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GLOBAL CLIMATE CHANGE: CAUSES, CONCERNS AND ECONOMIC CONSEQUENCES

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ABSTRACT

Since the nineteenth century, scientists have been aware of the planetary impacts of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere which is a global common into which individuals and firms can release pollution. Global pollution creates a "public bads" affecting every one---a negative externality with a wide impact. In recent decades, concern has grown over the issue of global climate change caused by increased accumulation of these gases. Evidence for climate change abounds, from the top of the atmosphere to the depth of the oceans. Putting climate change in the framework of economic analysis, we can consider greenhouse gas emissions, which cause planetary warming and other changes in weather pattern, as both a cause of environmental externalities and a case of the overuse of a common property resource. Scientists have modelled the results of a projected doubling of accumulated CO_2 in the earth's atmosphere. Some of the many negative predicted effects are—loss of land area, including beaches and wetlands, sea-level rise, loss of species and forest area, disruption of water supplies to cities and agriculture, increased air conditioning costs, health damage and deaths from heat waves, spread of tropical diseases and losses of agricultural output due to droughts etc.Economists perform a cost-benefit analysis, they weigh the consequences of the projected increase in carbon emission versus the costs of current policy actions to stabilize or even reduce CO_2 emissions. Strong policy action to prevent climate change will bring benefits equal to the value of damages that are avoided and these benefits of preventing damage can be referred to as avoided cost. Further without policy intervention, carbon emission in a business-as-usual scenario would be expected to continue to rise. As regard to policy responses to climate change, adaptive measures to deal with the consequences of climate change and mitigation or preventive measures intended to lower the magnitude or timing of climate change are significant here. Under this backdrop, the present work is an attempt to provide an economic analysis of the causes and consequences of global climate change and suggest some remedial measures for the benefit of global commons.

KEY-WORDS: Global Climate Change, Impact of climate change, Green house gases, Global commons, Public bads, Cost-benefit studies, Adaptation, Mitigation etc.

1. INTRODUCTION

Since the nineteenth century, scientists have been aware of the planetary impacts of carbon dioxide (CO_2) and other green house gases in the atmosphere. In recent decades, concern has grown over the issue of global climate change caused by increased accumulation of these gases. The problem of Global Warming is more accurately called Global Climate Change. Multiple studies published in scientific journals show that 97 percent or more of climate scientists agree that climate-warming trends over the past century are extremely likely to be due to human activities (Cook et al, 2016).The 2013 and 2014 Reports of the Intergovernmental Panel on Climate Change (IPCC) clearly attribute the majority of recently observed global climate change to human–made green–house gas emissions. The IPCC

projects a temperature increase by 2100 of between 1.5℃ (8.6℉), relative to pre-industrial levels.

U.S. Global Change Research Programme (2014) states ---

"Evidence for climatic change abounds, from the top of the atmosphere to the depth of the oceans. Scientists and engineers from around the world have meticulously collected this evidence, using satellites and networks of weather balloons, observing and measuring changes in locations and behaviours of species and functioning of ecosystems. Taken together, this evidence tells us unambiguous story: the planet is warming, and over the half century, this warming has been driven primarily by human activity".

Putting global climate change in the framework of economic analysis, we can consider greenhouse gas emissions as both a cause of environmental externalities and a case of the overuse of common property resources, which causes planetary warming and other changes in the weather patterns. Although, economic analysis of climate change is a comparatively new issue, numerous studies have estimated the impacts of climate change on economic growth in different regions of the world. Due to climate change, some sectors may grow faster in comparison to the others and at the same time, the size and composition of some countries' Gross Domestic Product (GDP) may change. Climate change may also affect the long-term growth potential of the country. Furthermore, the effects of climate change are not homogeneous within countries; it was found that agriculture, coastal zones and elderly people are more heavily affected than their counterparts (Lucas and Valente, 2011). According to Stern and others (2006), in the next fifty years, world temperatures are expected to rise 2-3℃. This increase will have severe consequences on economic development as it will affect water quality, agricultural productivity and human health. It was further calculated that about 5 percent of global GDP per annum would be lost by these impacts.

