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Research Article

CLIMATE CHANGE AND ECONOMIC GROWTH: ISSUES CHALLENGES AND MITIGATION

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A R T I C L E I N F O

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A B S T R A C T

Climate change is a civilization-threatening consequence. Increasing temperature and more frequent natural disasters will impact the economy in many ways, inflicting damage on output and assets. Climate change induced
by greenhouse gas lowers profitability, reducing investment and cutting output in the short and long runs. Short-run employment falls due to deficient demand. In the long run productivity growth is slower, lowering potential income levels. This paper deals with economics of climate change with reference to carbon dioxide emission and economic growth, climate change mitigation option, cost of climate change mitigation, adaptation to climate change, modeling scenarios, cost-effectiveness, multi-criteria analysis and cost-benefit analysis. It outlines the global economic impact of climate change scenario and climate change economic effects. This paper makes a special note on climate change and Indian economic growth and climate change mitigation in India. This paper concludes with some interesting findings along with policy suggestions.

INTRODUCTION

“Climate change” is used to describe a change in the climate, measured in terms of its statistical properties in terms of the global mean surface temperature. In this context, “climate” is taken to mean the average weather. Climate can change over period of time ranging from months to thousands or millions of years. The classical time period is 30 years, as defined by the World Meteorological Organization. The climate change referred to may be due to natural causes in terms of changes in the sun's output, or due human activities by the way of changing the composition of the atmosphere. Any human-induced changes in climate will occur against the “background” of natural climatic variations. Sathaye *et al*., (2007) bring to attention that economic growth is a key driver of CO2 emissions and ultimately basic caused for manmade climate change. As the economy expands, demand for energy and energy-intensive goods increases, pushing up CO2 emissions. On the other hand, economic growth may drive technological change and increase energy efficiency. Economic growth may be associated specialization in certain economic sectors. If specialization is in energy-intensive sectors, then there might be a strong link between economic growth and emissions growth. If specialization is in less energy-intensive sectors in the services sector, then there might be a weak link between economic growth and emissions growth.

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William D. Nordhaus Contribution to Economics of Climate Change

In 2018, noble prize was awarded to William D. Nordhaus "for integrating climate change into long-run macroeconomic analysis". But he is one of the awardees of the Noble Prize. It clearly reveals that climate change has significant impact on economic growth. In 1994, Nordhaus published the now-famous Dynamic Integrated Climate-Economy model. This was the first major effort to develop a method of estimating the economic costs of climate change, and one of the first Integrated Assessment Models. It aims to measure the impact of environmental degradation on economic growth and to calculate the social cost of carbon, a key metric used by governments to design climate policy. It became one of the main analytical tools used to assess the damage posed by climate change.

Nordhaus’s work is so recognized because it took on the challenge of examining the feedback loop between human activity and the climate. He understood that nature is a constraint on economic activity but economic activity is also a constraint on nature. “Nordhaus became the first person to design simple, but dynamic and quantitative models of the global economic-climate system. These models allow for other researchers to simulate how the climate and economy will evolve together under different future assumptions, including the impacts of specific policy actions.

Nordhaus modelled the global emissions of carbon under four universal policies. The first scenario is a baseline estimate, in which no policies are adopted. In the second scenario carbon taxes start out at around $30 per metric ton of carbon dioxide and rise over time at about the same rate as global GDP. The third and fourth scenarios show would happen with carbon taxes six to eight times higher than the "optimal" level—and lead to far more drastic drops in CO_2 emissions. This work led Nordhaus to become an early advocate for a universal carbon tax.

The difference between these two types of effects matters when one starts to contemplate permanent changes to temperature: would a 1ºC permanent increase in temperature reduce per-capita GDP by 1.1 percentage points, or would it reduce the growth rate by 1.1 percentage points year after year. It is observed that higher temperatures reduce the growth rate in poor countries, not simply the level of output. Since even small growth effects have large consequences over time, these growth effects - if they persist in the medium run - imply very large impacts of permanent temperature increases.

One can find that temperature affects numerous dimensions of poor countries' economies in ways consistent with an effect on the growth rate. While agricultural output contractions appear to be part of the story, one can find adverse effects of hot years on industrial output and aggregate investment. Moreover, it is documented that poor countries produce fewer scientific publications in hot years, which suggests that higher temperatures may impede innovative activity. Higher temperatures lead to political instability in poor countries, as evidenced by irregular changes in national leaders. Many of these effects sit outside the primarily agricultural focus of much economic research on climate change and underscore the challenges in building aggregate estimates of climate impacts from a narrow set of channels. These broader relationships also help explain how temperature might affect growth rates in poor countries.

