The findings in Table-4 also support the outcomes of Figure-1(b). While determining the pollution level, the impact of favorable variations in energy consumption is stronger than for the unfavorable variations. However, initially, the effect of unfavorable deviations on CO_2 emissions is stronger than for unfavorable deviations, as shown by the dynamic asymmetric adjustment procedure (Figure-1c). Lastly, the outcomes of Figure-1(d) suggest that, compared with the unfavorable variations in trade openness, the level of CO_2 emissions is strongly affected by favorable variations over time. Table-4 corroborates these results. In fact, the asymmetric dynamic adjustment procedure corroborates the results of Table-4 for all variables.

IV.III Variance decomposition

Variance decomposition (VD) analysis could help assess the strength of the variables in the system. That is, using the VD approach, the relative contribution of the chosen indicators can be assessed. In this regard, if the variances of other variables are unable to affect the dependent variable, then the dependent variable can be treated as a self-explanatory or exogenous variable. The generalized VD enables us to ignore the specific ordering and does not isolate the impact of other variables. Instead of treating in a tabular manner, the outcomes of the VD are displayed using variance decomposition Figures (2a to 2d), as the graphical approach makes the comparison more self-explanatory.

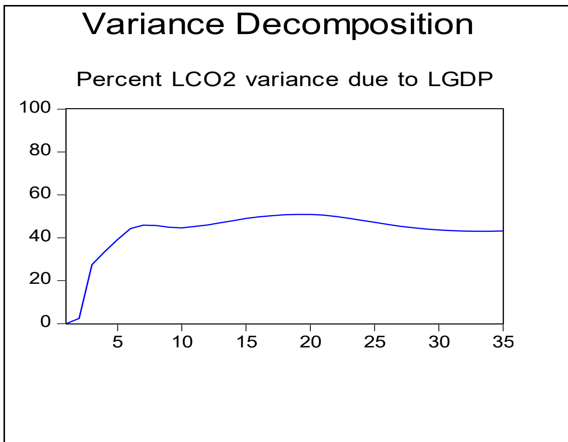

Figure 2 (a)

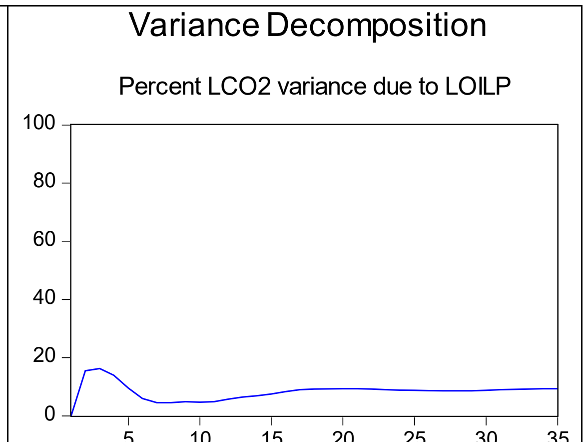

Figure 2(b)

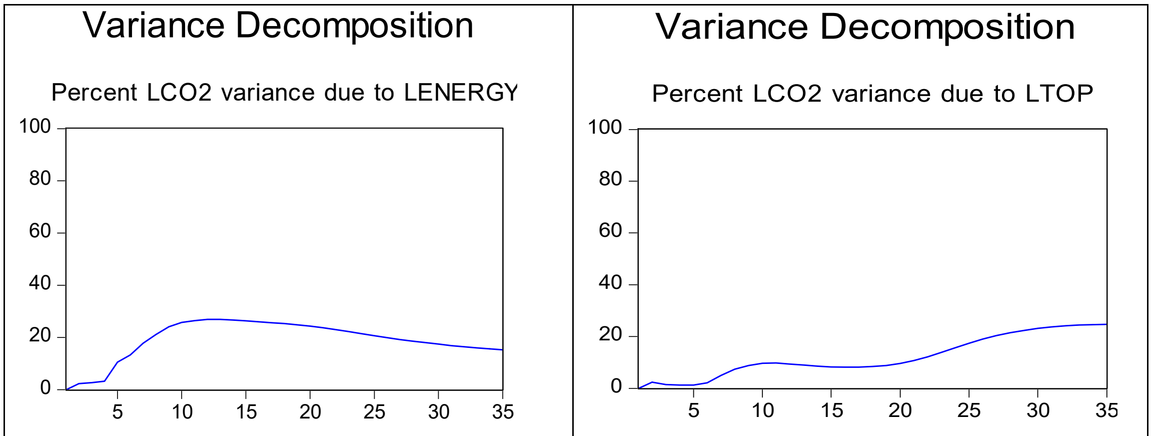

Figure 2(c)	Figure 2(d)

