# Ecology and Economy– Survival of the Fittest

Edited by:
Dr. Sandeep Poddar

*Published by:*

LINCOLN UNIVERSITY COLLEGE
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# FOREWORD

Environmental degradation mainly occurs through drastic reduction of biological diversity. It is accelerated mostly by human activities. This phenomenon causes deterioration of the earth's natural surroundings due to excessive exploitation of the available resources. This book "Ecology and Economy-Survival of the Fittest" is a compendium of some research articles and case studies which is mainly focused on current issues, related to environmental pollution.

The book discusses the role of various pollutants causing environmental degradation. Increased emissions of carbon dioxide and the consumption of excessive energy is destroying the rhythm of the nature around us and retarding the economic growth of a country.

The discharge of surfactants in wastewater causes serious effects on the ecosystem. Surfactant toxicities results in biodegradation. If these surfactants are not used in proper manner it may cause aquatic toxicity which is costly and risky to human health. Therefore, it is necessary to remove highly toxic and non-biodegradable compounds from commercial use.

Changing weather affects the agricultural history and food supply. This as a result changes the growing conditions for food crops in many areas casing food prices to rise around the world. The increase in global temperatures may lead to rise in seawater levels resulting in a reduction of available agricultural lands. So, it is necessary to reduce greenhouse gas emissions and consider the whole food value chain.

Green chemistry is an approach that aims to eliminate the usage and generation of hazardous substances by designing better manufacturing processes for chemical products. By limiting the hazard intrinsic substances in the chemical products, the risk induced can be consequently reduced. Through the proper application decoupling of various pollutant emission, use of effective and equitable carbon emissions policy, the sustainability of liveable environment is possible.

The basis of sustainable development and resource management is to increase biological diversity. This is an inherently important aspect of every nation's heritage leading to productive, sustainable resource management upon which depends our present and future welfare.

The transition of the global energy system is the chief drifts that offers openings as well as challenges for the economy. Owing to the lesser energy density of many renewable energy sources, renewable energy generation will be more decentralised process in the present times. This will cause potential changes in the regional economy when transforming into a renewable energy system.

I sincerely thank all the authors for their contribution of such wide-ranging topics that will help to create awareness of our environment among the mass. I believe from the core of my heart that our earnest endeavour will be beneficial for the readers so that we can make a better and liveable world for our future generation.

**Prof. Dr. Amiya Bhaumik**
Vice Chancellor and CEO
Lincoln University College

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# CONTENT

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# Green Chemistry and Environmental Sustainability

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## INTRODUCTION

Nature consists of two very complex, interdependent mutually reactive and interrelated entities - the organisms and environment. The organisms can survive only in appropriate environments, interact with each other and influenced by the whole complex of environmental factors. In context of human beings, environment can be defined by the sum of all social, economic, biological, physical, or chemical factors which constitute the surroundings of man. Thousands of tons of toxic wastes are released to the environment by industry every hour of every day. The chemical industry is the biggest source of such wastes.

However, it was not until the 1980s that the environment became a priority for the chemical industry. This was prompted largely by stricter environmental regulations and a need to address the sector's poor reputation, particularly due to pollution and industrial accidents. Attempts at controlling pollution and improving environmental quality since late 1970s led to the emergence of sustainable chemistry or Green chemistry. "Chemistry has an important role to play in achieving a sustainable civilization on earth."

*- Dr. Terry Collins, Professor of Chemistry, Carnegie Mellon University*

### What is sustainable civilization?

A Sustainable Civilization is one where the needs of the present can be met without compromising the ability of future generations to meet their own needs.

"In our every deliberation, we must consider the impact of our decisions on the next seven generations"- Great Law of the Iroquois Nation

### What is Green chemistry?

Green chemistry is the design of products and processes reducing or eliminating hazardous substances. Green chemistry aims to use sustainable, safe and nonpolluting chemicals which enable man to manufacture compounds with minimum consumption of materials and energy and also production of minimum waste. In short, Green chemistry is sustainable chemistry.

Important examples of green chemistry include: phasing out the use of chlorofluorocarbons (CFCs) in refrigerants, which have played a role in creating the ozone hole; developing more efficient ways of making pharmaceuticals, including the well-known painkiller ibuprofen and chemotherapy drug Taxol; and developing cheaper, more efficient solar cells.

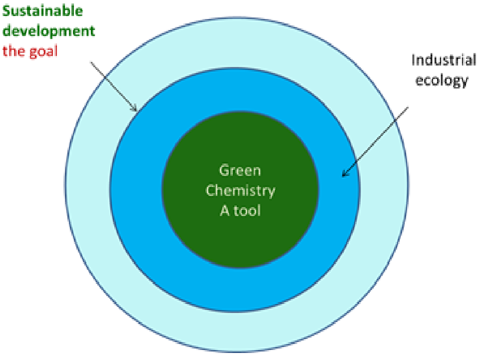



*Figure 1: Green chemistry, lies at the heart of the industrial ecology*

### Twelve important principles of Green chemistry

1. **Prevention:** it is best to prevent pollution/waste
2. **Atom Economy:** synthetic methods should maximize the incorporation of all materials used in the process into the final product
3. **Less Hazardous Chemical Syntheses:** synthetic methods should use and generate non toxic substances
4. **Designing Safer Chemicals:** products should be nontoxic & designed to effect their desired function
5. **Safer Solvents and Auxiliaries:** auxiliary substances (e.g., solvents, separation agents) should be avoided and innocuous when used
6. **Design for Energy Efficiency:** Run chemical reactions at ambient temperature and pressure
7. **Use of Renewable Feedstocks:** raw material or feedstock should be renewable rather than depleting
8. **Reduce Derivatives:** Avoid unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) because such steps require additional reagents and can generate waste.
9. Catalysis: Catalytic reagents (as selective as possible) are superior to stoichiometric reagents which are used in excess and work only once
10. **Design for Degradation:** Chemical products should be designed so that at the end of their function they break down into innocuous degradation products
11. **Analyze in real time to prevent pollution:** Include in-process real-time monitoring and control during syntheses to minimize or eliminate byproducts

12. **Minimize accidents:** Design chemicals and their forms (solid, liquid, gas) to minimize the potential for chemical accidents, releases, explosions, and fires. In the past, waste management strategies concentrated only on the disposal of toxic byproducts, present day efforts have shifted to eliminating waste from the outset by making chemical reactions more efficient.

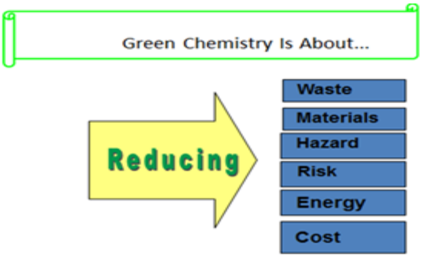



*Figure 2: Aim of Green Chemistry*

Hence green chemistry means, preventing pollution before it happens rather than cleaning up the mess later, saving companies money by using less energy and fewer or safer chemicals, thus reducing costs and impacts of pollution, mitigating climate change, water or resource depletion and growing demands for safer food and cleaner energy.

### Green Chemistry in Industry

Chemistry is undeniably a very prominent part of our daily lives; making chemical compounds, particularly organic molecules (composed predominantly of carbon and hydrogen atoms), is the basis of vast multinational industries from perfumes to plastics, farming to fabric, and dyes to drugs. Chemical developments also bring new environmental problems and harmful unexpected side effects. It is widely acknowledged that there is a growing need for more environmentally acceptable processes in the chemical industry.

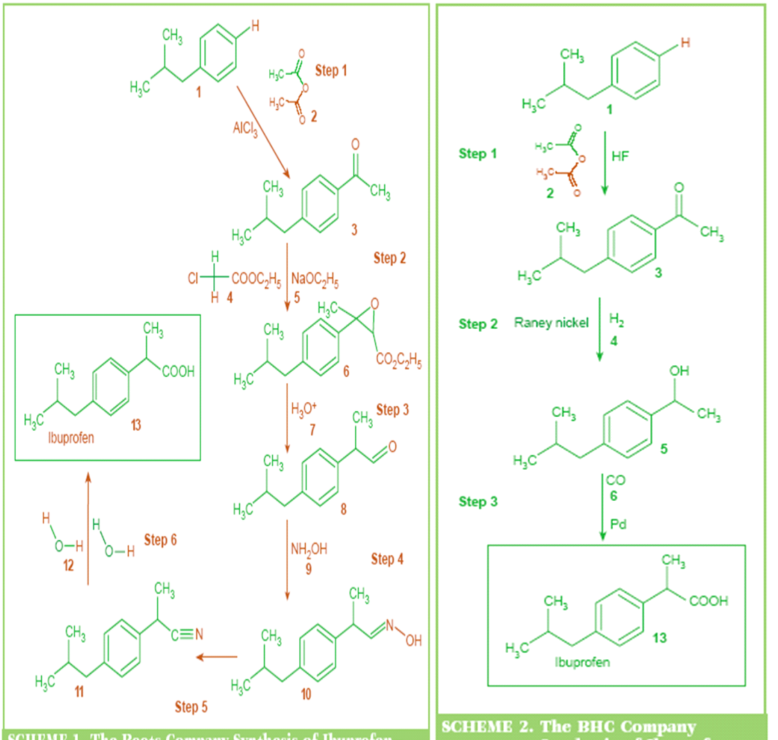
***Chemists must place a major focus on the environmental consequences of chemical products and the processes by which these products are made. We must consider our chemical ecological footprint.***

In a perfect world, chemical compounds would be prepared from inexpensive, renewable sources in one practical, efficient, safe and environmentally benign chemical reaction. Unfortunately, with the exception of the chemical processes found in nature, the majority of chemical processes are not completely efficient, require multiple reaction steps and generate hazardous byproducts.

The Green Chemistry program supports the invention of more environmentally friendly chemical processes which reduce or even eliminate the generation of hazardous substances

### Ibuprofen – a case study in green chemistry

Ibuprofen is a well-known pain killer (for headache, toothache, muscular aches, period pain etc), and becomes available without prescription in maximum countries all over the world. It was patented by the Boots company in 1960s.




SCHEME 1. The Boots Company Synthesis of Ibuprofen– The Brown Synthesis

SCHEME 2. The BHC Company Synthesis of Ibuprofen– The Green Synthesis

*Figure 3: Traditional synthesis of ibuprofen vs Catalytic synthesis of ibuprofen*

Boots company synthesis of ibuprofen contains 6 stoichiometric steps and overall atom utilization is <40%, This means that more than half the materials used in the synthesis are wasted. On the other hand BHC company synthesis of ibuprofen contains 3 catalytic steps with 80% atom utilization (99% with recovered acetic acid), this green synthesis has other advantages as well as its fewer steps and greater atom economy. These factors make the green synthesis cheaper as well as more environmentfriendly.

While in the past traditional waste management strategies focused only on the disposal of toxic byproducts, today efforts have shifted to eliminating waste from the outset by making chemical reactions more efficient.

**Green Catalysis**

Catalysis dominates the literature on green synthesis, the goals of catalyst development led to the advent of more sophisticated and effective chemical reactions, which reduce the amount of waste. Chemists want to synthesize a fast, long-lived, and highly selective catalyst that works under mild conditions.

Since a catalyst regenerates itself after a reaction, one molecule of catalyst can perform several transformations that allow scientists to get high yields from a reaction that uses only a relatively small amount of catalyst.

The catalytic processes are ***"the only methods that offer the rational means of producing useful compounds in an economical, energy-saving and environmentally benign way"***.

-RyojiNoyori, Chemistry Nobel Laureate, 2001

The development of new catalytic reactions is one particularly important objective of green chemistry. As well as being more environmental friendly, these processes are also typically more cost effective.

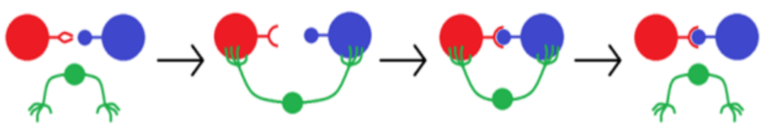


Figure 4. Graphic of a catalyst's function in a catalytic reaction. The catalyst is green, and the reactants are red and blue.

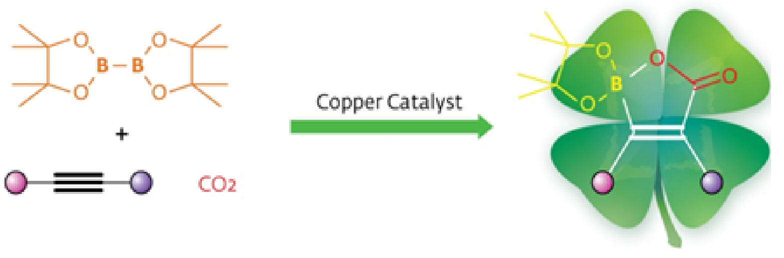



Figure 5: *Because carbon dioxide ($CO_2$) gas is a freely available resource, there are concerted efforts worldwide to convert this molecule into a chemical feedstock, here Hou Z et. al. has used*

copper catalyst to turn waste carbon dioxide ($CO_2$), alkyne molecules and boron complexes into a uniquely shaped ring system suitable for organic synthesis- Majority industrial chemical processes apply catalysts and at least 15 Nobel Prizes in Chemistry have been delivered for research in catalysis. This represents a tremendously important and active area of both fundamental and applied research.

**Synthesis in Micro Reactors**

The miniaturization of chemical reactors offers many fundamental and practical advantages of relevance to the pharmaceutical and fine chemicals industry, which are constantly searching for controllable, information rich, high throughput and environmentally friendly methods of producing products with a high degree of chemical selectivity. Micro reactors may revolutionize chemical synthesis by solvent free mixing, in situ reagent generation and integrated separation techniques.

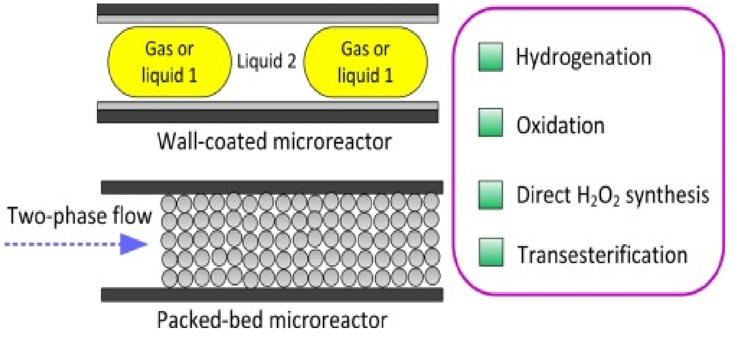



Figure 6: Multiphase flow processing in microreactors combined with heterogeneous catalysis for efficient and sustainable chemical synthesisby (June Yue, Catalysis tody,volume 308, 15 June 2018, Pages 3-19)

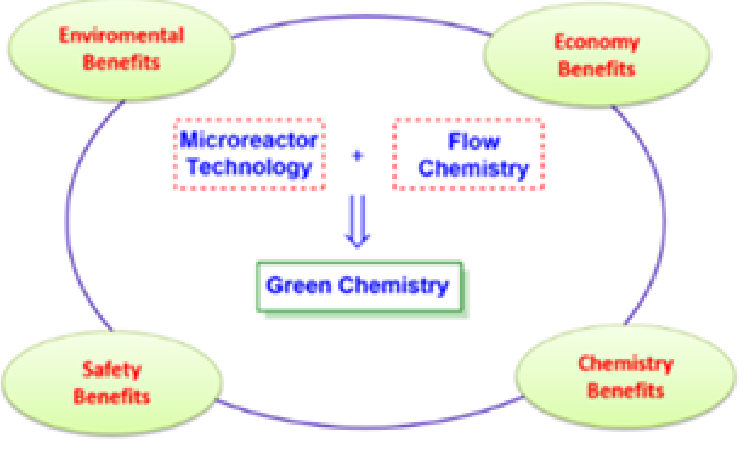



Figure 7: Contribution of microreactor technology and flow chemistry to the development of green and sustainable synthesis

**Green Solvents**

Green solvents are environmentally friendly solvents or biosolvents, which are derived from the processing of agricultural crops. They do not emit volatile organic compounds or VOCs. Green solvents were developed as a more environmentally friendly alternative to petrochemical solvents.

The miniaturization of chemical reactors offers many fundamental and practical advantages of relevance to the pharmaceutical and fine chemicals industry, which are constantly searching for controllable, information rich, high throughput and environmentally friendly methods of producing products with a high degree of chemical selectivity. Micro reactors may revolutionize chemical synthesis by solvent free mixing, in situ reagent generation and integrated separation techniques.

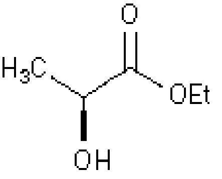


Figure 8: Ethyl actate is a green solvent derived from processing corn.

Ionic liquids are highly solvating, non-coordinating medium in which a variety of organic and inorganic solutes are able to dissolve. They are outstanding good solvents for a variety of compounds, and their lack of a measurable vapour pressure makes them a desirable substitute for VOCs.

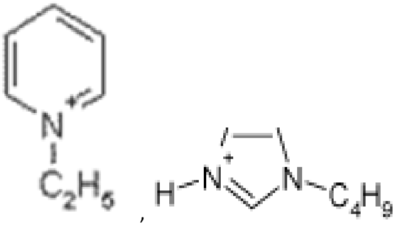


Figure 9: alkylpyridiniumcation anddialkylimidazoliumcation are the examples of ionic liquids

**Supercritical $CO_2$: A Green solvent**

Supercritical carbon dioxide is an attractive alternative in place of traditional organic solvents. $CO_2$ is not considered a VOC. Although $CO_2$ is a greenhouse gas, if it is withdrawn from the environment, used in a process, and then returned to the environment, it does not contribute to the greenhouse effect.Supercritical $CO_2$ is a good solvent for many nonpolar, and a few polar, low-molecular-weight compounds. Itis non-flammable, inert, non-toxic, has a relatively low cost and has moderate critical constants. Its solvation strength can be fine-tuned by adjusting the density of the fluid. $CO_2$leaves a lower amount of residue in products compared to conventional solvents, and it is available in relatively pure form and in large quantities.Supercritical $CO_2$'s use in extraction processes has grown fairly quickly. In fact, extraction of food and natural products using supercritical or liquid $CO_2$ can be considered a relatively mature $CO_2$ technology.

**Bio Based Renewable Feed Stock**

Renewable resources have been used as industrial feedstocks throughout human history, and only in the past two centuries have fossil fuels become the primary sources of carbon-based chemicals. Today, fossil resources are used to supply 96% of the synthetic organic chemicals produced in refineries and chemical production plants. Consequently, one of the most important challenges is sustainable development is, how to meet the needs of the present without compromising the ability of future generations to meet their needs. Because the depletion of fossils fuels will occur sooner or later,a renewable feedstock can be defined as a natural resource that can replenish itself in a limited time, preferably within several months, although years, or at maximum a few decades, may be acceptable as well. Biomass is produced in nature by using sunlight to convert carbon dioxide and water into organic compounds, of which 75% is carbohydrate-based with an empirical formula of C6H12O6

$$6CO_2 + 6H_2O \xrightarrow{h\nu} C_6H_{12}O_6 + 6O_2$$

The simplest carbohydrates are the naturally occurring five- and six-carbon monosaccharides, which can be linked together by glycosidic bonds in various combinations to form di-, oligo-, and polysaccharides. The other main components are tannins, resins, fatty acids, and inorganic salts, as microcomponents. Various other substances can be found in biomass such as vitamins, dyes, flavors and aromatic essences, and certain oils and proteins. To use the different components as raw materials or intermediates, appropriate and economical processing technologies should be available in biorefineries by integrating the essential physical, chemical, and biological processes to convert natural raw materials to products such as basic chemicals, intermediates, fine chemicals, and pharmaceuticals.

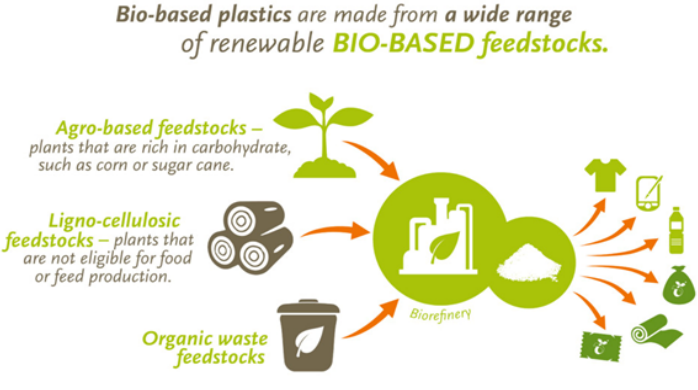



*Figure 10: Bio based renewable feed stock*

**Challenges in Green Chemistry**

In the past 20 years since green chemistry was established, there have been tremendous advances in the industry. Nevertheless, there remains considerable room for improvement.

Specific challenges include: capturing and fixing carbon dioxide and other greenhouse gases; developing a greater range of biodegradable plastics; reducing the high levels of waste in pharmaceutical drug manufacture; and improving the efficiency of water-splitting employing visible light photocatalysts.

### Green Chemistry Education

The Green Chemistry program supports the invention of more environmentally friendly chemical processes which reduce or even eliminate the generation of hazardous substances. Chemistry students need to be encouraged to consider the principles of green chemistry when designing processes and choosing reagents. Interactive Teaching Units (ITU) have been developed specifically to introduce undergraduate students to green chemistry. There are numerous scholarships and grants available for researchers and young scholars who are furthering the goals of green chemistry

### CONCLUSION

The motto of Green chemistry is: **Preventing Pollution sustaining earth**

Green chemistry has come a long way since its birth, growing from a small grassroots idea into a new approach to scientifically-based environmental protection. All over the world, governments and industries are working with "green" chemists to transform the economy into a sustainable enterprise.Green chemistry may be the next social movement that will set aside all the world's differences and allow for the creation of an environmentally commendable civilization.

History suggests that society can develop creative solutions to complex, intractable problems. However, success will most likely require a concerted approach across all areas of science, strong leadership, and a willingness to strategically invest in human capital and value fundamental research.

Green chemistry is Chemistry's unique contribution to environmental sustainability.

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# Impact of $CO_2$ and Decoupling $CO_2$ Emissions Hypothesis

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## INTRODUCTION

Green House Gas and $CO_2$ play a vital role in regulating temperature of earth's surface. Global warming melts down glaciers and raises sea level, produces typhoons, cycles and floods. It changes ecosystems and biodiversity of earth, reduces agricultural produces ,alarms food security, increases climate refugees, damages coastal areas, helps to create diseases, and changes marine species and acidification status. Nuclear test aggravates the level of concentration of $CO_2$ in the earth. International climate institutions failed repeatedly to reduce the level of $CO_2$ emission towards a common consensus where the developing countries suffered too much including in the policy of carbon trading. Even, the clause of environment and trade of WTO helped indirectly to the OECD countries. Global summit with UNFCCC formed Global Climate Fund which is ineffective and serves developed nations. The policy of REDD and LULUCF failed to conservation of world forest which can control the GHG level. Above all, the climate policies adopted by UNFCCC or advised by IPCC are not independent in favouring the OECD nations. Moreover, in the world, there is no fundamental legal international institution that can control $CO_2$ and GHG levels by adopting constitution and policy implementations so that all countries must abide by this institution as like as UNO.

The prediction is that the warming above 3.4ºC of the pre-industrial level will extinguish entire ecosystems and destabilize human civilization. Now, $CO_2$ concentration is 400ppm, if other things are unchanged then by 2250, the concentration will be 2000ppm and the polar regions will be free of ice and the first dinosaurs will emerge in this earth.

## NATURE AND INFLUENCE OF $CO_2$

Our planet would be too cold without $CO_2$ or GHG and surface temperature of earth would be 18º C. After the industrial revolution $CO_2$ emission began to increase rapidly. Since 1850, temperature was 0.4ºC colder than 1961-1990 base line but it was 0.8ºC higher in 2015 which means temperature increased by 1.2ºC since pre industrial revolution. (Figure 1).The Paris climate agreement estimated average warming by 2100 will be 2.6°C-3.2°C.

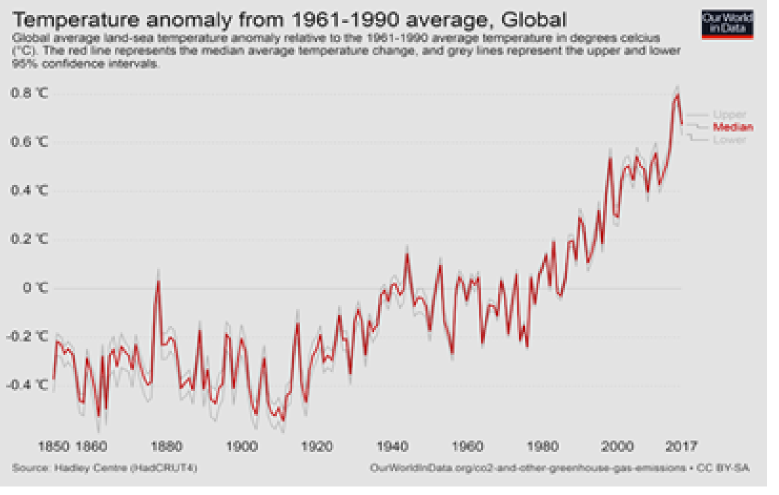



*Figure 1: Temperature anomaly from 1961-1990 average, global*

United Kingdom was the first and largest emitter of $CO_2$ after industrial revolution followed by other European countries and USA. Latin America, Asia and African nations started contributing to global $CO_2$ emissions much later to the 20th and 21$^{st}$ centuries. (Figure 2).

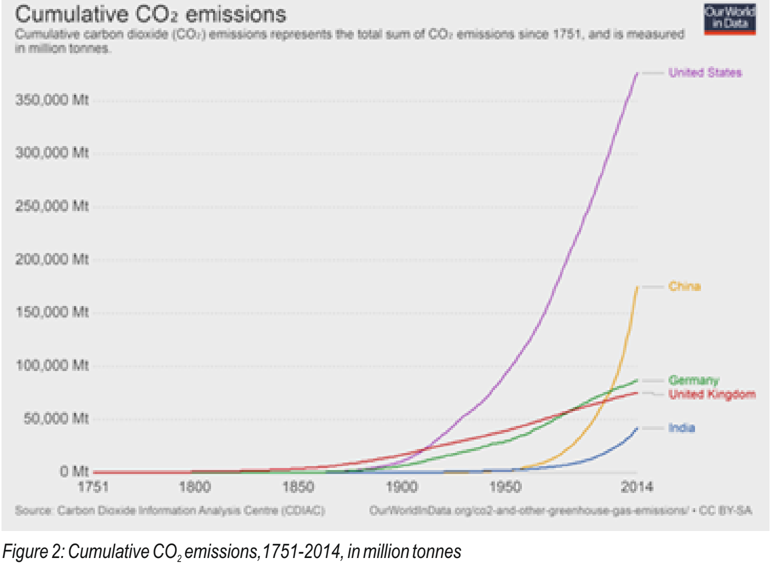



*Figure 2: Cumulative $CO_2$ emissions, 1751-2014, in million tonnes*

In fact, China is now the largest emitter, followed by (in order) the US, EU-28, India, Russia, Indonesia, Brazil, Japan, Canada and Mexico. Global emissions increased from 2 billion tonnes of $CO_2$ in 1900 to over 36 billion tonnes 115 years later.

Atmospheric concentration of $CO_2$ over the past 2000 years was stable at 270-285 parts per million (ppm) until the 18th century but after industrial revolution it increased to 400ppm now (Figure 3).

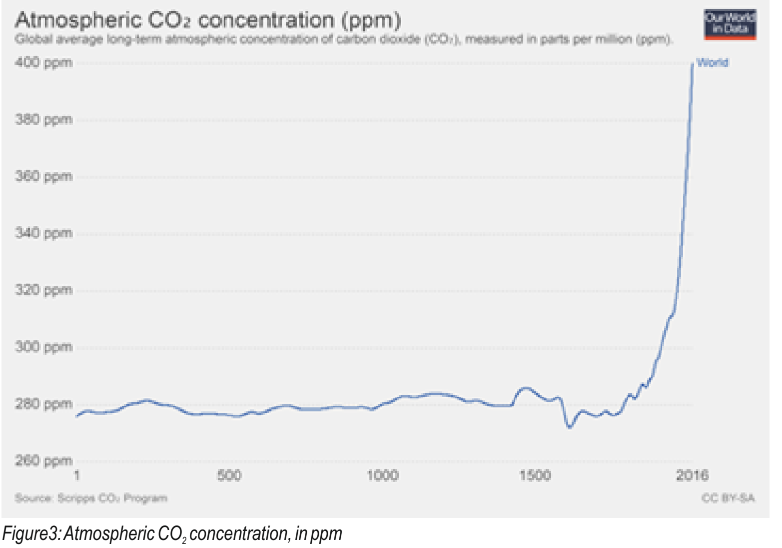



*Figure3: Atmospheric $CO_2$ concentration, in ppm*

$CO_2$ accounts for around 3/4th of total greenhouse gas emissions and methane and nitrous oxide accounts for 17% and 7% respectively. F gases such as HFC, PFC and SF6 emitted in very small quantity (Figure 4).

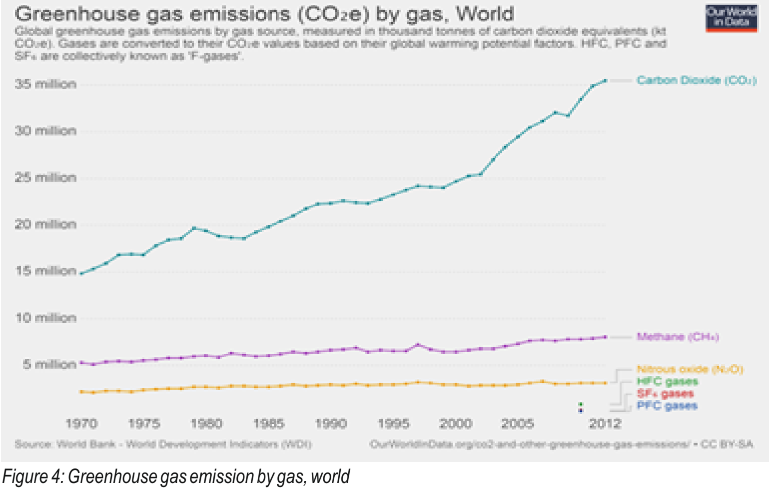



*Figure 4: Greenhouse gas emission by gas, world*

The important sources of $CO_2$ emission are energy and transport sectors, international bunkers, residential, commercial, institutional, industry, agriculture sectors, waste, land use and fossil fuels etc. Their contributions to global emission in Gigagram $CO_2$ level is plotted in Figure 5.