Review of the Studies on Economics of Climate Change

World economic activity is a cause of climate change and climate change impacts economic activity. Governments, firms, and individuals are grappling with establishing policies to reduce emissions of the greenhouse gases that are causing the climate to change - referred to as the mitigation of climate change - and facing up to the need to adapt to a climate that will change quite drastically whatever mitigation actions are taken. The most popular approaches to explaining historical emissions are the environmental Kuznets curve and the decomposition approach using the Kaya identity. These approaches can also be used to produce simple projections of future emissions given information on the relevant drivers.

Carbon dioxide Emission and Economic Growth

The environmental Kuznets curve (EKC) hypothesis proposes that concentrations or per capita emissions of various pollutants rise and then fall as per capita income increases. Shafik (1994) bring to attention that EKC for carbon dioxide among various other environmental indicators. The econometric estimates showed that per capita carbon emissions rise monotonically with per capita income within the observed range. If there is convergence in GDP per capita, then if the income emissions relation is monotonic there should also be convergence in emissions, at least conditionally. Strazicich and List (2003) examined the time paths of carbon dioxide emissions in twenty-one industrial countries from 1960 -1997 to test for stochastic and conditional convergence. They estimated both panel unit root tests and cross-section regressions. Overall, they found significant evidence that CO_2 emissions have converged.

Raupach *et al*. (2007) show that global emissions growth since 2000 was driven by a cessation or reversal of earlier declining trends in the energy intensity of gross domestic product (GDP) (energy/GDP) and the carbon intensity of energy (emissions/energy), coupled with continuing increase in population and per-capita GDP. Nearly constant or slightly increasing trends in the carbon intensity of energy were observed in both developed and developing regions and no region was significantly decarbonizing its energy supply. The growth rate of emissions was strongest in rapidly developing economies, particularly China.

Deforestation and land-use change is an important source of emissions of CO_2. Levels of emissions are much lower than from energy related sources, more stable over time, but also very uncertain. Houghton (2003) presents estimates of CO_2 emissions from land-use change from 1850 to 2000, globally and by region. In general, the level of annual emissions rises from 1 to 2 Gt C over the 150 years with an acceleration in the trend around 1950 in common with emissions from energy-related sources. Therefore, there is a clear link with economic growth. Tropical deforestation, particularly in Asia and Latin America is the dominant source of emissions. In recent decades there has been net reforestation in developed countries. The data are increasingly uncertain in recent decades with estimates from different researchers varying substantially.

An important greenhouse gas in the atmosphere and the second most important in terms of anthropogenic emissions is methane. In comparison to CO_2, relatively little work has been done on CH_4. Stern and Kaufmann (1996) used available data to reconstruct the first time series of historic emissions from 1860-1993. They found that anthropogenic emissions had increased from 80 million tonnes of carbon in 1860 to 380 million in 1990. The relative importance of the various emissions sources changed over time, though rice farming and livestock husbandry remained the two most important sources.

Stern (2007) described the climate change as "the biggest externality the world has ever seen" because the negative impacts from any person's or firm's greenhouse gas emissions are spread across the globe and over a long period of time. The release of green house gas is the outcome of economic production of goods and services. According to Barrett (1990) pollution externalities create coordination problems between countries, because from the perspective of a nation states, there are strong incentives for free-riding on other nations' mitigation efforts. There are also important questions about how the global mitigation effort should be distributed between nations in terms of burden sharing" or "effort sharing" and how reductions in emissions can be reconciled with economic development especially in the poorer nations.

Climate Change Mitigation Option

There is scientific consensus that reducing greenhouse gas emissions is necessary in order to reduce future climate change impacts and to limit the risk of extreme climate change impacts. The global consensus on climate change action is reflected in the 1992 UN Framework Convention on Climate Change, which states that "the ultimate objective of the Convention is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

The majority of economic analyses of climate change mitigation only look at the economic costs of policies to reduce emissions, not the economic effects of the resulting differences in climate change impacts. Weyant (1993) made works on climate change and such works contains thousands of applications using different modelling approaches most frequently computable general equilibrium models, but also partial equilibrium models, and engineering type models, as well as macroeconomic models - and applications to different scenarios, regions and economic sectors. It could be noted that the costs of climate change mitigation also focuses only on the costs of changing production systems to a lower-emissions technologies and practices, not on the potential co-benefits of mitigation action that may occur, in addition to less damages from climate change. Groosman *et al*., (2011) study deals with reduction in air pollution that goes hand in hand with reduced or more efficient use of fossil fuels, and which could yield large economic cobenefits.

