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Nexus between Anthropogenic Activities and GHGs Emission in India: An Empirical Analysis

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The worst consequences of environmental degradation are realised all across the globe and environmental sustainability is, thus, the call of the day. Consumption and production activities to fulfil human wants pollute all the means of sustainability through exhaustion and overexploitation of scarce natural resources. This empirical study tries to establish the nexus between anthropogenic activities and GHGs emissions, using ARDL based bound test for India over a period of 44 years spanning 1971 to 2014. The study reveals that fertility rate, population density, Economic Growth, and consumption of primary energy have a positive and statistically significant impact on the emission of GHGs both in the short and longrun.

Key words: *Greenhouse Gasses, Economic Growth, Population Growth, Primary Energy, Forest, India, ARDL.*

Introduction

Rapid population growth with urbanisation, industrialisation and modernisation in the era of the 21st century made the Indian economy risky and hazardous, and is considered to be a retarding factor for future development. India, the world's second largest coal consumer, fifth largest car seller, fourth largest wind power generator, third largest Greenhouse Gases (GHGs) emitter and fourth largest Carbon Dioxide (CO_2) emitter, and a faster-growing middle-income country, is highly vulnerable to global warming and climate change. Growing human tendencies towards satisfying unlimited desires at the cost of the future are the sole cause of environmental degradation. Anthropogenic activities play a significant role in increasing population density, land degradation, declining agricultural and forest areas, loss of biodiversity, loss of resilience in ecosystem and livelihood security, which results in air pollution, water pollution, noise pollution, global warming and leads to environmental degradation (Meena & Chourasia, 2018; Zhao *et al*. 2013). Human-induced activities like electricity generation, transportation and industrialisation enhance economic growth and bring climate change (Jawara, 2016). Other anthropogenic activities like industrial emission and coal combustion are also responsible for degrading the natural environment and soil quality through Arsenic, Cadmium, Carbon monoxide, Chromium, Copper, Mercury, Manganese, Nickel, Lead, Selenium, Vanadium, and Zinc present in the atmosphere (Lv *et al*. 2015).

Population growth is treated as a driving force for increasing CO_2 emissions in the atmosphere (Mulatu & Eschete, 2018). Population size, population distribution, and population density are three major demographic components having a negative impact on the environment that leads to a rise in GHGs emission (Swim *et al*. 2011). Population size and structure brings household demand for consumer goods and services and consumes more energy, which leads to the emission of more carbon (Neill *et al*. 2010; Zaman *et al*. 2011; Liddle, 2014; Ohlan, 2015; Ssali *et al*. 2018). Increased pollution arising out of consumption of energy in various activities like transportation, industrialisation and agriculture is responsible for environmental degradation (Shaari *et al*. 2013; Huang *et al*. 2018).

Industrialisation and urbanisation resulting from accelerated economic development and rapid population growth demand over utilisation of natural resources, which disrupts the natural ecosystem (Orimoogunje *et al*. 2011). The onset of industrialisation, caused by human activities, stipulates excessive use of fossil fuel and increases atmospheric carbon emissions (Steffen *et al*. 2007). Industrialisation brings different modern tools and technologies to enhance GDP growth rate. Technology has multiple effects on the environment, as it uses mainly fossil fuel as a source of energy in the production process and emits a huge quantity of carbon (Unger *et al*. 2010; Hang & Sheng, 2011). Continuous growth process along with the wider use of natural resources in this finite world leads to paucity and has a future adverse impact on the environment.

Carbon emission due to excessive use of energy in infrastructural arrangements for industrial and residential sector development is treated as key drivers of environmental pollution (Wang *et al*., 2019). Further, the growing need for housing, infrastructure, and other construction activities in the growth process, necessitates more demand for the production of cement, which requires high rates of energy consumption during production activities and brings global warming and climate change through the emission of sulphur dioxide, nitrogen oxide and carbon monoxide (Ali *et al*. 2015). As the economy grows, the average income of people rises and they, in order to enjoy a modern lifestyle, start shifting their consumption pattern towards modern amenities, which requires a huge quantity of energy and has a negative effect on the environment by emitting GHGs contents (Neagu & Teoduru, 2019). Overconsumption and conspicuous consumption habits of higher income groups results in more production of luxurious goods that require more energy which pollute the atmosphere (Girod & Haan, 2010; Das Gupta, 2011).