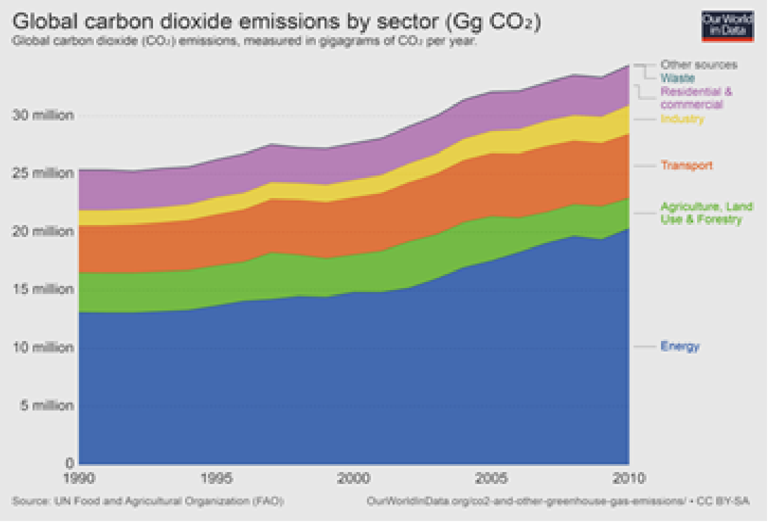



*Figure 5: Global $CO_2$ emissions by sector, (Gg $CO_2$)*

## Nexus Between per Capita $CO_2$ Emissions and GDP per Capita

### [I] Concept

Decoupling $CO_2$ emissions from income growth is an important world issue today and the focal point of the nexus between emission and GDP. Generally, decoupling can be represented by the income elasticity of $CO_2$ emissions. If the elasticity is positive and greater than or equal to +1.0, then $CO_2$ emissions is directly coupled with income growth; there is no decoupling. If the elasticity is positive and less than +1.0, there is relative decoupling. The percentage growth of $CO_2$ emissions is smaller than that of income growth. There is absolute decoupling when the elasticity is zero or negative. As income grows, $CO_2$ emissions will either stay at the same level or even decline. If the decoupling either in absolute or relative exists, then EKC hypothesis is satisfied and the curve is inverted U or N shaped. It needs a long run relationship between $CO_2$ emission and GDP or between per capita emission and per capita GDP of a nation. The empirical evidences vary country to country and regions to regions(Scripps $CO_2$ Program, 1956)

### [ii]Literature

Grossman and Krueger(1995) found the inverted U-shaped relation first time between income and environmental evolvement when analyzing the environmental effect of NAFTA, and verified it as well. Azomahou,Laisney and Van(2005)

examine the empirical relation between $CO_2$ emissions per capita and GDP per capita during the period 1960-1996, using a panel of 100 countries.They find evidence supporting specifications which assume the stability of the relationship between $CO_2$ emissions per capita and GDP per capita over time during the period of the study. They show that within estimation of a parametric specification yields an EKC, but that the underlying strict exogeneity assumption of per capita GDP is rejected, whereas both the nonparametric and the first-difference estimations clearly contradict the existence of an EKC for $CO_2$ emissions. Jalil and Mahmud (2009) using the autoregressive distributed lag method in their study found that the relationship between carbon dioxide emissions and income per capita for China was an inverted U-shape.Paraskevopoulos(2009) investigated the empirical analysis for the validity of the Environmental Kuznets Curve Hypothesis in USA from 1800 to 2005 and for the United Kingdom from 1830 to 2005.The OLS estimation results and Symmetric, Asymmetric and Non-Linear Error Correction Models show that instead of inverted-U shaped curve, the relation between pollution and income is described by a N-shaped curve. Iwata, Okada and Samreth (2010) empirically investigated the environmental Kuznets curve (EKC) for per capita $CO_2$ emissions in the cases of 11 OECD countries by taking into account the role of nuclear energy in electricity production. The results indicate that energy consumption has a positive impact on per capita $Co_2$ emissions in most countries in the study. However, the impact of trade is not statistically significant. The results provide evidence for a role of nuclear power in reducing $CO_2$ emissions only in some countries. Additionally, although the estimated long-run coefficients of income and its square satisfy the EKC hypothesis in Finland, Japan, Korea and Spain, only Finland's EKC turning point is inside the sample period of the study, providing poor evidence in support of the EKC hypothesis. Lean and Smyth's (2010) VECM (Vector Error-Correction Model) analysis for five ASEAN (Association of Southeast Asian Nations) countries over the period 1980–2006 is a typical example of such an approach. Based on quadratic specification, they concluded, among other,that there is a statistically significant non-linear relationship between emissions and economic growth in support of EKC. Mir and Storm (2016) studied 40 countries and 35 industries during 1995-2007 to estimate per capita $Co_2$ emission and per capita GDP .It supports EKC pattern for production based $CO_2$ emission but not support consumption based $CO_2$ emission. There is no automatic decoupling between growth and emission which implies to give up EKC hypothesis. To fix 2ºC, it needs to check consumption and production patterns.Cohen, Jalles, Loungani and Marto(2018) studied 20 countries during 1990-2014 to investigate the decoupling of emissions and growth and found the average trend elasticity, viz. the response of trend emissions to a 1 percent change in trend GDP, is 0.4. For the advanced economies within this group, the elasticity averages zero. Some countries have negative elasticities, suggesting that they had made progress in decoupling their trend emissions from trend GDP.Consumption-based emissions weakens the case for progress but does not overturn it. Encouragingly, they found suggestive evidence that trend elasticities could be lowered through policy efforts on the part of countries. Moreover, their investigation of the historical relationships between emissions and GDP showed that elasticities in recent decades were considerably lower than in previous decades. Mikayilov, Hasanov and Galeotti (2018) allow the income elasticity of emissions – a critical metrics for the study of decoupling – to vary over time. The reason is that the elasticity might change through the time due to the factors affecting the drivers of the $CO_2$ emissions. They use a time-varying coefficients cointegration approach to investigate the $CO_2$ emissions-GDP relationship for 12 Western European countries over a long period ranging from 1861 to 2015.The main finding is that the income elasticity of $CO_2$ emissions are found to be positive in all investigated countries. In addition, we find evidence in favor of relative decoupling – emissions increasing more slowly than GDP – in 8 out of the 12 European countries. The remaining 4 cases the income elasticity of $CO_2$ emissions are in excess of unity. In nearly half of cases the analysis confirms a statistically significant time-varying pattern for the income elasticity.

**[iii] Objective, Data and Methodology**

Author tried to show the relationship between per capita $CO_2$ emission and GDP per capita in Euro Area and South Asian regions through fixed effect panel regression, panel cointegration and vector error correction models during 1991-2017 with the hypothesis of decoupling to justify the Environment Kuznet Curve in the form of inverted U or N shaped. The short and long run association between per capita $CO_2$ emission and GDP per capita with higher order were also analyzed.To find the relationship between per capita $CO_2$ emission in metric ton and GDP per capita in US$ in current prices during 1991-2017, author used fixed effect panel regression model after verifying the Hausman Test (1978) taking decoupling model. Fisher (1932)-Johansen cointegration test (1991) was used to show cointegration. Johansen (1991) Panel VECM was also used to show long and short run association between $CO_2$ emission and GDP where Wald test(1943) was verified in the system equations. Data of per capita $CO_2$ emission in metric ton and GDP per capita in US$ in current prices for Euro Area and South Asia from 1991 to 2017 were taken from the World Bank.

**[iv] Observations from the econometric models**

Per capita income and per capita $CO_2$ emission are positively correlated in Euro Area and South Asian regions during 1991-2017 as suggested by panel regression fixed effect model when Hausman test is rejected from the random effect model(Chi-Square(1)=55.31). The regression equation asserted that one per cent increase in per capita income per year leads to 0.556% increase in $CO_2$ emission per year during 1991-2017 in South Asia and Euro Area.

$$\text{Log}(y)=-3.657008+0.556058\log(x)$$
$$(-43.31)^{*} \quad (56.66)^{*}$$

R=0.99, F=119.91*, DW=0.096 ,*=significant at 1% level where y=CO2 emission per capita in metric ton, x=per capital GDP in current US $.

After rejection of random effect model whose Chi-square(4)=119.51 from Hausman test, the decoupling hypothesis claims that per capita $CO_2$ emission is polynomial related with per capita GDP of South Asia and Euro Area in the successive higher orders during 1991-2017 which is observed from fixed effect panel regression model.

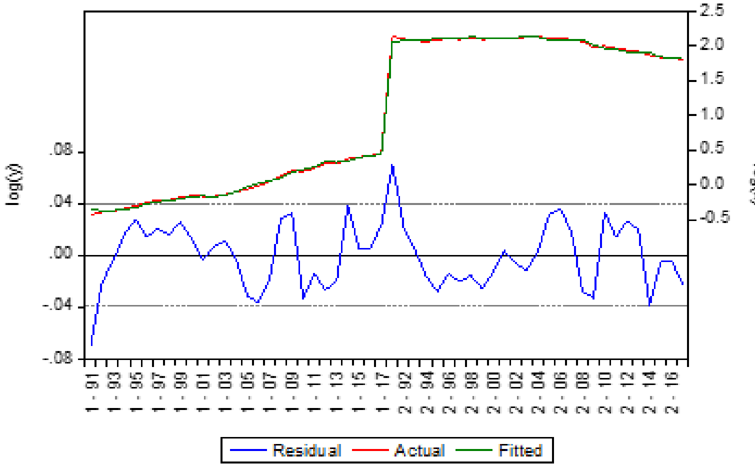
$$\text{Log}(y)=60.01288-33.27118\log(x)+6.544079\log(x)^2-0.546387\log(x)^3+0.01666\log(x)^4$$
$$(3.25)^{*} \quad (-3.52)^{*} \quad (3.64)^{*} \quad (-3.64)^{*} \quad (3.59)^{*}$$

$R^2$=0.99,F=1321.44*,DW=1.03,*=significant at 1% level where

$\delta\log(y)/\delta\log(x)<0, \delta\log(y)/\delta\log(x)^2>1, \delta\log(y)/\delta\log(x)^3<0, \delta\log(y)/\delta\log(x)^4>0<1.$

The regression is a good fit with high $R^2$ and F values and all t values of the coefficients are significant at 5% level. Since DW is low then there is the existence of autocorrelation problem. The absolute value of income elasticity of emission decreases as per capita GDP goes to higher order. The estimated equation concludes that in EA and SA under panel regression there is absolute decoupling in income elasticity, no decoupling in square of income elasticity, absolute decoupling in cubic income elasticity, and relative decoupling in income elasticity to the power four respectively during 1991-2017.

The estimated and actual lines of regression between per capita $CO_2$ and per capita GDP at higher order look like partially inverse U shaped which is plotted in Figure 6.




*Source: Plotted by plotted*

*Figure 6: Actual and fitted lines*

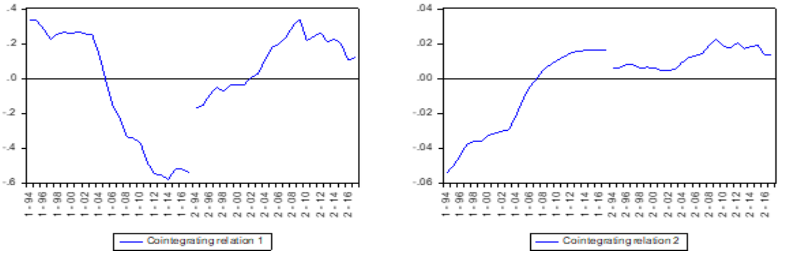
Johansen-Fisher Panel cointegration test among log(y), log(x),log(x)$^2$, and log(x)$^3$ assuming linear deterministic trend in first difference series during 1991-2017 confirmed that there are two significant cointegrating equations both in Trace and Max Eigen statistic which are shown in Table 1.

***Table 1: Panelcointegration test***

| Hypothesized No. of CE(s) | Fisher Stat.* (from trace test) | Prob | Fisher Stat.* (from max-eigen test) | Prob |
|---|---|---|---|---|
| None | 22.82 | 0.0001 | 20.01 | 0.0005 |
| At most 1 | 7.319 | 0.1200 | 6.590 | 0.1592 |
| At most 2 | 3.561 | 0.4687 | 1.786 | 0.7751 |
| At most 3 | 4.754 | 0.3135 | 4.754 | 0.3135 |

**Probabilities are computed using asymptotic Chi-square distribution, Source-Calculated by author*

In Figure 7, the two cointegrating equations are shown below.




*Source: Plotted by author*

Figure 7: Cointegrating equations.

The estimated equations of the VECM are as follows:

[1] $\Delta logy_t = -0.0914EC_1 - 1.3024EC_2 - 0.3478\Delta logy_{t-1} - 0.09702\Delta logy_{t-2} - 2.719\Delta logx_{t-1} - 0.1343\Delta logx_{t-2}$

(-1.83)* (-4.86)* (-2.33)* (-0.66) (-1.01) (-0.049)

$+0.3924\Delta logx_{t-1}^2 + 0.0302\Delta logx_{t-2}^2 - 0.01677\Delta logx_{t-1}^3 - 0.00149\Delta logx_{t-2}^3 + 0.00538$

(1.14) (0.088) (-1.21) (-0.105) (1.21)

$R^2=0.707, F=8.95^*, AIC=-4.65, SC=-4.22$

[2] $\Delta logx_t = -0.0321EC_1 - 0.8877EC_2 - 0.0773\Delta logy_{t-1} - 0.3472\Delta logy_{t-2} - 8.429\Delta logx_{t-1} - 0.8156\Delta logx_{t-2}$

(-0.44) (-1.08) (-0.169) (-0.77) (-1.02) (-0.098)

$+1.194\Delta logx_{t-1}^2 + 0.0932\Delta logx_{t-2}^2 - 0.0493\Delta logx_{t-1}^3 - 0.00413\Delta logx_{t-2}^3 + 0.0303$

(1.13) (0.08) (-1.18) (-0.098) (2.23)*

$R^2=0.326, F=1.79, AIC=-2.41, SC=-1.98$

[3] $\Delta logx_t^2 = -0.487EC_1 - 11.621EC_2 + 0.6936\Delta logy_{t-1} - 7.1301\Delta logy_{t-2} - 183.921\Delta logx_{t-1} + 9.528\Delta logx_{t-2}$

(-0.33) (-0.71) (0.076) (-0.813) (-1.12) (0.058)

$+24.644\Delta logx_{t-1}^2 - 1.368\Delta logx_{t-2}^2 - 1.002\Delta logx_{t-1}^3 + 0.0453\Delta logx_{t-2}^3 + 0.5357$

(1.186) (-0.06) (-1.19) (0.054) (1.99)

$R^2=0.23, F=1.11 AIC=3.55, SC=3.98$

[4] $\Delta logx_t^3 = -5.1819EC_1 - 118.8208EC_2 + 34.587\Delta logy_{t-1} - 11.57\Delta logy_{t-2} - 2907.77\Delta logx_{t-1} + 343.291\Delta logx_{t-2}$

(-0.23) (-0.48) (0.25) (-0.83) (-1.17) (0.137)

$+377.027\Delta logx_{t-1}^2 - 45.746\Delta logx_{t-2}^2 - 15.0135\Delta logx_{t-1}^3 + 1.682\Delta logx_{t-2}^3 + 7.366$

(1.19) (-0.14) (-1.17) (0.13) (1.80

$R^2=0.18$, $F=0.84$, $AIC=9.0$, $SC=9.43$, *=significant at 5% level in all equations.

Only equation [1]is found to be a good fit in which coefficients of $EC_1$ and $EC_2$ are significant but all other t values of the coefficients are insignificant.

In the VECM-1,the system equation-1 showed the estimated two cointegrating equations are:

$EC_1 = -0.0886logy_{t-1} - 0.307836logx_{t-1}^2 + 0.021188logx_{t-1}^3 + 0.015377t + 6.90309$

(-3.63)* (-9.94)* (8.42)* (1.78)

$EC_2 = -1.6162logx_{t-1} - 0.117137logx_{t-1}^2 + 0.004527x_{t-1}^3 - 0.00019t - 2.795$

(-4.75)* (-44.09)* (20.94)* (-0.269)

Both the equations of error correction terms have been moving towards equilibrium since the coefficients of logyt-1 and logxt-1 are negative and their t values are significant at 5% level,even other t values of the coefficients are significant except coefficients of trend. It proves that there is a long run association between per capita $CO_2$ emission and square and cubic functions of per capita GDP of South Asia and Euro Area during 1991-2017.The speeds of adjustment of error corrections are 8.86% and 161.6% per annum respectively.

But, by applying Wald test, the short run causality between per capita $CO_2$ emission and per capita GDP is given in the Table 2.

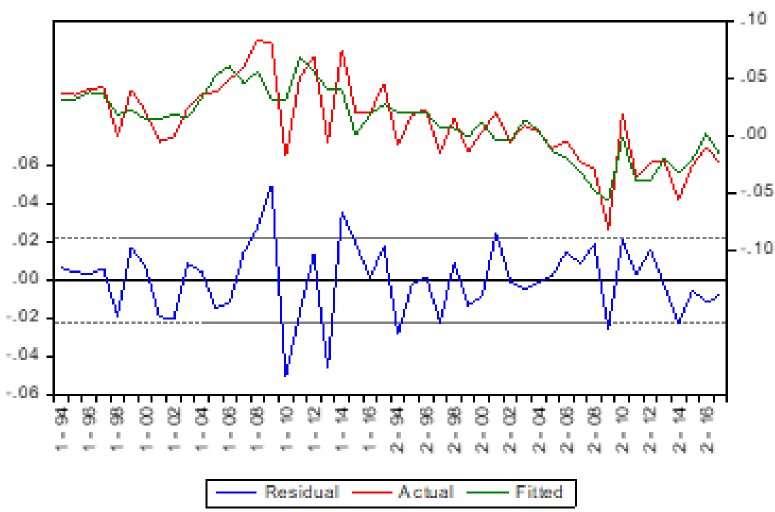
***Table 2: Short run causality***

| Short run causality, $H_0$=no causality | $\chi^2(2)$ | Prob | Accept/ reject | Causality Yes/no |
|---|---|---|---|---|
| Causality from $\log x_{t-1}, \log x_{t-2}$ to $\Delta \log y_t$ | 3.127 | 0.20 | Accept | No |
| Causality from $\log x_{t-1}^2, \log x_{t-2}^2$ to $\Delta \log y_t$ | 4.00 | 0.13 | Accept | No |
| Causality from $\log x_{t-1}^3, \log x_{t-2}^3$ to $\Delta \log y_t$ | 4.56 | 0.102 | Accept | No |

*Source: Calculated by author*

Thus there are no short run causalities running from $\log x_{t-1}$, $\log x_{t-2}$, $\log x_{t-1}^2$, $\log x_{t-2}^2$ and $\log x_{t-1}^3$, $\log x_{t-2}^3$ to $\Delta$logyt. But there is significant long run causality.

The long run equilibrium of the VECM-1 through the long run causality is plotted in Figure8 which is shown below.




*Source: Plotted by author.*

Figure 8: Long run association

In the VECM-2, the system equation-2 showed the estimated two cointegratingequations:

$$EC_1=-0.060logy_{t-1}-0.307836logx_{t-1}^2+0.021188logx_{t-1}^3+0.015377t+6.90309$$

(-0.82) (-9.94)* (8.42)* (1.78)

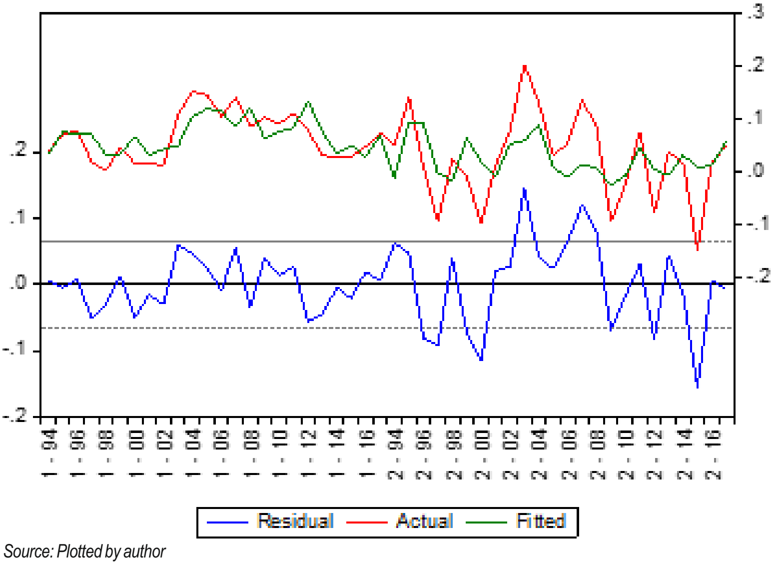
$$EC_2=-1.274logx_{t-1}-0.117137logx_{t-1}^2+0.004527x_{t-1}^3-0.00019t-2.795$$

(-1.24) (-44.09)* (20.94)* (-0.269)

Since the coefficients of $logy_{t-1}$ and $logx_{t-1}$ in $EC_1$ and $EC_2$ system equation are negative but their t values are not significant at 5% level, then it can be said that there are insignificant long run causalities from $logx_{t-1}$,$logx_{t-2,}$ $logx_{t-1}^2$,$logx_{t-2}^2$andlog$x_{t-1}^3$,$logx_{t-2}^3$to $\Delta$logxt.

Moreover, there are no short run causalities from $logy_{t-1}$, $logy_{t-2}$ to $\Delta$logxt because Chi-Square (2)value of Wald test is 0.792 whose probability is 0.67 which accepts the null hypothesis of no causality.

In Figure 9, the system equation of VECM-2 is plotted where the above notions are shown.




*Source: Plotted by author*

Figure 9: Long run association

In the VECM-3,the system equation-3 showed the estimated two cointegrating equations :

$$EC_1=-1.29logy_{t-1}-0.307836logx_{t-1}^2+0.021188logx_{t-1}^3+0.015377t+6.90309$$

(-0.90) (-9.94)* (8.42)* (1.78)

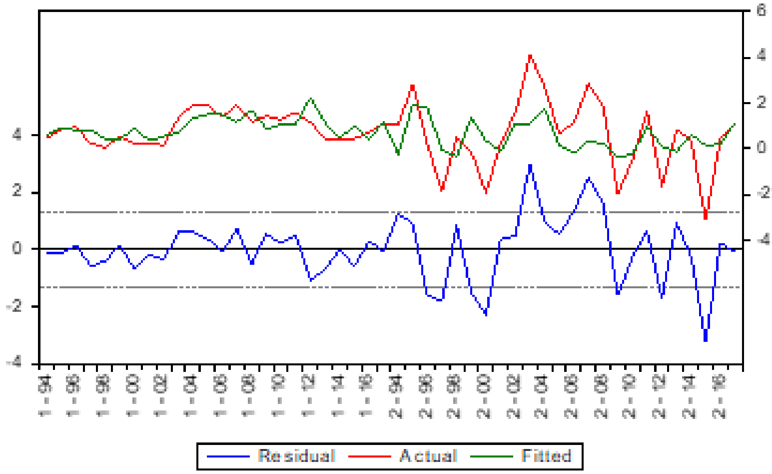
$$EC_2=-21.65logx_{t-1}-0.117137logx_{t-1}^2+0.004527x_{t-1}^3-0.00019t-2.795$$

(-1.07) (-44.09)* (20.94)* (-0.269)

Since the coefficients of $logy_{t-1}$ and $logx_{t-1}$ in $EC_1$ and $EC_2$ system equation are negative but their *t* values are not significant at 5% level, then it can be said that there are insignificant long run causalities from $logx_{t-1}$,$logx_{t-2,}$ $logx_{t-1}^2$,$logx_{t-2}^2$andlog$x_{t-1}^3$,$logx_{t-2}^3$to $\Delta logx_t^2$.

Moreover, there are no short run causalities running from $logy_{t-1}$ ,$logy_{t-2}$ to $\Delta logx_t^2$ because Chi-Square (2)value of Wald test is 0.978 whose probability is 0.61 which accepts the null hypothesis of no causality.

In Figure 10, the system equation of VECM-3 is plotted where the above notions are shown.




*Source: Plotted by author*

Figure 10: Long run association

In the VECM-4, the system equation-4 showed the estimated two cointegratingequations :

$$EC_1=-20.213logy_{t-1}-0.307836logx_{t-1}^2+0.021188logx_{t-1}^3+0.015377t+6.90309$$

(-0.92) (-9.94)* (8.42)* (1.78)

$$EC_2=-292.82logx_{t-1}-0.117137logx_{t-1}^2+0.004527x_{t-1}^3-0.00019t-2.795$$

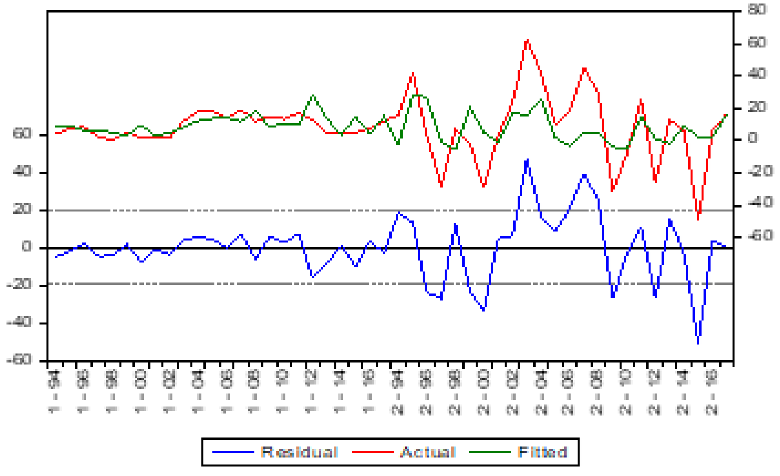
(-0.95) (-44.09)* (20.94)* (-0.269)

Since the coefficients of $logy_{t-1}$ and $logx_{t-1}$ in $EC_1$ and $EC_2$ system equation are negative but their *t* values are not significant at 5% level, then it can be said that there are insignificant long run causalities from $logx_{t-1}$, $logx_{t-2,}$ $logx_{t-1}^2$,$logx_{t-2}^2$and $logx_{t-1}^3$,$logx_{t-2}^3$to $\Delta logx_t^3$.

Moreover, there are no short run causalities running from $logy_{t-1}$ ,$logy_{t-2}$ to $\Delta logx_t^3$ because

Chi-Square (2)value of Wald test is 1.179 whose probability is 0.55 which accepts the null hypothesis of no causality.

In Figure 11, the system equation of VECM-4 is plotted where the above notions will be shown.




*Source: Plotted by author*

Figure 11: Long run association

In VECM, in income elasticity of the two-period lag there is absolute decoupling which is decreasing. ($\delta logyt/\delta logx_{t-1}$=-2.719<0,$\delta logyt/\delta logx_{t-2}$=-0.1343<0).Square of Income elasticity of two periods lag ensure relative decoupling which is dwindling. ($\delta logyt/\delta logx_{t-1}{}^2$=0.392 >0<1, $\delta logyt/\delta log_{xt-2}{}^2$= 0.0302>0<1).Lastly,cube of income elasticity of two periods lag confirm absolute decoupling whose value is also falling.($\delta logyt/\delta logx_{t-1}{}^3$=-0.0167<0 ,$\delta logyt/\delta logx_{t-2}{}^3$=-0.00149<0). These imply that the relation between per capita $CO_2$ emission and GDP per capita in South Asia and Euro Area during 1991-2017 satisfy EKC hypothesis.

Thus, the fixed effect panel regression analysis showed that there is absolute decoupling in income elasticity,no decoupling in square of income elasticity, absolute decoupling in cubic income elasticity, and relative decoupling in income elasticity to the power four respectively during 1991-2017 in Euro Area and South Asia. Cube of income elasticity of two periods lag confirm absolute decoupling whose value is also falling. These imply that the relation between per capita $CO_2$ emission and GDP per capita in South Asia and Euro Area during 1991-2017 satisfy EKC hypothesis.

**Impact of $CO_2$ Emissions**

**[i] On agriculture**

Cline (2008) studied that the global agricultural productivity (output per hectare) will decline by 16% without fertilization and 3% with fertilization by 2080 with respect to baseline global warming. In industrial countries those rates will be 6% and 8% and in developing countries those rates will be 25% and 10-15% respectively.

IPCC (2007) stated that every 1°C rise in temperature reduces wheat production by 4-5 million tones. Small changes in temperature and rainfall have significant effects on the quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants, and basmati rice. It will reduce the yields from dairy cattle and decline in fish breeding, migration, and harvests and it is projected that agricultural produce will be 10-40% less in crop production by 2100.Shah and Srivastava (2017) verified that India observed a rise of 0.03°C per year from 1990 to 2013 and every rise of 1°C temperature throughout the growing period, even after considering carbon fertilization ,wheat production decline 4-5 million tons. Knox *et al.* (2012) estimated that mean yield change for all crops is -8% by the 2050s with strong variations among crops in South Asia and Africa(especially in wheat, maize, sorghum and millet).Jemma ,Betts, Burke, Clark, Camp, Willett, and Wiltshire (2010) showed in their studies that temperature above 29°C for corn, 30°C for soya bean,36ºC for Maiza,40ºC for groundnut and 32°C for cotton negatively impact on yields in the USA.

Rising atmospheric $CO_2$ and climate change may also impact indirectly on crops through effects on pests and diseases (Gregory *et al.*, 2009). Increasing atmospheric $CO_2$ concentrations can also directly affect plant physiological processes of photosynthesis and transpiration. Theoretical estimates suggest that increasing atmospheric $CO_2$ concentrations to 550 ppm, could increase photosynthesis in such C3 crops by nearly 40 per cent. Ozone has significant negative impacts on crop yields through photosynthetic and leaf senescence (Van Dingenen *et al.*, 2009) which were visible in Europe, Asia and North America. A temperature rise of 2 °C to 3.5 °C increases loss in net revenue at the farm level ranging between 9% and 25%. Scientists also estimated that a 2°C rise in mean temperature and a 7% increase in mean precipitation would reduce net revenues by 12.3% for the country as a whole. Agriculture in the coastal regions of Gujarat, Maharashtra, and Karnataka in India is found to be the most negatively affected.

**[ii] Global Warming, Ecosystem and Biodiversity**

The early victims of global warming will be the endangered species. (VU) in the 2004 International Union for Conservation of Nature and Natural Resources (IUCN) and Wildlife Institute of India(WII) have listed Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) animals, birds and species.10 species are Critically Endangered such as Jenkin's Shrew (Crocidurajenkensii). (Endemic to India.), Ganges Shark (Glyphisgangeticus) (Endemic to India.) and Himalayan Wolf (Canishimalayensis) (Endemic to India and Nepal.) etc. There are 41 species which are Endangered such as Andaman Shrew (Crociduraandamanensis). (Endemic to India), Andaman Spiny Shrew (Crocidurahispida). (Endemic to India), Asian Arowana (Scleropagesformosus), Asiatic Black Bear (Selenarctosthibetanus), Asiatic Lion (Pantheraleopersica) etc.There are more than 70 Vulnerable “Endangered Mammal in the world namely, Wildlife Institute of India (WII), Andaman Horseshoe Bat (Rhinolophuscognatus). (Endemic to India.), Andaman Rat (Rattusstoicus),(Endemic to India.), Argali (Ovisammon) , Himalayan W-toothed Shrew (Crocidura attenuate), Sri Lankan Highland Shrew (Suncusmontanus), Asiatic Black Bear (Ursusthibetanus) Etc.

Myers, Mittermeier, Mittermeier, Da Fonseca, and Kent (2000) showed the types of birds, species and other plants and animals in the world and India which are facing unfavouable biodiversity situation as a result of global warming.

### *Table 3: Biological Diversity of India and the World*

| Group | No. of species in the world | No. of species in India | % of world species in India |
|---|---|---|---|
| Mammals | 4629 | 350 | 7.6 |
| Birds | 9702 | 1224 | 12.6 |
| Reptiles | 6550 | 408 | 6.2 |
| Amphibians | 4522 | 197 | 4.4 |
| Fishes | 21730 | 2546 | 11.7 |
| Flowering plants | 250000 | 15000 | 6.0 |

*Source-Myers et al.,2000*

### *Table 4: Biological Diversity in Himalayan Region*

| Group | No. of species in the world | No. of species in India | % of world species in India |
|---|---|---|---|
| Plants | 10000 | 3160 | 31.6 |
| Mammals | 300 | 12 | 4.0 |
| Birds | 977 | 15 | 1.5 |
| Reptiles | 176 | 48 | 27.3 |
| Amphibians | 105 | 42 | 4.0 |
| Fresh water fishes | 209 | 33 | 12.3 |

*Source: Myers et al., 2009*

A series of place-based observations, meta-analyses, and models indicate that global warming began to change geographical range of plants and animal species on land (NRC, 2010). In the extreme, some plants and animals have experienced maximum range shifts over the past 30 years. Arctic and Antarctic sea ice is rapidly diminishing and polar bears and various species of seals and penguins began to vanish [NRC, 2008b]. Warming of streams, rivers, and lakes also potentially affect cold-water fish, through impacts on reproduction, food resources and disease (Faostat, 2010)

The phenology of species is also changing with warming. Earlier appearance of spring in the Northern Hemisphere and the growing longer season can disrupt the synchronicity between species and their food and water sources, pollinators, and other vital interactions (Walther *et al.*, 2002). However, ecosystem processes such as plant growth and decomposition are also determined by interactions with other factors such as nitrogen and carbon supplies, soil moisture, length of growing season, land use, and disturbance (Eviner & Chapin, 2003). Recently, marine scientists have detected widespread poleward shifts in species distributions that are consistent with patterns of a warming ocean (Mueter & Litzow, 2008). Marine species can be highly mobile, which lead to larger and faster geographic shifts than in terrestrial ecosystems. The unpredictability of responses by different species is a key barrier to anticipating and adapting to the resulting ecosystem rearrangements. $CO_2$ released by human activities can influence ecosystem dynamics in aquatic systems by altering water chemistry particularly, the reaction of $CO_2$ with water to form carbonic acid ($H_2CO_3$), which lowers (acidifies) ocean pH which has decreased by approximately 0.1 units since preindustrial times. While this might not seem like a large change, it actually represents a 25 percent increase in acidity, because pH is measured on a logarithmic scale. By the end of this century, the oceans are projected to acidify by an additional 0.3 to 0.4 units (Orr *et al.*, 2005) under the highest IPCC emissions scenario. A broad array of marine species produce $CaCO_3$ skeletons during at least part of their life cycle, so ocean acidification threatens nearly all ocean ecosystems by altering calcification rates while simultaneously increasing the rate of $CaCO_3$ dissolution. Acidification is especially challenging for coral reefs, which are defined by the $CaCO_3$ skeletons of corals. Ocean acidification could also have dramatic consequences for polar food webs due to inability of forming shells. Overall, ocean acidification has the potential to alter marine ecosystems catastrophically ( NRC, 2010).