However, there is also a research study that addresses the more complex empirical question of the optimal amount of mitigation, and the social cost of carbon emissions. The classic global models of optimal mitigation is William Nordhaus' (1996) DICE and RICE models and are referred to as "integrated assessment models" because they model simultaneously the costs of climate change impacts and the costs of climate change mitigation.

Economic models are by necessity limited in the extent to which they can incorporate detailed and reliable cost estimates. This is true in particular for future climate change damages which tend to be much more uncertain than estimates of mitigation costs. Most economic integrated assessment models use simple aggregate damage functions that translate temperature increases to changes in economic output. Ackerman *et al*., (2009) warn that these limitations are generally acknowledged by the creators and users of integrated assessment models, and have been highlighted in the critical literature.

A key limitation of assessments of the benefits of climate change mitigation are that typical economic analyses include only the impacts from climate change that are reflected in markets in terms of lower agricultural yields, greater costs for infrastructure maintenance, reduced labour supply due to illness, and so forth. Even these may not be completely covered, because some of the likely future market impacts are difficult to quantify. It is evident from the work done by Garnaut (2008) that nonmarket impacts may include the loss of ecological functions, reduction in quality of life, and loss of cultural values. It could be noted that economic analysis sometimes attempts to proxy these costs but the valuations necessarily remain subjective.

An important limitation is that climate change impacts are uncertain. Future physical impacts from climate change are subject to significant uncertainty, and this is compounded by uncertainty about how physical impacts will translate into economic effects. Some economic modelling exercises attempt to capture this uncertainty by doing a stochastic analysis of impact scenarios, and reporting results as averages over many different model runs. This approach was adopted for example by the Stern (2007) review, an report on the economics of climate change mitigation produced for the UK government.

The importance of the discount rate applied to climate change damages and mitigation costs is an key aspect of economics of climate change. The extent to which costs and benefits that occur decades or centuries into the future are valued today can be the decisive parameter choice in the empirical analysis of optimal mitigation and the social cost of carbon. Goulder and Williams (2012) argue that whether climate change analysis should follow a positive approach and use discount rates calibrated to observed interest rates in markets, or a normative approach.

Ramsey (1928) rule, where the dollar discount rate is the sum of the pure rate of time preference and the rate at which future generations' income should be discounted in order to account for the fact that they are expected to be richer than people today. The latter is a multiple of elasticity of the marginal utility of consumption and the future rate of economic growth. Stern (2008) made the case for a near zero pure rate of time preference in climate change analysis, and today this is a widely accepted normative assumption. However, Quiggin (2008) argues that there is ongoing debate about the relevant parameter range for the elasticity of the marginal utility of consumption. The social discount rate also relies on assumptions about the future growth in per capita income. Thus a wide range of different social discount rates can be justified, and they lead to different conclusions about the optimal extent of global mitigation. Economic welfare analysis of climate change policy is further beset by the necessity to aggregate individual welfare into a collective welfare function, putting a value on lives lost, and many other issues that require normative judgments. As a result, the question of how much the world should mitigate greenhouse gas emissions is not just one of economic analysis, but fundamentally one of ethics and values.

Cost of Climate Change Mitigation

The climate change impacts experienced and the associated costs and benefits will differ greatly across individuals, groups in society, and nations. The opportunities to reduce emissions and the costs of achieving a given reduction vary across countries, as does their economic capacity to pay for these costs. The annual contribution to global greenhouse gas emissions also varies greatly among countries on a per capita basis, and accumulated emissions time vary even more.

Developing countries occupy a special place in discussions of equity and effectiveness of global mitigation. The rising share of developing and industrialised countries in global emissions means that they will need to be fully engaged in mitigation for any effective global results. On the other hand, poorer countries have strong arguments on equity grounds that they should be free to catch up in their economic development, and that richer countries should pay for the cost of some or all of the mitigation action undertaken in poorer countries. The historical responsibility for greenhouse emissions already accumulated in the atmosphere lies predominantly with developed countries, a fact which has been used to underpin the argument that developed countries should shoulder the bulk of the global mitigation burden or the costs of a more distributed mitigation approach. In this connection, Ellerman *et al*., (2007) note that economic modelling of mitigation usually assumes that emissions reductions are made in the most cost-effective manner, usually represented by a uniform price signal on emissions, through an emissions tax or an emissions trading scheme. The largest such actual price-based scheme is the European emissions trading scheme.