A strong correlation exists between energy consumption and economic growth. Energy use results in accelerating Green House Gas (GHG) emissions. Estimates indicate that approximately 75% of all CO_2 emissions have come from developed countries. These results imply that economic growth depends on energy usage that leads to environmental degradation (Grossman and Krueger, 1995; Hitz and Smith, 2004). Recently, accelerating emissions of GHGs in developing countries, especially in emerging economies, such as Brazil, China and India, have raised serious concerns about the relationship between climate change and economic growth. Although climate change may initially have some positive effects for some developed countries, it will be destructive in the long-run (Hope, 2006).

Dell, Jones and Olken (2008) found that because of climate change, the growth rate of poor countries would be reduced by 0.6 to 2.9 percent points. According to Fankhauser and Tol (2005), climate change affects capital accumulation and people's propensity to save, which, in turn reduces economic growth. By using different growth model specifications, it was found that dynamic effects are relatively larger as compared to direct or static impacts of climate change. Moreover, the impacts of climate change are not evenly distributed. The poorest countries and people feel the adverse impacts of climate change first and will suffer the most from them as these countries are more vulnerable to the negative effects of rising sea level and the impact on water resources, ecosystems, crop production, fisheries and human health (Nordhaus,1991). In less developed countries, a large percentage of the population is dependent on climate-sensitive sectors and there is low capacity to develop and implement adaptation strategies. Nevertheless, these countries have to bear the cost for promotion and adoption of different mitigation strategies (Adger, 2006).

Evidence is growing that changes in the climate system are contributing to a range of biophysical and economic impacts that are already affecting the economy. Future impacts are expected to be much larger (IPCC, 2014). Asian Countries collectively encompass the world's greatest economic, cultural and ecological diversity. About 60 percent of the world's population live in these countries, making Asia the most populated continent. The total economic activities of Asia make up about 25% of the world's GDP (World Bank, 2010). Consequently, the region is facing many environmental and socio-economic challenges.

According to Lecocq and Shlizi (2007), GDP will be affected indirectly by variations in demand structure even though there is no direct effect of climate change on it. Climate change can result in resource scarcity which could lead to violent conflict and consequently reduce economic growth in the long run (Zhang and others, 2007; Tol and Wagner, 2010). Parry and others (2007) projects that a decline in water supplies stored in glaciers and snow cover will result in water scarcity. If global average temperature increases by 1.5—2.5℃ then approximately 20-30 percent of plant and animal species will face the danger of extinction. An increase of temperature in the range of 1-3℃ has the potential to increase food production but an increase in temperature beyond that would result in a decline in food production. As temperature and precipitation are direct inputs in agricultural production, many believe that the largest effects of climate change will be on agriculture. However, under the conditions of climate change, agriculture production rises in the higher latitudes, partly because of an increase in arable land and production trends to fall in the tropics mainly due to an assumed decline in the availability of water (Cooper,2000; Parry and others,2007).

Thus, climate is the key factor which determines the distribution of vegetation. The relation of climate change to the conservation and development of the world's forests is therefore, an important issue to consider. Forests can contribute to the greenhouse effect; they can also be affected by climate change and they offer opportunities to mitigate its effects. Under this backdrop, the present study is an attempt to provide an economic analysis of the causes and consequences of global climate change with a review of the studies of global climate change and suggest some remedial measures for the benefit of global commons and the study is a purely theoretical analysis based on secondary data.