**[iii] Global Warming and Hurricane, Typhoons and Cyclones**

Hurricanes, Typhoons and Cyclones that occur in the Atlantic Ocean, Pacific, South Pacific and Indian oceans have long-term negative effects on economic growth, particularly for small states and islands. Tropical cyclones have resulted in an estimated average annual loss of US$180million for the past 50 years. Across the Caribbean, the economic costs of tropical cyclones have averaged approximately 2% of GDP annually since the 1950s. Tropical cyclones also have significant environmental implications, including damages to coral reefs which provide critical ecosystem services including coastal protection from storms. On a global scale, the impacts of climate change are projected to significantly increase damages from tropical cyclones and result in costs of between US$28-68billion per year by 2100 depending on global warming of between 2.7°C-4.5ºC. In the Caribbean, with 4ºC of global warming, the region is projected to face losses of US$350-$550 million per year by 2100 projections. For a warming of about 2.5°C by the end of the century, occurrence probabilities of Category 4 or 5 cyclones are found to increase substantially up to nearly double across all major basins relative to the recent past. For the South Pacific, an increase by a factor of 4 is reported.

**[iv] Sea Level Rise**

A 2017 NOAA report suggests a range of GMSL rise of 0.3 to 2.5 metres (1 ft 0 inch to 8 ft 2 inch) possible during the 21st century.Sea level rise is expected to continue for centuries. It has been estimated that we are committed to a sea-level rise within the next 2,000 years of approximately 2.3 metres (7.5 ft) for each degree Celsius of temperature rise. Since 1880, the ocean began to rise briskly, climbing a total of 210 mm (8.3 inch) through 2009 causing extensive erosion worldwide and costing billions. Sea level rises can considerably influence human populations in coastal and island regions and natural environments like marine ecosystems.

The IPCC TAR WGII report claimed that the impacts of sea level rise will be increased coastal erosion, higher storm-surge flooding, inhibition of primary production processes, more extensive coastal inundation, changes in surface water quality and groundwater characteristics, increased loss of property and coastal habitats, increased flood risk and potential loss of life, loss of non-monetary cultural resources and values, impacts on agriculture and aquaculture through decline in soil and water quality, and loss of tourism, recreation, and transportation functions. Also, fish, birds, and coastal plants could lose parts of their habitat. In 2016 it was reported that the Bramble Cay melomys, which lived on a Great Barrier Reef island, had probably become extinct because of sea level rises.

### [v] Health and Global Warming

Warmer average temperatures will lead to various diseases and health hazards. Exposure to extreme heat can lead to heat stroke and dehydration, as well as cardiovascular, respiratory, and cerebrovascular disease. Warmer temperatures and shifting weather patterns can worsen air quality, which can lead to asthma attacks and other respiratory and cardiovascular health effects. Wildfires due to rise in temperature create smoke and other unhealthy air pollutants. Rising carbon dioxide levels and warmer temperatures also affect airborne allergens, such as ragweed pollen. Ground-level ozone can damage lung tissue, reduce lung function, and inflame airways. This can aggravate asthma or other lung diseases. Inhaling fine particles can lead to a broad range of adverse health effects, including lung cancer, chronic obstructive pulmonary disease (COPD), and cardiovascular disease. Climate change can affect exposure to waterborne pathogens (bacteria, viruses, and parasites such as Cryptosporidium and Giardia); toxins produced by harmful algal and cyanobacterial blooms in the water; and chemicals that end up in water from human activities. Climate change creates Vector borne diseases which can carry infectious pathogens, such as viruses, bacteria, and protozoa, from animals to humans. Climate change may affect allergies and respiratory health, stomach and intestinal illness, worsening mental health, traumatic stress disorder, and mosquitoes transmitted virus diseases and so on.

### Concluding Remarks

In Siegel, E. (2015) wrote, "Global warming will destroy life on earth in the end,not just human life but all life on the planet surface including in the seas".And ,in the Washington Post,Mooney (2016) claimed, " In 10000 years,if we totally let it rip the planet could ultimately be an astonishing 7ºC warmer on average and future seas 52 metres (170ft) higher than now.There would be no mountain glaciers left in temperate latitudes, Greenland would give up almost 45 meters worth of sea level rise".Scientists of Geo-engineering showed us some hopes that humans can artificially moderate the Earth's climate allowing us to control temperature,thereby avoiding the negative impact of climate change by introducing huge reflectors in space or using aerosols to reduce the amount of carbon in the air. (The Gurdian, 29/11/2013). British Royal Academy of Sciences launched a study to examine Geo-engineering options and their risks. NASA is also looking at ways of managing how solar radiation hits the planet.The mixed emotions surrounding Geo-engineering hint at a dark mood.Jason Mark (2009) rightly expressed that Geo-engineering takes a problem,signifies its like a Rube Goldberg machine,employing eight or nine steps when one or two would do.Indeed Geo-engineering involves a surfeit of technological imagination and poverty of political imagination,an imbalance that's ingrained in the notion that if we can do something we should do it.In the climate change policy debates in the Gurdian, Richard Vernon and Dave Hunter (2018) argued that capitalism alone cannot reverse climate change. In replying Larry Elliots' opinion is that capitalism can crack climate change but only if it takes risks where he suggested that the world needs to wage war against climate change.

However, tireless efforts are going on the sides from climate research institutes, universities, international climate institutions, governments of the world, series of conventions and summits to combat the rate of global warming in national and international levels. Along with them, let us do the needful steps in our daily life to help our planet to survive.

[I] Switch to energy-efficient lighting,[ii] Improve the efficiency of home appliances, [iii] Buy energy-efficient appliances when shopping for a new appliances, [iv] Reduce energy needed heating,[v] Reduce energy needed for cooling,[vi] Practice fuel efficient driving, [vii] Buy a fuel efficient car, [viii] Recycle air conditioner coolant,[ix] Drive less, [x] Reduce lawn size, [xi] Recycle whenever possible, [xii] Eat locally produced foods, [xiii] Eat vegetarian foods, [xiv] Paint your home a light colour if you live in a warm climate or dark colour in a cold climate, [xv]Choose clean energy options, [xvi] Buy clean energy certificate and carbon offsets.

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# Preserving Biodiversity in South –East Asia : improving Management of natural Resources

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## INTRODUCTION

South East Asia has gone through great demographic and economic growth (UN 2015). Deforestation has become increasing threat to one of the most bio diverse areas of planet (Mc Donald, Kareiva and Forman 2008) jointly with climate change and other exploitative land use.

### Why should we preserve Biodiversity?

Biodiversity loss has tremendous impact on the earth system and ecosystem stability. It impacts the vulnerability of aquatic and terrestrial ecosystems due to Climate Change as the rate of speciation is lower than the rate of extinction (Steffen 2005). Human activity has crossed biodiversity boundary, if it continues it would replace million species facing great extinction (Myers *et al* . 2000). Human activity may destroy biodiversity specially species which are slow to adapt to non-linear change.

Biodiversity accounts for communal diversity, species diversity and genetic diversity. Southeast Asia concentrates biodiversity due to conducive environmental conditions: variety of abiotic factors, high isolation ,impact of glaciation events & higher productivity create abundance of species richness. Out of 25 biodiverse hotspots in the world 6 are situated in Southeast Asia (Myers *et al.*2000). Statistics shows that 2,216 new species were discovered in the Greater Mekong (from Myanmar to Vietnam) between 1997 and 2014 (WWF 2014) which makes it one of the most prolific regions of the world.

### What are the Threats to Biodiversity in Southeast Asia ?

Biodiversity loss in Southeast Asia is caused due to deforestation, climate change and exploitative land use including dams, mines and hunting.

Deforestation is the main cause of loss biodiversity. Southeast Asia has undergone massive deforestation in biodiversity hotspots partly due to rubber and palm oil production which plays havoc with the ecosystem which are essential for rural forest-dependent communities. For example, Indonesia has lost 2281000 ha between 2000 and 2005, nearly 1.92 % of its forest cover every year and it continues today (Graham *et al*. 2017).

Climate Change is of the pivotal factor which directly and indirectly affect ecosystem. It affects distributions, extinction rates reproduction (CBD 2007). Because South east Asia consist major islands with less mountain ranges many island species may not be able to migrate under climate change (Bickford *et. al* ,2010).

Forest fires in Southeast Asia negatively affect species and communities. For example, Sumantran bird diversity declined with open field species replacing forest specialists over time (Adeney *et. al*, 2006).

Hunting in South east Asia has given rise to fourth biggest illegal trade in the world producing $ 20 billion every year for medicine ,sport targeting endangered species like elephants or pangolians.

Southeast Asia has the highest rate of dams planned to be constructed which reduces 20 % to 70 % the number of migratory fish (Ziv *et al*. 2012).Fisheries also destroy the unique freshwater biodiversity to feed more than 65 million people.

Industrial agriculture has become alarming threat to forest & biodiversity (Rudel et al. 2009). At present Indonesia & Malaysia produce 170 metric tons of oil palm fruits each year which accounts for 80 % of global production.(FAo,2011).Conversion of natural habitats into a monoculture such as oil palm leads to tremendous loss in biodiversity.

**Improve Knowledge of Our Biodiversity and Natural Environment**

Under this strategy, the actions required are :

**1. To encourage and facilitate research.**

It especially applies to research about our ecosystem and conservation of selected species that are part of our biodiversity. Information about the interaction between biological factors and environmental factors, information about impact of climate change and studies that valuates our biodiversity are all important and wanted.

**2. To develop and maintain a central information portal on biodiversity to facilitate more informed decision-making.**

To do this NParks has set up the National Biodiversity Centre (NBC) on 22 May 2006. NBC serves as a central information portal to contain all information about the biodiversity in Singapore.

**3. Maintain a list of species with their conversation status**

The list that NParks create was called the Red Data Book. The Red Data Book was first published in 1994 to act as essential source of reference for both the government and the non-government organisations. It is also an important resource for the education and research sector when they want to better appreciate and understand Singapore's biodiversity.

## IMPACT ON ENVIRONMENT

### Species Status & Trends

### Plants

Southeast Asia possesses an estimated flora of around 60,000 species (Frodin, 2001). Of 1371 red-listed plant species in Southeast Asia, 292 are critically endangered, 196 endangered, 737 vulnerable, 31 near threatened. A recent detailed assessment of 155 Dipterocarp trees of peninsular Malaysia finds that five of them are critically endangered, 42 are vulnerable and 46 are near threatened (Chua *et al*, 2010).

**Table 1 : Decrease in mangrove area in Southeast Asia from 1980 to 2005.**

| Countries | Area (ha) | | Change 2005-1980 | | |
|---|---|---|---|---|---|
| | 1980 | 2005 | Area (ha) | % | % yr-1 |
| Brunei | 18,400 | 18,400 | 0 | 0.0 | 0.0 |
| Cambodia | 91,200 | 69,200 | -22,000 | -24.1 | -1.1 |
| Indonesia | 4,200,000 | 2,900,000 | -1,300,000 | -31.0 | -1.5 |
| Malaysia | 674,000 | 565,000 | -1,09,000 | -16.2 | -0.7 |
| Myanmar | 555,500 | 507,000 | -48,500 | -8.7 | -0.4 |
| Philippines | 295,000 | 240,000 | -55,000 | -18.6 | -0.8 |
| Singapore | 500 | 500 | 0 | 0.0 | 0.0 |
| Thailand | 280,000 | 240,000 | -40,000 | -14.3 | -0.6 |
| Timor-Leste | 4250 | 1800 | -2450 | -57.6 | -3.4 |
| Vietnam | 269,150 | 157,000 | -112,150 | -41.7 | -2.1 |
| Total | 6,388,000 | 4,698,900 | -1,689.100 | -26.4 | -1.2 |

Source Mangrove area data collated from FAO (2007) The world's mangrove 198-2005: A thematic study prepare in the framework of the global forest resources assessment 2005. FAO Forestry Paper 153. Rome, Italy : Food and Agricultural Organization of the United Nations.

Note that Lao PDR is excluded from the table as it is a landlocked country with no mangrove forest.

### Insects :

The effects of land-use change and deforestation on the mega fauna of Southeast Asia have been well reported (Sodhi *et al.*, 2009).

In Southeast Asia, 87, terrestrial insect species are listed as threatened on the IUCN Red List, which represents 12% of total threatened terrestrial insect species worldwide. These threatened species are classified as "critically endangered" (CR), "endangered" (EN) or "vulnerable" (VU; IUCN, 2011). Of the 87 threatened insect species, 43 are Lepidoptera (butterflies or moths – CR: 1, EN: 14, and VU: 28) are 42 are Odonata (dragonflies or damselflies – CR:6 EN-9, and VU:27). There is also one vulnerable ant species (Monomoriumhospitrum; VU) and one extinct stick insect (Pseudobactriciariddeyi). Because of the high proportion of endemic species in Southeast Asia, the loss of many of these threatened species likely will result in global extinctions.

**Table 2 : Generic richness by regions in Southeast Asia**

| Region | Genera | Endemic genera | Genera standardized by area[3] | Genera standardized by collecting intensity[2] |
|---|---|---|---|---|
| Cambodia | 686 | ? | 598 | 922 |
| Laos | 767 | 4 | 622 | 1028 |
| Burma/Myanmar | 1304 | 10 | 812 | 1987 |
| Thailand | 1605 | 17 | 1097 | 199 |
| Vietnam | 1401 | 21 | 1061 | 1642 |
| Borrneo | 1396 | 31 | 841 | 1704 |
| Java | 1403 | 3 | 1307 | 1206 |
| Nusa Tengarra | 812 | 1 | 802 | 964 |
| Malaya | 1457 | 19 | 1354 | 1288 |
| Moluccas | 898 | 3 | 1026 | 1009 |
| Philippines | 1406 | 20 | 1062 | 1467 |
| Sulawesi | 1000 | 5 | 850 | 1285 |
| Sumatra | 1300 | 7 | 877 | 1696 |

Regression-based estimates correcting for area and collection effect (for full details see Marsh *et al.*, 2009)

Source Reproduced from Marsh St. Brummitt NA, de Kok RPJ, and Ulteridge TMA (2009) Large-scale patterns of plant diversity and conservation priorities in South East Asia. Blumea 54: 103-108, with permission from National Herbarium Nederland.

Reptiles and Amphibians of Southeast Asia is a hotspot for amphibian species richness and endemism (Bickford *et al.*, 2010). More than 730 species of amphibians have been described for the region (IUCN, 2011) and many more are likely undescribed (Giam *et al.*, 2010a, 2011c). The conservation status of most amphibians has been assessed as a result of the 2004 Global Amphibian Assessment (Stuart *et al.*, 2004) and subsequent yearly assessments by IUCN (IUCN, 2011). Of the 738 native amphibians assessed on the 2011 IUCN Red List, 135 are threatened with extinction (i.e., Red List categories, critically endangered, endangered, or vulnerable), while a further 76 are near-threatened. Rowley *et al*, 2010.

Reptiles In 2008, Southeast Asia (excluding Philippines and islands east of Western Nusa Tenggara) harboured 975 native reptile species (Das, 2010). However, the conservation status of most of these species remains unknown - less than a quarter have been assessed by the IUCN as of October 2011 (IUCN, 2011). The proportion of species that were assessed differed across major groups of reptiles. The conservation statuses of croco-diles (83% of species assessed; 5 of 6 species) and turtles (75%, 40 of 53 species) were better elucidated compared to snakes (27%, 132 of 484 species) and lizards (15%, 65 of 432 species). Of the 242 species that were assessed, 50 species were found to be threatened.

The main threats to turtles appear to be from the wildlife trade, bush meat hunting, degradation of habitat for nesting (for sea turtles), pollution, and by catch mortality (i.e., mortality from entanglement in fishing nets; (Shanker & Pilcher, 2003; Pacini & Harpar, 2008; Nijman, 2010; IUCN, 2011). Crocodiles are threatened mainly by habitat degradation (Pacini and Harper, 2008); persecution and exploitation for bush meat and wildlife trade are also important threats (IUCN, 2011).

The low proportion of threatened lizards and snakes (relative to turtles and crocodiles) may have arisen partly due to a lack of information on population and range trends of many species.

**Birds**

Birds represent one of the best-studied groups in Southeast Asia. Among the main tropical regions in the world, Southeast Asia has the highest mean proportion of country-endemic (9%) and the highest mean proportion of threatened bird species (6%; Sodhi *et al*., 2010a). The relatively high degree of endangerment may be related to the high rate of recent de-forestation observed in this tropical region. Up to 67% of forest bird species have been lost as a result of more than 90% forest loss in the highly urbanized Singapore representing one of the world's highest estimates of long-term loss of forest species (Castel 1 *et al*., 2000).

**Mammals**

Southeast Asia hosts exceptional levels of mammal diversity, with the highest degrees of endemism of any tropical region (Sodhi *et al.*, 2010b). However, mammals in Southeast Asia also have the highest proportion of threatened species among any tropical region (Morrison *et al*., 2007; Schipper *et al*., 2008; Sodhi *et al*., 2010b) and an estimated 85% of species are at risk of extinction during this century due to deforestation (Sodhi and Brook, 2006).

Forest loss and disturbance affect mammals in different ways. Despite general trends of decreased diversity and abundance (Sodhier *et al*., 2009), many species are able to persist or recover following forest degradation (for a comprehensive review, see Sodhi *et al.*, 2010a). In Borneo, selectively logged forests can support large numbers of mammal species (e.g., the tarsier Tarsiusbancanus), but the response varies by species based on ecological requirements (Meijaard *et al.*, 2008).

Bats comprise a third of all Southeast Asian mammals, and of Southeast Asia's 330 species, 60% are endemic to the region (Kmgston, 2010). Other mammals in the region are at high risk of extinction due to illegal poaching. Southeast Asia's pangolin species are threatened by trade for use in food, medicine, and clothing, particularly in Vietnam and China (Newton *et al.*, 2008).

Vietnam's primates are also highly threatened by poaching with 21 of 24 species listed as threatened (Nadler *et al*., 2007).

Large mammals may face the greatest threats because they are particularly vulnerable to habitat loss and are often targeted for hunting.

**Challenges and Opportunities**

**Enhance Protected Area Networks**

Protected are networks represent one of our core strategies in biodiversity conservation and protection of ecosystem services (Chape *et al.*, 2005; Luck *et al.*, 2009). Reserves in Southeast Asia have been shown to be safe havens for butterflies, forest endemic birds and bats, for instance (Koh and Sodhi, 2004; Lee *et al*., 2007;

Struebig *et al*. 2010). In addition, protected areas can be effective in buffering against human encroachment such as deforestation (e.g., Myanmar, Songer *et al.*, 2009).

**Safeguard Biodiversity in Human-Dominated Landscapes**

Well-enforced protected areas have demonstrated their effectiveness at preserving biodiversity in some countries (e.g., in the Philippines *et al*., 2007). Improving the management of protected areas is therefore one of the most important strategies to safeguard biodiversity in human-dominated landscapes across the region; even a modest in-crease in funds can help improve their effectiveness (Bruner *et al*., 2001). Community-based conservation within protected areas should also be explored as local collaborative programs can aid wildlife population recovery (e.g., in Thailand; Steinmetz *et al*., 2010).

To mitigate specific threats such as illegal hunting of threatened species in the around forests, NGSOs have established antipoaching groups in association with enforcement authorities to combat the threat of poaching (e.g., in Malaysia and Indonesia; Clements *et al*., 2010a; Ahmad Zafir *et al*., 2011).

To deal with the treat of emerging infectious diseases (EIDs) to native biodiversity, control measures include: (1) minimizing contact with the direct host. (2) monitoring of intermediate hosts, (3) improving bio security on farms, and (4) better disease recognition and diagnosis (Field and Mackenzie, 2004.

**Forest Restoration**

Reversing these trends through restoration is attracting attention across the tropics (Braxton Little, 2008; Chazdon, 2008; Normile, 2009; Lamb, 2011), motivated by the need to mitigate greenhouse gas emissions (Drummond *et al*., 2010), restore key habitats for species of conservation concern, and enhance the biodiversity value of human-modified landscapes (Gardner *et al.*, 2009).

**Interventions for better Management**

Intervention incorporates a shift towards better management of resources like strict protection of biodiversity rich areas and also regulation of current malpractices. The intervention integrates local land use strategies that provide the basic needs of communities (Water Resource Institute 2000).

National and International legislation has started to regulate the impact of forestry production to protect biodiversity (OWG8 2014).The Convention on Biological Diversity was propounded in 1992 at the Earth Summit in Rio de Janerio which is now the biggest institution publishing policy briefs and promoting Government interventions worldwide(Carrizosa 2004).

Southeast Asian Diversity is promoted by the UN-REDD program which implements more sustainable Forest Management including logging(Meijaard et al 2005).Reduced - impact logging leads to shift in forestry methods promoting sustainable forest management. However sustainable forest management does not cater to underlying causes of deforestation like the demand for wood and food due to waste(OWG8 2014).

Swidden agriculture is pivotal to livelihood in south East Asia and to its cultural identity (Cramb *et al*. 2009). Institutions for management of land have started to emerge in communities. Community induced management of resources with legal support has turned out to be more fruitful than large scale top-to-bottom decisions. Swidden agriculture transformation has left some communities marginalised and heavy handed state interventions have increased the process of differentiation (Cramb *et al*. 2009).

Protection of biodiversity can be either from market based regulations creating incentives for farmers or from government regulations through laws which are coercive (UNPD 1999). Protecting biodiversity requires interventions from both origins.

Global scale drivers of biodiversity loss should be tackled by cooperation of multiple agents: Global governance, Government, Non –profit Organisation, the private sector and communities. Local involvement must incorporate positive market incentives and supportive bottom to top government policies (IGBP 2012).

Biological corridors between protected areas where human activity is allowed to some extent is an example like carbon credits and ecotourism of incentives and soft interventions of the government viable for farmers (Villamor and Lasco 2008).

New forms of legislation has been incorporated which includes Nitrogen saturated wetlands with protected areas to preserve ecosystems storing carbon and the fragile balance with climate change (Van Roon 2012).

Overconsumption of natural resources is one of the major reasons causing biodiversity loss.

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# Energy Consumption, Pollutant Emissions and Economic Growth in India: A Dynamic Causality Analysis

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## INTRODUCTION

Over the past decades the emission of the $CO_2$ and the consumption of the energy is gradually increased which may directly hamper the economic growth. Now a day's environmental destruction is one of the most frequently global matters and $CO_2$ emission is a major cause of global warming and striking serious threat to the destruction of environment as well as human life, to prevent the global warming a Kyoto Protocol agreement, (1997) between several countries was signed to reduce their emission level globally. Climate change issues are of paramount importance for emerging economies like India which uses mainly fossils fuels and where energy is consider lifeline of the economy.

In the present study we consider India because India is energy dependent economy and the major sources of energy is from crude oil (29.38%), and coal (56.90%) According to the report of (CMIE), which is the major components of the carbon emission and India is the third biggest after China and USA in terms of total primary energy consumption. Currently, around 87% of rural households and 26% of urban households in India depend on biomass for cooking. From this statement it is clearly understood that emission of the $CO_2$ and the consumption of the energy is increased and reducing energy consumption and carbon emission control obligations directly may hamper the economic growth momentum. The growing threat of global warming and climate change has drawn attention to examine the long run and causal relationship between energy consumption, carbon emissions and economic growth in India by applying different econometric approach. The present study is an attempt to gather additional evidence by applying Johansen co-integration approach for long-run equilibrium relationship followed by Granger causality approach in VAR model to explore short-run causality.

Many studies of Narayan and Smyth (2008); Tiwari (2011); Wang *et al.* (2011); Andersson and Karpestam (2012); Vidyarthi (2013) and Nain *et al.* (2015) have examined the relationship between environmental degradation and economic growth and provide an empirical evidence which suggesting that carbon emission reduction policies without proper development of low carbon technologies will not translate into sustained high economic growth. The main focus of the research is Environmental

Kuznets Curve hypothesis. The relationship between environmental destruction and the per capita income is called Environmental Kuznets Curve (Kuznets, 1955). As par the Environmental Kuznets Curve hypothesis when the environmental pollution will increase as the income per capita increases. But after some achievement the relation will changed, and the trends of the economic growth and the income tends to fell down. Rothman and Bruyn (1998) argue that economic growth may become a solution rather than a source of the problem.

To empirically examine the long run and causal relationship between energy consumption, carbon emissions and economic growth in India over the period 1971-2014 within multivariate framework. The present paper is divided into five sections, where section 2 provides a brief review of the literature regarding the relationship between $CO_2$ emission, energy consumption and economic growth. Section 3 describes the data and methodology of the research work. Section 4 provides the empirical analysis of the data and discussion of results while Section 5 concludes the research.

**Literature Review**

In the 21st century, globally the threat of global warming and the climate change gradually increasing and that has drawn attention to the relationship between economic growth, energy consumption and environmental pollutants ($CO_2$ emission). From the last two decades, a large no of research studies addressed to the relationship between energy consumption, $CO_2$ emissions, and economic growth in different country and regions. Form the past literature study it is found that there have been basically three strands of research to extensively examined the relationship between economic growth, energy consumption, and environmental quality ($CO_2$ emission). The first strand mainly focuses on the environmental pollutants and economic growth nexus by critically examine the validity of Environmental Kuznets Curve (EKC) Kuznets (1955). It shows the relationship between economic progress and environmental degradation through time as an economy progresses that indicates an inverted U-shape relationship between the environmental pollution and per capita income (economic growth of country). In this context, a large no of study has been conducted to test the existence of EKC in different country by Grossman and Krueger (1991); Shafik and Bandyopadhyay (1992); Selden and Song (1994); Friedl and Getzner (2003); Dinda and Coondoo (2006); Managi and Jena (2008); Coondoo and Dinda (2008); and Pao and Tsai, (2011) but the results of the such study is contradictory and most of the time in real life data the researcher cannot establish the inverted U-shaped relationship.

However, the second strand mainly concentrates on the economic growth and energy consumption nexus which indicates that economic growth and energy consumption may be jointly determined. This approaches basically investigates the weather energy consumption will boost economic growth or vice versa. The economic growth is closely related to the energy consumption and for the better development of the economy required more energy consumption. Various studies are taken in this field to examine the causal relationship between energy consumption and economic growth by using co-integration and Granger causality, but the most exhaustive study has been conducted by the Kraft and Kraft, (1978) and the following seminal work also conducted by Soytas and Sari (2006); Akinlo (2008); Apergis and Payne (2012); Ozturk (2010); Payne (2010); Tang and Tan (2013); Apergis and Tang (2013); Baranzini *et al*. (2013) and Mirza and Kanwal (2017) find that the results still remain controversial due to some constraint (like time, variable, region and model employed) in their study.

The third strand of research combines the earlier two approaches by examining the dynamic relationship between the carbon emissions, energy consumption, and economic growth. Soytas and Sari (2007) and Zhang and Cheng (2009) studied the presence and direction of Granger causality between energy consumption, carbon emissions and economic growth for USA & China over a period of 1960-2007 using Toda-Yamamoto procedure and found that unidirectional Granger Causality Between energy consumption and carbon emissions, and also unidirectional Granger causality between GDP and energy consumption. Ghosh, (2010) analyzed the dynamic relationship between carbon emissions, energy consumption, and income after incorporating real investment and employment for India over the period 1971-2006 using autoregressive distribution lag model of cointegration and causality. The study confirmed the absence of long-run causality between carbon emissions – national income. However, bidirectional causality between carbon emissions – national income, unidirectional causality from national income to energy supply and energy supply to carbon emissions exists in short run.

Pao and Tsai (2010, 2011) examined the nexus between carbon emissions, energy consumption and income for BRIC countries as well as Brazil by using panel cointegration, causality tri-variate VECM model and found there is a bidirectional causality between energy consumption, carbon emissions, and economic growth. Al-Mulali (2011) inspected the dynamic relationship between oil consumption, carbon emissions and economic growth for MENA countries by using panel cointegration and Granger causality whereas the Results tends to there is a bi-directional causality between oil consumption, carbon emissions and economic growth in both the short run and long run. However the recent study of the Vidyarthi (2013) which examined the dynamic relationship between energy consumption, carbon emissions and economic growth for India over the period 1971-2009 within multivariate framework by using Johansen cointegration, and Granger causality based on vector error correction method and found that the presence of long-run relationship among the variables that indicating carbon emissions and energy consumption are positively correlated with economic growth and unidirectional ganger cause between variables. Mirza and Kanwal (2017) explored the presence of dynamic causality between economic growth, energy consumption and Carbon emissions for Pakistan by using Johansen-Julius co-integration, Grangers causality test, and ARDL approach to cointegration in a VECM framework and found that the bidirectional causality relationship between energy consumption and economic growth both in the short as well as in the long run.

Form the above literature study clearly indicates that Relationship between energy consumption, $CO_2$ emission, and economic growth is still questionable because of the different country, climate, government policies, income levels, development stages of the country, lifestyle of the people and as well as the methodologies applied in different author in their study. Still, the empirical results of the above research findings reflect that the issue lacks consensus and signifies the importance of additional evidence on this topic. The present study is examined the long run and causal relationship between energy consumption, carbon emissions and economic growth in India over the period 1971-2014 within a multivariate framework of VAR environment. There are three major factors which motivating us to select INDIA AS my research area. First of all, the primary energy consumption in India is the third biggest after China and USA with 5.5% global share in 2016 and the fourth largest carbon dioxide emitter after the, China, USA and European Union. Secondly, as per the estimates of Planning Commission in India the consumption need of energy is expected to rise 5.70% to 5.40 % p.a. during 12th and 13th Five-Year Plan. and finally, we desire to country-specific study because the cross-country wise study was failing to capture the economic situation due to their Geographical location, climate, culture government policies, income levels, development stages and the market structure of the country. Thus, for policy formulation and implication the country-specific study provides a better insight.

## Data and Methodology

This section explains the data and methodology of the paper. It has been partitioned into two subsections. The first subsection gives the data and its sources, sample and period of the study. The next subsection relates to the methodology and procedures.

### (i). Data and Data Sources

The paper evaluates the long run as well as short-run (causal) relationship between energy consumption, carbon emissions and economic growth in India. The study was conducted by using secondary annually time series data covering a period of forty-four years from 1971 to 2014. The time series data are obtained from World Development Indicators of World Bank which was published in 2016. The study uses total primary energy consumption (kilotons of oil equivalent) as a proxy for energy consumption, real gross domestic product (GDP constant US$2,000) as a proxy for economic growth and total carbon dioxide ($CO_2$) emissions (in kilotons), as a proxy for carbon emissions, respectively, based up on the common practices in the literature of Soytas *et al*. (2007), Tiwari (2011), Vidyarthi (2013), Zaidi *et al*. (2017) and Zhang *et al*. (2017).