In reality, many other types of economic and regulatory policies are being used for mitigation, which differ in their stringency and marginal costs, and have overlaps and interactions. Sorrell and Sijm (2003), bring to attention that overlapping policies will usually increase the economic costs relative to the first-best outcome. On the other hand, existing market failures will require specific interventions that go beyond uniform pricing of emissions. According to Jaffe *et al*., (2005) innovation of lower carbon technologies, where knowledge externalities can result in suboptimal private investment even in the presence of emissions pricing. Social rates of return on R&D are usually higher than private rates of return. Boyd (2012) and Kennedy (2013) argue that different policy instruments may also serve policy objectives that are distinct from but connected with mitigation, in terms of support for renewable energy technologies with the objective of giving new industries a competitive advantage or improving domestic energy security.

Adaptation to Climate Change

Adaptation to the impacts of climate change was generally regarded in the 1980s as a policy complement to the reduction (mitigation) of greenhouse gas emissions, but was largely ignored by the scientific community until the past decade or so. A particular problem in analysing adaptation to climate change is the varied effects and impacts that climate change will have and the ways these impacts will affect different activities and be experienced by individuals. Berkhout (2005) and Scheraga and Grambsch (1998) highlighted the difficulty of generalizing impact of climate change. The spatial impacts of climate change are likely to differ: although average global temperatures may have risen to date, some parts of North America have experienced falls, with increases in others. Different demographic groups will similarly experience the effects of climate change differently, and adapt to them in different ways. Even a single effect may simultaneously generate costs and benefits: increased water temperatures may reduce the viable habitat of cool water fish like trout, but increase that of other fish sought for recreational fishing. Implementation of adaptation measures may yield benefits but it also comes at a cost: both must be assessed in considering various trade-offs, including residual impacts. Different climate change effects may occur simultaneously, so their effects on complex systems cannot be considered independently.

Modeling Scenarios

Much of the early adaptation literature flowed from the focus of the IPCC on identifying and specifying the impacts of climate change scenarios. Burton *et al*. (2002) offer a number of reasons why 'models and climate scenario-based methods have not yielded useful results for the purposes of adaptation response and policy options'. Climate scenarios are generally global or regional, while adaptation needs to be site-specific, and is determined by extreme climatic events rather than the average values produced by climate models. Scenarios themselves only offer a range of possibilities in diverse fields such as health, education, energy, ecosystems etc, thus compounding the uncertainties of modeling climate impacts: decision makers have no concrete basis for making decisions. Further, impact analysis is not designed to assess alternative adaptation measures such as reducing perverse incentives such as long term drought support. Universal, 'obvious' adaptive responses also ignore the realities of local institutions, culture, and potential barriers to change. Human societies have always adapted to changes in climatic environments, so that adaptation policy should be considered more holistically, for example in the context of broader agricultural policy. Mercer (2010) takes a similar position in terms of considering climate change within the context of development policy.

Mendelsohn *et al*., (2000) and Tol, (2002) estimate the statistical and equilibrium models and the net costs of climate impacts with and without adaptation. Such broad scale studies tend to assume that some form of assumed or hypothetical adaptation will automatically occur, and that its marginal cost is equal to the marginal benefit of avoiding the impact. Hanemann (2000) critiques aspects of impact models, pointing out that adaptation may involve changes in preferences (habituation or hedonic adaptation) as well as in behaviour. In commenting on the Ricardian approach pioneered by Mendelsohn *et al*. (2000) to assess global market impacts of climate change on agriculture and other sectors, Hanemann (2000) contrasts it with agronomic models that estimate the impact of climate change on crop yields to predict the economic effect on agriculture. In contrast, the Ricardian approach uses cross-sectional data from different locations to estimate the effect on land values of changes in climate variables such as temperature or rainfall, while controlling for soil types and other geographic and socioeconomic factors. Different scenarios are then used to assess the impact of climate change on the value of farmland, and, by inference, on agricultural productivity. Although Hanemann's (2000) focus is on errors in estimation of the agronomic and Ricardian approaches, the author notes that the latter assumes that all farmers have identical choice sets in terms of crops to plant, costs, etc. More recent work by Kurukulasuriya and Mendelsohn (2008) seeks to integrate the agro-economic and Ricardian approaches by allowing for switching of output choices by African farmers, using a multinomial logit model while distinguishing different agro-ecological zones.

Cost-Effectiveness, Multi-Criteria Analysis and Cost-Benefit Analysis

Cost-effectiveness analysis is often used in everyday life, and it is easily presented to, and understood by policy makers. A measure of technical efficiency, it expresses a result in terms of the cost of achieving a specific objective. It could be noted that the number of lives saved for the cost of a dyke. De Bruin *et al*. (2009) made an application of multi-criteria analysis to identify and rank adaptation priorities in the Netherlands. Their study considers 96 specific adaptation measures for seven climate-sensitive sectors in the Netherlands.