2. THEORETICAL APPROACHES

There are two types of approaches which are most widely used for analysing the impacts of climate change on economic growth. They are the enumerative approach and the dynamic approach. In the enumerative approach, the economic impacts of climate change are analysed separately sector by sector, such as the effects of climate change on agriculture, the ecosystem or tourism (Nordhaus, 1991). These effects are evaluated together to obtain an estimate of the total change in social welfare stemming from climate change (Cline, 1994; Tol, 1995).In this approach, the effects of climate change are analysed by focusing on only one period . Intertemporal effects are ignored. These studies, however, have failed to provide information on how climate change may affect welfare in the long run. This approach also ignores the significant 'horizontal interlinkages', such as the interaction of sectoral impacts. It mostly uses computable general equilibrium (CGE) models and simulation techniques.

In the dynamic approach, different specifications of growth models are used by incorporating the damage function. The Solow-Swan and Ramsey-Cass-Koopmans Models are most widely used Growth Models for analysing the impacts of climate change on economic growth. The

Mankiw, Romer and Weil (1992) Model is also applied (Fankhauser and Tol; 2005), but to a lesser degree. In all three of these models, under the assumption of a constant savings rate, it has been found that if climate has a negative impact on output, then the amount of investment will also be reduced. In the long run, capital stock and consumption per capita will decline, which will result in shrinking aggregate demand and will adversely affect GDP. In an endogenous growth model, the situation becomes even worse if lower investment slows the technical progress and improvement in labour productivity or human capital accumulation (Lecocq and Shalizi, 2007).

3. STUDIES OF GLOBAL CLIMATE CHANGE –A REVIEW

Economic analysis of climate change has been done by various eminent environmental economists. The studies have estimated the impacts of climate change on economic growth in different regions of the world. Most of these studies are numerical in nature and a bit speculative but they do not provide a solid foundation for future research. In their study, O'Brien, Sygna and Haugen (2004) found that due to climate change, some sectors of the economy may grow faster in comparison to the others and at the same time, the size and composition of some countries' Gross Domestic Product (GDP) may change. Climate Change may also affect the long-term growth potential of the country. Furthermore, the effects of climate change are not homogeneous within countries. It was found that agriculture; coastal zones and elderly people are more heavily affected than their counterparts. According to Stern and others (2006), in the next fifty years, world temperatures are expected to rise 2-3℃. This increase will have severe consequences on economic development as it will affect water quality, agricultural productivity and human health. It was further found that about 5% of global GDP per annum would be lost by these impacts. But Weitzman (2007) has criticised these findings by indication that there are uncertainties associated with the measurement of the impacts of climate change and the conclusions drawn were based on a very low discount rate. According to Fankhauser and Tol (2005), climate change affects capital accumulation and people's propensity to save, which, in turn, reduces economic growth. By using different growth model specifications, it was found that dynamic effects are relatively larger as compared to direct or static impacts of climate change.

Dell, Jones and Olken (2008) found that because of climate change, the growth rate of poor countries would be reduced by 0.6 to 2.9 percentage points. Climate change and saving is interrelated as found by Calzadilia, Pauli and Roson (2007) who concluded that extreme weather would result in savings. This is based on the assumption that in line with expectation that global damage would increase, people would increase savings to avoid the anticipatory negative effects of climate change. Notably, extreme weather is expected to boost investment as well. According to Lecocq and Shalizi (2007), GDP will be affected indirectly by variations in demand structure even though there is no direct effect of climate change on it. Climate change can result in resource scarcity, which could lead to violent conflict and consequently reduce economic growth in the long run (Zhang and others, 2007).

A decline in water supplies stored in glaciers and snow cover will result in water scarcity. If global average temperature increases by 1.5-2.5℃ then approximately 20-30 percent of plant and animal species will face the danger of extinction. An increase of temperature in the range of 1-3℃ has the potential to increase food production but an increase in temperature beyond that would result in a decline in food production. A rise in sea surface temperature of 1-3℃ would cause more frequent coral bleaching events and widespread mortality. Unless there is thermal adaptation or acclimatization by corals (Parry and others, 2007), sea level rise will

negatively affect the coastal wetlands, including salt marshes and mangroves (Nicholls and Tol, 2006). Projections made by Agrawala and others (2003) reveal that the economy of Bangladesh is affected by climate change through sea level rise, higher temperatures enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation and an increase in cyclone intensity. This situation has created serious hurdles for the sustainable economic development of the country. Temperature and precipitation are direct inputs in agricultural production, many believe that the largest effects of climate change will be on agriculture. However, under the conditions of climate change, agriculture production rises in the higher latitudes, partly because of an increase in arable land and production tends to fall in the tropics, mainly due to an assumed decline in the availability of water (Cooper,2000).