Transport and communication activities expand with the growth of urbanisation, modernisation and industrialisation. Transport through vehicular progress makes everyone's journey more convenient than previously, but the emission of GHGs from motor vehicles contributes significantly and negatively to the atmosphere. Motor vehicles, fitted with modern appliances and amenities, require a huge quantity of energy, particularly fossil fuel, which emit enormous GHGs that pollute the atmosphere (Chowdhury *et al*. 2012). People's daily travel pattern and their ordinary movements, influenced by lack of consciousness towards the environment, generates more dust and smoke, which makes city life intolerable and thus, has a negative impact on both peoples' lifestyles and the environment (Hankey & Marshal, 2010).

Energy, both renewable and non-renewable has been regarded as an engine of development. Total energy consumption like electricity, natural gas, oil combustions generates a major portion of GHGs emissions (Fayez *et al*. 2017). The basic infrastructures like power, transport, communication, housing and other facilities require a huge quantity of fossil fuel as a source of energy for fulfilling urban and industrial requirements that pollute the environment through the emission of carbon and are responsible for climate change accompanied by global warming (Hossain & Yuzuru, 2014). Excessive coal combustion in power plants and industries pollutes the environment through the emission of carbon (Ohara *et al*. 2007).

Forests play a vibrant role in offsetting carbon emissions and reducing GHGs emissions (Aukland & Costa, 2002). Rapid population growth with urbanisation and industrialisation leads to cutting down more trees for human settlements, industrial set ups and construction of civil structures for private and commercial purposes, which brings ecological imbalance and loss of biodiversity (Sikuzani *et al*. 2019; Jorgenson & Clark, 2013). Conservation and regeneration of forest resources are the answers for environmental sustainability and sustainable economic development, both for developed and less developed economies. Afforestation through reforestation and tree planting activities neutralises carbon emissions and cleans and protects our natural ecosystem (Aukland & Costa, 2002; Azmy, 2015). Forest areas brings an increase in carbon storage in forest land that would reduce carbon concentration and absorb more CO_2 (Ibrahim, 2015; Boyland, 2006).

With this backdrop, it is imperative to conclude that human-induced activities such as population growth, industrialisation for increase in GDP per capita, use of primary energy, use of motor vehicles, and use of forest resources are responsible for the increase in GHG emissions. Therefore, this research work seeks to examine the nexus between anthropogenic activities and environmental sustainability in India during the period from 1971 to 2014.

Literature Review

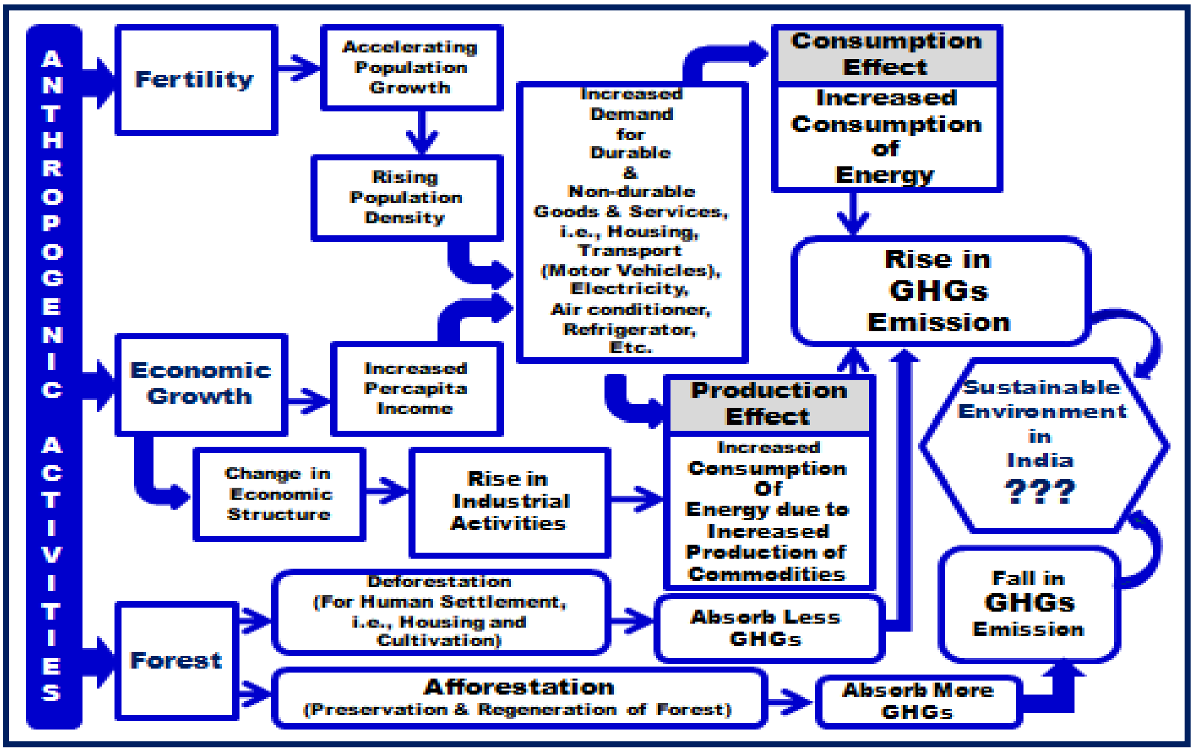
The past few years has witnessed some empirical studies investigating the linkage between emission of GHGs, population growth, economic growth, transportation activities, energy use, deforestation and /or afforestation. By employing VECM and FMOLS techniques, Ssali *et al*. (2018), found a positive and statistical significant long-run relationship between population growth and CO_2 emission; energy use and CO_2 emission in Sub-Saharan Africa. The evidence from another study made by Mulatu & Eschate (2018), suggests that population pressure through excessive human interaction such as more energy consumption and heavy dependence on natural resources has a significant and positive impact on the emission of carbon dioxide in Ethiopia. Using the VECM method, Liu & Bae (2018) conclude that economic growth through urbanisation, accompanied with a rise in basic infrastructure such as building, transportation and supporting facilities in China, emits more CO_2 and degrades the environment. By using VECM, Sodri & Garniwa (2016) conclude that in Jakarta, urbanisation has a positive impact on transport and road energy consumption that induces emission of CO_2. Ali *et al*. (2016), using the ARDL model, conclude that economic growth and energy use have a positive impact on CO_2 emission due to the combustion of fossil fuel in Nigeria. Applying ARDL and VECM models, Sarkodie & Owusu (2016), found the existence of a long-run relationship between CO_2, energy use, population growth and GDP in Ghana. In another study for Rwanda, Sarkodie & Owusu (2017) observed that population pressure, along with increasing demand for energy consumption, is responsible for an increase in carbon emissions.