Figure-2. Decomposing the variance in CO_2 emissions caused by independent variables with ± 2 S.E. (Source: Authors' calculations)

The variance decomposition outcomes illustrated in Figure-2 prove that the selected variables appear to be endogenous in the system. However, the variance decomposition Figure-2(a) for GDP reveals that, owing to GDP variations, the long-run movement in the level of CO_2 emissions is stronger than for other variables. It substantiates the long run estimation outcome regarding the unsustainability of the economic growth pattern prevailing in India. Similarly, energy consumption appears to be a strong driver of emissions over time, as the influence of its variations on CO_2 emissions is stronger compared with oil price and trade expansion. Notably, from the policy formulation view, this information may be beneficial because these variables are likely to drive CO_2 emissions in India. The VD figures suggest that, in the short run, their impact may not be strong, but with the passage of time, the variations in these variables may significantly influence CO_2 emissions in the region. Figure-3 allows to understand the NARDL approach and highlighting how the model parameters influence CO_2 emissions.

V. Conclusion and Policy Framework

Using Indian scenario, the present study explores whether CO_2 emissions are nonlinearly influenced by per capita GDP, energy use, oil prices, and trade expansion between 1980 and 2019. NARDL approach allowed to examine the bifurcated (i.e., favorable and unfavorable) impact of the explanatory variables on CO_2 emissions. To compute the CO_2 function, a dummy variable for the series discontinuity was incorporated. The unit root test outcomes show that the series are integrated. Following this, Wald test results suggest the suitability of the NARDL approach and the observed shocks are significant. The outcome of the study can be utilized for designing a policy framework for attaining the objectives of SDGs, and this framework can set an example for the Asian countries, which are also encountering difficulties to attain the SDG objectives.

V.I. Central policy framework

As the demand for crude oil is seemingly inelastic in nature for the Indian manufacturing sector, therefore, imposition of the import substitution policies might create a rise in energy demand in this sector. Now, in the wake of the rising energy demand paradigm, the policymakers will have an incentive to bring changes in the prevailing energy consumption pattern. However, any sudden or overnight changes in the energy consumption pattern might have a negative impact on economic growth pattern, which is largely driven by fossil fuel-based energy consumption. Hence, the policymakers might adopt a phase-wise energy transformation approach, which will help in bringing transformation in the energy consumption pattern, without causing any harm to the economic growth pattern. In the first phase, sectors with higher price elasticity of demand for crude oil should be targeted for crude oil substitution. These sectors might be endowed with renewable energy solutions against a pro-rata rate from the government with a certain interest rate holiday period, so that the implementation cost of these solutions can be borne by the firms without having any significant impact on their revenue stream. Now, in this phase, government will incur certain fiscal losses due to the interest rate holiday mechanism. However, these losses can be recovered gradually in the second phase. In the second phase, sectors with lower price elasticity of demand for crude oil and fossil fuel-based energy should be targeted. The policymakers should follow differential pricing mechanism for providing the solutions to the firms operating in these sectors, and the price difference should be decided based on the carbon footprint of the firms. This differential pricing mechanism can be viewed as the Pigouvian Taxation mechanism for internalizing the negative environmental externalities exerted by these sectors.

Once these two phases are implemented, not only the rise in the energy demand can be handled in an effective way, but also the renewable energy providers will also get an opportunity to achieve the economies of scale. This will help India in making a progress towards achieving the objectives of SDG 7. Furthermore, gradual decline in the dependence on natural resources for energy production will help in preserving the pool of natural resources, and at the same time, the associated biodiversity loss can also be prevented. Moving away from depletion of natural resources and rising dependence on renewable energy solutions will help India in making a progress towards achieving the objectives of SDG 12. With the import substitution policies in place, it will also be possible for the policymakers to reduce the dependence on crude oil, and it will have three major economic benefits: (1) the economic growth pattern will be gradually free from crude oil price volatility, (2) replacing crude oil with the endogenous renewable energy solutions will help the domestic producers to become cost competitive in the global export market, and (3) the emergence of renewable energy providers will create job opportunities in the domestic market. In this way, the trade openness pattern might help in sustaining the economic growth pattern, and thereby, helping India to progress in the pursuit of attaining the objectives of SDG 8. Lastly, the rising reliance on the renewable energy solutions and the departure from fossil fuel-based energy solutions will help the economic growth pattern in exerting positive environmental externality by reducing the level of ambient CO_2 emissions. This will help India to make progression on the way to achieve the objectives of SDG 13.