Gregory, Ingram and Brklacich (2005) suggested that climate change was playing an important role for agriculture but its relative importance varied among regions as well as among different societal groups within a region. For example, in Southern Africa, climate is among the most frequently cited driver of food insecurity. In other parts such as the Indo-Gangetic Plain of India, other factors such as inefficient labour, availability and quality of ground water for irrigation, ranked higher than the direct effects of climate change as a factor influencing food security. Climate change can affect food systems in several ways such as having direct effects on crop production through changes in rainfall and temperature. Changes in rainfall lead to drought or flooding, whereas warmer or cooler temperatures will change the length of the growing season.

Mendelsohn and Dinar (1999) found in their studies that higher temperature would reduce grain yields. They also found that India and Brazil had attempted to minimize the effects of global warming on agriculture and that individual farmers had played a very crucial role in that regard. The effect of climate change on livestock systems is very important. The impacts of climate change on live stocks in developing countries are relatively neglected research area. While discussing about a report of the World Health Organization, Gilbreath (2004) states that climate change may increase the risk of death and suggests that most of the diseases common in developing countries are sensitive to climate change. The discussion also notes that even a proportionately small change in the global incidence of some diseases could result in significant public health impacts. It has been estimated that in some regions, the effects of climate change will increase the risk of diarrhoea to 10% in 2030 from the 1990 level.

Environmental regulations are generally perceived to impose constrains on production, which lead to harmful impacts on economic growth. It is argued that the effects of environmental policy on economic growth vary through the stages of development (Bretschger and Smuldus, 2001). Environmental regulations will enhance the prospects for growth if improved environmental quality increases the productivity of inputs. Because environmental regulation promotes pollution abatement activities, increasing the returns to scale and these regulations can also stimulate innovations (Ricci, 2007).

Greiner (2004) has found that an increase in GHG emissions will negatively affect the aggregate output and the marginal productivity of capital and that higher abatement activities might reduce GHG emissions and lead to higher economic growth. Tol (2009) has also argued that GHG emissions had severely affected economic development and called for a higher carbon tax to reduce the emissions. It is worth mentioning here that the variation in climate and geographic features among Asian Countries is very large. On the other hand,

South-east Asia and the Pacific Island generally experience temperatures above 25℃ throughout the year. Consistent with global temperature trends, Asian Countries have also been experiencing a warming trend in recent decades. Climate modelling indicates an increase in temperature in Asia by 0.5-2℃ by 2030 and 1-7℃ by 2070 and predicts that arid areas of Northern Pakistan and India and Western China are likely to warm more quickly. In addition, models indicate increasing rainfall during the summer monsoon season and a reduction in winter rainfall and predict that Asia will also be affected by a rise in global sea level of approximately 3-16cm by 2030 and 7-50cm by 2070(Parry and others,2007).

Climate change is resulting in the degradation of land, ecosystems, water and air quality in Asian Countries. It is threatening to undermine food security as well as causing health problems. Crop yields are estimated to fall by up to 30% and one billion people may be affected by a water shortage, leading to drought and land degradation by the 2050s (Christensen and others, 2007). Climate change has also resulted in the melting of the Himalayan glaciers which in the short run has raised the risk of mud slides, erosion and flooding. The health impacts primarily consist of epidemics of malaria, dengue and other vector-borne diseases (Martens and Others, 1999).