The study observes a uni-directional causality running from population growth to carbon emissions. The existence of a positive and statistically significant relationship between economic growth, urbanisation, energy consumption and CO_2 emission is observed for GCC through the application of a co-integration test (Asif *et al*. 2015). Employing the ARDL model, Lacheheb *et al*. (2015), found that per capita GDP has a positive impact on carbon emissions from consumption of solid fuel and production of electricity and heat in Algeria. Employing the Pedroni Co-integration test and DOLS, the empirical results of Mulali *et al*. (2013) depicts the existence of a long-term bi-directional relationship between carbon emissions, urbanisation and energy consumption in MENA countries. By using ARDL and VECM, Hossain (2012), observed that higher consumption of fossil fuel as a source of energy in automobile and industrial sectors leads to the emission of more carbon dioxide and environmental degradation in Japan in the long run. By employing a linear regression model, Sajjad *et al*. (2010), conclude that CO_2 emission in Karachi is only through the heavy demand for fossil fuel consumption for meeting the energy needs of domestic, industrial and transport sectors, but rapid increase in vehicle use is mainly responsible for carbon emissions. Udofia *et al*. (2011), in the study, "Stemming Environmental Degradation" relating to Nigeria, concludes that sustainable afforestation through carbon sequestration like afforestation and planting more trees offsets atmospheric CO_2 emissions and helps to remove GHGs.

Extant literature reveals that human-induced activities influence environmental sustainability in an economy through different channels, such as population growth, economic growth, deforestation and /or afforestation, which is depicted in Figure 1.

Figure 1 reveals that (i) increase in population size due to high fertility rates leads to increased demand for housing, transport and communication, and infrastructure including electricity, which requires a huge quantity of energy for consumption activities and results in more emission of GHGs; (ii) increased demand for goods and services due to economic growth indicated by rise in per capita income, leads to the expansion of industrial activities to produce more goods and services, which requires a huge quantity of energy for production activities and the resulting rise in emission of GHGs, (iii) deforestation for human settlement, i.e., for housing, road, railways and dam construction, and conversion of forest area for agricultural purpose results in less absorption of GHGs, and (iv) afforestation through preservation and regeneration of trees results in more absorption of GHGs and generation of oxygen for human survival through the photosynthesis process to achieve environmental sustainability.