Agrawala and Fankhauser (2008) assess adaptation measures in terms of so-called 'cost-benefit' analysis. However, such approaches are more accurately characterised as 'cost-cost' studies, because they compare the cost of implementing an adaptation measure with the cost of avoided damage due to climate change effects. While there is sometimes no alternative to using the 'damage costs avoided' approach, it can only provide a rough proxy for benefits in terms of willingness to pay or willingness to accept. It could be noted that flood damage to a household will generally underestimate economic costs because it will not include the value of destroyed photographs or other family memorabilia. Valuing the destruction of crops, on the other hand, may overestimate damage costs because farmers may adapt in future by planting alternative crops or by substituting capital in the form of irrigation drip systems. At the international level, estimating the likely costs of the impact of future climate change is a popular line of inquiry, probably because it provides a negotiating basis for requesting financial assistance. However, the estimation of damage costs alone provides little policy basis for determining the socially desirable extent or nature of adaptation activity. In this respect, Dietz and Maddison (2009) argue that surprisingly little is known 'about people's preferences for a particular climate or their willingness to pay to avoid negative impacts of climate change'.

Insurance

Hallegate (2009) and Adger *et al*., (2005) bring to attention that insurance as a means of ameliorating the financial consequences of the physical impacts of climate change. Linnerooth-Bayer and Mechler (2006) put forward the establishment of insurance-based climate risk funding as a particularly efficient way of channelling disaster relief to developing countries. Kunreuther and Pauly (2006) argue that ex-post disaster relief in the USA discourages investment in protective measures before disasters, resulting in unnecessarily costly and poorly targeted assistance after the event, especially before elections. Disagreeing with the view that 'charity hazard' associated with disaster assistance reduces incentives to purchase insurance Naess *et al*., (2005) and Raschky and Weck-Hannemann (2007) argue that people avoid even subsidised insurance because of misperceptions of risk, as well as premiums that are high relative to income.

Global Economic Impact of Climate Change Scenario

In May 2018, Stanford University scientists calculated how much global warming would cost the global economy. If the world's nations adhered to the Paris Climate Agreement, and temperatures only rose 2.5 percent, then global gross domestic product would fall 15 percent. If temperatures rose to 3 degrees Celsius, global GDP would fall 25 percent. If nothing is done, temperatures will rise by 4 degrees Celsius by 2100. Global GDP would decline by more than 30 percent from 2010 levels. That's worse than the Great Depression, where global trade fell 25 percent. The only difference is that it would be permanent.

The World Employment and Social Outlook 2018 estimated that climate change threatens 1.2 billion jobs. The industries most at risk are agriculture, fisheries, and forestry. Maine is already seeing a decline in its lobster catches. Natural disasters have already cost 23 million working life years since 2000. On the other hand, efforts to stop climate change would create 24 million new jobs by 2030.

Climate change is causing mass migration around the world. Immigrants are leaving flooded coastlines, drought-stricken farmlands, and areas of extreme natural disasters. Since 2008, extreme weather has displaced 22.5 million people according to the United Nations High Commissioner for Refugees. By 2050, climate change will force 700 million people to emigrate.

Dell, Jones, and Olken (2009) looking at a current cross-section of the world, national income per-capita falls 8.5% on average per degree Celsius rise in temperature suggesting a simple method to calculate how warming might influence future standards of living. However, while the magnitude of this correlation is impressive, its interpretation is uncertain. Sachs (2003) Acemoglu, Johnson and Robinson (2002), and Rodrik, Subramanian and Trebbi (2004), argue that substantial debate continues over whether the temperature-income relationship is simply a happenstance association, while other variables, such as a country's institutions or trade policy, drive prosperity in contemporary times. These uncertainties cloud not just the historical debate over climate's role in economic development but also, by extension, current debates about the potential impact of future climate change.

Mendelsohn *et al*. (2000), Nordhaus and Boyer (2000) and Tol (2002) bring to attention that the total economic effects of climate harnesses micro-evidence, quantifying various climatic effects and then aggregating these to produce a net effect on national income. This approach is favoured in the climate change literature and forms the basis of many current policy recommendations regarding greenhouse gas emissions. However, this approach, while useful, also faces difficult challenges. The set of mechanisms through which climate may influence economic outcomes is potentially enormous and, even if each mechanism could be enumerated and its operation understood, specifying how the micro-level effects interact and aggregate to shape macroeconomic outcomes poses additional difficulties. Indeed, the climate change research, at the micro level, suggests a wide array of potential climatic effects, including influences on agricultural productivity, mortality, cognitive performance, crime, and social unrest, among other outcomes, most of which do not feature in current implementations of these models.