Notably, Asia is dealing with increasing cases of natural hazards, such as landslides in the Philippines (2006), extreme weather events in China (2006) including storms, flooding in the east and south, heat and drought in the central and north-eastern regions and catastrophic floods in Pakistan (2010 and 2011). The impacts of these disasters include hunger, disease, loss of income and livelihoods, collateral damage to infrastructure, all of which affect the survival and well-being of the population.

4. FACTORS CAUSING CHANGES IN THE EARTH'S CLIMATE

Changes in the Earth's temperature and associated changes in climate have complex causes. These can be classified into the following categories

a. Astronomical factors: Factors such as changes in solar activity, variations in the eccentricity of the Earth's orbit around the Sun, changes in the tilt of the Earth's axis precession of the Earth's axis and collisions with asteroids or comets are the causes that can change the Earth's temperature. Changes in solar activity, such as the frequency and intensity of sunspots or the gradual warming of the sun as its supply of hydrogen is consumed, are believed to have significant effects on climate (FAO, 1998)

b. Geological factors: Factors such as continental drift, changes in the topography of the ocean floor, volcanic eruptions, mountain building, erosion and weathering of rock are geological factors causing changes in Earth's temperature. Volcanoes occasionally erupt with such violence that large quantities of dust and gas are projected high into the atmosphere. Particles which reach the stratosphere may persist for several years. They cause cooler temperatures by reflecting solar radiation. The Little Ice Age was a period characterized by frequent volcanic activity when compared to the present century. The eruption of the Indonesian volcano, Tambora in 1815, the largest eruption in recorded history, was followed by a period of cool weather in portions of Europe, North America and possibly other parts of the world, known as **"The Year without Summer"**. This resulted in a failure of the corn crop in portions of the United States and massive crop failures in Western Europe (Stommel and Stommel, 1983). In Ghet, Belgium, for example, the summer of 1816 was the coldest recorded between the years 1753 and 1960.Volcanic emissions due to the eruption of EI

Chichon in Mexico in 1982 and Pinatubo in the Philippines in 1991 also caused a slight cooling effect.

c. Oceanic factors: Factors such as the El Nino effect, changes in ocean circulation, sea level changes, ice formation, phytoplankton blooms and dimethysulphide production are also responsible for changing Earth's temperature. The ocean plays an essential role in the global climate system. Over half of the solar radiation reaching the Earth's surface is first absorbed by the ocean, where it is stored and redistributed by ocean currents before escaping into the atmosphere. The ocean currents are driven by the exchange of momentum, heat and water between the ocean and the atmosphere (Cubasch and Cess, 1990). The oceans also contain chemical and biological mechanisms which are important in controlling CO_2 .CO_2 is transferred from the atmosphere into the ocean by difference in the partial pressure of CO_2 in the ocean and the lowest layers of the atmosphere. The oceans also contain phytoplankton which convert dissolved CO_2 into particles carbon which sinks into deep water (Cubasch and Cess, 1990)

d. Land surface factors: Factors including the effect of vegetation on surface albedo (the whiteness or degree of reflection of incident light from an object), and avapo-transpiration, open water effects including irrigation and dust are factors causing changes Earth's temperature.

e. Atmospheric factors: Factors such as the effect of greenhouse gases, sulphur dioxide and air pollutants, cloud effects and interactions between the air, the land and the sea are another factor causing changes Earth's temperature.

The greenhouse effect is the retention of heat in the lower atmosphere due to absorption and re-radiation by clouds and certain gases. The earth receives its energy from the sun as solar radiation. Short-wave solar (visible) radiation received from the sun passes through the atmosphere with little or no interference and warms the Earth's surface. Long-wave thermal radiation emitted by the warmed surface of the Earth is partially absorbed by a number of trace or "greenhouse" gases (GHGs). These gases occur in small amounts in the atmosphere and reflect the long wave thermal radiation in all directions. The greenhouse effect is a well understood phenomenon based on established scientific principles. The Earth's average surface temperature, for example, is warmer by about 33℃ than it would be without the presence of these gases (FAO, 1998).