Figure 1: Anthropogenic Activities and Environmental Sustainability in India



Source: Authors' Own Construction

The continuing debate among academicians, researchers, planners and policy makers is that by how much reduction in emission of GHGs arising out of emission-reducing factors, i.e., afforestation outweighs the increase in GHGs emission due to the operation of emission enhancing factors such as population growth, economic growth and deforestation. The debate also considers environmental sustainability, where the effect of emissionreducing factors is more than the effect of emission enhancing factors.

Against this backdrop, this paper examines the nexus between anthropogenic activities and environmental sustainability in India.

Data and Methodology

The primary objective of this paper is to examine the nexus between anthropogenic activities and GHG_s emission in India. The period of the study extends from 1971 to 2014 on the basis of availability of continuous data for India, against the variables stated below (Refer Table1). GHG_s emission is taken into consideration to represent a sustainable environment. It is perceived that the increase in GHGs emissions is one of the prime causes of environmental degradation, and thus, the factors that reduce GHGs emissions contribute to environmental sustainability. On the contrary, we have taken fertility rate, population density, the total number of registered motor vehicles, primary energy consumption and forest area to represent the basket of human-induced anthropogenic variables. Further, it is argued that these anthropogenic variables are induced by human affluence. Thus, we have taken per capita gross domestic product as a control variable to represent human affluence. These variables arguably influence environmental sustainability. All these variables have been taken in their natural logarithms to avoid the likely problems of heteroscedasticity. The theoretical construct, along with a brief description of these variables are given in Table 1.

Table 1: Variable Descriptions and the Theoretical Construct

Variables	Notation	Short Description	Data Source	Expected Sign in Regression
GHG_s emission	Ln(GHG)	Total emission of GHG_s measured in kilo ton of CO_2 equivalent. It has been taken as a proxy for sustainable environment.	WDI, World Bank	Dependent variable
Fertility Rate	Ln(FER)	Total number of children born to a woman. High fertility rate leads to an increase in population size and thus, threatens environmental sustainability.	WDI, World Bank	+
Population Density	Ln(DEN)	Total population per sq. km of land area in India. It is argued that an increase in the population density is a threat to a sustainable environment through the emission of GHGs.	WDI, World Bank	+
GDP Per-capita	Ln(GDPC)	Per head gross domestic product in India measured in constant 2010 USD. Increase in per capita income induces consumption of durable goods, and thus increases demand for industrial outputs, thereby giving scope for larger emissions of GHGs.	WDI, World Bank	+
Number of Motor Vehicles	Ln(MV)	Total number of motor vehicles registered in India. It is well accepted that an increase in the number of motor vehicles results in emissions of GHGs and thereby threatens environmental sustainability.	Ministry of Statistics and Programme Implement-ation, GoI	+
Energy Consumption	Ln(EC)	Per head primary energy consumption measured as kg of oil equivalent. The argument is that an increase in the consumption of primary energy causes emissions of GHGs.	WDI, World Bank	+
Forest Area	Ln(FAG)	The forest cover in India measured as the percentage of geographical area. Increase in such areas is always in favour of environmental sustainability by reducing GHGs emissions.	Directorate of Economics and Statistics, GoI	-

Source: Authors' Own Construct

On the basis of the above theoretical construct, the following model has been estimated in a multivariate framework to examine the nexus between anthropogenic variables and environmental sustainability.

$$\mathbf{Ln(GHG_t) = \beta_0 + \beta_1 Ln(FER_t) + \beta_2 Ln(DEN_t) + \beta_3 Ln(GDPC_t) + \beta_4 Ln(MV_t) + \beta_5 Ln(EC_t) + \beta_6 Ln(FAG_t) + } \boldsymbol{u_t}$$

Where, β_0 is the impact of those anthropogenic activities not measured in our model, all other β's measure the degree and direction of each of the anthropogenic variables included in the model and u_t measures the impact of all those variables not explained by our model.

Results and Discussion

At first, the stationary properties of all the variables included in the model have been examined by using ADF unit root test. The results are summarised in Table2. This exercise is essential for selecting the time series econometric technique of estimating the above mentioned model. It is observed that the null hypothesis of 'presence of unit roots' in all the cases could not be rejected at the level, but rejected at the 1st differences. This means all the variables are integrated of order one, i.e., I(1).