V.II. Tangential policy framework

As the central policy framework can be derived directly from the study outcomes, the tangential policy framework might help in achieving the additional SDG objectives, by extending the study outcomes. The tangential policy framework might follow the central policy framework, while building upon the two phases of the latter, with an objective of sustaining those two phases. Now, in order to sustain the initiatives on promoting renewable energy solutions, it is necessary to create an environmental awareness among the citizens. Therefore, policymakers should encourage the people-public-private partnerships in pursuit of promoting environmental awareness to enhance the acceptability of renewable energy solutions among the citizens. To reach the grassroots level of this initiative, the policymakers might ponder upon revising the educational curricula so as to reflecting on the benefits of renewable energy solutions. This might help the nation of make certain progress towards achieving the objectives of SDG 4, i.e. quality education. Subsequent to this phase, the households in India might be ready to embrace the renewable energy solutions, and the households might be provided these solutions at a pro-rata rate from the local government bodies. Like in case of the industrial sector, the households will also be given a certain interest rate holiday, so that they are able to replace their existing fossil fuel-based energy solutions in a hassle-free manner. The short-run fiscal loss to be borne by the government during this phase might be compensated by means of the interest income and tax revenue being generated from the industrial sector. Once the demand for renewable energy solutions can be created at the household level, then the initiatives towards promoting renewable energy solutions can be sustained and diminishing demand of fossil fuel solutions will be able to complement this scenario.

V.III. Policy caveats

While stating the policy frameworks, it is also needed to mention the assumptions and caveats, without which these frameworks might not prove to be effective. First, the policymakers should continue import substitution to discourage the import of crude oil, and in this pursuit, the import duties on crude oil can be gradually increased. Second, the laws for environmental protection should be made more stringent, so that the depletion of natural resources can be minimized. Third, while boosting the renewable energy sector, the traditional fossil fuel energy generation sector will face a demand pressure, and consequent unemployment might be seen in this sector. In order to maintain the social balance, the surplus labor from this sector should be provided proper vocational training, so that they can be employed in the emerging renewable energy sector. It might give further sustenance to the economic growth pattern.

V.IV. Limitations and scope for future research

Before bringing a conclusion to the study, it is imperative to mention that any policy framework should not be considered as an absolute one, as it might not be conceivable to capture all the pertinent policy parameters within the boundary of a sole framework, and the present study is no exception. Only two parameters for energy and one parameter for international trade have been used in designing the framework, and there lies the limitation of the study. The innovation and sectoral aspects could have been considered to bring forth additional robustness in the policy design. Saying this, it also needs to be mentioned that this study can act as a baseline study for the other Asian countries, as the issues being discussed pertain to the majority of the Asian countries, and therefore, the policy frameworks discussed in the study has the benefit of generalizability. Future research on this aspect can be taken up by considering the spatial panel estimation of the Asian countries, by extending this framework. In methodological terms, quantilogram approach can be considered for analyzing the correlational aspects at a granular level.

Appendix

Appendix-1: Results of BDS nonlinearity test

Dimension	CO_2	GDP	OILP	ENERGY	TOP
2	0.186***	0.179***	0.143***	0.174***	0.179***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
3	0.281***	0.292***	0.223***	0.277***	0.295***
	(0.000)	(0.000) ***	(0.000)	(0.000)	(0.000)
4	0.401***	0.365***	0.264***	0.341***	0.368***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
5	0.461***	0.407***	0.276***	0.374***	0.410***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
6	0.509***	0.428***	0.262***	0.383***	0.434***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Source: Based on the author(s) calculations.

Notes: (i) Notes: 1% significance level is exhibited using (***). (ii) By using the residuals of CO2 emissions, we employed VAR approach to calculate the different dimensions. (iii) The null hypothesis is that series are linearly distributed.

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