Climate Change Effects on Inflation

Agricultural yields are sensitive to weather conditions and as our climate becomes ever more extreme, more frequent droughts may reduce crop yields in areas where food production is vital. Higher global food prices will likely thus squeeze consumers' income in the process. One must acknowledge that these effects will be partially offset as other regions becoming more suitable for crop production and new drought resistant crops are developed. However, in aggregate, and as the level of warming becomes even greater, food price inflation should rise.

Rising inflation may also materialize through reduced land availability. The surge in global temperatures may eventually cause some areas of the world to become uninhabitable and with this will come mass migration. Alongside the political and socioeconomic implications of these moves will be higher demand for an ever decreasing amount of land. In essence, the world's population will be forced to live in an increasingly concentrated space. In similar fashion to food inflation however, this effect will also be moderated by some areas of land becoming more habitable.

Increase in Cost of Renewable Energy

Higher energy costs are also likely to boost inflation. As our climate becomes more extreme we are likely to demand greater energy to both cool our working and living environments during the summer, and heat them when we experience harsher winters. Not only will energy demand change, but supply may shrink as the efficiency of existing power stations is compromised due to higher temperatures. Policy actions by governments to encourage a transition to green energy may further contribute to energy inflation in the short- to medium-term whereby taxes are placed on fossil fuel-derived electricity. Given that energy forms the basis of most of the world's production, the secondary effects of higher energy prices on inflation will be felt throughout the global economy. Conversely, depending on the pace of change, the greater prominence of renewable energy could limit the cost of energy increases going forward.

Increase in Cost of Insurance

The insurance industry recognizes that it is likely to bear much of the risk of global warming. Companies have already felt the force of extreme weather events on profits; from unseasonal floods in the UK to Hurricane Katrina in the US, extreme weather-related damage to properties has seen insurance companies pay out to cover these costs. It is believed that 2011 was the most expensive year on record for natural disasters, with insured losses costing the industry more than $126 billion.

The industry has been at the forefront of assessing climate risk, and as a consequence, the costs of global warming could be felt earlier than expected in the form of higher premiums. Rising insurance costs add to inflation and will deter firms and households from locating in areas at risk. From this perspective, the costs of climate change are already being incorporated into business decisions and in this way, are already affecting global activity. Insurance companies may go as far as to refuse to provide insurance cover, posing a challenge for governments who may either have to underwrite, and/or mitigate the risk of damage.

Climate Change and Economic Development

Climate change poses the serious challenge of carbon dioxide emission reduction. Emission control by developing countries is becoming a key for effective mitigation of climate change, as those countries now account for more than a half of global emissions and are still expanding their energy infrastructure. Substantial emission reduction in developing countries would require strong policy commitments and subsequent investments in a green economy. Some highly efficient, emission-saving production technologies could already be implemented without technical complexities. The challenge is therefore how to bring these technologies to countries that do not have the financial means to invest in them.

The successful implementation could generate a "triple dividend," that is, energy saving, emission reduction and job creation. In this sense climate change can be seen as a chance for economic development in these countries. Meanwhile, climate experts indicate that the damages of climate change will fall disproportionately on developing countries and particularly on the poor, which are the most vulnerable and least able to adapt. Those damages could inhibit economic development.

The World Bank estimates that developing countries will need $145-$175 billion for mitigation and $30-$100 billion for adaptation annually by the year 2030. However, the amount of international funding is currently $9 billion for both measures combined. There are two areas in which we need international solutions. The first is how to promote implementation of efficient technologies in developing countries. The second one is how to finance the adaption to climate change in developing countries. The first part can be solved not only on the political level, but to a high degree on a business level, particularly by multinational firms. How can we encourage the business sector in implementation of efficient technologies? What will be effective ways of public-private partnerships to achieve the goal? In order to solve the second part, there is a need for intensified communication between politics and development partners. How can we guarantee such communication given the multiplicity of institutions involving development assistance, which include bilateral aid organizations as well as multilateral ones such as UN institutions. Also, how should we set priorities in the distribution of funds in terms of finding a balance between financial support of climate change adaptation and conventional development aid, streamlining funding bodies for climate change adaptation and for other types of development assistance. Meanwhile, should governments also establish new mechanisms to raise such funds, such as the allocation of revenues from auctioning emission permits and the introduction of a new global tax.