Table 2: Results of Stationarity Tests

Variables in the Model	**ADF Unit Roots Test (at Level)**	**ADF Unit Roots Tests (at 1st Difference)**	**Decision on the Level of Stationarity (with intercept & linear trend)**
Ln(GHG)	-2.52(0.31)	-8.15(0.000)*	I(1)
Ln(FER)	-3.17(0.11)	-4.72(0.002)*	I(1)
Ln(DEN)	1.36(0.99)	-3.62(0.042)**	I(1)
Ln(GDPC)	-1.36(0.85)	-7.95(0.000)*	I(1)
Ln(MV)	-1.41(0.84)	-3.37(0.068)***	I(1)
Ln(EC)	-0.206(0.99)	-6.15(0.000)*	I(1)
Ln(FAG)	-2.72(0.23)	-6.61(0.000)*	I(1)

Note: Values within parentheses are p-values of the corresponding test statistic
*, **, *** are the levels of significance at 1%, 5% and 10% respectively
Source: Authors' Own Estimation

Since all variables are I(1), we have chosen the ARDL based bounds test technique for analysing the short-run and long-run dynamics between the variables under consideration. This ARDL approach is not only appropriate to examine the co-integration relationship between variables, but also helpful in analysing the short-run and long-run dynamics of the model. We have estimated the ARDL(1,0,0,0,1,1,0) model in which the lags of regressor have been selected by the Akaike Information Criterion (AIC). This model has been found robust with adjusted R-sq. of 0.99, and DW statistic of 2.11. The results are presented in Table3.

Table 3: Results of ARDL based Bounds Test

Lag Structure	**F-Stat**	**Critical Value Bounds**		
		1%	**5%**	**10%**
ARDL(1,0,0,0,1,1,0)	5.782566	3.15 to 4.43	2.45 to 3.61	2.12 to 3.23
Residual Diagnostics	JB Normality test BG Serial Correlation test (LM test) BPG Heteroskedasticity test			2.95(0.228) 0.465(0.633) 0.778 (0.637)
Model Stability	Ramsey RESET test			0.991 (0.327)

Source: Authors' Own Estimation

Since the F-statistic for the Ln(GHG) model is greater than the critical upper bound value at 1% level of significance, the null hypothesis of 'no co-integration (no long-run relationship)' between the variables is rejected. The results of standard diagnostics – normality test, serial correlation, heteroscedasticity, and stability tests – are presented in the lower part of Table3, which implies that the estimations are unbiased and robust. Thus, the existence of the long-run equilibrium relationship in the model is confirmed.

The long-run relationship as estimated in this model is evident from Table4. It is revealed from Table4 that fertility rate, population density, per capita GDP and consumption of primary energy has a positive and statistically significant impact on the emission of GHGs, and thereby threats to environmental sustainability in India. The empirical result shows that ceteris paribus, 1% increase in fertility rate causes 1.217% increase in emission of GHGs, 1% increase in population density causes 1.274% increase in emission of GHGs, 1% increase in per capita GDP causes 0.172% increase in emission of GHGs and 1% increase in consumption of primary energy causes 1.177% increase in GHGs emission. It is further found that use of motor vehicles has a positive but statistically insignificant impact on the emission of GHGs in India, i.e., ceteris paribus, 1% increase in the use of motor vehicle leads to 0.039% increase in emission of GHGs. The empirical result also shows that development of forest areas has a negative and statistically insignificant impact on environmental sustainability through absorption and reduction of GHGs, i.e., ceteris paribus 1% increase in forest area leads to 0.267% decrease in emission of GHGs.

Table 4: Long-Run Relationship in the Model

Variables	Coefficient	t-Statistic	p-value
Ln(FER)	1.217149*	4.031017	0.0003
Ln(DEN)	1.274392*	4.259668	0.0002
Ln(GDPC)	0.172550**	2.171483	0.0372
Ln(MV)	0.039415	0.777763	0.4422
Ln(EC)	1.177473*	11.419115	0.0000
Ln(FAG)	-0.267021	-0.841912	0.4059
Constant	-2.600137	-1.176177	0.2479

*, ** indicate the significance of coefficients at 1% and 5% levels respectively
Source: Authors' Own Estimation

On the basis of the results of the bounds test, the short-run dynamics between the variables have also been estimated in a VAR framework, and the results are summarised in Table5.