Greenhouse gases (GHGs) present in the Earth's atmosphere include water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide(N_2O), nitrogen oxide (NO_x), ozone(O_3), carbon monoxide (CO) and chlorofluorocarbons (CFC). The concentration of these gases in the Earth's atmosphere has changed over geological time scales. Since the last glacial period, the levels of these gases remained relatively constant. As agriculture and animal husbandry developed the world's population increased and human society became more industrialised, the levels of some of these gases increased significantly (Houghton, 1991). Thus, changes in the world's climate, due to increase in the concentration of carbon dioxide and other greenhouse gases in the Earth's atmosphere, have the potential to significantly affect forests and the practice of forestry. The probability of climate change is one of today's leading environmental concerns. The issue is complex and filled with uncertainties. Information available on the subject is often confusing and conflicting

5. MAIN CONSEQUENCES OF CLIMATE CHANGE

Climate change will have pervasive socio-economic consequences that will not only affect major economic sectors such as agriculture, energy or healthcare, but will also result in changes to the supply and demand for goods and services of all sectors of the economy, albeit with varying levels of intensity. Higher temperatures, sea level rise, and other climatic change (changes in regional precipitation patterns, the water cycle, frequency and intensity of extreme weather events), are also impact aspects of life that are not primarily based on or related to economic activity, for example, human security, health and well-being, culture, people's capabilities and environmental quality.

The following is a subset of all impacts of climate change. These impact aspects are not entirely discrete nor can they be separated from each other. Extreme events not only affect human health, land and capital damages, but might induce people to migrate to other places as a form of adaptation. Extreme events can also cause long lasting trauma for those directly or indirectly affected by their log-run consequences.

Table-1: Categories of Climate Impacts

Sector	Impact Aspects
(1)	(2)
Agriculture	Changes in crop yield, live stock mortality and morbidity from heat and cold exposure, changes in pusture and rangeland productivity, changes in agricultural productivity, changes in fisheris catches.
Coastal Zone	Loss of land and capital from sea level rise, non-market impacts in coastal zones.
Extreme Events	Mortality, land and capital damages from hurricanes, mortality, land and capital damages from floods.
Health	Mortality from heat exposure, mortality from heat and cold exposure, mortality and morbidity from infectious diseases, cardiovascular and respiratory diseases.
Energy Demand	Changes in energy demand for cooling and heating.
Tourism Demand	Changes in tourism flows and services
Ecosystems	Loss of ecosystems and biodiversity, changes in forest plantation yields
Water Stress	Changes in energy supply, changes in availability of drinking water to end users
Human Security	Civil conflict, human migration
Tipping points	Large scale disruptive events

Source: OECD, 2015),

In agriculture, climate change will have consequences for various subsectors, including crop production, livestock, pusture and rangeland and aquaculture. Changes in rainfall, atmospheric carbon dioxide (CO_2) and ozone concentrations, changes in pest and disease prevalence and extreme events spurred by climate change will likely affect future agricultural activities, sometimes positively and sometimes negatively. According to the IPPC (2014), there is high confidence that higher CO_2 concentration in the atmosphere will have a stimulatory effect on crop yields, while higher levels of ozone are likely going to be damaging. In addition, climate change might have consequences for outcomes that depend on

the way agriculture is conducted, including conservation of the countryside, food security and the maintenance of biodiversity. It might also affect negative externalities produced by agricultural activity, for example, soil and water pollution.