Climate Change and Indian Economic Growth

Tom Kompas, Van Ha Pham and Tuong Nhu Che (2018), predict that Impacts of Global Warming (3°C) on the Indian GDP. The authors point out that global warming results in 1.023 per cent decline in Indian GDP in 2027, 2.99 per cent decline in 2037, 3.22 per cent decline in 2047, 5.532 per cent decline in 2067 and 10.351 per cent decline in the long run. Further they predicted that 1°C increase in temperature will reduce 2.92 per cent Indian GDP, 2°C increase in temperature will reduce 6.434 per cent Indian GDP, 3°C increase in temperature will reduce 10.351 per cent Indian GDP and 4°C increase in temperature will reduce 14.622 per cent Indian GDP. The authors estimated the long-term GDP loss per year under global warming scenarios in terms of US$ Billion per year to the year 2100. It could be at the rate of 4°C increase in global temperature results in GDP loss of 4,484.96 US$ Billion per year, at the rate of 3°C increase in temperature results in GDP loss of 2,070.06 US$ Billion per year, and at the rate of 2°C increase in global temperature results in GDP loss of 1,149.36 US$ Billion per Year.

The farm sector in India is in distress and several state governments have responded with loan waivers, which could affect their fiscal math and the ability to push capital expenditure at a time when the Indian economy has slowed significantly. This comes after India faced deficient rainfall for two consecutive years in 2014 and 2015. According to estimates, production of kharif crops in the recent year is expected to decline by 2.8% because of an uneven monsoon. The possibility of such weather events is likely to increase in the future. And that means a serious challenge for a country like India where about 50% of the population directly or indirectly depends on agriculture for a livelihood.

As per the report by IMF over the years, India has done well to reduce its dependence on the monsoon, which is evident from the fact that two successive years of drought did not result in runaway inflation. However, more needs to be done to enhance productivity in the agriculture sector. Financial losses can be reduced by higher penetration of insurance products.

Further, India can work on programmes that will help improve the quality of land and reduce the risk of climate change. In Ethiopia, for example, food and cash is provided to the poor who participate in local environmental programmes. This has resulted in reduction in soil loss and has increased the availability of water. India can perhaps use employment under the Mahatma Gandhi National Rural Employment Guarantee Act in a better way to enhance soil and water conservation. India also needs to strengthen its overall capability by investing in and adopting technology as the impact of climate change is not limited to agriculture. For instance, better use of technology can reduce energy consumption for air conditioning. A district cooling system is being constructed in Gujarat International Finance Tec-City. It will be interesting to see if this can be adopted in other cities as well.

A study by the World Bank indicates that due to rising temperatures and changing monsoon rainfall patterns from climate change, India's gross domestic product (GDP) may dip by 2.8 percent amounting to $1177.8 billion by 2050. The living standards of nearly half the country's population will get depressed. Chhattisgarh and Madhya Pradesh will be the worst affected and may face more than nine percent decline in their current living standards. Out of the top 10 most affected districts in India belong to the Vidarbha region of Maharashtra with the remaining three districts located in Chhattisgarh and Madhya Pradesh. In all, a carbon-intensive climate scenario is likely to impact lives of about 800 million people in South Asia of which 600 million will be in India. They reside in areas identified as "climate hotspots"—areas where the impact of climate change on living standards is expected to be the most severe.

The report, South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards, released on June 28, 2018, in New Delhi predicts that climate hotspots may see an 11-12 percent dip in living standards, measured in terms of consumption expenditure. These hotspots were mostly found to be water-stressed with minimal access to electricity and roads. They are not necessarily in higher temperature zones but reflect the local population's socio-economic capacity to cope with the climatic changes.

The report provides a granular, spatial analysis of the long-term impacts of changes in average temperature and precipitation. It uses climate data in combination with household surveys to explain how changes in average weather will affect living standards. It provides long-term forecasts at a district level. The report also analyses two future climate scenarios—"climate-sensitive" in which some collective action is taken to limit greenhouse gas emissions and carbon-intensive" in which no action is taken. India's average annual temperatures are expected to rise by 1°C to 2°C by 2050 even if preventive measures are taken along the lines of those recommended by the Paris climate change agreement of 2015. If no measures are taken, the average temperatures in India are predicted to increase by 1.5°C to 3°C by 2050.

Climate Change Mitigation in India

India's Integrated Energy Policy Report (IEP) (2006) estimates that India needs to increase primary energy supply by 3 to 4 times and electricity generation by 5 to 6 times to meet the lifeline per capita consumption by 2031, and sustain economic growth at 8 % with an equivalent installed capacity of 320 to 332 GW. To address these needs, India needs an order-of-magnitude increase in renewable energy growth in the next decade, and substantive success in its demand side management and energy efficiency programs.