### (ii). Methodology

To analyse the impact of $CO_2$ emission and energy consumption and economy growth the Globally accepted econometric techniques like Descriptive statistics, ADF Unit Root Test, Correlation analysis, Granger Causality Test and Johansen's Co-integration test as used Soytas *et al.* (2007); Tiwari (2011); Vidyarthi (2013); Zaidi et al. (2017) and Zhang et al. (2017) is employed.

**Step -1 Testing Unit-Roots & Correlation Analysis**

For the data stationarity purpose, we have applied the unit-root test of The Augmented Dicky-Fuller statistic. This test is normally used to analyze or to check the stationarity and trend stationarity of the time series data. The Augmented Dicky-Fuller statistic is used in the test is a negative number. More negative is the stronger rejection of hypothesis at some level of confidence. The Augmented Dicky-Fuller statistic is measured by applying following formula.

$$\Delta Y_t = \alpha + \beta_t + \gamma y_{t-1} + \delta_1 \Delta Y_{t-1} + \cdots + \delta_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where: α = constant, β = coefficient on a time trend, p = the lag order of the autoregressive process.

On the other hand, we have applied The Phillips-Perron Unit Root Tests. This test is different from the above ADF test because it mainly dealt with serial correlation and heteroskedasticity in the error terms. Generally, ADF tests use a parametric auto-regression to approximate the ARMA structure of the errors in the test of regression, where the PP tests ignore the serial correlation in the test regression. The test regression for the PP tests is

$$\Delta y_t = \beta' Dt + \pi y_{t-1} + \varepsilon_t \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where $u_t$ is I(0) and may be heteroskedastic. The PP tests correct for any serial correlation and heteroskedasticity in the errors $\varepsilon_t$ of the test regression by directly modifying the test statistics $t_\pi$=0 and $T\pi$.

Before going to the application of any model in data series it is required to standardized data series. To make data series standardized natural logarithmic applied in all variables such as Energy Consumption, Gross Domestic Product, and Carbon Dioxide Emissions. A logarithm is one of the most important mathematical toolkits for statistical modeling and analysis of data. To transforming the normal to logarithms data the following formula will be applied.

$$yi=\log(xi) \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

**Step-2 Testing for Co-integration and Causation**

**Testing for Co-integration Using Johansen's approach**

The Johansen Cointegration test is an econometric test of time series variable which predicts the long run or equilibrium economic relationship between two or more time-series variables based on the augmented Dickey-Fuller test and having unit roots. This approach mainly determines the number of co-integrated vectors for any given number of non-stationary variables of the same order. That means two or more random variables are said to be cointegrated if each of the series is themselves non – stationary. The Johansen Cointegration approach basically takes its starting point in the vector auto-regression (VAR) of order p given by

$\mathbf{y}_t = \boldsymbol{\mu} + \mathbf{A}_1\mathbf{y}_{t-1} + \ldots\ldots + \mathbf{A}_p\,\mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t$ ............................................................... (4)

where $\mathbf{y}_t$ is an $n$x1 vector of variables that are integrated of order one – commonly denoted I (1) – and $\boldsymbol{\varepsilon}_t$ is an $n$x1 vector of innovations. This VAR can be re-written as

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + \varepsilon_t \quad \ldots\ldots (5)$$

$$\text{where } \Pi = \sum_{i=1}^{p-1} A_i - I \text{ and } \Gamma_i = -\sum_{j=i+1}^{p} A_j$$

**Testing for causation using Granger Causality approach in VAR framework**

The Granger causality test is a technique of econometric which determining whether one time-series variable is significant in forecasting another time series variable in the same period or past values of a variable help to predict changes in another variable in the same period (Granger, 1988). In the present study, the Granger Causality approach in VAR framework will follow. Suppose there are two variables X and Y then Granger causality analysis in the VAR framework will be based on the following equations.

$$\Delta X_t = \alpha_x + \sum_{i=1}^{k} \beta_{x,i} \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_{x,i} \Delta Y_{t-i} + \varepsilon_{x,t} \quad \ldots\ldots (6)$$

$$\Delta Y_t = \alpha_y + \sum_{i=1}^{k} \beta_{y,i} \Delta Y_{t-i} + \sum_{i=1}^{k} \gamma_{y,i} \Delta X_{t-i} + \varepsilon_{y,t} \quad \ldots\ldots (7)$$

**Empirical Results and Discussion**

The Empirical results are based on the methodology employed in the study have been explained in the current section. The results have been provided in two parts: the first part gives the preliminary results of all the variables like unit-root test and correlation test between variables and the second part focuses on the impact of the $CO_2$ Emission and Energy Consumption on Economic Growth.

***Table 1: Descriptive Statistics of Selected Economic Variable***

| Variable | LNCO2 | LNENG | LNGDP |
|---|---|---|---|
| Mean | -0.29756 | 5.923412 | 26.58898 |
| Median | -0.25184 | 5.90021 | 26.4417 |
| Maximum | 0.548122 | 6.457442 | 28.34171 |
| Minimum | -1.01175 | 5.591292 | 24.91975 |
| Std. Dev. | 0.465408 | 0.254555 | 0.946386 |
| Skewness | 0.06385 | 0.4714 | 0.241412 |
| Kurtosis | 1.824594 | 2.183884 | 2.266101 |
| Jarque-Bera | 2.562794 | 2.850682 | 1.414833 |
| Probability | 0.277649 | 0.240426 | 0.492916 |

*Source: Author's Own Calculation and Compliance*

Table 1 presents the descriptive statistics of selected economic variables for the entire period of April 1971 to March 2014. Basically, the descriptive stat is used to reveal the main features of the data. They include the mean, median, maximum, minimum, standard deviation, skewness, kurtosis, Jarque-Bera tests for selected economic variables. All the variables have shown positive skewness which indicates steeper tails than the normal distribution. In addition, it should be noted that all aggregated set of macroeconomic determinants is stationary because the Unit -Root Test of Augmented Dicky Fuller (ADF) test statistics are higher than the critical values (Table 3).

**Step -1 Preliminary Analysis: Testing Unit-Roots & Correlation Analysis**

This section presents the preliminary analysis of Unit-Roots testing & correlation analysis of all the selected variables. Before going to the model, a preliminary analysis of testing regular unit roots and testing of correlation is required. For the testing the correlation we have applied Pearson coefficient of correlation and for stationarity, the tests statistics such as Augmented Dickey-Fuller (ADF) and Phillip-Perron test is followed (Table 1). The hypothesis of the Augmented Dickey-Fuller test and Phillip-Perron test of unit root indicates that:

H0: The variables have unit root (Not Stationary).

H1: The variables have no unit root (Stationary).

***Table 2: Unit Root Test of Selected Economic Variable***

| Variable name/ Test | Augmented Dickey-Fuller test | | | Phillip-Perron test | | |
|---|---|---|---|---|---|---|
| | LNCO2 | LNENG | LNGDP | LNCO2 | LNENG | LNGDP |
| ADF Test statistics | -6.142178 | -4.814941 | -5.95468 | -6.18917 | -5.042372 | -5.973082 |
| 1% critical value | -3.596616 | -3.596616 | -3.596616 | -3.596616 | -3.596616 | -3.596616 |
| 5% critical value | -2.933158 | -2.933158 | -2.933158 | -2.933158 | -2.933158 | -2.933158 |
| 10% critical value | -2.604867 | -2.604867 | -2.604867 | -2.604867 | -2.604867 | -2.604867 |
| P value | 0.0000 | 0.0003 | 0.0000 | 0.0000 | 0.0002 | 0.0000 |
| R-squared | 0.485374 | 0.366925 | 0.469905 | 0.485374 | 0.366925 | 0.469905 |
| Adj R sq. | 0.472508 | 0.351098 | 0.456653 | 0.472508 | 0.351098 | 0.456653 |
| Significant at | 1st Level | 1st Level | 1st Level | 1st Level | 1st Level | 1st Level |

*Source: Author's own calculation and compliance*

The empirical preliminary analysis starts with checking stationarity of the time series variables as a prerequisite for applying any time series model, for this study model like cointegration and causality test. The optimal lag length selection for the unit root tests are restricted to three for the sample size of 43 using a T1/3 formula. Table 1 presents the results of ADF and PP unit root and the Results clearly indicates that the variables are not stationary at levels since computed test statistics could not reject the null hypothesis of non-stationarity. But they become stationary after taking the first difference (lag1). Hence, we conclude that the series are integrated of order one, i.e. I (1) at the 1%, 5% and 10% level of significance.

***Table 3: Coefficient of Correlation of Selected Economic Variable***

| VA RIABLES | LNCO2 | LNENG | LNGDP |
|---|---|---|---|
| LNCO2 | 1 | 0.98869 | 0.9746 |
| LNENG | 0.98869 | 1 | 0.98083 |
| LNGDP | 0.97459 | 0.98083 | 1 |

*Source: Author's Own Calculation and Compliance*

Pearson's coefficient of correlation method has been used to check the correlation and find out the strength of the relation between the economic variables such as Energy Consumption, $CO_2$ Emissions, and the GDP. Table 3 indicates that LN $CO_2$, and LNENG, are showing a high correlation with LNGDP indicates a good mathematical fit to a linear model.

**Step-2 Secondary Analysis: Testing for Co-integration and Causation**

***Table 4: Johansen's Co-Integration Test***

Unrestricted Cointegration Rank Test (Trace)

| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.473435 | 52.77855 | 29.79707 | 0.0000 |
| At most 1 * | 0.366384 | 26.48192 | 15.49471 | 0.0008 |
| At most 2 * | 0.172700 | 7.773089 | 3.841466 | 0.0053 |
| Trace test indicates 8 cointegrating eqn(s) at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) *p*-values | | | | |

***Unrestricted Cointegration Rank Test (Maximum Eigenvalue)***

| Hypothesized No. of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.473435 | 26.29663 | 21.13162 | 0.0086 |
| At most 1 * | 0.366384 | 18.70883 | 14.26460 | 0.0093 |
| At most 2 * | 0.172700 | 7.773089 | 3.841466 | 0.0053 |
| Max-eigenvalue test indicates 4 cointegrating eqn(s) at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) *p*-values | | | | |

*Source: Author's Own Calculation and Compliance*

Since, all the variables like GDP, ENG and $CO_2$ are integrated (stationary) of order one (i.e. lag 1) in both ADF and PP methods. So, we move towards the examine the presence of long-run cointegrating relationship among the variables. Table 4 reported the results of Johansen cointegration test There are basically Two types of test statistics are reported. The first block reports the so-called trace statistics ($\lambda$ trace) and the second block reports the maximum eigenvalue ($\lambda$ max) statistics. Both the trace statistic and the maximum eigenvalue statistics indicating that maximum of our variables is co-integrating equations at the 0.05 level. Hence, it will conclude that there is a long-run equilibrium relationship between energy consumption, carbon emissions and economic growth in India.

The variables are integrated into first lag (order one) means that there must some causal relationship exist between them in at least one direction (Engle & Granger, 1987). To test the direction of causality between variable, the VAR is used. In Table 5, we present the results of causality based on VAR.

***Table 5: VAR Granger Causality Test***

| | | | |
|---|---|---|---|
| Vector Autoregression Estimates | | | |
| Included observations: 42 after adjustments | | | |
| Standard errors in ( ) & t - statistics in [ ] | | | |
| | LNGDP | LNENG | LNCO2 |
| LNGDP(-1) | 0.947977 | 0.024615** | 0.050636** |
| | (0.16917) | (0.02832) | (0.05581) |
| | [ 5.60355] | [ 0.86924] | [ 0.90736] |
| | | | |
| LNENG(-1) | 1.942823 | 0.717527 | -0.156593 |
| | (1.20508) | (0.20171) | (0.39752) |
| | [ 1.61220] | [ 3.55714] | [-0.39393] |
| | | | |
| LNCO2(-1) | -0.809591 | 0.090431* | 0.789339 |
| | (0.60341) | (0.1010) | (0.19905) |
| | [-1.34169] | [ 0.89532] | [ 3.96558] |
| | | | |
| C | -0.660439 | -0.590221 | -1.185656 |
| | (2.35421) | (0.39406) | (0.77658) |
| | [-0.28054] | [-1.49778] | [-1.52676] |
| R-squared | 0.992943 | 0.997456 | 0.996956 |
| Adj. R-squared | 0.991733 | 0.99702 | 0.996434 |
| Sum sq. resids | 0.232038 | 0.006501 | 0.025249 |
| S.E. equation | 0.081423 | 0.013629 | 0.026859 |
| F-statistic | 820.7196 | 2286.922 | 1910.43 |
| Log-likelihood | 49.57362 | 124.6463 | 96.15405 |
| Akaike AIC | -2.027315 | -5.602204 | -4.245431 |
| Schwarz SC | -1.737704 | -5.312592 | -3.955819 |
| Mean dependent | 26.66706 | 5.939224 | -0.264354 |
| S.D. dependent | 0.895497 | 0.249649 | 0.449778 |
| Determinant resid covariance (dof adj.) | | 5.37E-10 | |
| Determinant resid covariance | | 3.11E-10 | |
| Log-likelihood | | 280.9473 | |
| Akaike information criterion | | -12.37844 | |
| Schwarz criterion | | -11.50961 | |
| Note: (1)***, **, and * denotes significant at 1%, 5% and 10% level respectively; | | | |

*Source: Author's own calculation and compliance*

### *VAR Granger Causality/Block Exogeneity Wald Tests*

| VAR Granger Causality/Block Exogeneity Wald Tests | | | |
|---|---|---|---|
| Dependent variable: LNGDP | | | |
| Excluded | Chi-sq | df | Prob. |
| | | | |
| LNENG | 3.272715 | 2 | 0.1947 |
| LNCO2 | 1.946747 | 2 | 0.3778 |
| All | 4.258488 | 4 | 0.3722 |
| Dependent variable: LNENG | | | |
| Excluded | Chi-sq | df | Prob. |
| LNGDP | 6.476203 | 2 | 0.0392 |
| LNCO2 | 1.336376 | 2 | 0.5126 |
| All | 8.874111 | 4 | 0.0643 |
| Dependent variable: LNCO2 | | | |
| Excluded | Chi-sq | df | Prob. |
| LNGDP | 9.729139 | 2 | 0.0077 |
| LNENG | 1.216129 | 2 | 0.5444 |
| All | 10.79577 | 4 | 0.0290 |

*Source: Author's own calculation and compliance*

In the short-run causality form Table 5 shows that the past values of $CO_2$ emissions, energy consumption and GDP have a positive and significant impact on its own current value and simultaneously Granger-cause economic growth. from the results, it is also found that the GDP is found to be statistically significant at 5 percent level in both carbon emissions and energy consumption equation indicating the presence of unidirectional causality from GDP to carbon emissions and energy consumption in the short run (i.e. there is unidirectional causality from energy consumption to carbon emissions) which indicates that India is highly dependent on fossil fuels such as coal, oil and natural gases to meet its energy needs in end-use sectors such as industry, transport, commercial, households, and agriculture etc. so it implies that energy conservation and carbon emissions policies should be implemented without compromising socio-economic developments in short run.

Further to test the validity of the vector autoregressive (VAR) results we performed diagnostic checks analysis to the models used for VAR to test the stochastic properties of the model such as normality, heteroskedasticity, and autocorrelation. For testing the presence of autocorrelation /serial correlation this study has used Lagrange Multiplier (LM) test, to test the presence of heteroskedasticity, White heteroskedasticity test with cross products. For testing the normality of residuals Urzua's (1997) method of residual factorization (orthogonalization) has been preferred for testing the normality of residuals in order to check the specification of the VEC model which provides Jarque-Bera test statistic. Further, we move towards the sequential analysis technique of

CUSUM and CUSUM square test (this technique typically used for monitoring change detection), ARCH-LM test and multivariate ARCH-LM test also has been performed. Results of the diagnostic checks analysis are reported in the following Table 6 and Figure 1 and 2.

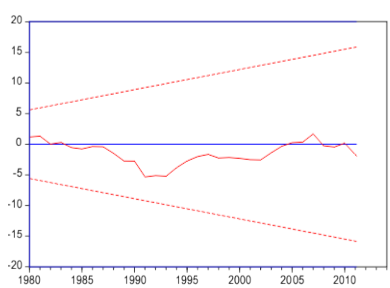
***Table 6: Diagnostic Checks Analysis***

| VAR Residual Serial Correlation LM Tests statics with lag 3 | | | | | |
|---|---|---|---|---|---|
| Lags | | LM-Stat | | LM-Stat | |
| 1 | | 7.572362 | | 7.572362 | |
| 2 | | 12.2036 | | 12.2036 | |
| 3 | | 7.704139 | | 7.704139 | |
| VAR Residual Normality Tests -Joint J-B test value (Orthogonalization: Residual Covariance (Urzua) | | | | | |
| Component | Jarque-Bera | | df | Prob. | |
| 1 | 6.608473 | | 2 | 0.0367 | |
| 2 | 4.238395 | | 2 | 0.1201 | |
| 3 | 3.364914 | | 2 | 0.1859 | |
| Joint | 36.62794 | | 25 | 0.0626 | |
| VAR Residual Heteroskedasticity Tests static value: Includes Cross Terms (Joint test of Chi-square) | | | | | |
| Chi-sq | | df | | prob. | |
| 167.7848 | | 162 | | 0.3615 | |
| Individual components: | | | | | |
| Dependent | R-squared | F(27,14) | Prob. | Chi-sq(27) | Prob. |
| res1*res1 | 0.410516 | 0.361096 | 0.9888 | 17.24169 | 0.925 |
| res2*res2 | 0.881778 | 3.86746 | 0.0053 | 37.03468 | 0.0944 |
| res3*res3 | 0.763756 | 1.676325 | 0.1558 | 32.07775 | 0.2292 |
| res2*res1 | 0.834677 | 2.617877 | 0.0311 | 35.05643 | 0.1374 |
| res3*res1 | 0.833786 | 2.601073 | 0.032 | 35.01903 | 0.1384 |
| res3*res2 | 0.844579 | 2.817697 | 0.0228 | 35.47231 | 0.1273 |

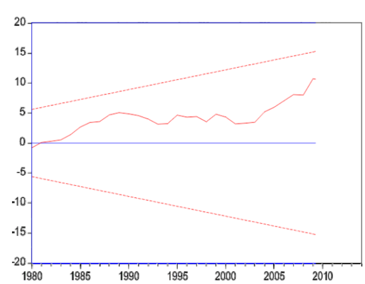
*Source: Author's own calculation and compliance*

From Table 5 clearly specified that our VAR model is correct as no test is rejecting the null hypothesis. But the maximum times in time series analysis the estimated parameter are varied. That's why we move towards the parameters stability test. To assess the parameter constancy in parameters stability, test each equation of VAR will be applied the cumulative sum of recursive residuals (CUSUM) and Cumulative Sum Squared (CUSUMSQ) tests proposed by Brown *et al*. (1975). The related graphs of CUSUM and CUSUMSQ tests are presented in (Figure 1 and 2) for the dependent variables LN $CO_2$, LNENG, and LNGDP, respectively.

**CUSUM test statistics for LNGDP equation**




**CUSUM test statistics for LNENG equations**



**CUSUM test statistics for LN $CO_2$ equations**

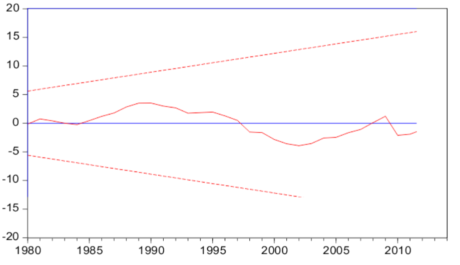
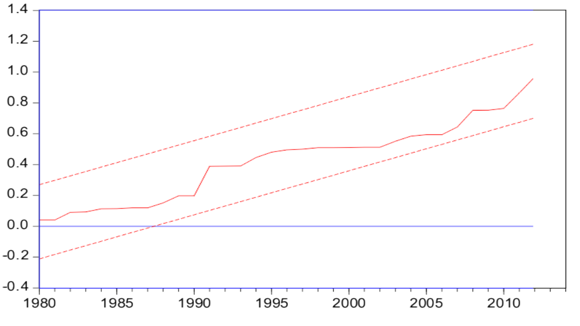


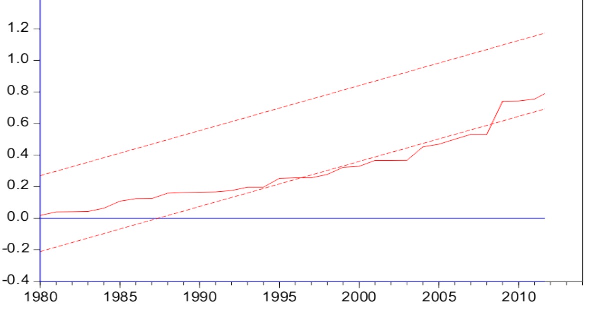

*Figure 1: CUSUM test*

From Figure 1 of CUSUM test statistics presents that the plots of the coefficients are all well within the critical bounds, implying that all the parameters coefficient estimations in the VAR models are stable. But the Results for CUSUM and CUSUMSQ (Figure 2) test are conflicting since CUSUM test indicates that parameters of VAR are stable but CUSUMSQ test did not support the argument as for equation 2 and 3rd of VAR-CUSUMSQ plots crosses the 1% boundary limit.

**CUSUM square test LNGDP equation**




**CUSUM square test LNENG equations**



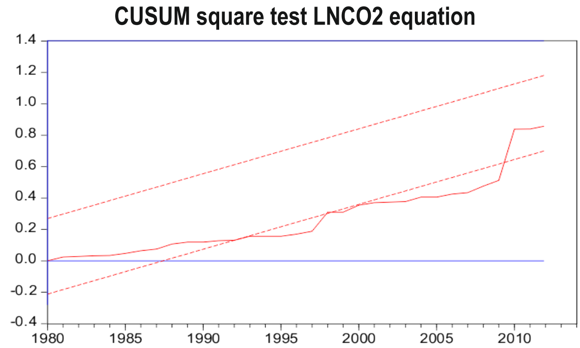



*Figure 2: CUSUM square test*

All the model of VAR is performing well and allows to analyze the properties of the VAR system by using Impulse Response Functions (IRFs). The Impulse Response Functions analysis traces out the responsiveness of the dependent variable in VAR to shocks to each of the other explanatory variables over a period of time. (10 years taken in the present study).

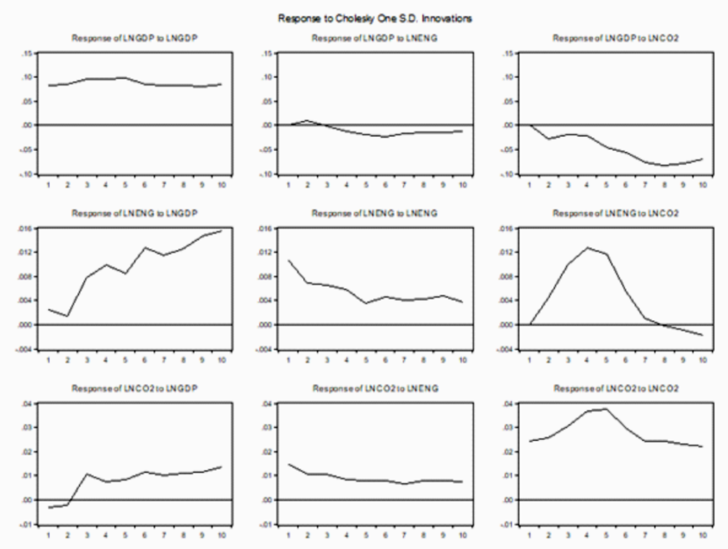



*Figure 3. Impulse response functions. IRFs analysis*

The results of the Impulse Response Functions will have presented in the (Figure 3) that GDP it has a negative impact in first 7 years and then its impact is positive on $CO_2$ emissions and fully negative impact on energy consumption. $CO_2$ emissions have a positive impact on its own value, energy use, and GDP. energy consumption has a positive impact on its own value and GDP and negative impact on $CO_2$ emissions.

## CONCLUSIONS

Over the past years, the Indian economy has demonstrated a spectacular economic development, with an annual growth rate of 7.11% (2016). However, behind this economic growth, it depends upon some other factors. Indian economy also faces the challenge of balancing continuously increasing energy use and rapid economic growth with environmental responsibility. The present study has extended the research work on the long-run and dynamic causal relationship between energy consumption, carbon emissions and economic growth using yearly data for India over the period of 1971–2014 within multivariate framework by using ADF unit root test, Johansen cointegration approach, and Granger causality test approach based on VAR environment followed by the CUSUM, CUSUMSQ test and Impulse Response Functions analysis. The empirical results for unit root tests reveal that all the variables are integrated of order one (i.e. with lag-1 first difference). The results also reveal that the there is a long-term relationship among all the variables indicating that the $CO_2$ emissions and energy consumption are positively correlated with the economic growth in long run perspective. and the findings of Granger causality test reveals that there is a unidirectional causality among the variables which indicates that Energy consumption increases $CO_2$ emissions which will have a negative impact on the economic growth(GDP). However, the results advocates that the economic policy maker should take corrective measure to implement energy efficiency and conservation policies to decreasing the use of fossils fuels and replace fossils fuel by renewable sources of energy (like solar energy, wind power. biomass, hydro and nuclear, etc.) for consumption and production purposes without reducing the energy consumption because the reduction in the energy consumption will have negative impact on the economic growth.

The present study can further have extended by analyzing the role of the energy consumption and carbon emission individually in order to get more understanding so that proper corrective measure should be taken in face of deregulation of Indian economy. The study can further have extended to carry out non-linear Granger causality analysis to check the robustness of the causality test results.

Globally, India is the fourth largest consumer of oil and imports around 80% of the oil it consumes, and also the third biggest primary energy consumption country after China and USA with 5.5% global share in 2016. It is an energy-dependent economy and needs to implement energy efficiency and conservation policies to decreasing the use of fossils fuels and replace fossils fuel by renewable sources of energy. The study will give an insight of the present scenario of the energy consumption and $CO_2$ emission India and which will lead to the development of the current economic policy and boosting the energy efficiency, developing alternative sources for carbon-free energy for faster and sustainable inclusive growth of India in upcoming futures.

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# Effect of Surfactant Towards Environment: A Review

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## INTRODUCTION

Surface active agent commonly known as surfactant have function on the interaction with surface (Yangxin, Zhao & Bayly, 2008; Alwadani, & Fatehi, 2018; Ying, 2006). Surfactant are widely used in the chemical industry with different classification. There are many industry applications of surfactant used in daily life such as pharmaceutical, additives in paints, coatings, and concrete mixtures (Miller & Neogi, 2007; Song *et al.*, 2016, Bera *et al.*, 2013;Schramm, Stasiuk & Marangoni, 2003; Gaubert *et al.*, 2016) . Surfactant contribute about half annual account in household cleaning and personal care (Bera *et al.*, 2013; Gaubert *et al.*, 2016). The different structures of surfactant have their own specific function (Alwadani & Fatehi, 2018). The extensively used of surfactant enhance the improvement of worldwide industry.

### Surfactant Classification and Characterisation

Surfactant have amphiphilic properties. Amphiphilic describe that surfactant have hydrophilic head and hydrophobic tail. This properties interface with layer so they can attract to their own segment pair. The hydrophobic segments interact with non- polar compounds which acts as hydrophobic phase, while the aqueous phase attracts to hydrophilic segment (Alwadani & Fatehi, 2018; Ashwina *et al.*, 2018; Antony, Balachandran & Mohanan, 2014; Shah, Bhattarai & Chatterjee, 2011; Pradhan & Bhattacharya, 2017; Kim *et al.*, 2009; Schramm, 2000).

Basically, surfactant can be classified into four common group which is anionic, cationic, non-ionic and amphoteric. (Yangxin, Zhao & Bayly, 2008; Kemmei *et al.*,2007). Anionic surfactant is most applicable for washing due to ability to remove the dirt. When it mixes with the water solvent the fabric surface and dirt particle are in negatively charge. Non – ionic surfactants interact with water molecule and absent of any radicals with the electric charge. This surfactant commonly used as hair conditioner and fabric softener. For amphoteric surfactant or also familiar as zwitterionic surfactant. It has both positive and negative charges which commonly used in cosmetic cream and shampoo (Kogawa *et al.*, 2017).

Anionic surfactants are commonly used among other group due to the low cost of manufacture (Yangxin, Zhao & Bayly, 2008). Carboxylates, sulfonates, sulphates, and phosphates are the most important forms of anionic surfactants. Anionic surfactant contributes wide application in food and chemical. For example, Na stearate are used in food additive while, Lignosulfonate helps in clay dispersant (Alwadani & Fatehi, 2018).

Other than that, cationic surfactants have the advantages in modify and affinity adhere surface properties in solid surface. Fuel and lubricant oil additive are the one of the cationic surfactant applications. For example, laurylamine hydrochloride contribute as corrosion inhibitor (Alwadani & Fatehi, 2018; Chistyakoy, 2001).

Non-ionic surfactant usually uses in combination with another surfactant. Non-ionic surfactant extensively used in personal care application also in textile processing (Yangxin, Zhao & Bayly, 2008). Non-ionic surfactant can effectively remove nonpolar oils in synthetic fabric compared to the anionic surfactant for detergent application. Coconut diethanolamide is one of the non-ionic surfactants that used in cosmetic processing (Alwadani & Fatehi, 2018).

Amphoteric surfactant plays a vital role in help to improve the primary surfactant uses. This because of the positive and negative charge on the hydrophilic head which able to alter the interaction with the surface (Yangxin, Zhao & Bayly, 2008). In oil field application, lauryl betaine is one of the amphoteric surfactants uses (Alwadani & Fatehi,2018).

There is another type of surfactant which rarely known, it is silicone surfactants. This surfactant can be found in cosmetic formulations. Basic structure of silicon surfactant can be divided into two types which is linear and cyclic polydimethyl silicones. Linear polydimethyl siloxanes give a specific effect of smooth like a silk feel on skin and hair when applied to skin or haircare formulations. In addition, cyclic silicones can improve smoothness and softness of the skin as well as hands, combing characteristics and glossiness of treated hair. However, the effect is only for short time due to their volatility. In contrast, the linear polydimethyl siloxanes type are insoluble in water and non-volatility but poorly compatible with cosmetic oils(Yangxin, Zhao & Bayly, 2008).

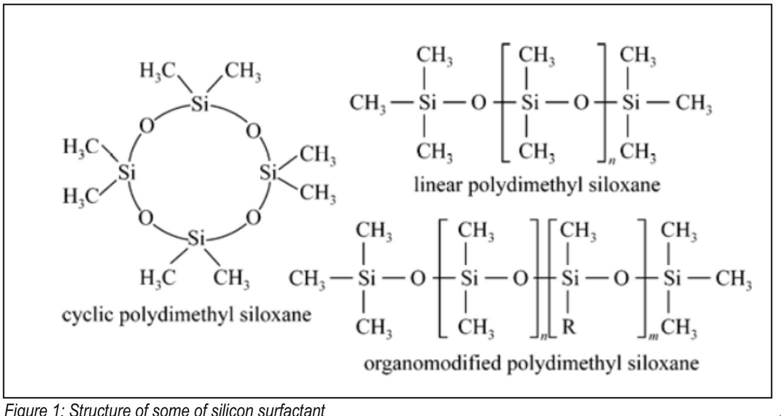


*Figure 1: Structure of some of silicon surfactant*

### Surfactant on detergent formulation

Detergents are one of the surfactant applications. Basically, detergents are known as any cleaning agent compound which can control dirt and germ (Sodeopec, 2004). Detergent undergoes saponification process to be form. This process formed when the triglyceride and lye solution interact chemically (Félix *et al.*, 2017) The surfactant amphiphilic properties make it suitable to be used as additive in detergent. Laundry detergents are complex mixtures which contain a large of compounds such as surfactants, enzymes, sequestering agents, polymers and fragrances (Gaubert *et al.*, 2016).