Coastal Zones or Coastal systems include natural ecosystems (beaches, cliffs, lagoons, etc) and human systems (settlements, cities, ports, food production etc.). They comprise distinct coastal features and ecosystems, as well as built environment, human activities and institutions that organize these human activities (IPCC, 2014). Various climate change-related drivers can impact on these systems. Beyond likely changes in the frequency and intensity of storms, increases in precipitation, warmer ocean temperatures and ocean acidification, sea level rise is potentially the most significant contributing factor to coastal zone damage. There is high agreement among authors of the IPCC and other reports that rising sea levels can negatively impact the provision of market and non-market goods and services in coastal zones through events such as storm surge, submergence, salt-water intrusion and coastal erosion. Both natural and human systems will be affected by sea level rise.

Extreme weather events are very likely to be affected by climate change, although the regional changes vary. Tropical cyclone activity, including hurricanes, is more likely than not to become more intense by the end of the 21st century, as global mean surface temperature rise (IPCC, 2014). The IPCC (2013) Reports that with higher temperatures, extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intensive and more frequent by the end of this century. Similarly, river floods are also projected to increase in number and severity in most river basins. Reduced rainfall and increased evaporation can both lead to droughts, which are projected to "become longer or more frequent, or both, in some regions and seasons" (IPCC, 2014). The main direct channels through which economies will experience these damages are impacts on physical capital (e.g., factories, houses streets and bridges, machinery, computers, but also energy infrastructure), land (e.g., the work force). These events also lead to indirect economic effects e.g., through the disruption to electricity supply or transport or temporary halt to almost all local economic activity. The increase in frequency and intensity of extreme events as a consequence of climate change also leads to premature deaths and injuries and force people to leave their homes and temporarily or permanently more to other places, affecting well-being and welfare.

Health impacts of climate change include both direct and indirect effects including heat and cold related mortality and morbidity, water, food and vector-borne disease, deaths and well-being and changes in air pollution and allergies. There are also risks to health infrastructure and to occupational health (WHO, 2012). The economic costs of health impacts are not easy to assess as they include both market and non-market costs. For example, morbidity costs include market impacts, such as the effects of illnesses on labour productivity and non-market impacts, such as the costs of pain and suffering. The demand for energy will also be affected by climate change. The main channels for changes in energy demand are through reduced need for heating in winter, and increased need for cooling in summer. Energy supply may also get disrupted, e.g., by water shortages and this may in turn affect energy demand. With regard to tourism, the effects of climate change arise from changes in local climate conditions, making certain tourist locations less attractive and other more.

Ecosystem on land and in water provide a multitude of precious services to humans and other species, including the supply of food, raw materials, climate and air quality, habitat for species and opportunity for aesthetic appreciation and inspiration. Climate change may place ecosystem services under further stress-directly as well as indirectly by interacting with and intensifying other aggravating factors, such as human development. Warming as a major direct climatic driver, and changes in extreme events, will likely reduce biodiversity and diminish abundance of species (both animals and plants) to shift range to higher latitudes or higher elevations with more bearable temperatures to increase the chance of survival. Northward migration of fish and birds is one example for range shift as a response to warming to the Northern Hemisphere. Heavy precipitation, in turn, might act as an indirect impact on ecosystems, by accelerating the erosion of forest areas that have already been put under pressure, e.g. from recent logging (EPA, 2015). Changes in availability and quality of ecosystem services will also affect the functioning of economic sectors, not least the land-based agricultural sector, forestry and fisheries.

According to the IPCC (2014), there is high confidence and robust evidence that climate change will intensify stressors that negatively impact human security, which can be defined as 'a condition that exists when the vital core of human lives is protected, and when people have the freedom and capacity to live with dignity (IPCC,2014). Forced migration and incidence of civil conflict are two key stressors to human security that have been widely discussed in the literature and that many expect to be magnified by climate change.