Table 5: Short-run Relationship in the Model

Variable	Coefficients	t-Stat	p-value
Δ Ln(FER)	1.444425*	3.843861	0.0005
Δ Ln(DEN)	1.512356*	3.636885	0.0009
Δ Ln(GDPC)	0.204770**	2.194477	0.0353
Δ Ln(MV)	-0.140848	-1.532236	0.1350
Δ Ln(EC)	1.026466*	6.402363	0.0000
Δ Ln(FAG)	-0.316882	-0.822081	0.4169
ECT_{t-1}	-1.186728*	-7.157032	0.0000

*, ** indicate the significance of coefficients at 1% and 5% levels respectively
Source: Authors' Own Estimation

Since the lagged error correction term (ECT_{t-1}), the long-run component, is negative and significant at 1% level, so the short-run deviation from the long-run equilibrium can be adjusted at the speed of 11.86% in a year. It is found from the result that in the short-run, fertility rate, population density, per capita GDP and primary energy consumption has a positive and statistically significant impact on emission of GHGs, i.e., ceteris paribus 1% increase in fertility rate causes 1.444% increase in emission of GHGs, 1% increase in population density causes 1.512% increase in emission of GHGs, 1% increase in per capita GDP causes 0.204% increase in emission of GHGs and 1% increase in consumption of primary energy causes 1.026% increase in GHGs emission. However, the impact of the use of motor vehicles and forest areas has no statistically significant impact on environmental sustainability in India through the emission of GHGs.

It is also observed from Tables 4 and 5 that there exists a positive and statistically significant relationship between fertility rate and emission of GHGs both in long and short run, which corroborates to the study made by Wynes & Nicholas (2017). These two tables also show a positive and statistically significant relationship between population density and emission of GHGs both in long and short run, which supports the studies made by Dodman (2009), Swim *et al.* (2011), Jones & Kameen (2014) and Yanghong *et al.* (2017). The positive and statistically significant relationship between GDP per capita and emission of GHGs both in the long and short run corroborates to the study made by Neagu & Teoduru (2019), Sterpu *et al.* (2018), Khan & Siddique (2017), Lu (2017), Li *et al.* (2016), Vavrek & Chovancoa (2016), Barido & Marshall (2014), Sadorsky (2014) and Haggar (2012). Further, a positive and statistically significant relationship between primary energy consumption and emission of GHGs both in the long and short run upholds the studies made by Neagu & Teoduru (2019), Lizbetin *et al.* (2018), Fayez *et al.* (2017), Khan & Siddique (2017), Lu (2017), Barido & Marshall (2014), Sadorsky (2014), and Ren *et al.* (2013). Statistically insignificant relationships between use of motor vehicles and emission of GHGs and between forest coverage and emission of GHGs both in the long and short run calls for further in-depth studies for India, since earlier studies support a positive and significant relationship between use of motor vehicles and GHGs emission (Khan & Siddique, 2017; Zheng *et al.* 2015; Chowdhury *et al.* 2012; Hankey & Marshall, 2010) and a negative and significant relationship between forest coverage and GHGs emission (Aukland & Costa, 2002; Fearnside & Laurance, 2004; Laurence *et al.* 1998).

Conclusion

India, a high populous and fast growing middle-income country, ranks third as GHG_s emitter and fourth as carbon dioxide emitter and, thus, is highly vulnerable to global warming and climate change. The study reveals that fertility rate, population density, GDP per capita and primary energy consumption have a statistically positive impact on GHGs emission both in the shortand longrun. But the impact of motor vehicles used and forest coverage on GHGs emissions was found to be statistically insignificant. Further, possible adjustment of any short-run deviation from the long-run equilibrium is explained through the negative and statistically significant error correction term.

On the basis of the results, this study suggests re-orienting the population policy to check fertility rate and rapid population growth. In this context, awareness of opting out of a small family to maintain a sustainable environment needs to be vigorously created among all. Further, it is needed to sensitise all to use renewable energy sources, i.e., solar, wind and nuclear for use in domestic, industrial and transport sectors. Further, programmes need to be undertaken to create public awareness for the use of energy efficient products such as LED lighting and energy efficient consumer durables. Urban bodies need to adopt energy efficient measures, particularly in street lights, by using LED lighting and in public transport by using the Bus Rapid Transit System (BRTS). It is also suggested that pollution charges on the entities responsible for huge carbon emission should be imposed. It is also suggested that the entities responsible for emission of GHGs above a specified level fixed by appropriate authorities may be asked to pay the required amount to be invested for generation of renewable energy, forest protection and regeneration to neutralise carbon emissions. In order to have a clean environment, although India has ratified the COP21 protocol and is programmed to invest \$100 billion over the next five years in clean energy and planned to generate at least 40% of total electricity from renewable and other low-carbon sources by 2030, still there remain many miles to go.

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