A number of analyses have been done to assess potential measures for India to achieve low carbon growth which have established that India is following a path of low-emissions growth. India's 12th Five Year Plan is expected to include a lower GHG emission inclusive growth strategy in order to achieve the voluntary mitigation goal of reducing GHG emissions intensity of GDP by 20 to 25 percent by 2020 against a 2005 level. An Expert Group on Lower Carbon Strategies for Inclusive Growth is currently working to provide inputs on identification of sectors and mitigation actions along with their financial and technological implications.

The scale of the growth of energy demand in India raises questions about the time path of the country's GHG emissions. Various modeling projections indicate that the largest share of greenhouse gas emissions in India will continue to be from the power sector (captive generation and grid supply) by 2032. For instance, the Expert Group indicated that should India wish to sustain 9 percent economic growth until 2020, it will need to increase its installed capacity to 377 GW (from current levels of 172 GW). According to these projections, emission from the power sector could be in the range of 1452 to 1620 million tonnes of CO_2 equivalents by 2020 (from the current 719 million tones of CO_2 equivalent). Hence, any effort in this sector, whether on the introduction of renewable sources of energy, or on the reduction on the demand, has the potential to significantly reduce the total quantity of emissions against a business as usual scenario.

Government of India has already identified a range of initiatives that form a core part of the climate strategy of India. It is important to ensure that the strategies are translated on the ground through comprehensive programs that are aligned to the strategies. These programs need to be provided with adequate funding as well as other essential implementation support to ensure that the strategies are converted to action on the ground that yield the desired outcomes.

Investment Plan for Clean Technology Fund

The power sector programmes require foremost attention. This sector has traditionally fallen behind the emerging demand requirements resulting in chronic imbalances between demand and supply. Lack of adequate utility supply has resulted in use of expensive and inefficient back-up power resources. Even as coal based generation would continue to be a mainstay for some time, alternative approaches for catering to the growing demand need to be promoted on a very large scale. This would primarily be in the area of renewable energy. Simultaneously, energy efficiency measures must be promoted and lent the scale that permits significant reductions in energy intensity of India's GDP growth.

Government of India has identified a range of interventions that could support its climate and sustainable growth strategies. An inventory of these potential strategies is annexed at the end of the report. For Clean Technology Fund (CTF) financing, a priority set of initiatives to which such interventions will be addressed in the initial phase has been identified. For subsequent Phase of financing, the immediate priorities identified by Government of India in accordance with its National Action Plan on Climate Change and the lower carbon inclusive growth strategy would need to be covered.. In the subsequent phases larger number of interventions covering a wider set of sectors and interventions could be taken up with the funds dedicated to addressing climate change in accordance with agreed principles of international actions in this field.

The reduced energy intensity of the Indian economy has been marked by over nine per cent per annum economic growth rate. This reduced energy intensity, at the relatively low level of India's per-capita GDP, has been made possible by a range of factors, including India's historically sustainable patterns of consumption, enhanced competitiveness, proactive policies to promote energy efficiency, and more recently, the use of the Clean Development Mechanism to accelerate the adoption of clean energy technologies.

In order to meet the challenge of increasing power requirements, India will need to pursue all available forms of energy. The current energy share of coal is 53 per cent, 31 per cent of oil, 9 per cent of natural gas and 6 per cent of hydropower, whereas the share of nuclear energy is merely 1 per cent. If this mix remains the same then it is estimated that by 2030-31, India would have to import 66 per cent of its coal, 90 per cent of its oil and 60 per cent of its natural gas.

CONCLUSION

It could be seen clearly from the above discussion that the climate change has significant impact on economy and economic growth throughout the world. It could be noted that William D. Nordhaus contribution to economics of climate change received the 2018 Noble prize in economics and it clearly reveals the influence of climate change in determining economic growth across the nations. Many research studies have been conducted focusing on climate change impact on economic growth and release of pollutants and green house gases during the production of economic goods and services. Such type of release of pollutants and green house gases during the production of economic goods and services results in climate change. Hence there is a need to mitigate the negative impact of climate change an environment by the way of adoption of clean development mechanism renewable energy consumption, application of green chemistry principles in production of goods and services. In order to promote mitigation of climate change, the following measures can be considered.

- Facilitate the strengthening of institutional and policy framework for addressing climate change
- Support the integration and implementation of climate change and adaptation strategies in economic and development activities at national and sectoral level
- Promote the use of evidence-based approaches to policy planning and programming related to climate change and development
- Promote broad-based participation in the formulation and implementation of a national climate change Strategy and Policy
- Create awareness of National Climate Change Strategy and Policy

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