Commonly surfactant can act as emulsifiers for stabilizing liquid–liquid mixtures and as dispersants for solid–liquid mixtures (Gaubert *et al.*, 2016). For detergent formulation, surfactant usually it plays role as solubilizing, wetting, foaming, dispersing and emulsifier (Yangxin, Zhao & Bayly, 2008; Alwadani & Fatehi, 2018). The combination of several surfactants with different group are used to strengthen the performance and safety in laundry industry (Yangxin, Zhao & Bayly, 2008).

Anionic surfactant is essential surfactant that used in detergent and cosmetic product (Yangxin, Zhao & Bayly, 2008). Soap are the first anionic surfactant which derived from fatty acid or vegetable oil and interact with alkali (Félix *et al.*, 2017). Soaps is the sodium salts of long-chain alkanoic. Soap perform supportable characteristic in detergent formulation. The interaction of fatty acid with the alkali resulting emulsifier. In addition, soaps act as anti-foaming and wetting agents able to improve laundry detergent action and reduce foam formation in washing machines (Yangxin, Zhao & Bayly, 2008; Ho, 2000).

Due to the low performance of soap to the low temperature synthetic linear alkyl benzene sulfonate (LAS) produce. Alpha olefin sulfonate (AOS) introduced with better performance in reducing precipitation under high water-wash hardness. Over the years, many surfactants produce to improve their performance in detergent formulation such as highly soluble alcohol sulphates (HSAS) which allow better surface activity and solubility and modified linear alkyl benzene sulfonates (MLAS) to become favourable biodegradability and high solubility (Yangxin, Zhao & Bayly, 2008).

Non-ionic surfactant also used in detergent formulation with anionic surfactant combination (Yangxin, Zhao & Bayly, 2008). Mostly the non-ionic surfactant in the form of linear alcohol ethoxylates. The alcohol usually derived from petrochemical material. The main structure of non-ionic surfactant include alcohol ethoxylate (AE), alkylphenol ethoxylate (APE), methyl ester ethoxylate (MEE), ethoxylated amine, ethoxylated amide,alkyl polyglycoside (APG), polyethylene oxide-polyalkylene oxide diblock copolymer.Non-ionic surfactant are suitable to use for animal fibre such as silk and wool due to not sensitive to the hard water(Yangxin, Zhao & Bayly, 2008).

Cationic surfactant is another surfactant that also used in detergent formulation. This surfactants have negative charged at their hydrophilic head, so the nitrogen atom needed to assist in carrying positive charge (Yangxin, Zhao & Bayly, 2008). These cationic surfactant like quaternary ammonium and ethoxylated quats are more suitable for fabric softener and hair conditioner (Yangxin, Zhao & Bayly, 2008; Kemmei et al., 2007). Other than that, dioctadecyl dimethylammonium chloride are used as antistatic agent.In addition, for the textile softening agent an changes produce from dialkyl quats to ester quats to ensure the reduction of aquatic toxicity. Moreover, the polyanionic ammonium uses help to enhance the fabric whiteness (Alwadani & Fatehi, 2018).

Zwitterionic surfactant can acts differently depend on the pH of the solution due to the presence of two different charge at the surface (Yangxin, Zhao & Bayly, 2008) Betaines and sulfobetaines are the example of zwitterionic surfactant that widely used in household cleaning. Betaines can act as many functioning agents. For example, for laundry application it can act as dispersing agent in fabric softener and dye transfer inhibitors for acidic and direct dyes. In addition, it also acts as foaming booster when the betaines combine with anionic mixtures (Eder, 2006).

In addition, the silicone surfactant also used in detergent composition which help in hydrophobic waxy fatty soil removal like lipstick soil from the surface ware. This reaction due to the combination of polyethylene oxide condensates of alkyl phenols with a polydimethyl siloxane. Thus, it reduces surface tension between the soil and the ceramic. This is one of the reasons it names as silicone surfactant (Yangxin, Zhao & Bayly, 2008).

### Surfactant Side Effect Towards Environment

Surfactants have developed many changes and improvement to our worldwide industry. Surfactant help us in good performance of some application. It acts as additive, foaming, emulsifying, stabilizer, dyeing and wetting agent in laundry industry (Alwadani & Fatehi, 2018; Shah, Bhattarai & Chatterjee, 2011).

However, the surfactant also contributes some of environmental problem (Paxeus, 1996). Anionic surfactant which mainly used in household cleaning application have recorded significantly in wastewater pollution (Shah, Bhattarai & Chatterjee, 2011). For example, benzalkonium chloride (BAC) and linear alkyl benzenesulfonate (ABS) is anionic surfactants has reported the risk toxicity to ecosystem problem in the previous study (Yangxin, Zhao & Bayly, 2008; Giagnorio *et al.*, 2017). There also contains significant amount of phosphates in anionic surfactant which leads to eutrophication of water resources. Eutrophication is the uncontrollable of algae production, it has several negative consequences for the environment and society (Yangxin, Zhao & Bayly, 2008; Giffin, 2017). Thus it will be worse due to most commercial surfactants employed in the petroleum industry are also non-biodegradable that may cause long-term detrimental effects on the reservoir (Warwick *et al.*, 2013; Ashforth & Calvin, 1973). Moreover, a record state that about 60% of the total surfactant production enters the aquatic environment (Venu *et al.*, 2012). In addition, the toxicity from the synthetic surfactant can give high risk of carcinogenic on their consumer (Farn, 2007).

## Conclusion

This review presents some knowledge about surfactant, the classification and the effect to the detergent formulation towards environment. The surfactant is extensively used in household cleaning and personal care. There are many functioning agents of surfactant that play a vital role in improvement of detergent formulation. However, if the surfactant not used in proper ways it may give side effect to us included aquatic toxicity problem, costly and risk in human health.

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# How Does Climate Change Affect Agriculture, Sustainability and Food Security in India?

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*Mere desh ki dharti sona ugle ugle heerey moti*
*(My country's soil where crops grow like gold, diamonds, and pearls)*
*---Manoj Kumar, The Hindi Film Upkaar*
*Kaa barakhaa, jab krishi sukhaanee*
*(What's the use of that untimely rain after the crop has dried up)*
*--Tulsidas, Ram Charit Maanas.*

## INTRODUCTION

Since the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1984 by the World Meteorological Organization (WMO) and the United Nations Environment Programme(UNEP), we can no longer afford to ignore the likely consequences of climate change, in the form of global warming, on economic and social development. The IPCC predicts that the global temperature will rise by 1.4-5.8°C and the global average sea level by 0.11-0.77 metres by 2100.

A published report from the Global Humanitarian Forum (2009) argues that climate change is having a disproportionate effect on the world's poorest and most vulnerable populations, those who live in harsh environments such as coastal flood areas, desert borderlands, tropical cyclone zones and urban shanty towns and least able to adapt to it. The most critical areas of the global impact of climate change are identified as food, health, poverty, water, human displacement and security. The failure to deal adequately with these problems will lead to both the failure to achieve the MDGs and the wider failure to achieve anything approaching a process of sustainable development.

The findings of the Forum report are stark. It is estimated that every year climate change leaves over 300,000 people dead; 325 million people seriously affected and incurs economic losses of US$125 billion. Four billion people are vulnerable and 500 million people are at extreme risk. Developing countries bear 90 per cent of the climate change.

Thus, climate change is the biggest environmental challenge facing the planet, with a very clear evidence that recent and projected human activity(anthropogenic) threats to significantly raise global temperatures with serious impacts on agriculture, food security, water supply, sea levels, disease and living conditions ( Stern Review, 2006). The economic consequences of climate change were highlighted by the Stern Review, which pointed out that global warming could disrupt economic and social activity that a failure to address it could mean global GDP being up to 20 per cent lower than it otherwise might be. If unaddressed, though the task of tackling climate change is notoriously difficult, it will have catastrophic implications for human welfare, and for the future of mankind.The human activity which has been responsible for almost all of the recent rise in global temperatures has taken place in higher-income developed countries, but the environmental and economic impact of the temperature rise has affected lower- income developing countries at least as much as the higher-income countries. In economic terminology, this impact on the lower –income countries is a classic example of an external diseconomy and of market failure. The lower- income countries experience economic costs ( or reduced benefits) which is not caused by themselves but the international markets do not provide any form of compensation from the countries which has caused the costs.

The ghost of Malthus still looms large. The still rapidly growing populations of the developing countries now face multiple threats from depletion and pollution of water resources, rising temperatures that reduce yields in already hot areas, and progressive soil erosion and desertification under modern industrial agriculture and over-grazing. The intensive utilization of water in the cultivation of wheat and rice in India, for example, has already led to environmental degradation and rise in water land, threatening the sustainability of agricultural development in many states of India.

In addition to these threats, climate models generally predict an increasing probability of declining rainfall and major droughts in many arid regions in the future, as well as more frequent flooding in other areas. Today more than one billion people in the world are chronically hungry and malnourished in late 2018, more than at any time in history. Everyday 25,000 adults and children die from hunger or hunger related disasters. Climate change is already considered to be the root cause of hunger and malnutrition for about 45 million of these undernourished people. Living a long and healthy life for instance, will undoubtedly depend on food production and food security, both within and between generations, which is expected to be at severe risk from climate change-induced soil erosion and water scarcity. One of the goals for development set by the UN in its 2002 Millennium Declaration, when over 920 million people worldwide were thought to be undernourished, was to reduce by half the proportion of people who suffer from hunger by 2015.This ambitious target is not likely to be achieved. This is because, with no climate change, the number of people at risk from hunger decreases under the unmitigated scenario; it is estimated that the additional number of people at risk from hunger due to climate change would be around 20 million by the 2050s. The current trade regime, guided by rules and regulations governed by the WTO, is often characterized by developing countries as being run by the developed nations to serve their appetite for cheap consumer goods while protecting their own industries, environmental quality and resources. At the same time, the WTO does not have any special provision for the environment with onus put on its member states. It is common knowledge that at the Doha Round, even discussions about reducing tariffs for environmental goods and services did not amount to any action. Enabling policies that allow for easier transfer of clean climate-mitigating technology, while important, do not address the real resource constraints issue. This approach has been the usual response from international agencies ranging from the WTO to the UN and World Bank even as the latter two acknowledge that trade increases the speed and scale of resource consumption and therefore consequences such as climate change (Karmakar and Jana, 2015).

The Fifth Assessment Report by Working Group I of the IPCC provides the latest assessments from the field of climate science regarding our knowledge of the earth's climate system (IPCC 2013). This report concluded that it is 95 per cent certain that humans are the 'dominant cause' of global warming. Besides, in this Assessment Report, the IPCC noted a range of changes to climate conditions. The IPCC estimates that by 2080, if current trends continue, anything from 1.2 to 3.2 billion people will be experiencing water scarcity, 200-600 million people will be malnourished or hungry and between 2 and 7 million people each year will be subject to coastal flooding. An estimated 200-850 million people could be forced to move to more temperate zones by 2050 due to water shortage, food insecurity, famine, deteriorating pasture lands-all linked to climate change.

The World Bank report on 'International Trade and Climate Change (2008)' states that 'the trade-environmental debate has so far considered little in terms of global-scale environmental problems — declining biodiversity, depletion of fisheries, overexploitation of shared resources. These public goods which require international cooperation can lead to trade tensions.'

For an organization such as the WTO, which is meant to help frame the international laws to govern trade, the significant omission and inability to direct action to the most pressing challenges of our time very clearly highlights the stupidity and cleverness on its part and which is now in need of urgent and major surgery (Karmakar, 2012a).

In the above backdrop, the paper investigates the impact of climate change on agriculture, sustainability and food security in India. Section II highlights the meaning of climate change and its potential impact. Section III endeavours to have a look on how the climate change will affect the four dimensions of food security. That a threat of climate change is a serious global concern is examined under the heading "climate change, agriculture and food security" in Section IV. Section V focuses strategic attention on the part of the Government of India to tame the adverse impact of climate change. How to combat climate change is suggested in Section VI. Section VII is the concluding observations.

## CLIMATE CHANGE AND ITS POTENTIAL IMPACT

Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Increasing levels of fossil fuel burning and land-use changes have, and are continuing to emit, greenhouse gases (mainly $CO_2$, methane and nitrous oxide) into the earth's atmosphere. This increasing level of emissions of greenhouse gases has caused a rise in the amount of heat from the sun trapped in the earth's atmosphere, heat that would normally be radiated back into space. This has led to the greenhouse effect resulting in climate change. Climate change as a result of greenhouse gas emissions has emerged as a highly debated and controversial subject in recent times. The industrialized countries have the largest total $CO_2$ emissions and India's share of global $CO_2$ emission is only 4% — one of the lowest per capita rate of Greenhouse Gas Emissions, about one-twentieth that of the US. IPCC's Fourth Assessment Report states that the climate system is warming .The Report cites as evidence:

- Annual global emission of greenhouse gases are growing at an accelerating rate;
- The extent of glacier and snow cover is decreasing;
- global average sea level is rising at an accelerating rate. For Sea-level rise in this century will be in between 0.8 and 0.59 metres:
- Beyond 2100 changes in climate and sea level will continue even if greenhouse gas concentrates can be stabilized.

Table I shows in detail how the world will change if it continues to warm. Besides, we will be able to learn from the Table itself that why is it so that the historic climate change agreement under the United Nations Framework Convention on Climate Change (UNFCCC) in Paris in December 2015 aims at keeping the rise in global temperatures well below 2°C, which will set the world towards a low carbon, resilient and sustainable future.

**Table I : The Effect of Climate Change**

| **+2$^0$C impacts** | |
|---|---|
| Human Health | Between 90 million and 200 million more people will be at risk of malaria and other vector and water-borne diseases. More people in low-income countries will suffer from diarrhoeal disease and malnutrition. |
| Agriculture | A decline in agricultural production will lead to increased hunger in sub -Saharan Africa and South Asia. Canada, Russia and Scandinavia may benefit from a boost to crop yields but rapid rates of warming here could damage roads and buildings. |
| Water | Between 662 million and 3 billion more people will be at risk from water shortages. Dwindling global water supplies and parched soils will result in land being used more intensely, resulting in dissertation. |
| Ice and Glaciers | A 60 per cent loss of summer sea ice in the Arctic is likely. Antarctica's sea ice could decrease by 25 per cent. A 1.5 $^0$C increase in temperature could trigger melting of Greenland's ice sheet. |
| Ecosystems | We stand to lose onequarter of current species. Ninetyfive per-cent of most corals could perish by the middle of the centry, with adverse impacts to subsidence and commercial fishing, tourism and the coastal protection provided by reefs. The associated economic cost could be A$4.3 billion (US#3.8 billion) per year for Australia's Great Barrier Reef alone. There will be a 43 per cent risk of change in global forest to non-forest ecosystems, along with the expansion of forests into the Arctic and semi-arid savannas. Areas that have historically been stores of carbon, such as the Amazon rainforest and Arctic areas dominated by permafrost, could turn into sources instead. A major proportion of the tundra and about half of boreal forests may disappear. |

| | |
|---|---|
| Sea-Level Rise | Between 25 million and 50 million people will be at risk from sea -level rise and coastal flooding, costing nations hundreds of billions of dollars. |
| Extreme Weather | Increases in the frequency and intensity of floods, droughts, storms, heat waves, tropical cyclones, hurricanes and other extreme events will drive up economic costs and decrease opportunities for development. |
| **+3$^{0}$C impacts** | |
| Human Health | More than 300 million more people will be at risk of malaria globally, and 5-6 billion more people could contract dengue fever. Human health will be threatened by water stress and flooding, especially in Africa and South Asia. |
| Agriculture | 50-120 million more people will face hunger. A decline in agriculture will cause food prices to increase globally. |
| Water | As many as 3.5 billion more people could be at risk of water shortages. Migrations caused by drought could lead to socio-economic and political instability. There will be a high risk of drought for southern Europe, West Africa, Central America, the Middle East, and parts of North America, Amazonia and China. |
| Ice and Glaciers | Scientists expect the summer sea i ce to almost completely disappear from the Arctic. A 3$^{0}$C warming over several centuries will destroy the Greenland ice sheet and the Antarctic ice shelves. |
| Ecosystems | We could lose around 33 per cent of current species. There will be little hope of recovery from annual bleaching of the remaining coral owing to the increased acidity of the oceans from abnormally high levels of absorbed $CO_2$. There is an 88 per cent risk that the global forests will change to non -forest systems, along with risks of forest losses in parts of Eurasia, Amazonia and Canada. Forests may also disappear from parts of the southern boreal zone, eastern China, Central America and the Gulf Coast of the USA. We face a much higher risk of terrestrial carbon sinks switching permanently to become carbon sources and irreversible damage to the Amazon forest leading to its collapse. Scientists anticipate the loss of half of wetlands in the Mediterranean and Baltic, along with several migratory bird habitats in the USA. Many ice -dependent species will likely become extinct, including Polar Bears. |
| Sea-Level Rise | 180 million people will be at risk of coastal flooding due to sea level rise and water stress. Hundreds of thousands of people may have to migrate to other regions or countries. Besides, salinisation and cyclone damage are anticipated, affecting agriculture, fisheries and urban development<br><br>s, including port infrastructure. The survival of some countries, most notably low-lying island states in the Indian and Pacific Oceans, such as the Maldives and Kiribati, is under threat even from moderate sea level rise, |
| Extreme Weather | Scientists expect massive increases in the frequency and intensity of fire, drought, storms and heat waves. Socio-economic losses from global damage could range from 3 to 5 per cent of GDP for developing countries, with a global average of 1-2 per cent for warming of between 2.5$^{0}$C and 3$^{0}$C. |

| **+4⁰C impacts** | |
|---|---|
| Human Health | Mosquitoes will thrive, exposing 80 million more people to malaria in Africa; 2.5 billion more people are likely to become exposed to dengue fever. If malaria spreads to populations which have not previously been exposed, their lack of immunity could increase the incidence of epidemics. Climate change is likely to have other effects on human health, as well as impacts on animal diseases, with knock-on implications for agriculture. |
| Agriculture | Droughts will cause African crop yields to slump by 15 to 35 per cent. Global food production could fall by 10 per cent. Both the land area available for farming and the length of the growing season are expected to decreas e in many parts of the continent. Coupled with changes in rainfall, this would decrease food production and increase malnutrition. |
| Water | The availability of fresh water will be halved in southern Africa and the Mediterranean. Climate change is likely to affect rainfall patterns, increasing desertification and the risk of droughts and floods, but specific changes are difficult to predict due to multiple uncertainties. In some parts of the continent there is already evidence that rainfall patterns have become more variable over recent decades. Water availability is an historic and existing problem and in the future, changes in rainfall patterns may increase these pressures for some areas whilst decreasing them for others. |
| Ice and Glaciers | Half the Arctic tundra will be at risk. Europe stands to lose 80 per cent of its Alpine glaciers. Melting of the West Antarctic and Greenland ice sheets will speed up. |
| Ecosystems | Half of land species may now be threatened with extinction.Substantial pressures on plant and animal habitats are anticipated. The implications for livelihoods are complex, but people living a subsistence lifestyle and directly dependent on natural resource exploitation are the most vulnerable. Predicted impacts include loss of product ivity from forests and freshwater fisheries and loss of tourism income. |
| Sea-Level Rise | According to the IPCC's FAR, sea levels could rise by as much as 59 cm. Bangladesh and Vietnam will be the worst hit, along with coastal cities such as London, New York, Tokyo, Hong Kong, Calcutta and Karachi. Small islands in the Caribbean and Pacific would become uninhabitable. There will be 1.8 million people at risk from coastal flooding in Britain alone. |
| Extreme Weather | Hurricane wind strengths could increase by 1 5 to 25 per cent, causing great damage to buildings, roads and telecommunications infrastructure. |

*Source: Author's compilation from Carolyn Fry (2008): The Impact of Climate Change: The World's Greatest Challenge in the 21st Century, New Holland Publishers (UK) Limited and Other sources*

IPCC ( 2007) predicted Climate change is expected to have profound effects on India. Key potential impacts include:

- higher temperatures increasing potential evaporation and duration of heat-waves as a result of which food production will decrease, thus affecting agriculture adversely
- serious health impacts due to heat-related stress and vector-borne diseases.

- enhanced variability in summer monsoon rainfall;
- significance decline in winter rainfall leading to severe water scarcity during early summer months;
- more intense droughts over large areas adversely affecting crop production, specially wheat and rice;
- more intense floods, especially in the flood-plains of the Eastern Himalayan rivers, their major tributaries and the delta regions;
- coastal flooding and salinity intrusion from sea-level rise in combination with the amplification of storm surges from more intense tropical cyclones in the Bay of Bengal, and
- rapid, melting of Himalayan glaciers, leading initially to greater river flows and hence sedimentation, and subsequent reduced flow, especially in the dry summer months to river basins and watersheds. Most of the rivers flowing in northern regions in India, for example, are dependent on snow and glacial melt, thus climate change threatens the perennial nature of these rivers.This has huge implications for agriculture and allied activities and resultant livelihoods leading to more severe food shortages through direct and indirect effects on crops, soils, livestock, fisheries and, pests, increased loss of life and infrastructure from coastal inundation and river-line flooding, loss of life from heat stress and vector-borne diseases and potential displacement of tens of millions of residence of low-lying coastal areas, causing problems of internal and cross-border migration.

The (IPCC), 2010, Report classifies South Asia as highly vulnerable to climate change in terms of food and fibre, bio-diversity, water resources, coastal eco-systems and settlements and highly vulnerable as regards health.

This is happening precisely at a time when India is confronted with huge development imperatives. A recent India-Pacific report warns of impacts from climate change such as sea-level rise, increase in cyclonic intensity, stress on livestock, reduction in milk-productivity, increased flooding and spread of malaria, reduced crop-yield in rainfed crops. Many of the farmers (in India) are thus vulnerable to the expected increased frequency of droughts, heat-waves and floods. Large scale agricultural collapse due to warming and water shortages will almost certainly be the most important climate change impact on the poor, if present trends continue much longer, leading to astronomical rise in food prices, massive starvation and migration.

## HOW WILL CLIMATE CHANGE AFFECT FOUR DIMENSIONS OF FOOD SECURITY?

**Food Availability:** Depending on the agricultural activity and the geographical location, the effects of climate change can be both positive and negative. In temperate latitudes, for instance, higher temperatures are expected to be predominantly beneficial to agriculture: the areas potentially suitable for cropping will expand, the length of the growing period will increase and crop yields may rise. A moderate incremental warning (1-2$^0$C) in some humid and temperate grassland areas may increase pasture productivity. On the other hand, the projected increase in the frequency of extreme events, such as heat waves and droughts, in the Mediterranean region or increased heavy precipitation events and flooding in temperate regions could substantially lower production and productivity. Likewise, semiarid and arid pastures are expected to experience a decline in productivity, which will lead to reduce livestock productivity and increase livestock mortality. In drier areas, climate models predict increased evapo-transpiration and lower soil moisture levels (IPCC 2007). As a result, some cultivated areas may become increasingly arid. Temperature increases will also extend the range of many agricultural pests. In addition, higher temperatures may increase the ability of pest populations to survive the winter season and then to attack new crops in spring.

At a regional level, the biggest losses in suitable cropland are likely to be in Africa, whereas the largest expansion of suitable cropland would be in the Russian Federation and in Central Asia.

**Food Stability:** Global and regional weather conditions are also expected to become more variable, with increases in the frequency and severity of extreme events such as cyclones, floods, hailstorms and droughts (IPCC, 2007). This may bring greater fluctuations in crop yields and increase the risks of landslides and erosion damage. As a consequence, the stability of food supplies would decline.

**Utilization:** Climate change will affect the ability of individuals to utilize food effectively by altering conditions for ensuring food safety and by changing the pressure from vector-, water-, and food-borne diseases. The IPCC (2007) report examines how the various forms of diseases, including vector-borne diseases such as malaria, are likely to spread or recede in response to climate change. We discuss below the impact on diseases that affect food safety directly, i.e, food- and water-borne diseases.

The main concern about climate change and food security is that changing climatic conditions can initiate a vicious circle in which an infectious disease causes (or compounds) hunger, which in turn makes the affected populations more susceptible to infectious diseases. The result can be a substantial decline in labour productivity, an increase in poverty and even an increase in mortality. Essentially every manifestation of climate change, be it drought, higher temperatures or heavy rainfalls, has an impact on disease pressure and there is growing evidence that these changes affect food safety and food security (IPCC, 2007).

The IPCC (2007) report also emphasizes that increases in temperatures will raise the incidence of food poisoning, particularly in temperate regions. Warmer seas may contribute to increased cases of poisoning in humans who eat shelfish and reef-fish (ciguatera) in tropical regions and expansion of the disease towards the poles. However, there is little new evidence that climate change significantly alters the prevalence of these diseases.

**Access to food:** Access to food is closely linked to the power of individuals to purchase food and the evolution of real incomes and food prices. Although the various Special Reports on Emissions Scenarios (SRES) differ with regard to population and policy assumptions, essentially all SRES development paths describe a world of robust economic growth and rapidly shrinking importance of agriculture in the long run and thus assume a continuation of a trend that has been under way for decades in many developing regions. It is a world where income growth will allow the largest part of the world's population to address possible shortfalls in local food production through imports and, at the same time, find ways to cope with safety and stability issues of food supplies. It is also a world where real incomes rise more rapidly than real food prices, which suggests that the share of income spent on food should decline. In this case, even high food prices are unlikely to create a major dent in the food expenditures. However, not all parts of the world perform equally well in the various development paths and not all development paths are equally benign for growth. Where income levels are low and shares of food expenditures are high, higher prices for food may still create or exacerbate a possible food security problem.

A number of studies have attempted to measure the likely impacts of climate change on food prices. The basic messages that emerge from these studies are:

a) On average, prices for food are expected to rise moderately in line with moderate increases in temperature (until 2050); some studies even foresee a small decline in real prices until 2050.

b) After 2050, and with further increases in temperatures, prices are expected to increase more substantially. In some studies and for some commodities (rice and sugar), prices are forecast to increase by as much as 80 per cent above their reference levels in the absence of climate change.

c) Price changes expected to result from the effects of global warming are, on average, much smaller than price changes resulting from different socio-economic development paths. For instance, there might be an increase in real cereal prices of about 170 per cent. The (additional) price increase as a result of climate change would only be 14.4 per cent.

**Quantifying the Impact of Climate Change on Food Security**

A number of studies have recently quantified the impacts of climate change on agriculture and food security. The messages can be summarized as follows:

First, it is very likely that climate change will increase the number of people at risk of hunger compared with no climate change. Second, it is likely that the magnitude of these climate impacts will be small in comparison with the impact of socioeconomic development. Third, although there is significant uncertainty as to the effects of elevated $CO_2$ on crop yields, there is much less uncertainty about food security. Finally, in addition to the socioeconomic pressures, the prospect of lasting high energy prices and a diversion of agricultural resources into energy production could significantly understate future food security problems. Studies addressing the possible consequences of such a situation on world food supply have only just started to become available. From a long-term perspective of commercial agriculture, high food prices could provide the agricultural sector with the long-hoped-for basis for improved economic profitability. Yet, from a short-term perspective of subsistence agriculture, a high-energy/high-food price scenario could further undermine food security. Moreover, higher food and energy prices could also pose additional food security problems for the landless rural poor as well as for urban dwellers. Subsistence producers face higher input prices without producing a marketable surplus that would earn them higher revenues. Urban dwellers have to cope with price surges on several fronts-not only for food but also for fuel, electricity, transport, and many other basic necessities (Diouf and Schmidhuber 2008). These changes suggest a further increase in food insecurity over the short and medium term. Importantly, none of the major world food models that have examined the links between climate change and food security have yet fully incorporated these new food-energy price links and the resulting competition for resources.

The study of Kumar *et al.* (2014) estimates the impact of climatic and non-climatic factors on food grain productivity to facilitate the development of appropriate farm policies to cope with climate change. Major finding of present study indicates a need to adapt separate policies for various crops to mitigate the adverse effect of climate change in India. The results also highlight the important of irrigation and optimum use of fertilizer to mitigate the adverse effect of climate change. The study also suggests that policy makers should ensure adequate and consistent pricing for the farmer's product during the harvesting season.

## CLIMATE CHANGE, AGRICULTURE AND FOOD SECURITY

The threat of climate change is a serious global concern. There is near consensus among scientists that climate change is unequivocal. Increase in anthropogenic activities, since the advent of industrialization in the mid-eighteenth century, has built up concentration of greenhouse Gases (such as Carbon Dioxide, Methane, Nitrous Oxides and so on) in the Earth's atmosphere. Greenhouse Gases (GHGs) trap infra-red radiations reflected by Earth, leading to global warming; which, in turn, could lead to changes in rainfall patterns, disruption in hydrological cycles, melting of ice caps and glaciers, rise in sea levels, and increase in frequency and intensity of extreme events such as heavy precipitation or cyclones. These developments can have a serious impact on sustainability of water resources, agriculture, food security, forests and ecosystems, affecting the well-being of billions of people on Earth. In case of attaining food security in India, this would mean non-achievement of both physical and economic access to food as changing rainfall pattern, the circumstances generated by global warming like more events of droughts and floods, all affect any country's food security, not to speak of India. Weather patterns have an impact on output of some crops. In particular, the droughts that occurred in Australia and Ukraine in 2006-2007 create local shortages of wheat, strong enough to put pressure on the global markets. Morocco experienced an outright failure in wheat in 2007.In 2005, all three countries together contributed about 20 per cent of the global volume of wheat traded, while in

2007 their contribution was about 8 per cent. The temperature differences disturb the crop period and also the productivity and production, and make a solid base of price rise of the food-grains. And, due to low percentage increase of production of food grains, the food prices rule becomes so high that poor have low access to food. Thus climate change slows down the pace of development either through its adverse impact on natural eco-systems, or through erosion of adaptive capacity of the people, particularly those who are socially and economically vulnerable. The need to support smallholder farmers, small –scale, ecological farming and means of bio-diversified-based agricultural production that are sustainable, particularly in the context of climate change, is the need of the hour.

**Why Agriculture Matters in India?**

First, and foremost, agriculture matters in India for deep reasons, not least because the farmer being innocent, unsullied, hard-working, in harmony with nature; and yet poor, vulnerable, and the victim, holds a special place in Indian hearts and minds, as the lines quoted from UPKAR and RAM CHARIT MANAS in the beginning reveal.

Agriculture also matters for economic reasons because it still accounts for a substantial part of GDP (16 percent) and employment (49 percent). Poor agricultural performance can lead to inflation, farmer distress and unrest, and larger political and social disaffection—all of which can hold back the economy.

Third, agriculture is the provider of livelihoods for nearly half of our working population. So good agricultural performance is necessry. Climate change affects agriculture badly. Studies done at the Indian Agricultural Research Institute indicate the possibility of loss of 4–5 million tones in wheat production for every 1°C rise in temperature throughout the growing period. Losses for other crops are also certain. Agriculture sector contributes 18 per cent of the total GHG emissions from India. The emissions are primarily due to methane from the rice paddies, enteric fermentation in animals, and nitrous oxides from the application of manures and fertilizers.

India, like most of the South Asian counterpart, is highly vulnerable to climate change. As per recorded observations, India has seen an increase of 0.4 degree Centigrade, in the mean surface air temperature over the past century (1901–2000). Change in mean temperature and precipitation will require change in cropping patterns. It has been estimated that a 2.0 to 3.5 degree Centigrade increase in temperature, and the associated increase in precipitation, can lower agricultural GDP by 9 to 28 per cent. Yields of most crops will fall in the long run. Every 1 per cent rise in temperature reduces wheat production by 4 to 5 million tons. The quality of fruits, vegetables, will tea, coffee, medicinal plants and basmati rice is also affected. It is estimated that India could lose 4 million tons of wheat due to climate changes by 2020, 12 million tons by 2050.An increase in temperature from 0.5 degree Centigrade to 1.5 degree Centigrade could produce a decline of between 2.5 per cent in wheat and maize production (*11th Five Plan, Vol-1)* The impact in the short run may be small, but the heat stress will affect the productivity of animals and milk production may even decrease over the present levels.

Agriculture technology can adapt to these changes to partially offset the adverse impact by adoption of water conservation practices, by changing cropping patterns and practices, and by developing new varieties that can withstand short term variability in weather patterns. So the climate challenge facing Indian agriculture needs to be taken seriously.

With 60 per cent of the total foodgrains and oilseeds produced being grown in the kharif season, and with just about 35 per cent of arable area being irrigated, Indian agriculture is still heavily dependent on rainfall. Significant warming of temperatures, lower mean rainfalls and higher rainfall variability have been recorded by the Indian Meteorological Department (IMD) till date. It is noteworthy that temperature conditions have deteriorated even more. Periods prior to 1997 can be considered normal, but warming has increased at an accelerating pace since then  The Eleventh Plan period contained the two warmest years (2010 and 2009) ever recorded since 1900. Even the coolest year (2008) during these five years was the thirteenth warmest in the last 110 years (*Twelfth Five Year Plan, Vol. II: 2-3*).

Of late, using district-level data on temperature, rainfall and crop production, one important survey articulates that climate change could reduce annual agricultural incomes in the range of 15 percent to 18 percent on average, and up to 20 percent to 25 percent for unirrigated areas.

Table 2 provides a detailed quantitative break-up of the effects of temperature and rainfall shocks between irrigated and unirrigated areas in the kharif and rabi seasons ( district specific) .

**Table 2. Impact of Weather Shocks on Agricultural Yields**

(percentage decline in response to temperature increase and rainfall decrease)

| | Extreme Temperature Shocks | Extreme Rainfall Shocks |
|---|---|---|
| Average Kharif | 4.0% | 12.8% |
| Kharif Irrigated | 2.7% | 6.2% |
| Kharif, Unirrigated | 7.0% | 14.7% |
| Average Rabi | 4.7% | 6.7% |
| Rabi, Irrigated | 3.0% | 4.1% |
| Rabi, Unirrigated | 7.6% | 8.6% |

*Source: 2017-18 Economic Survey's adopting Survey calculations from Indian Meteorological Department ( IMD) and University of Delaware data.*

Table 2 also shows that extreme temperature shocks, when a district is significantly hotter than usual (in the top 20 percentiles of the district-specific temperature distribution), results in a 4 percent decline in agricultural yields during the kharif season and a 4.7 percent decline in rabi yields. Similarly, extreme rainfall shocks - when it rains significantly less than usual (bottom 20 percentiles of the district-specific rainfall distribution), results in a 4 per cent decline in agricultural yield during a kharif season and a 4.7 per cent decline in Rabi yield. Similarly, extreme rainfall shocks - when it rains significantly less than usual (bottom 20 percentiles

of the district-specific rainfall distribution). The result is a 12.8 percent decline in kharif yields, and a smaller, but not insignificant decline of 6.7 percent in rabi yields.

**Policy Implications**

The policy implications are stark. India needs to spread irrigation – and do so against a backdrop of rising water scarcity and depleting groundwater resources.

There has been a13 percent decline in the water table over the past 30 years. So the challenge is that the spread of irrigation will have to occur against a backdrop of extreme groundwater depletion, especially in North India.

Fully irrigating Indian agriculture, that too against the backdrop of water scarcity and limited efficiency in existing irrigation schemes, will be a defining challenge for the future. Technologies of drip irrigation, sprinklers, and water management—captured in the "more crop for every drop" campaign—may well hold the key to future Indian agriculture (Shah Committee Report, 2016) and hence should be accorded greater priority in resource allocation. And, of course, the power subsidy needs to be replaced by direct benefit transfers so that power use can be fully costed and water conservation furthered.

Another conclusion is the need to embrace agricultural science and technology with renewed ardor. Swaminathan (2010) urged that anticipatory research be undertaken to pre-empt the adverse impact of a rise in mean temperature. Agricultural research will be vital in increasing yields but also in increasing reliance to all the pathologies that climate change threatens to bring in its wake: extreme heat and precipitation, pests, and crop disease.

Of course, climate change will increase farmer uncertainty, necessitating effective insurance. Building on the current crop insurance program (Pradhan Mantri Fasal Bima Yojana), weather-based models and technology (drones for example) need to be used to determine losses and compensate farmers within weeks (Kenya does it in a few days).

**THREAT OF CLIMATE CHANGE AND INDIA'S ENDEAVOUR**

Amidst the above unfavourable situations, very critical is, therefore, to build climate resilience. Potential adaptation strategies to deal with the adverse impacts of climate change are developing to mitigate heat, moisture, and salinity stresses; modifying crop management practices; improving water management; adopting new farm practices such as resource-conserving technologies; crop diversification; improving pest management; making available timely weather-based advisories; crop insurance; and harnessing the indigenous technical knowledge of farmers (Economic Survey 2011-12). India's Twelfth Five Year Plan's explicit theme is 'faster, more inclusive and sustainable growth'. It is the first time that a five year plan has sustainability as a prominent focus with a low carbon strategy for development that aims at inclusive growth. The Plan for agriculture, food security, environment, forests, wildlife and climate change has already focused strategic attention on the following:

- Securing ecology of watersheds and catchments;
- Cumulative environmental impact assessments for vulnerable regions;
- Carrying capacity studies in selected river basins;
- Maintaining acceptable water quality and quantity through pollution control of water resources;
- Restoration of wetlands/lakes; and
- Management of waste water discharge from industrial and commercial establishments into major water bodies.

It also emphasized in conservation and sustainable use of biodiversity to enhance livelihood security, promotion and evaluation of ecosystem services in the national planning process.

It is praiseworthy that to address climate change, India has announced a National Action Plan for Climate Change (NAPCC) in June 2008, which incorporates its vision of sustainable development and the steps it must take to realize it. For the purpose, several national missions like National Mission for Sustaining Himalayan Ecosystem, National Water Mission, Green India Mission, National Mission for Sustainable Agriculture (NMSA) etc. are introduced. Of them., the NMSA aims at ensuring food security, enhancing livelihood opportunities and protection of resources such as land, water, biodiversity, and genetic resources by developing strategies to make Indian agriculture more resilient to climate change ( Karmakar,2012b). While promotion of dry land agriculture would receive primary importance by way of developing suitable drought-and pest-resistant crop varieties and ensuring adequacy of institutional support, the Mission would likely expand its coverage to rainfed areas for integrating farming system with livestock and fisheries so that agriculture continues to grow in a sustainable manner. The Ministry of Agriculture has initiated activities under the Mission during year 2013-14.

Besides, the Rain-fed Area Development Programme (RADP), which adopts a holistic approach to enhance farmers 'incomes in rainfed areas, was implemented in 22 states in 2013-14 and will be substantially upscaled during the Twelfth Plan.

Other initiatives include the National Initiative on Climate Resilient Agriculture (NICRA) under the Indian Council of Agricultural Research (ICAR) to enhance resilience of Indian agriculture to climate change and vulnerability through strategic research and technology demonstration, capacity building, and sponsored/competitive languages to 600 districts, which are currently subscribed to by over 4.8 million farmers, while Gramin Krishi Mausam Sewa has initiated these advisory services at block level.

For the 1981-2010 period, the mean, maximum and minimum temperatures increased almost at an equal rate of around 0.2$^0$C per decade, which is much higher than the trends for the period 1901-2010. Hence, it is no surprise that India takes the challenge of climate change seriously. India has always engaged constructively at the multilateral level under the United Nations Framework Convention on Climate Change (UNFCCC) and India is now actively engaged in the efforts towards developing guidelines for effective implementation of the Paris Agreement on climate change.

On the domestic front, in recent regime under BJP- led NDA government, India continued to take ambitious targets in its actions against climate change. As a part of its contributions to the global climate change mitigation efforts, India announced its Intended Nationally Determined Contribution (INDC) and has launched various policies and set up institutional mechanisms to advance its actions which set ambitious targets for domestic efforts against climate change, including efforts which includes eight national missions covering solar, energy efficiency, agriculture, water, sustainable habitat, forestry, Himalayan ecosystem and knowledge, apart from various commitment to address climate change. The country has set itself an ambitious target of reducing its emissions intensity of its gross domestic product (GDP) by 33-35 per cent by 2030, compared to 2005 levels, and of achieving 40 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. Besides, as part of the mission on strategic knowledge on climate change, India has established 8 Global Technology Watch Groups in the areas of Renewable Energy Technology, Advance Coal Technology, Enhanced Energy Efficiency, Green Forest, Sustainable Habitat, Water, Sustainable Agriculture and Manufacturing. In addition to that, climate change has been given high importance in policy decisions, The Fifteenth Finance Commission Terms of Reference outlined climate change as an important aspect for consideration.

The broad policy initiatives of the central government are supplemented by actions at the sub-national levels. 32 States and Union Territories have put in place the State Action Plans on Climate Change attempting to mainstream climate change concerns in their planning process. Climate Change Action Programme, was launched in 2014 with an objective of building and supporting capacity at central & state levels, etc.

## SUGGESSIONS FOR COMBATING CLIMATE CHANGE

Since global warming depends upon the total concentration of GHGs, minimization of the threat of climate change requires concerted action by all the countries. However, whatever the world community does, some effects of climate change seem unavoidable at this stage. It is , therefore, important for India to minimize the vulnerability of various sectors, and take its economy, society and environment adapt to climate change, even as it takes strong actions to enhance sustainability of its development path.

Realizing that climate–change and development policy are indivisible because neglecting climate change will harm development, a nationally agreed strategy should be implemented to achieve lower carbon inclusive growth and to realize the domestic goal of reduction in the emissions intensity of its GDP. Besides, since contributing to climate change without due regard to its effect on human rights of future generations would be a grave human-rights violation, one should not ignore human rights, as was largely ignored by the IPCC itself and the negotiations held under the UN Framework Convention on Climate Change ( FCCC). Lastly, the Twelfth Plan had taken scientific and institutional initiatives for regular climate change assessments, GHG measurement, capacity building for technical analysis, monitoring and management of such complex systems at various levels (Ahmad, Dastgir S. Haseen, 2011).

Some policy and programmatic interventions can help farmers and other stakeholders adapt to climate change and reduce the losses. Change in cropping patterns, for example, can help adjustment to changes in mean temperature and precipitation. Amongst the key actions that are needed for adapting Indian agriculture to climate change are improved land management practices, development of resource conserving technologies, development of crop varieties that can withstand climate-stress, effective risk management through early warning, credit-insurance support to farmers and nutritional strategies for managing heat stress in dairy animals. Complementary actions in terms of identification of cost-effective opportunities for reducing methane generation, emissions in ruminants by modification of diet, and in rice paddies by water and nutrient management will help make adaptation measures sustainable. New policies should support the new land use arrangements, enhance investment in water harvesting, and promote small-farm mechanization and efficient water use technologies. A package of financial incentives for improved land management, including resource conservation water, carbon, energy and balanced fertilizer use may facilitate quicker adoption of these measures.

## CONCLUSION

India remains vulnerable to the adverse effects of both climate variability and change. And the impact of climate change is heavily felt in agriculture and in food security. While the continued robustness of Indian agriculture is significant in the context of food security and climate change, some major concerns remain. Growth rates of productivity are far below global standards; productivity levels of rice and wheat have declined after the green revolution of the 1980s. Another issue is soil degradation due to declining fertilizer-use efficiency. Global and domestic actions are urgently required to minimize the threat and damage that climate change can inflict on us. For example, Good governance for food security and agriculture must start with the provision of rural public goods (those with benefits that are available to all and still available even when consumed). A number of public goods are needed to promote farm productivity, food security and rural environmental sustainability. These include internal peace; the protection of property rights including common property rights; the provision of rural social services; and investments in basic rural infrastructure.

Agricultural development in this context needs to focus on decrease on GHG emissions through sundry measures namely enhance the forest coverage areas, improve conservation and its management, efficient management of livestock waste, and develop scientific instruments and more expenditure on research. It is necessary to make huge investments to support and respond to climate change to adaptation, mitigation or, most recently, geo-engineering. Adaptation means changing the way we live in response to climate change, for example building sea defenses to protect against rising sea levels, or changing the type of crops which are grown to better match changed patterns of temperature and rainfall. Effective adaptation strategies, involving technological innovation and institutional development, which would help to improve food security under climate change is urgently called for. As mentioned above, more investment in a new generation of agricultural technologies and more sustainable farming systems are essential. Farm management methods promoting enhanced efficiency in the use of water and land resources, and crops that are able to cope with weather extremes need to be developed, specifically to address the needs of small firms in a country like India. While, on the other hand, mitigation means taking action to reduce the extent and impacts of climate change, for example, through reducing the rate of increase of greenhouse gases in the atmosphere. Most mitigation strategies involve reducing emissions of greenhouse gases.

As a responsible nation, India has already shown its commitment to help address the global climate challenge. It is determined to work, both at domestic and international levels, in accordance with the principle of common but differentiated responsibility under the United Nations FCCC. India is an active participant in the Clean Development Mechanism (CDM) under the Kyoto Protocol, with the second highest number of projects registered for any country; and these have the potential to offset almost 10 percent of India's total emissions per year. Furthermore, in December 2009, India announced that it would aim to reduce the emissions intensity of its GDP by 20–25 per cent over the 2005 levels by 2020. India's voluntary actions will hopefully lead other nations to reduce their emissions, and to arrive at an effective and just global agreement.

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# Environmental Degradation a Global Issue: A Challenge for world community

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## INTRODUCTION

Today the countries of the world are worried about the environmental issue, which is natural. From time to time, international seminars, conventions have been held on this subject, so if there is no applied concrete strategy to save this environment within the time, then there will be further preparedness to face the consequences of the upcoming generation. Human being on the earth is disturbing, destructing, damaging and exploiting all the natural resources in their self-interest. Today universe is suffering from scarcity of water, global warming, polluted air, noisy environment; the tweet of birds does not get to hear in the morning time, it is not easy to buy fruits and vegetables free from insecticides and pesticides and increasing number of patients suffering from asthma, hypertension, diabetes, cancer etc. In this article major issues of environmental degradation have been emphasized and general public is suffering with its consequences.

Globally, there are increasing pressures on water supply. In particular, population growth and economic development are putting pressure on available freshwater resources. Water quality is inextricably linked to human health in many ways and poor water quality can lead to disease, reduced food availability and malnutrition. Improved access to fresh water has a direct positive impact on people and communities leading to significant social, economic and environmental benefits.

As our human population grows, new homes, communities, and expansions of cities will occur. Connecting all of the new expansions will be roads, a very important part in our daily life. Rural roads promote economic development but also facilitate deforestation. About 90% of the deforestation has occurred within 100 km of roads in most parts of the Amazon (Mehta, 2016).

Due to deforestation, the forest cover of India has fallen below the minimum recommended level. According to experts, forests should cover about one-third of the total area of country. But in India forests covers around 24% of the total area.

Satellite pictures show that India has gained a forest area of 5,871 square kilometre during the period between 2010 and 2012. However, the increase in forest area is not even throughout the country. In some places, forests land is being used for various development projects like dams, industries, roads and agriculture (Mehta, 2016).
Today world is facing 5 most problems i.e.

**a. Biodiversity:** Biodiversity refers to the variety and variability of life on Earth. Biodiversity is typically a measure of variation at the genetic, species, and ecosystem level. Biodiversity of the planet is in danger due to increase in global warming, pollution and deforestation. Billions of species are going or have gone extinct all over the world. A 2017 study published in PLOS One found that the biomass of insect life in Germany had declined by three-quarters in the last 25 years. Dave Goulson of Sussex University stated that their study suggested that humans "appear to be making vast tracts of land inhospitable to most forms of life, and are currently on course for ecological Armageddon. If we lose the insects then everything is going to collapse (Carrington,2017).

**b. Climate change:** Climate change occurs when changes in Earth's climate system result in new weather patterns that last for at least a few decades, and maybe for millions of years. The climate system is comprised of five interacting parts, the atmosphere (air), hydrosphere (water), cryosphere (ice and permafrost), biosphere (living things), and lithosphere (earth's crust and upper mantle). The climate system receives nearly all of its energy from the sun, with a relatively tiny amount from earth's interior.

**c. Water:** water is most precious and essential resource gifted by nature. It is not only essential for human survival, but its requirement as ecological water below which our natural world cannot function. Water has a number of competing uses as following

- As an element of *ecosystems*.
- A foundation of livelihoods.
- A resource of value.
- An anchor of cultural meaning.

China is home to the world's largest population, and yet the economic powerhouse still suffers from polluted water sources. According to reports, a staggering 85 percent of the water in the city's rivers was deemed unfit for consumption in 2015. In Beijing, one of China's largest cities and a popular tourist destination, almost 40 percent of the water was so dirty that it couldn't be used for any purpose (Greenwald, 2018).

In fact, the water crisis in India is so bad that over 21 percent of the country's diseases stem from the water supply, according to The Water Project (Synder, 2019).In the end, this is what makes India one of the worst countries without clean water. India's water crisis is often attributed to lack of government planning, increased corporate privatization, industrial and human waste and government corruption. In addition, water scarcity in India is expected to worsen as the overall population is expected to increase to 1.6 billion by year 2050. To that end, global water scarcity is expected to become a leading cause of national political conflict in the future, and the prognosis for India is no different.

India needs solutions now. Children in 100 million homes in the country lack water and one out of every two children are malnourished. Environmental justice needs to be restored to India so that families can raise their children with dignity and providing water to communities is one such way to best ensure that chance.

**d. Deforestation:** Deforestation, clearance, clear cutting or clearing is the removal of a forest or stand of trees from land which is then converted to a non-forest use. Deforestation can involve conversion of forest land to farms, ranches, or urban use. The most concentrated deforestation occurs in tropical rainforests. About 31% of Earth's land surface is covered by forests (Bradford, 2018). Rapidly growing economies also have an effect on deforestation.

**e. Pollution:** Pollution is the introduction of contaminants into the natural environment that causes adverse change. Pollution can take the form of chemical substances or energy, such as noise, heat or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Pollution is often classed as point source or nonpoint source pollution. In 2015, pollution killed 9 million people in the world (Beil, 2017; Pearce, 1989; Krugman, 2013)

Major forms of pollution include: Air pollution, light pollution, littering, noise pollution, plastic pollution, soil contamination, radioactive contamination, thermal pollution, visual pollution, water pollution.

**Objective of the study:**

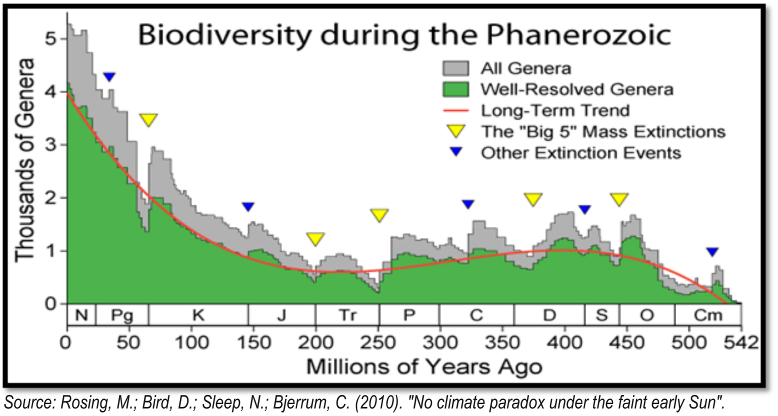
1. To identify the various threats to natural resources gifted by nature.
2. To be acquainted with the reasons degradation in "Biodiversity."
3. To know the impact of forest transition theory on our environment.
4. To know the major emitters of carbon dioxide emissions from fuel combustion at global level.
5. To know the Socially optimal level of pollution
6. To suggest strategies to improving the healthy environment.

**Research methodology:** The data for this study has been collected through secondary Sources such as Links between global taxonomic diversity, ecological diversity and the expansion of vertebrates on land Roads, lands, markets, and deforestation: a spatial model of land use in BelizeWorldwildlife.org, Deforestation: Facts, Causes & Effects, Global pollution kills 9m a year and threatens 'survival of human societies, Global Forest Transition: Prospects for an end to deforestation, Beyond Natural Resources to Post-Human Resources: Towards a New Theory of Diversity and Discontinuity.

**Result and discussion Data analysis:**

1. The history of biodiversity during the Phanerozoic (the last 540 million years), starts with rapid growth during the Cambrian explosion—a period during which nearly every phylum of multicellular organisms first appeared. Over the next 400 million years or so, invertebrate diversity showed little overall trend and vertebrate diversity shows an overall exponential trend. This dramatic rise in diversity was marked by periodic, massive losses of diversity classified as mass extinction events (Sahney, Benton & Ferry, 2010) A significant loss occurred when rainforests collapsed in the carboniferous. The worst was the Permian-Triassic extinction event, 251 million years ago. Vertebrates took 30 million years to recover from this event.

**Figure 1: Apparent marine fossil diversity during the Phanerozoic**




*Source: Rosing, M.; Bird, D.; Sleep, N.; Bjerrum, C. (2010). "No climate paradox under the faint early Sun". Nature. 464 (7289): 744-747*

### 1. Forest transition theory:

The forest area change may follow a pattern suggested by the forest transition (FT) theory, whereby at early stages in its development a country is characterized by high forest cover and low deforestation rates (HFLD countries) (Rudel, 2005).

Then deforestation rates accelerate (HFHD, high forest cover – high deforestation rate), and forest cover is reduced (LFHD, low forest cover – high deforestation rate), before the deforestation rate slows (LFLD, low forest cover – low deforestation rate), after which forest cover stabilizes and eventually starts recovering. FT is not a "law of nature", and the pattern is influenced by national context (for example, human population density, stage of development, structure of the economy), global economic forces, and government policies. A country may reach very low levels of forest cover before it stabilizes, or it might through good policies be able to “bridge” the forest transition (Baofu, 2014).

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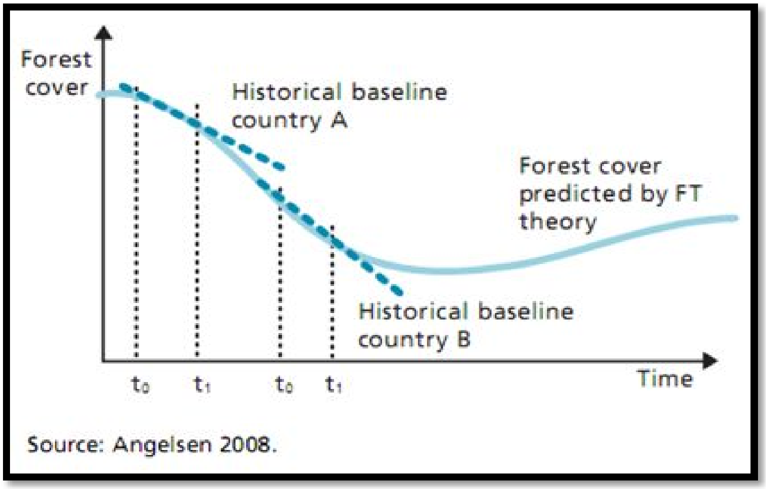
## Figure 2: The forest transition and historical baselines




The table 1 reveals that china and India are most populated country of the world their Total Carbon Dioxide Emissions from Fuel Combustion (Million Metric Tons) was also high, but Per Capita Carbon Dioxide Emissions from Fuel Combustion (Metric Tons) was low in comparison to developed countries. Therefore, developed country should minimise their Per Capita Carbon Dioxide Emissions.

## Table 1: 15 countries that emitted the most Carbon dioxide in 2015

| Rank | Country | Total Carbon Dioxide Emissions From Fuel Combu stion (Million Metric Tons) | Per Capita Carbon Dioxide Emissions From Fuel Combustion (Metric Tons) | Population of the country in million | Environmental Performance Index Ranking |
|---|---|---|---|---|---|
| 1 | China | 9040.74 | 6.59 | 1,420.06 | 120 |
| 2 | United States | 4997.50 | 15.53 | 329.09 | 27 |
| 3 | India | 2066.01 | 1.58 | 1,368.73 | 177 |
| 4 | Russia | 1468.99 | 10.19 | 147.05 | 52 |
| 5 | Japan | 1141.58 | 8.99 | 126.91 | 20 |
| 6 | Germany | 729.77 | 8.93 | 82.44 | 13 |
| 7 | South Korea | 585.99 | 11.58 | 51.30 | 60 |
| 8 | Iran | 552.40 | 6.98 | 82.82 | 80 |
| 9 | Canada | 549.23 | 15.32 | 37.28 | 25 |
| 10 | Saudi Arabia | 531.46 | 16.85 | 34.03 | 86 |
| 11 | Brazil | 450.79 | 2.17 | 212.39 | 69 |
| 12 | Mexico | 442.31 | 3.66 | 99.77 | 72 |
| 13 | Indonesia | 441.91 | 1.72 | 269 | 133 |
| 14 | South Africa | 427.57 | 7.77 | 57.94 | 142 |
| 15 | United Kingdom | 389.75 | 5.99 | 66.96 | 6 |

*Source: Data compiled by International Energy Agency*

The picture that emerges from these figures is one where—in general—developed countries and major emerging economy nations lead in total carbon dioxide emissions. Developed nations typically have high carbon dioxide emissions per capita, while some developing countries lead in the growth rate of carbon dioxide emissions. Obviously, these uneven contributions to the climate problem are at the core of the challenges the world community faces in finding effective and equitable solutions.

**Table 2: Environmental Performance Index of Most populated 10 countries of the world**

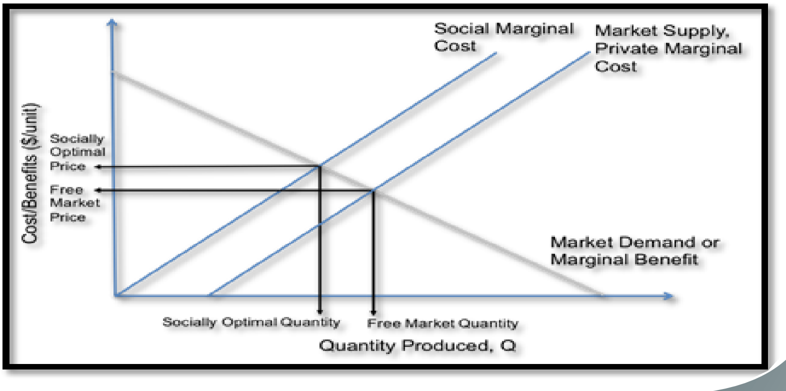
| S. No. | Country | Estimated* population in March, 2019 | **EPI Ranking | **Environmental performance index | **Environmental Health | **Ecosystem vitality |
|---|---|---|---|---|---|---|
| 1. | China | 1,420,062,022 | 120 | 50.74 | 31.72 | 63.42 |
| 2. | India | 1,368,737,513 | 177 | 30.57 | 9.32 | 44.74 |
| 3. | United states | 329,093,110 | 27 | 71.19 | 93.91 | 56.04 |
| 4. | Indonesia | 269,536,482 | 133 | 46.92 | 45.44 | 47.90 |
| 5. | Brazil | 212,392,717 | 69 | 60.70 | 67.44 | 56.21 |
| 6. | Pakistan | 204,596,442 | 169 | 37.50 | 16.80 | 51.30 |
| 7. | Nigeria | 200,962,417 | 100 | 54.76 | 36.64 | 66.84 |
| 8. | Bangladesh | 168,065,920 | 179 | 29.56 | 11.96 | 41.29 |
| 9. | Russia | 147,053,966 | 52 | 63.79 | 75.48 | 55.99 |
| 10. | Mexico | 99,775,434 | 72 | 59.69 | 66.04 | 55.46 |

*Source: *https://www.internetworldstats.com/stats8.htm*
***https://epi.envirocenter.yale.edu/epi-topline*

## 3. Socially optimal level of pollution

For economists, pollution is an “external cost and occurs only when one or more individuals suffer a loss of welfare,” however; there exists a socially optimal level of pollution at which welfare is maximized. This is because consumers derive utility from the good or service manufactured, which will outweigh the social cost of pollution until a certain point. At this point the damage of one extra unit of pollution to society, the marginal cost of pollution, is exactly equal to the marginal benefit of consuming one more unit of the good or service.

**Figure 3: A visual comparison of the free market and socially optimal outcomes**



In markets with pollution, or other negative externalities in production, the free market equilibrium will not account for the costs of pollution on society. If the social costs of pollution are higher than the private costs incurred by the firm, then the true supply curve will be higher. The point at which the social marginal cost and market demand intersect gives the socially optimal level of pollution. At this point, the quantity will be lower and the price will be higher in comparison to the free market equilibrium. Therefore, the free market outcome could be considered a market failure because it "does not maximize efficiency".

This model can be used as a basis to evaluate different methods of internalizing the externality. Some examples include tariffs, a carbon tax and cap and trade systems.

In the list of 500 cities most polluted by PM2.5 annual mean concentration measurement as documented by the World Health Organization covering the period from 2008 to 2017. 287 cities were counted from china, 32 cites from India, 17 cities from Poland, 3 cities from Cameron, one city from Nepal, 2cities from Vietnam, and 6 cities from Bahrain.

**Summary and Conclusion:**

In the present position of development phase China or India or USA cannot reduce sudden their consumption of energy level. But following necessary actions should be taken to solve the issue.

1. Expand the use of renewable energy and transform our energy system to one that is cleaner and less dependent on coal and other fossil fuels.
2. Increase vehicle fuel efficiency and support other solutions that reduce U.S. oil use.
3. Place limits on the amount of carbon that polluters are allowed to emit.
4. Build a clean energy economy by investing in efficient energy technologies, industries, and approaches.
5. Water is a very scarce resource on the earth, which should be restore, harvest rain water and use carefully.
6. There is need of social forestry and agro forestry to be expanding for fulfilling the requirement of rising population.

Reduce tropical deforestation and its associated global warming emissions.

We can reduce global warming emissions and ensure communities have the resources they need to withstand the effects of climate change—but not without you. Your generous support helps develop science-based solutions for a healthy, safe, and sustainable future.

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# Are We Moving Towards an Effective and Equitable Carbon Emissions Policy? : An Empirical Recital with a Special Focus on India

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## INTRODUCTION

Bargaining situations and negotiations frequently resemble a striving for fairness when bargainers feel that they are at disadvantaged position to receive their "fair share". But the meaning of "fair" is often heavily debated. The perception of fairness may, however, differ across the involved parties. Several strands of economic as well as psychological literature indicate that the understanding of what is fair is – at least to a certain extent – driven by the economic costs of the respective equity rules : Babcock *et al.* (1996) consider a "self-serving bias in judgments of fairness" in an experimental bargaining situation. This notion of self-serving biases usually refers to unconscious distortions in perceptions of fairness. In contrast, our paper establishes a self-interested use of equity which includes potentially intentional distortions of equity beliefs. Babcock and Loewenstein (1997) review psychological and experimental evidence for this interaction between material payoffs and fairness perceptions. Self-serving social comparisons from teacher contract negotiations are discussed by Babcock et al. (1996). In a different approach, Hennig-Schmidt (2002) shows the self-interested use of equity arguments in a video-bargaining experiment. If conflicting principles of fairness are part of the negotiation process, a potential agreement requires weighing and reconciliation of the different proposed equity bases. Moving on, Bosello *et al.* (2001) study the stability of international agreements if they are based on a single equity rule but do not find major improvements upon the relatively pessimistic predictions from traditional economic models of coalition formation (Carraro & Siniscalco, 1993). Böhringer and Helm (2008) consider an axiomatic approach of fair division and calculate the burden resulting from such an allocation mechanism. Lange and Vogt (2003) and Lange (2006) take a different approach and model preferences which trade-off payoffs with equity concerns. Such equity preferences may potentially increase cooperation rates but are based on the assumption that countries evaluate their position based on a single given equity criterion.

In this backdrop, negotiations thus become more complicated when there is more than one justifiable fairness norm (Raiffa, 1982). Now what negotiators do is potentially choose those fairness principles in line with their demands and not in line with the equity principles. Herein lies the conflict. In spite of the graveness of the situation, the actual role of equity principles in shaping negotiation processes has received only limited attention in the literature. Several studies identify different typologies of equity principles. This paper follows Lange *et al.* (2010) and primarily focuses on the dominating principles in the context of international climate policy, like, egalitarian rule, sovereignty rule, polluter-pays rule, ability-to-pay rule. The issue of equity principles in the context of $CO_2$ emissions assumes a critical position. This happens on account of the claim that developing countries have regarding developed countries with high per capita greenhouse gas emissions being responsible for taking a lead in global warming. Often similar emission reduction targets are seen as fair based on present or recent emission levels (Cazorla & Toman, 2001).

The concept of justice and being "fair" is often heavily debated. More so, when it comes to the international negotiations on the mitigation of climate change. A peep into the charter of UN Framework Convention on Climate Change highlights the importance of distributive fairness or in other words, equity. The concepts of "equal per capita $CO_2$ emissions", "polluter-pays principle", etc. in some way provide different perspectives on the issue of equity. For long, the economics literature has been focusing on the efficient allocation of optimum levels of the provision of some common resources among different associated parties. But strangely, less attention has been given to the equity aspects of such allocations. For example, developing countries as well as environmental interest groups in industrialized countries claim that developed countries with high per capita greenhouse gas emissions are responsible for global warming and must take the lead in combating climate change. In consequence, weaker obligations for developing countries may be based on equity arguments. Another dimension of equity issues is concerned with a fair distribution of burdens among the countries with comparable per capita GDP and industry structure. As UNFCC puts it,

*"…….Within the UN Framework Convention on Climate Change (UNFCCC) negotiations, debate on equity and climate justice focuses on responsibility for reducing climate change damage. Equity concepts are used conventionally, as criteria in deciding the share and manner of reducing greenhouse gas emissions. The notions of justice and injustice are used to argue against the unjust burden of climate change impacts and costs."*

As Bomassi (2013) puts it, it appears that Europe and India are dissimilar in terms of culture, history, demography, etc.. But a closer look can give a different picture — India and Europe are not so different. Both have had to rethink their place in the world as a result of China's changed role on the global stage. In India, like we have so many states having different cultures pushing for a different agenda; in Europe, the different member states actually push for their competing national interests. Coupled with this, both Europe and India have been strategically aligned in terms of development of clean energy, energy efficiency, renewables under the likes of FOWIND (facilitating off-shore wind development in India), SCOPE BIG (CSP optimized power plant engineered with biomass gasification), CECI (generation of clean energy in cooperation with India), CDSC (clean development technology and creation of sustainable cities) to integrate low-carbon strategies into urban development and hence the motivation for doing the analysis. The story, however, is not complete. The future scope of research is to bring in the '4 Powerhouses' that we have in the world at present, namely, USA, China, India and the European Union.

Out of the existing equity criteria, i.e. egalitarian rule, sovereignty rule, polluter-pays rule, ability-to-pay rule, the first objective is to quantify the significance of these equity principles across two major power houses in the world at present, India and the European Union in 2014-15 (actual) and in terminal years of 2021-22 and 2031-32 for the future. To assess the distributions implied by the egalitarian, sovereignty, polluter-pays, and ability-to-pay rules, the paper makes use of the trends in the respective countries' or groups of countries' population data, baseline carbon emissions, and GDP. Based on a projection based empirical set-up, the author tries to model the carbon emissions policy, vis – a – vis, two sets of scenarios, the BAU Scenario (Business as Usual) and the Accelerated Scenario (i.e. with 20 per cent $CO_2$ emissions reduction). The main objective of trying out such an exercise is to predict the decision-making authority's future choice of equity principle after weighing the benefits and costs arising out of such equity principles. The results indicate that in the long run the polluter-pays principle becomes comparatively insignificant. However, when it comes to the $CO_2$ emissions abatement, as already existing in the literature, the support for egalitarian principle comes from the developed countries. Furthermore, the novelty of the contribution lies in the formulation of a convex combination of all the four principles to see the relative effectiveness of such equity principles across the two selected countries.

IPCC's predictions is that global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate of 0.8°C – 1.2°C (IPCC, 2018). Limiting global warming to 1.5°C would require "rapid and far-reaching" transitions in all aspects, namely, energy consumption, land use pattern, industrial output, transportation, etc. But, most importantly, over and above anything, "global net human-caused emissions of carbon dioxide ($CO_2$) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050" (IPCC 2018). To sum up, this paper compares European Union and India in the light of how to design the carbon emissions policy for the future based on the BAU (Business as Usual) and Accelerated Scenario (with a 20 per cent $CO_2$ emissions reduction) design based on the above mentioned equity principles.

The rest of the paper goes as follows. The discussion of the self centered approach of using equity rules in section 2 is followed by the formulation of the research hypothesis in section 3. Then we have the comparison of both the scenarios across EU and India. Finally, the paper ends with a conclusion in the light of the international policy agreements governing the two countries.

**Self Centered Approach of Using Equity Rules**

In Nash's (1950) seminal work on bargaining, all differences between the players were supposedly captured in the disagreement point and the shape of the bargaining set. Many other explanations for bargaining power have been suggested since then – not least differences in time or risk preference (Roth 1979). However, if one follows many negotiation processes, the concept most parties follow is the "fairness" argument in order to convince the other party to agree to their demands.The payoff to a player in these (axiomatic) solutions increases in their legal claim. Recently, Gächter and Riedl (2005) studied the effects of "moral property rights" on bargaining. Here, individual views on fairness inform the bargaining situation and thereby influence the bargaining outcome. That is, the entitlements or individual claims are not given by some (incompatible) legal property rights but by what bargainers perceive as a fair agreement. Similar to these approaches, the frequency of equity arguments in negotiations indicates that there is an interaction between bargaining power, i.e. the ability to influence the negotiation outcome favorably, and the availability of equity arguments: for example, if all equity criteria required that a negotiating party receives a larger share of the surplus, this party would be likely to be able to influence the bargaining outcome in its favor. Conversely, the lack of an equity or fairness argument for one's position would, in our view, results in a reduction of bargaining power. The end result of negotiations may thus hardly be understood without analyzing the underlying equity principles and their use by the respective parties.

There is substantial evidence that individual perceptions of "what is fair" are correlated with the economic costs and benefits implied by the respective equity criteria (for instance, Babcock and Loewenstein 1997, Dahl and Ransom 1999). These differing perceptions are also apparent in the use of equity principles as arguments in bargaining processes (Hennig-Schmidt 2002). This could be the case for two reasons : (i) a self-serving bias, i.e. individuals might subconsciously interpret fairness in a way that benefits their interests, or, (ii) a conscious decision on self-interested use of equity, i.e. individuals might use specific fairness notions to consciously pursue their own interest while exploiting the others' sense of justice (see for details Konow 2001). Also, in papers like Messick and Sentis (1979), Thompson and Loewenstein (1979) evidence for the subconscious self-serving bias has been found while Dahl and Ransom (1999) and Gächter and Riedl (2005) find relatively little evidence in this regard. In either way, a self-interested perception and/or use of equity is essential in explaining bargaining outcomes if a party successfully influences the bargaining process in its favor by referring to equity arguments.

In this paper, in the context of international climate policy, we consider the four equity criteria as mentioned. Based on the arguments and empirical findings outlined above, each negotiating party may be predicted to use equity arguments which lead to lower costs compared to other equity criteria and to what extent the results vary when evaluated across different countries.

**A Comparison of the Economic Costs of different Equity Principles**

To begin with, the paper generates predictions on the four diferent equity criteria the respective parties would prefer in their own self-interest by comparing the distribution of costs under the "burden sharing of abating carbon emissions" (Lange *et al.*, 2007) in line with the equity rules. We assume that the aggregate emissions target is exogenous and for any given overall target (or equivalently, any given marginal abatement costs), the different equity criteria therefore implies a specific distribution of costs and benefits. In order to assess the distributions implied by the egalitarian, sovereignty, polluter-pays, and ability-to-pay rules, we use information on abatement costs in the respective countries, their population data, baseline carbon emissions, and GDP levels and set up the BAU Scenario (Business as Usual) and the Accelerated Scenario (i.e. with a 20 per cent $CO_2$ emissions reduction).

## Constructing the research hypothesis

The projections for GDP, $CO_2$ emissions (both lifecycle and current) and populations for 2021-22 and 2031-32 have been discussed in details in the annexure section. Coming to the methodology of calculating the emissions distribution under these equity principles, the author frames the equity principles as follows,

$$\textit{Egalitarian Principle (EGA)} : \frac{Emissions_t}{Population_t}$$

$$\textit{Sovereignty Principle (SOV)} : \frac{Emissions_t - Abatement_t}{Emissions_t}$$

$$\textit{Polluter-Pays Principle (POL)} : \frac{Abatement_t}{Emissions_t}$$

$$\textit{Ability-to-Pay Principle (ABI)} : \frac{Abatement_t}{GDP_t}$$

for the $t^{th}$ year for the $j^{th}$ country, where $j$ = {India, European Union}

Marginal abatement cost curves for 2021-22 are generated based on data from the modified POLES model ( see for details on POLES Model in Lange et al. (2010). Tables 1 and 2 contain all relevant data on the projected marginal costs and subsequently the projected costs under the different equity criteria for both the BAU scenario and the accelerated scenario. The author now develop a quantitative model for projection of growth of future demand for energy of the Indian economy and Eurozone which would support certain basic economic targets in terms of carbon emissions. We describe in Table 1 the abatement costs under different equity conditions of the model of projection of electricity requirement or demand and supply. All scenarios assume 8 per cent overall GDP growth and alternative rates of energy conserving technical change and that of introduction of carbon free new renewable fuels targeted at 20 per cent reduction of emissions.

## Results and Discussions

### Table 1. Calculation of Abatement Costs

| Countries | Total abatement costs (Bn USD2000) | | | | |
|---|---|---|---|---|---|
| | *40* | *80* | *120* | *160* | *200* |
| **2021-22** | | | | | |
| EU | 1.4 | 4.7 | 9.4 | 15.0 | 21.2 |
| India | 9.5 | 30.7 | 58.2 | 89.9 | 124.7 |
| **2031-32** | | | | | |
| EU | 1.6 | 7.8 | 16.2 | 25.5 | 36.9 |
| India | 17.2 | 50.5 | 87.1 | 125.4 | 160.1 |

Source : Author's own computations based on the methodology used in Lange *et al.* (2010)

### Table 2. $CO_2$ emission coefficient (current and lifecycle) India

| Fuels | Current | Lifecycle |
|---|---|---|
| Coal | 1.04 | 0.820 |
| Gas | 0.60 | 0.490 |
| Nuclear | 0 | 0.012 |
| Hydro storage | 0 | 0.024 |
| Solar PV | 0 | 0.048 |
| Solar CSP | 0 | 0.048 |
| Distributed Solar PV | 0 | 0.048 |
| Total Solar | 0 | 0.048 |
| Onshore Wind | 0 | 0.012 |
| Offshore Wind | 0 | 0.012 |
| Total Wind | 0 | 0.012 |
| Other Renewables | 0 | 0.230 |

Source : Compiled by the author from IEA database and World Bank database

Note : For European Union we do not have a detailed break up available, so we make use of the components (whichever are applicable) and the total value of the coefficients on the whole.

**Table 3. Projected costs for the terminal years of 2021-22 and 2031-32 implied by the respective equity criteria for the respective countries or groups of countries (in per cent of GDP) when marginal abatement costs are equalized at 80 USD2000/tC, corresponding to a worldwide reduction from BAU emissions by 20 per cent**

| Countries | Different Equity Criteria | | | |
|---|---|---|---|---|
| | *EGA* | *SOV* | *POL* | *ABI* |
| **2021-22** | | | | |
| EU | 0.323 | 0.055 | 0.062 | 0.049 |
| India | -0.473 | 0.044 | 0.055 | 0.059 |
| **2031-32** | | | | |
| EU | 0.298 | 0.050 | 0.057 | 0.049 |
| India | -0.512 | 0.045 | 0.060 | 0.069 |

Source : Authors' own calculations

These would indicate the relative physical benefits and financial costs of CO2 emission reductions under the different equity criteria. Table 2 provides the normative CO2 emission coefficients — current as well as life cycle ones for the different generation technologies. These coefficients have been assumed for the current emission to be as per CEA norm and that for the life cycle emission to be as per IPCC norms for the generation technologies. The egalitarian rule has the most cost so is realistically not applicable as there is no guarantee of an equal distribution. Given the comparatively larger amount of emissions between 1860 and 2020 in the EU, the polluter-pays principle based on the cumulated carbon emissions would be also very costly for the EU (see Table 3). This is followed by the sovereignty rule and relatively the least cost wise, the ability to pay principle. Given EU's combined GDP and the sharing of abatement costs, ABI is possible. The ranking goes as follows,

ABI > SOV > POL > EGA

We now discuss the costs which are implied by the different equity rules for India. The ranking of equity criteria – given by the cost projections as reported in Table 3 as follows:

EGA > SOV > POL > ABI

It is evident that India with its large share in global population would profit most from a strict application of the egalitarian principle. In contrast, India, would oppose a support of the polluter-pays and ability-to-pay principles on the basis of their respective costs. The latter principle refers to the predicted high economic growth of India in the terminal years which would raise the costs associated with the ability-to-pay rule. The polluter-pays principle is based on the predicted large increase in emissions from India over the next decades so that the costs of the polluter-pays rule would be increased. From this 20 percent accelerated scenario, India has the capability to reduce it further if it goes by the three equity principles of EGA, SOV and POL except ABI. In this context, as put forward by Agarwal (2015),

*"India has said it aims to reduce the emissions intensity of its GDP by 33-35 per cent by 2030 from 2005 levels, and achieve 40 per cent of its cumulative electric power of around 350GW installed capacity from non-fossil fuel-based energy resources, mainly renewable power. While some experts welcomed India's submissions stating that India's climate action plan is far superior to ones proposed by the US and European Union (EU), others said it doesn't fully capture the emissions it would avoid if it succeeds in meeting its renewable energy goals."*

As expected, given the cost in Table 3, EU in 2031-32 as per the different equity principles has an opportunity to reduce more emissions in line with its INDC submitted to the UNFCCC, outlining its mitigation contribution of at least 40 per cent emission reduction through domestic efforts by 2030 below its 1990 levels. But this target is not feasible given the fact that in 2031-32 as per the predictions of this model, although cost would be going down but a reduction of 23 to 35 per cent is not really possible by 2030 - contrary to the case of India.

## Concluding Remarks

In this paper, we put forward equity as an important element to understanding negotiating positions, using the example of international climate negotiations. Taking a traditional economic standpoint, we argued that the use of equity criteria might be driven by cost consideration of the parties. Our econometric analysis based on data from an international survey of agents involved in climate policy largely supported our predictions based on a cost-ranking of the respective equity criteria for the different countries or groups of countries : the perceived support of equity criteria is the stronger, the less costly this criterion is compared to alternatives.

While the findings in this study indicate that equity principles in international negotiations are mostly correlated with the self-interest of the negotiating parties involved, the question remains how exactly their use influences the negotiation process. We believe that this potentially strategic role of using equity criteria will be essential in generating a better understanding of negotiation processes – not only in international climate policy but also for India and EU.

Making different countries from the world agree to a common framework on climate change and a set of SDGs in a single year was indeed a monumental achievement. But what is more important is the mobilization of the funds needed for realizing the bold targets envisaged under both and to have a clear action plan for implementation, taking note of the INDCs of individual countries. Successful implementation of the Paris Agreement, the SDGs and the ambitious targets set out in the INDCs will require huge financial resources which cannot be met through budgetary sources alone. Leveraging private finance along with public finance, both international and national, will be critical and there lies the scope for future research after incorporating the other two powerhouses in this context, namely, US and China.

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Annexure

For analyzing the energy consumption behaviour at sectoral level and overall economy level, we pose a simple model, which assumes that demand for energy *($EDD^i$)* of each sector of the economy is a function of its income*($I^i$)* and the real energy price*($RPE^i$)* it faces. The partial income elasticity of demand and the partial price elasticity are assumed to remain constant over the projections period. This gives us a demand function of the form-

$$EDD^i = A(I^i)^\alpha (RPE^i)^\beta ,$$

where *i* = Overall economy, agriculture, industry, residential, commercial and transport sectors.

Here,

$\alpha$, is the income elasticity of energy demand

$\beta$, is the price elasticity of energy demand

$A$, is the technology parameter

$\alpha$, $\beta$ and $A$ are constant over the entire projection period.

For the purpose of econometric estimation the above model can be transformed into a double log linear model of the form-

$$\log(EDD_t^i) = \log(A) + \alpha * \log(I_t^i) + \beta * \log(RPE_t^i) + \varepsilon_t^i$$

$\varepsilon_t^i$, is the random error component and conforms to the assumptions of the classical regression model

## Data and Sources

The econometric estimation of the model for the overall economy and for each sector requires data on energy demand, GDP that indicates the level of income or value added and the real energy price index. The nominal energy price is calculated using the fuel shares and the corresponding WPI of fuels faced by a given sector or by the aggregate economy. The real energy price is calculated by deflating the nominal price by the GDP deflator. The Private Final Consumption (PFCE) is used as an indicator of income for the residential sector. The model is estimated using data from 1990-2015. The data for energy demand is obtained from the Energy Balances of the non-OECD countries published by International Energy Agency (IEA), the IEA database and Eurostat database for the European Union. The data for GDP and PFCE for India are obtained from the National Account Statistics, and the data for WPI prices are obtained from the RBI database (Handbook of Statistics on the Indian Economy) and the website of the Office of the Economic Advisor. Also, for the European Union data on GDP and Gross Fixed Capital Formation, we make use of the Eurostat database.

## Estimation

We begin by applying the standard time series techniques. First to check the stationarity of the data we go for Augmented Dickey Fuller Test, the results of which have been reported in Table A1.

**Table A1. Unit Root results**

| Variables (order of integration) | Augmented DF test statistic | Probability |
|---|---|---|
| **INDIA** | | |
| INDUSTRY_GDP (2) | -5.28 | 0.00* |
| INDUSTRY_Energy Demand (2) | -6.38 | 0.00* |
| INDUSTRY_Real Energy Price (1) | -6.11 | 0.00* |
| AGRICULTURE_GDP (2) | -13.37 | 0.00* |
| AGRICULTURE_Energy Demand (2) | -6.72 | 0.00* |
| AGRICULTURE_Real Energy Price (1) | -6.23 | 0.00* |
| RESIDENTIAL_GDP (2) | -6.46 | 0.00* |
| RESIDENTIAL_Energy Demand (2) | -5.26 | 0.00* |
| RESIDENTIAL_Real Energy Price (1) | -6.20 | 0.00* |
| COMMERCIAL_GDP (2) | -5.69 | 0.00* |
| COMMERCIAL_Energy Demand (2) | -9.16 | 0.00* |
| COMMERCIAL_Real Energy Price (1) | -6.24 | 0.00* |
| TRANSPORT_GDP (2) | -4.34 | 0.01* |
| TRANSPORT_Energy Demand (2) | -5.46 | 0.00* |
| TRANSPORT_Real Energy Price (1) | -6.27 | 0.00* |
| OVERALL_GDP (2) | -6.33 | 0.00* |
| OVERALL_Energy Demand (2) | -7.12 | 0.00* |
| OVERALL_Real Energy Price (1) | -4.23 | 0.01* |

| **EUROPEAN UNION** | | |
|---|---|---|
| INDUSTRY_GDP (2) | -6.81 | 0.00* |
| INDUSTRY_Energy Demand (2) | -6.44 | 0.00* |
| INDUSTRY_Real Energy Price (1) | -5.97 | 0.00* |
| AGRICULTURE_GDP (2) | -11.3 | 0.00* |
| AGRICULTURE Energy Demand (2) | -5.72 | 0.00* |
| AGRICULTURE_Real Energy Price (1) | -4.66 | 0.00* |
| RESIDENTIAL_GDP (2) | -7.61 | 0.00* |
| RESIDENTIAL_Energy Demand (2) | -5.26 | 0.00* |
| RESIDENTIAL_Real Energy Price (1) | -5.30 | 0.00* |
| COMMERCIAL_GDP (2) | -5.98 | 0.00* |
| COMMERCIAL_Energy Demand (2) | -8.21 | 0.00* |
| COMMERCIAL_Real Energy Price (1) | -7.42 | 0.00* |
| TRANSPORT_GDP (2) | -5.44 | 0.01* |
| TRANSPORT_Energy Demand (2) | -6.21 | 0.00* |
| TRANSPORT_Real Energy Price (1) | -7.71 | 0.00* |
| OVERALL_GDP (2) | -5.83 | 0.00* |
| OVERALL_Energy Demand (2) | -8.22 | 0.00* |
| OVERALL_Real Energy Price (1) | -7.11 | 0.01* |

** denotes significance at 95 per cent level*

Given the unit root results and the order of integration, we estimate the following model,

$$\log(\Delta ED_0) = \beta \log(\Delta GDP_0) + \gamma \log(REP_0)$$

It needs that the sectoral GDP and the final energy demand of the concentrated sectors are integrated of the second order whereas the real energy prices faced by each of the sectors are integrated of order 1.

For applying the Engel and Granger (1987) methodology of cointegration in single equation specification, we consider the following model,

$$\log(\Delta ED_i) = \beta log(\Delta GDP_i) + \gamma \log(REP_i) + \epsilon \ \ where\ i = A, I, T, R, C \ \ and$$

$\Delta ED_i$ is the change in the energy demand of the $i^{th}$ sector, integrated of order 1.

$\Delta GDP_i$ is the change in GDP of the $i^{th}$ sector, integrated of order 1.

$REP_i$ is the real energy price faced by the $i^{th}$ sector, integrated of order 1.

The cointegration results deriving the long run elasticity coefficients of sectoral energy demand and real energy price of different sectors have been reported in Table A2.

## Table A2. Long run elasticity coefficients results

| Variables (logarithm) | Elasticity Coefficients | Probability |
|---|---|---|
| **INDIA** | | |
| Dep Var : Δ ( INDUSTRY_Energy demand) | | |
| Δ (INDUSTRY_GDP) | 0.83 | 0.00* |
| INDUSTRY_Real Energy Price | 0.03 | 0.00* |
| | | |
| Dep Var : Δ (AGRICULTURE_Energy demand) | | |
| Δ (AGRICULTURE_GDP) | 0.75 | 0.00* |
| AGRICULTURE_Real Energy Price | 0.12 | 0.06 |
| | | |
| Dep Var : Δ ( RESIDENTIAL_Energy demand) | | |
| Δ (RESIDENTIAL_GDP) | 0.72 | 0.00* |
| RESIDENTIAL_Real Energy Price | -0.02 | 0.00* |
| | | |
| Dep Var : Δ (COMMERCIAL_Energy demand) | | |
| Δ (COMMERCIAL_GDP) | 0.62 | 0.00* |
| COMMERCIAL_Real Energy Price | -0.38 | 0.00* |
| | | |
| Dep Var : Δ ( TRANSPORT_Energy demand ) | | |
| Δ (TRANSPORT_GDP) | 0.88 | 0.00* |
| TRANSPORT_Real Energy Price | -0.08 | 0.00* |
| | | |
| **EUROPEAN UNION** | | |
| Dep Var : Δ (INDUSTRY_Energy demand) | | |
| Δ (INDUSTRY_GDP) | 0.78 | 0.00* |
| INDUSTRY_Real Energy Price | 0.06 | 0.00* |
| | | |
| Dep Var : Δ ( AGRICULTURE_Energy demand) | | |
| Δ (AGRICULTURE_GDP) | 0.61 | 0.00* |
| AGRICULTURE_Real Energy Price | 0.09 | 0.06 |
| | | |
| Dep Var : Δ (RESIDENTIAL_Energy demand) | | |
| Δ (RESIDENTIAL_GDP) | 0.88 | 0.00* |
| RESIDENTIAL_Real Energy Price | -0.04 | 0.00* |
| | | |
| Dep Var : Δ ( COMMERCIAL_Energy demand) | | |
| Δ (COMMERCIAL_GDP) | 0.62 | 0.00* |
| COMMERCIAL_Real Energy Price | -0.38 | 0.00* |
| | | |
| Dep Var : Δ (TRANSPORT_Energy demand) | | |
| Δ (TRANSPORT_GDP) | 1.01 | 0.00* |
| TRANSPORT_Real Energy Price | -0.07 | 0.00* |

** denotes significance at 95 per cent level*

In order to project the final energy demand at the original level, we make use of the following derivation,

$$\log(\Delta ED_t) - \log(\Delta ED_0) = \beta[\log(\Delta GDP_t) - \log(\Delta GDP_0)] + \gamma[\log(REP_t) - \log(REP_0)]$$

$$\frac{\Delta ED_t}{\Delta ED_0} = \left(\frac{\Delta GDP_t}{\Delta GDP_0}\right)^{\beta} \times \left(\frac{REP_t}{REP_0}\right)^{\gamma}, t = 2015, 2016, \ldots \ldots, 2041$$

$$or, \qquad \Delta ED_t = \left(\frac{\Delta GDP_t}{\Delta GDP_0}\right)^{\beta} \times \left(\frac{REP_t}{REP_0}\right)^{\gamma} \times \Delta ED_0 \qquad \ldots \ldots \ldots (1)$$

Now, projecting the energy demand at 2021, we

Calculate (1) for t = 2015, 2016, 2017, 2018, 2019, 2020, 2021 and then add up these to get the total change from 2014 – 2021 and finally add it up with the base year value of 2014 to derive the final energy demand in the concerned year.

Similarly, we do it for 2031-32.

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# Impact of Climate Change on Production of Vegetables in India: Adaptation, Growth and Sustainability

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## INTRODUCTION

The climate change is a natural and long term phenomenon but the rate of change in the components of climate is one of the key concerns to the policy makers. Today, climate change is one of the most important issues for viable farming and sustainable agriculture. Climate is not only a crucial factor for agriculture but also it is very important for lives and livelihoods of the people. The major elements of climate change are changes in temperature, rainfall, $CO_2$, sea water level, variability in rainfall and temperature, and variability in weather conditions. Long run consistent data on temperature and rainfall are available to examine nature of climate change in India. Indian agricultural production activities still very much depend on weather and climate conditions. Horticulture is a sub-sector of agriculture which is very susceptible to climate change. Indian horticulture covers verities of crops from vegetables, fruits, flowers, to different medicinal plants. It is very difficult to assess impact of climate change on horticulture quantitatively because the basic and inherent characteristics of horticulture changes both quantitatively as well as qualitatively in the long run with technological innovations and modern practices. Development and growth of horticulture is a joint effort of several factors- economic, social, demographic, institutional, agro-climatic conditions and marketing infrastructures. The present study is a modest attempt to analyse the characteristics of climate change in India and its probable impact on production of horticulture with particular focus on potato. The paper follows cointegration and vector error correction model (VECM) and stochastic approach to infer results of the study. Analysis of climate change (changes in annual and monthly rainfall and temperature and their long run relationship) during a long period of time (1901-2017) and its two sub-periods (1901-1950 and 1951-2017) may provide some clues and guidelines for taking appropriate strategies/policies for growth and development of Indian horticulture.

### A Review of Climate Change and Agriculture

Climate change refers to a broad array of alterations in climatic (long period) and weather (short period) conditions characterized by shifts in average conditions and in the frequency and severity of extreme conditions (Pathak, 2014). The Energy and Resource Institute (TERI) showed that global average temperature increases at an annual compound growth rate of 0.044 per cent and atmospheric concentration of Carbon Dioxide increases at the rate of 0.517 per cent during 2000-2013. The growth rate of emissions from fossil fuel burning is estimated to be significantly high of 3.124 per cent per annum during 2000-2012. Thus, climate change is an unavoidable phenomenon due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. The Framework Convention on Climate Change (UNFCCC) makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. (IPCC, 2014). The relationships between climate change and agricultural development may not be unidirectional rather it is very complex and non-linear. The extreme incidences like floods, drought, erratic or delayed rainfall, storms, cyclones, heat waves, frost due to global warming and increase in $CO_2$ and other Greenhouse Gases in the atmosphere have direct adverse impact on farming system. The abnormality in weather and climate change may reduce or even no production in agriculture (Singh, 2011). Agriculture and allied activities are not only be affected by climate change but also contribute to it through emitting greenhouse gases (FAO, 2008). The Intergovernmental Panel on Climate Change (IPCC, 2001) has already identified the three major causes of the increase in greenhouse gases in atmosphere: burning of fossil fuels, land use, and agriculture.

The negative impact of climate change has already been well recognized in the literature of the subject (IPCC, 2014; Mahato, 2014; Pathak, 2014). Climate based proper planning and management of (controlled) agricultural resources is now a critical task for all of us to uphold farming community. Adaptation and mitigation in agriculture due to climate change is another important issue to the policy makers to meet future challenges of food and livelihood security (ICAR, 2014). There are different ways of linkages between climate change and agriculture: (i) Change in temperature and precipitation may alter the distribution of agro-climatic zones, crops duration, water availability, soil erosion, and soil moisture and content etc, (ii) Increase in $CO_2$ is expected to have positive impact on agriculture in terms of higher rate of photosynthesis and reduce water use and increase water use efficiency, (iii) Climate variability and extreme events like floods, droughts, cyclones, hailstorms, frost, changing temperature etc result in huge agricultural losses and change timing of farm operations, (iv) Water availability or run off is another critical factor in determining the impact of climate change on agriculture. Soil moisture and content, timing and length of sowing season affect agriculture in various ways (positively or negatively) in different agro-climatic zones, (v) Water pollution is another factor which affect not only agricultural labour productivity but also quality of agricultural products and seeds, (vi) In addition to causing ecosystem damage water pollution affects health and thereby impairs economic productivity of labour. Water pollution is a major cause of concern in India; about 90 per cent of India's surface water resources are polluted to the extent that they are not fit for bathing (Dewan, 2014), (vii) Raise sea level due to climate change results in loss of land, coastal erosion, flooding, salinisation of groundwater which greatly affects land use patterns and agricultural production, productivity and profitability, (viii) People living on the coasts and floodplains, mountains, dry lands and Arctic are most at risk (FAO, 2008). Thus, characterization of climatic variables are important for an appropriate planning for proper selection, combination and management of the farm resources both at macro and micro levels which may enhance production, productivity, efficiency and income of farming community in India (Keysheet 6).

## Data Base and Methodology

For characterization of climate change in India we have considered two important elements of climate indicators - temperature and rainfall. Monthly, seasonal and annual (average, minimum and maximum) temperature data during 1901-2017 and Monthly, seasonal and annual rainfall data during 1901-2014 in India are retrieved from

https://data.gov.in/, Ministry of Earth Sciences, India Metrological Department (IMD). Food and Agriculture Organisation of the United Nations (FAOSTAT) and National Horticulture Board, Government of India are the major sources of time series data (1961-2016) on production of Indian horticulture crops. For analysis of data we have used graphical and econometric methods to infer results of the study (Stata, 2019; National Horticulture Board, 2019; Food and Agriculture Organization of the United Nations, 2019)..

Augmented Dickey-Fuller Test for unit root (1979) is used to check stationary of the relevant time series of data by using STATA software. There are three different models for Dickey-Fuller Test for unit root:

(i) $\Delta y_t = \beta y_{t-1} + \varepsilon_t$ (suppress constant term in regression)

(ii) $\Delta y_t = \alpha + \beta y_{t-1} + \varepsilon_t$ (include drift term in regression)

(iii) $\Delta y_t = \alpha + \delta t + \beta y_{t-1} + \varepsilon_t$ (include trend term in regression)

where, $y_t$= time series variable and the variable $\varepsilon_t$ is independently and identically distributed error term. It is assumed that $\varepsilon_t$ are uncorrelated.

But in case the $\varepsilon_t$ are correlated, they have augmented these equations by adding the lagged values of the dependent variable $\Delta$yt and the specification of the equation with trend in regression is as follows:

$$\Delta yt = \alpha + \delta t + \beta y_{t-1} + \sum_{j}^{k} \gamma_j \Delta y_{t-j} + \varepsilon_t$$

Where, k is the number of lags. The test statistic for H0: β = 0 is Z(t) = $\frac{\hat{\beta}}{\text{SE of } \hat{\beta}}$ If the coefficient β is significant that means the value of Z(t) > critical value (DF) then reject $H_0$ which implies that $y_t$ has no unit root i.e. the time series is stationary.

For analysis of properties of climate variables (rainfall and temperature) we have estimated mean, standard deviation, coefficient of variation (cv), maximum value and minimum value, and annual average compound growth of these variables during 1901-2017 and the two sub-periods of 1901-1950 and 1951-2017 (rainfall data are available up to 2014). Growth rate of the relevant variables are estimated by using semi-logarithmic stochastic regression equation:

$$\ln(y_t) = a + bt + \varepsilon_t$$

Growth rate (r) = ($e^{b^*}$-1) X 100, where b* is the least squares estimate of b.

To examine whether there is any long run relationship (i) between these climate variables (rainfall and temperature) in India during 1901-2014 and (ii) between production of Indian vegetables and climate variables (specially, minimum temperature) during 1961-2014, we have used cointegration and vector error correction (VEC) models. The VEC model is a special case of a more general framework dynamic model of the vector autoregressive (VAR) for variables that are stationary in their first differences. There are three important steps to run cointegrating VEC model: (i) obtain lag-order selection statistics by using different criteria- sequential likelihood-ratio (LR), Expected Prediction Error (EPE), Akaike Information Criterion (AIC), Hannan–Quinn information criterion (HQIC), and Schwarz Bayesian information criterion (SBIC); (ii) estimate the cointegrating rank of VEC model; and then (iii) estimate the VEC model. If the sign of the estimated coefficient of the error correction term (_ce1L1. in Stata) included in the VEC model is negative and statistically significant then it can be said that there is long run equilibrium relationship (causality) between the variables. For diagnostic checking in the estimated diferent models, we have used Breusch-Godfrey LM test for autocorrelation, ADF unit test in residuals and other specification tests in our time series regression analysis.

**Results and Discussion**

**Properties of Climate change in India**

The increasing temperature, especially minimum level of temperature during winter season, longer span of summer and delayed winter may severely decrease productivity of the most of the horticulture crops and increase risk to the farmers. There is a chance of increasing insect and pest attacks on crops which may hamper farming of winter crops. The descriptive statistics of the time series data on air temperature (1901-2017) in India are summarized in Table 1. Average monthly temperature during 1901-2017 increases from 18.42℃ in January to 28.30℃ in June and thereafter it decreases monotonically to 19.17℃ in December in India,. The mean temperature (monthly and annual) during 1951-2017 is estimated to be high compared to the mean temperature during 1901-1950. The rate of change in temperature in the second period over the first period is found to be greater in the months of January, February, March, and November –December. Variability of temperature in terms of coefficient of variation is also increasing over the two periods and such variability is observed to be greater in these months compared to other months. As a result variability in temperature across the different months within a year decreases. It is recorded that the minimum temperature (annual) was 23.56 ℃ in 1917 and the maximum temperature was 26.45℃ in 2016 in India. Maximum and minimum Monthly temperature in India was recorded as 30.78℃ in May, 1921 and 17.25 ℃ in January, 1918 respectively (Open Government Data(OGD) Platform India, 2015).

**Table 1: Characteristics of temperature in India during 1901-2017**

| | Mean temperature (°C) | | | %change in | Variability of temperature (Coefficient of Variation %) | | |
|---|---|---|---|---|---|---|---|
| Month | 1901-2017 | 1901-1950 | 1951-2017 | two sub-periods | 1901-2017 | 1901-1950 | 1951-2017 |
| JAN | 18.42 | 18.21 | 18.58 | 2.03 | 3.33 | 2.61 | 3.54 |
| FEB | 20.14 | 19.71 | 20.46 | 3.83 | 4.47 | 3.59 | 4.39 |
| MAR | 23.43 | 23.06 | 23.71 | 2.82 | 3.68 | 2.75 | 3.83 |
| APR | 26.51 | 26.27 | 26.70 | 1.65 | 2.83 | 2.39 | 2.94 |
| MAY | 28.39 | 28.35 | 28.42 | 0.24 | 2.27 | 2.32 | 2.25 |
| JUN | 28.30 | 28.19 | 28.38 | 0.69 | 1.63 | 1.50 | 1.66 |
| JUL | 27.37 | 27.29 | 27.43 | 0.49 | 1.26 | 0.96 | 1.42 |
| AUG | 26.94 | 26.82 | 27.03 | 0.81 | 1.30 | 1.06 | 1.35 |
| SEP | 26.34 | 26.14 | 26.49 | 1.35 | 1.47 | 1.04 | 1.49 |
| OCT | 24.74 | 24.54 | 24.90 | 1.46 | 2.28 | 1.76 | 2.42 |
| NOV | 21.77 | 21.42 | 22.02 | 2.80 | 2.91 | 1.96 | 2.94 |
| DEC | 19.17 | 18.80 | 19.46 | 3.51 | 3.32 | 2.33 | 3.16 |
| **ANNUAL** | **24.28** | **24.04** | **24.46** | **1.76** | **1.80** | **0.84** | **1.95** |

*Source: IMD, Govt. of India*
*Note: Annual Temperature: Minimum=23.56Cin 1917, Maximum=26.45Cin 2016*

## Properties of Rainfall

Regarding the properties of rainfall during1901-2014 it is observed that annual average rainfall (normal) decreases from 1187.27 mm during 1901-50 to 1167.77 mm during 1951-2014 with more or less same variability in annual rainfall during these two sub-periods. But there is a great variation in monthly rainfall in India. Rainfall (normal) is found to be high with low variability during the months of July to September in India compared to other months (Table 2). In most of the months, average rainfall decreases during 1951-2014 from the average rainfall during 1901-50. The minimum annual rainfall was 947.1 mm in 1972 and the maximum annual rainfall was recorded 1463.9 mm in 1917 during the period of 1901-2014. Maximum and minimum Monthly rainfall in India was recorded as 375.5 mm in July, 1959 and 1.6 mm in December, 1972 respectively.

**Table 2: Characteristics of rainfall (in mm) in India during 1901-2014**

| | Mean Rainfall (in mm) | | | %change in | Variability (CV) in Rainfall | | |
|---|---|---|---|---|---|---|---|
| Monthly | 1901-2014 | 1901-1950 | 1951-2014 | two sub-periods | 1901-2014 | 1901-1950 | 1951-2014 |
| JAN | 19.02 | 20.88 | 17.56 | -15.89 | 48.96 | 53.59 | 41.55 |
| FEB | 22.90 | 24.15 | 21.93 | -9.21 | 49.40 | 52.92 | 45.68 |
| MAR | 27.59 | 26.58 | 28.38 | 6.75 | 42.68 | 45.33 | 40.84 |
| APR | 37.71 | 38.43 | 37.14 | -3.35 | 26.51 | 25.91 | 27.10 |
| MAY | 62.60 | 62.43 | 62.73 | 0.48 | 25.18 | 28.28 | 22.73 |
| JUN | 167.96 | 171.23 | 165.40 | -3.41 | 21.11 | 23.64 | 18.79 |
| JUL | 289.62 | 294.76 | 285.60 | -3.11 | 13.81 | 13.69 | 13.85 |
| AUG | 256.74 | 254.61 | 258.40 | 1.49 | 13.27 | 13.98 | 12.77 |
| SEP | 172.25 | 174.04 | 170.85 | -1.84 | 20.74 | 21.32 | 20.40 |
| OCT | 76.50 | 73.85 | 78.58 | 6.40 | 36.71 | 38.34 | 35.57 |
| NOV | 29.82 | 31.61 | 28.42 | -10.09 | 54.98 | 55.98 | 53.83 |
| DEC | 14.94 | 14.71 | 15.13 | 2.79 | 59.91 | 56.56 | 62.66 |
| **ANNUAL** | **1176.32** | **1187.27** | **1167.77** | **-1.64** | **9.07** | **9.04** | **9.09** |

*Source: IMD, Govt. of India*
*Note: Annual Rainfall: Minimum= 947.1 mm in 1972, Maximum= 1463.9 mm in 1917.*

## Growth of temperature and Rainfall

The annual average compound growth rates of rainfall and temperature in India during a long period of time (1901-2017) and its two sub-periods are depicted in Table 3. Annual Rainfall in India increases at 0.353% per year during 1901-1950 significantly (at 1% level of significance) and the growth rate of rainfall during 1951-2014 is estimated to be negative (-0.119% per year) but significant at 5% level of significance. The growth rate of temperature (annual) is statistically significant of 0.067% per year during 1951-2017 and the growth rate of temperature during 1901-1950 is also positive (0.013%) but not significant. Differential rates of growth of population, urbanization, and industrialization during these two sub-periods may be responsible factors for such variation in growth rates in temperature in India. India's population increases from 238.4 million in 1901 to 361.1 million in 1951 (i.e., growth rate is 1.03% per year during 1901-1951) and 1210.2 million in 2011 (growth rate is 3.92% per year during 1951-2011). After independence, agricultural activities which require huge water resources are also increased significantly in India. The annual average compound growth rates of production of paddy, wheat, vegetables, and fruits are estimated to be 2.31%, 4.06%, 3.43% and 3.65% respectively and significantly during 1961-2016. The increase in temperature during October- December and January-February seasons may hamper the production of winter crops especially vegetables cultivation in India. The growth rates of this seasonal temperature are found to be quite high and statistically significant of 0.087% (October- December) and 0.102% (January-February) during 1951-2017. The corresponding growth rates of this seasonal temperature during 1901-1950 are also positive (0.014% and 0.009% respectively) but not significant. Thus, scanty rainfall and increase in temperature may impact adversely on production of horticultural crops in India.

**Table 3: Annual average compound growth rate of Rainfall and temperature in India**

| | Growth rate (%) of Rainfall | | | Growth rate (%) of Temperature | | |
|---|---|---|---|---|---|---|
| YEAR | 1901-2014 | 1901-1950 | 1951-2014 | 1901-2017 | 1901-1950 | 1951-2017 |
| JAN | -0.218 | 0.456 | -0.599 | 0.041 | -0.009 | 0.089 |
| FEB | 0.155 | 1.039 | 0.740 | 0.069 | 0.027 | 0.109 |
| MAR | 0.126 | 0.635 | -0.196 | 0.053 | 0.032 | 0.085 |
| APR | 0.010 | 0.556 | 0.043 | 0.034 | 0.004 | 0.069 |
| MAY | 0.053 | 0.678 | -0.152 | 0.016 | 0.027 | 0.058 |
| JUN | -0.007 | 0.367 | -0.039 | 0.015 | 0.010 | 0.031 |
| JUL | -0.030 | 0.486 | -0.172 | 0.014 | -0.005 | 0.043 |
| AUG | 0.009 | 0.145 | -0.134 | 0.020 | 0.009 | 0.047 |
| SEP | 0.007 | 0.412 | -0.044 | 0.027 | 0.017 | 0.047 |
| OCT | 0.093 | 0.566 | -0.289 | 0.032 | -0.002 | 0.073 |
| NOV | -0.025 | 0.231 | 0.323 | 0.054 | 0.003 | 0.102 |
| DEC | 0.005 | -0.320 | -0.112 | 0.064 | 0.042 | 0.092 |
| ANNUAL | -0.013 | 0.353 | -0.119 | 0.035 | 0.013 | 0.067 |
| Jan-Feb | -0.062 | 0.744 | 0.165 | 0.058 | 0.009 | 0.102 |
| Mar-May | 0.050 | 0.562 | -0.070 | 0.035 | 0.027 | 0.068 |
| Jun-Sep | -0.013 | 0.327 | -0.104 | 0.019 | 0.009 | 0.042 |
| Oct-Dec | 0.039 | 0.387 | -0.198 | 0.050 | 0.014 | 0.087 |

*Source: Same as in Table 1.*

### Co-integration and long run relations

Now, let us examine the long run relationship between these climate variables (rainfall and temperature) and how and to what extent increase in minimum temperature impacts on production of fresh vegetables in India with the help of conintegration and vetor error correction models. Estimated results of these regression models are summarized in Table 4 to Table 7. An analysis of results of ADF test for unit root in the climate variables and production of fresh vegetables given in Table 4 shows that annual rainfall, temperature and production of vegetables series are non-stationary at level but the variables are stationary at their first differences. We have considered lag-3 on the basis of Lag-selection order criteria (Table 5). Results of Johansen tests for cointegration suggest that there is cointegration between rainfall and temperature in

India (Table 6). Finally, estimated VEC model for the existence of long run relationship between rainfall and temperature is shown in Table 7. The coefficient of error correction term (_ce1) in the first model (rainfall) is significantly negative (-0.5961876 with *p*-value=000) which implies that there is a long run relationship between rainfall and temperature in India. In general, cultivation of vegetables in India requires low temperature. In order check whether there is any long run relationship between production of fresh vegetables and annual minimum temperature in India during 1951-2014 we have resorted to cointegration and VEC model. Results of Johansen tests for cointegration and VEC model are depicted in Table 8 and Table 9 respectively. An analysis of the results of estimated VEC model shows that the variables are co-integrated and there is also a long run relationship between production of vegetables and minimum temperature in India.

### Table 4: Results of ADF test for Unit root

| Variables | No of | Model 1 (no constant) | | Model 2 (with drift) | | Model 3 (with trend) | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | Obs. | Test statistics Z(t) | 1% critical value | Test statistics Z(t) | 1% critical value | Test statistics Z(t) | 1% critical value | |
| Rainfall | 110 | -0.254 | -2.599 | -4.037 | -2.362 | -4.096 | -4.037 | Non-stationary |
| D.Rainfall | 109 | -7.984 | -2.599 | -7.947 | -2.363 | -8.009 | -4.037 | Stationary |
| Temperature | 110 | 1.202 | -2.598 | 0.175 | -2.361 | -2.075 | -4.036 | Non-stationary |
| D.Temperature | 109 | -7.085 | -2.598 | -7.240 | -2.362 | -7.411 | -4.036 | Stationary |
| Vegetables-fr. | 52 | 1.197 | -2.619 | -0.933 | -2.408 | -4.147 | -4.146 | Non-stationary |
| D.vegetables-fr | 51 | -5.114 | -2.62 | -5.592 | -2.410 | -5.534 | -4.148 | Stationary |

*Note: D. indicates first difference of the variable. Lag=3*

### Table 5: Lag Selection-order Criteria

| Sample:1905-2014, Number of obs =110 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (Results of varsoc: Annual Rainfall and Annual Temperature in India | | | | | | | | |
| lag | LL | LR | df | p | FPE | AIC | HQIC | SBIC |
| | | | | | | | | |
| 0 | -702.961 | | | | 1263.590 | 12.818 | 12.837 | 12.867 |
| 1 | -671.815 | 62.292 | 4 | 0.000 | 771.376 | 12.324 | 12.384 | 12.4712* |
| 2 | -664.287 | 15.056 | 4 | 0.005 | 723.521 | 12.260 | 12.359 | 12.505 |
| **3** | -655.869 | 16.836* | 4 | 0.002 | 667.82* | 12.1794* | 12.3188* | **12.523** |
| 4 | -652.219 | 7.299 | 4 | 0.121 | 672.350 | 12.186 | 12.365 | 12.628 |
| Endogenous: rainfall, temperature | | | | Exogenous: _cons | | | | |

## Table 6: Results of Johansen tests for cointegration

(Dependent variables: Rainfall, Annual temperature)

Johansen tests for cointegration
Trend: constant Number of obs =110
Sample: 1905 - 2014 Lags = 4

| m aximum rank | parms | LL | eigenvalue | Test Statistics | 5% critical value |
|---|---|---|---|---|---|
| 0 | 14 | -661.96 | . | 19.4731 | 15.41 |
| 1 | 17 | -653.91 | 0.13604 | 3.3883* | 3.76 |
| 2 | 18 | -652.22 | 0.03033 | | |

Note: Stata command: vecrank rainfall annualtemp, trend(constant) lags(4)

## Table 7: Estimated Vector error-correction model

Vector error-correction model
Sample: 1905 - 2014
Log likelihood = -653.9131
Det(Sigma_ml) = 499.4837

No. of obs = 110
AIC = 12.19842
HQIC = 12.3677
SBIC = 12.61577

| Equation | Parms | RMSE | R-sq | $chi^2$ | $P>chi^2$ | |
|---|---|---|---|---|---|---|
| D_rainfall | 8 | 101.29 | 0.5299 | 114.98 | 0.000 | |
| D_annualtemp | 8 | 0.24 | 0.3527 | 55.57 | 0.000 | |
| | | | | | | |
| | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. Interval] | |
| D_rainfall_ce1 L1 | -0.596 | 0.154 | -3.880 | 0.000 | -0.897 | -0.295 |
| rainfall | | | | | | |
| LD. | -0.347 | 0.151 | -2.300 | 0.021 | -0.643 | -0.052 |
| L2D. | -0.008 | 0.141 | -0.060 | 0.955 | -0.285 | 0.269 |
| L3D. | 0.142 | 0.101 | 1.410 | 0.159 | -0.056 | 0.339 |
| annualtemp | | | | | | |
| LD. | 93.023 | 40.995 | 2.270 | 0.023 | 12.673 | 173.373 |
| L2D. | 80.091 | 41.168 | 1.950 | 0.052 | -0.596 | 160.778 |
| L3D. | 51.066 | 38.516 | 1.330 | 0.185 | -24.423 | 126.555 |
| | | | | | | |
| _cons | 0.000 | 9.684 | 0.000 | 1.000 | -18.980 | 18.980 |

**Table: 8 Results of Johansen tests for cointegration between Vegetables production and Minimum temperature**

Johansen tests for cointegration

Trend: constant — Number of obs = 53

Sample: 1964 - 2016 — Lags = 3

| maximum rank | parms | LL | eigenvalue | Test Statistics | 5% critical value |
|---|---|---|---|---|---|
| 0 | 10 | -876.06 | . | 17.112 | 15.410 |
| 1 | 13 | -867.56 | 0.274 | 0.117* | 3.760 |
| 2 | 14 | -867.50 | 0.002 | | |
| maximum rank | parms | LL | eigenvalue | Max Statistics | 5% critical value |
| 0 | 10 | -876.06 | . | 16.995 | 15.410 |
| 1 | 13 | -867.56 | 0.274 | 0.117 | 3.760 |
| 2 | 14 | -867.50 | 0.002 | | |

Note: vegf_p = Production of fresh vegetables,
annualtemp_min = Minimum annual temperature

**Table: 9 Results of estimated Vector error-correction model**
(Dependent variables: Production of fresh vegetables, Minimum annual temperature)

Vector error-correction model

Sample: 1965 - 2016 — No. of obs = 52

AIC = 33.37046

Log likelihood = -850.632 — HQIC = 33.61502

Det(Sigma_ml) = 5.54e+11 — SBIC = 34.00837

| Equation | Parms | RMSE | R-sq | chi2 | P>chi2 | |
|---|---|---|---|---|---|---|
| D_vegf_p | 8 | **2.9E+06** | **0.387** | **27.816** | **0.001** | |
| D_annualtemp_min | 8 | **0.308** | **0.422** | **32.107** | **0.000** | |
| | | | | | | |
| | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. Interval] | |
| D_vegf_p_ce1 | | | | | | |
| L1 | -0.285 | 0.124 | -2.300 | 0.022 | -0.528 | -0.042 |
| vegf_p | | | | | | |
| LD. | -0.278 | 0.163 | -1.700 | 0.088 | -0.597 | 0.042 |
| L2D. | 0.144 | 0.169 | 0.850 | 0.396 | -0.188 | 0.475 |
| L3D. | -0.068 | 0.152 | -0.450 | 0.652 | -0.366 | 0.229 |
| annualtemp_min | | | | | | |
| LD. | -4789676 | 2026727 | -2.360 | 0.018 | -8761988 | -817363 |
| L2D. | -4202388 | 1708874 | -2.460 | 0.014 | -7551719 | -853058 |
| L3D. | -2831149 | 1609738 | -1.760 | 0.079 | -5986176 | 323879 |
| | | | | | | |
| _cons | 0.000 | 528221 | 0.000 | 1.000 | -1035294 | 10352 |

## Impact of climate change on Horticulture

India produces several horticultural crops throughout the year with varied natural resources and diversified agro-climatic zones. India is the second largest producer of vegetables and fruits after China. Production of horticulture crops very much depends on the area under cultivation, quality of land, extent and efficient use of other non-land resources along with climatic conditions. In order to examine impact of climatic variables (rainfall and temperature) jointly with area under crops as exogenous variable on production of total vegetables and total fruits in India we run the following multivariate ARIMAX regression model which includes exogenous variable, crop land area. The model has great policy implications. We have considered log of the concerned variables because it may reduce hetroscedastity problem and interpretation of regression coefficients as elasticity. It is expected that both area under crop and rainfall have positive impact on production of horticulture crops but the increase in temperature may reduce production of these crops. ARIMA (1,1,0) Regression results are shown in Table 10. An analysis of the regression results reveals that models are statistically significant. An increase in temperature significantly reduces production of horticultural crops in India but increase in rainfall may increase production of these crops. Area under crop is a significant input for expansion of horticulture in India. Therefore, diversification of Indian agriculture in favour of horticultural crops may accelerate agricultural growth in India. As climate change is a natural phenomenon, appropriate agricultural research should be developed and to disseminate modern farming practices to mitigate adverse impact of climate change on production of horticulture in India.

### Table 10: Impact of climate change on production of horticulture in India

| Results of ARIMAX regression model Sample:1961 - 2014 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dependent variable | Coefficient of explanatory variables | | | | | | Likelihood - Log | Wald chi$^2$ | Prob> chi2 | ADF test in Residuals | |
| Log of Production of: | InArea | InTemp | InRain | | lag dep. Variable (ARMA) | | | | | Z(t) | 1% critical value |
| Vegetables | X1 | X2 | X3 | _cons | L1. | sigma. | | | | | |
| coefficient | 0.660 | -0.895 | 0.031 | 10.173 | 0.998 | --- | 98.16 | 4392 | 0.000 | -7.54 | -3.57 |
| (t-value) | 7.16 | -1.96 | 0.62 | 7.03 | 60.77 | | | | | | |
| (p-value) | 0.000 | 0.050 | 0.534 | 0.000 | 0.000 | | | | | | |
| Fruits | | | | | | | | | | | |
| coefficient | 1.220 | -0.551 | 0.038 | 0.533 | 0.626 | 0.047 | 88.14 | 701 | 0.000 | -5.34 | -3.58 |
| (t-value) | 21.85 | -0.74 | 0.58 | 0.22 | 4.31 | 9.32 | | | | | |
| (p-value) | 0.000 | 0.457 | 0.560 | 0.825 | 0.000 | 0.000 | | | | | |

*Note: In= log. Vegetables= log of production of vegetables including melon, Fruits= log of production of fruits excluding melon.*
*Sources: IMD, India for climate variables and FAOSTAT for horticulture production.*

## Conclusions and policy prescriptions

Firstly, the study identifies some characteristics of climate change in India during 1901-2017 and then examines long run relations between climate variables-rainfall and temperature and between climate variables and production of horticultural crops in India. Cointegration and vector error correction models, multivariate ARIMA model with exogenous variable, and different pre-estimation and post-estimation tests are used for analysis of these time series data to infer results of the study. The study reveals that production of vegetables and annual minimum temperature are cointegrated and there is a long run relationship between these variables in India. There is also a long run relationship between climatic variables under study. An increase in minimum temperature significantly reduces production of vegetables but rainfall has positive impact on production of horticultural crops. The estimated multivariate time series models suggest that in the changing climatic conditions, an increase in area under horticultural crops significantly improves production of vegetables and fruits in India.

An analysis of climate change between two sub-periods of 1901-1950 and 1951-2017 reveals that temperature increases at a high rate during the second period (1951-2017) as compared to the first period (1901-50). Annual variability of temperature is also high during the second period. This may be attributed by the rapid growth of population, urbanization, industrialization, expansion of cultivation of crops, and changing consumption pattern during the second period than the first period of time. Minimum temperature is increasing rapidly during October-December period than other seasons which may hamper production of winter crops in India. The growth rates of monthly, seasonal and annual rainfall during 1901-1950 are estimated to be positive but in most cases such growth rates are found to be negative during 1951-2014. There is a decreasing tendency in monthly variations in rainfall and temperature that may affect cultivation of huge varieties of seasonal crops in India. Thus, appropriate action should be taken to mitigate the adverse effect of climate change on Indian horticulture. There is a scope of increase in area under horticulture through the judicious selection, combinations and management of agricultural resources. Diversifications of Indian agriculture towards horticultural crops may accelerate agricultural growth in India. More emphasis should be given on agricultural research for innovation of suitable climate friendly crops and disseminations of modern farming practices among farmers.

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# Energy – A Geographical aspect and Economy

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## INTRODUCTION

The growth of developed countries is mainly based on fossil fuels (coal, oil, and natural gas), nuclear power, and other sources of electricity, while in developing countries biomass energy sources still dominate as these societies struggle to develop and modernize. The most recent works address energy and the challenges of climatic changes, renewable energy, and sustainable development.

Economic development depends on the availability of energy, especially in supporting the current government's development priorities, while the goal of development is to improve the nation's competitiveness. This research aims to investigate the opportunity to utilize and use the energy sources. The more powerful explanatory geographic variable is latitude, from the equator to the poles, the economy of a country and energy resources varies relatively.

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Another most important contribution is from rivers as they provide water for irrigation purposes and industrial uses. Rivers and lakes also act as disposal system of waste water.

Renewable technologies offer a way to increase energy supplies, however they are often more expensive or less efficient at producing energy than fossil fuels. Therefore, they often require government subsidies.

1. Biomass - This is recently-formed material derived from living things, e.g. chicken droppings. 'Energy from waste' plants burn biomass and non-recyclable rubbish to generate electricity.
2. Hydroelectric power (HEP) - HEP is generated when river water is trapped behind a dam and used to turn turbines. Most suitable locations for dam building throughout the world is surveyed continuously and planned accordingly.
3. Wave power and tidal power - Wave energy harnesses the power of small movements on the surface of the sea. The technology is new and currently expensive. Tidal energy harnesses larger movements of the tides.

4. Geothermal power - This uses heat within the Earth to generate electricity. This is easier where geothermal heat is more accessible, e.g. Iceland. There are few suitable locations where this resource can be accessed so geothermal energy is rare in many countries. Ground source heat pumps are a similar idea, but they use the heat from the Sun that is stored within the surface of the Earth.

5. Solar power – All countries want to increase the use of solar power. Solar panels can be fitted onto buildings or within fields. They turn sunlight into electricity. New technology is making solar panels able to generate electricity on cloudy days. Snow-based triboelectric nanogenerator (snow-TENG) is integrated in Solar panels used as an energy harvester based on the principle of snow-triboelectrification (Ahmed *et al.*, 2019).

New technology, Snow-Triboelectrification is making solar panels able to generate electricity on cloudy days

*Pic: Solar panels on roof in Malaysia*

6. Wind power - Wind turbines convert air movements into electricity. The turbines on the land (onshore) and turbines in the sea (offshore) though these are more expensive than onshore turbines both are used widely.

*Wind power- pic Kanyakumari, India, by Dr Sandeep Poddar*

### Non-renewable energy

Global energy use is still dominated by non-renewable energy. The use of non-renewable resources can be made more efficient. This could increase energy supplies as less fuel would be used.

1. Fossil fuels - Coal and gas power stations can now re-use wasted heat. These are called combined-cycle systems. Re-using heat makes the most out of the fossil fuels. Also, some power stations now burn small amounts of biomass alongside fossil fuels. This is called co-firing and it makes the fossil fuel last longer. Fracking could exploit shale gas, which would increase supplies of fossil fuels.
2. Nuclear power - Uranium fuel rods still have some uranium left within them after they have been used. Reprocessing recovers the uranium from spent fuel rods so that it can be reused. This doesn't create new supplies of uranium, but it does use

the existing supplies more efficiently. This means that uranium supplies will last longer. Reducing the use of fossil energy and switch to renewable energy. One of the efforts to improve long-term national energy security length is through reducing dependence on fossil energy, and the government must take swift action to use renewable energy.

reducing dependence on fossil energy-- switch to renewable

Most studies concentrate on the minimization of the power generation system cost as the objective function, which most frequently includes the investment cost of new generating technology, the fuel price, the fixed and variable operating costs. Other costs considered in literature are: salvage and dismantling costs (Cabello *et al.*, 2014; Aghaei *et al.*, 2013), emissions costs (Ahn, Woo, & Lee, 2015; Georgiou, 2016; Hu *et al.*, 2014; Hu *et al.*, 2013), cost of electricity not supplied (Delgado *et al.*, 2011; Feng & Ryan, 2013; Jeppesen *et al.*, 2016), imports of fuel and electricity (Koltsaklis *et al.*, 2014; Georgiou, 2016; Hu *et al.*, 2014; Hu *et al.*, 2013), cost of carbon capture and storage units (Jeppesen *et al.*, 2016), cost of transmission (Koltsaklis *et al.*, 2014; Zakerinia & Torabi, 2010) and cost of storage (Zakerinia & Torabi, 2010; Krukanont & Tezuka, 2007).Many works have been established to develop optimization models that incorporate uncertain inputs in the energy generation planning Loannou, Angus & Brennan, 2017).

World total electricity generation is expected to grow by 69% from 2012 to 2040 and make up almost a quarter of total energy consumption by 2040 (EIA, 2016). Increase in urbanization leading to a paradigm shift in the formation of energy mix apart from traditional fuels (Eom *et al.*, 2012; Krey *et al.*, 2012). Renewable energy technologies can achieve a reduction in total greenhouse gas GHG emissions from power production, their ability to satisfy demand largely depends on the renewable resource potential of the region. Future research could explore a broader range of possible future socioeconomic, urbanization, technological development and climate scenarios to capture various uncertainties. The generation of power depends on continued technological progress and breakthroughs (Vajjhala,2008). The economics of renewables is about profitability, and profitability depends on three drivers:

(1) Market price or value of renewable electricity;

(2) Cost of renewables relative to those of other energy resources; and

(3) Policies to promote renewables and environmental goals (particularly climate and energy security policies) that raise costs of using fossil fuels and/or subsidize costs of renewables.

**Points to note:**

Generation of different types of energy from different sources varies completely on geographical location of the place.

For example, if we look at the following 10 Largest Wind Farms, we can see it is widely distributed in different geographical location.

| Rank | Wind farm | Current capacity (MW) | Country | State/Province |
|---|---|---|---|---|
| 1 | Gansu Wind Farm | 7,965 | China | Gansu |
| 2 | Alta Wind Energy Center | 1,548 | USA | California |
| 3 | Muppandal Wind Farm | 1,500 | India | Tamil Nadu |
| 4 | Jaisalmer Wind Park | 1,064 | India | Rajasthan |
| 5 | Shepherds Flat Wind Farm | 845 | USA | Oregon |
| 6 | Roscoe Wind Farm | 781.5 | USA | Texas |
| 7 | Horse Hollow Wind Energy Center | 735.5 | USA | Texas |
| 8 | Capricorn Ridge Wind Farm | 662.5 | USA | Texas |
| 9 | Fântânele-Cogealac Wind Farm | 600 | Romania | Fântânele & Cogealac |
| 10 | Fowler Ridge Wind Farm | 599.8 | USA | Indiana |

*Source: https://www.worldatlas.com/articles/the-10-largest-wind-farms.html*

The value of generation from renewables will vary geographically and by time of day, because the marginal generator, which sets the electricity price, varies with location and over the course of the day with fluctuations in total electricity demand and available supply.

**Discussion**

Natural disasters can strike anyplace, and the happenings of recent years—hurricanes, cyclones, flooding rains—have ramped up the exertions of utilities to make for extreme weather. Nowadays power companies are employing technology to implement new protocols and evolve their best actions to more swiftly and safely re-establish power to affected areas. Efficacies must prepare for, and be prepared to respond to, all means of extreme weather.

We must comprehend the impact of alternatives when evaluating their use at a particular locale. The intensity of environmental impact would differ depending on geographic location, climate, and other factors. So, careful choices must be made about deployment of particular technologies so that the most abundant local resources can be employed most effectively, and overall impacts are minimalized. To generate profitable renewable energy the environmental factor must be considered Renewable energy brings social, environmental and economic growth. It provides many direct and indirect economic benefits to micro and macro level. Through this energy one can offer solutions for the dual objective of confirming economic development and the imperative to

> To generate profitable renewable energy the environmental factor must be considered

decarbonize economies around the globe. So, to generate profitable renewable energy the environmental factor must be considered. To develop sound policies, policy makers must understand the relative environmental impacts of alternative energy sources, the climatic condition, altitude and environmental impacts of renewable energy technologies of that place for proper improvements in energy efficiency. In this manner the sustainable renewable energy can be generated for the economic development of the country.

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