6. OTHER CONSEQUENCES

The analysis with ENV-linkages aims to take into account the most significant market-based impacts of climate change. Yet, there are several reasons why it cannot be comprehensive. First, for some types of climate impacts, there is insufficient data or knowledge to robustly incorporate them in ENV-linkages. Secondly, ENV-linkages is an economic model based on a production–based measurement of economic activity and thereby has only limited capacity to quantify the consequences of climate change, and especially those not directly related to markets. Non-market impacts of climate change represent consequences that affect human and non-human activities for which no established economic markets exist such as biodiversity and culture as well as changes in welfare that are not fully captured by GDP,such as the welfare costs from premature deaths or pain and suffering(IPCC,2014).The total non-market impacts of climate change are likely to be significant, although there are insufficient comprehensive quantitative analyses to draw robust conclusions.

The majority of the literature, including the quantitative analysis relies on indicators related to changes in crop productivity to estimate the costs of climate change to agriculture (IPCC, 2014). However, climate change will have consequences for various other production and non-production aspects of agriculture, including livestock, pusture and rangeland, and aquaculture (OECD, 2001).

Livestock is likely to be considerably impacted on by climate change. It is an important part of the agricultural sector of the food supply of both OECD and non-OECD countries. Although the effects of climate change on livestock are much less exhaustively explored than crop production, the largest part of the literature finds negative effects of climate change, not least through heat and water stress, on animal growth, their health, and the commodities they produce e.g., dairy (IPCC,2014). Heat stress, which may increase with climate change, can have significant effects on livestock mortality. Changing precipitation patterns as well as

amplified need of cattle and other domesticated animals for water to cope with higher temperatures will likely contribute to this change.

In the United States, several states have respectively reported more than 5000 animals' deaths from single heat wave events in the past (USGCRP, 2009). Decreased cold exposure from higher average temperatures could be positive for livestock production, but has not been rigorously explored in the literature and numerical estimates are largely absent. In addition, climate change may increase the incidence of diseases among livestock, especially for ailments transmitted through vectors that are highly dependent on climate conditions (IPCC, 2014), while experts are highly confident that climate change will spur the spread of diseases, evidence for this relationship is small. Other studies suggest that there will be positive or non-measurable effects of climate change to livestock in some regions.

Pustures and rangeland, which encompasses various different types of land that is used to keep animals (e.g., grasslands, shrulands, savannals, hot and cold deserts and tundra), is expected to have positive effects in some regions and negative in others. Grasslands are expected to be affected in similar ways to crop yields. In addition, the CO_2 fertilisation effects might stimulate plant growth, help plants recover from water stress events more quickly, and contribute to reduced plant mortality (IPCC, 2014).

7. Cost-Benefit Studies of Global Climate Change

Various economic studies have tried to estimate the benefits and costs of policy action on climate change. When economists perform a cost-benefit analysis, they weigh the consequences of the projected increase in carbon emissions versus the costs of current policy actions to stabilize or even reduce CO_2 emissions. Strong policy action to prevent climate change will bring benefits equal to the value of damages that are avoided. These benefits of preventing damage can also be referred to as avoided costs and the estimated benefits should be compared to the costs of taking actions. In this attempt, the cost of climate change is measured in monetized terms or as a percentage of GDP which poses several inherent problems. In general, these studies can only capture the effects of climate change in so far as they affect economic production or create non-market impacts that can be expressed in monetary terms. Some sectors of an economy are potentially vulnerable to the effects of climate change, including farming, forestry and fishing, coastal real estate and transportation which constitute only about 10% of GDP. Other major areas such as manufacturing, services and finance are only lightly affected by climate change.

Scientists and economists have used "Integrated assessment" models to translate scenarios of population and economic growth, and resulting emissions into changes in atmospheric composition and global mean temperature. These models then apply "damage function" that approximate the global relationship between temperature changes and the economic costs from impacts such as changes in sea level, cyclone frequency, agricultural productivity and ecosystem function. Further, the models attempt to translate future damages into present monetary value (Revesz, Arrow et al, 2014). Economists evaluate future costs and benefits by the use of a discount rate. The problems and implicit value judgement associated with discounting add to the uncertainties that we have already noted in valuing costs and benefits. This suggests that we should consider some alternative approaches including techniques that can incorporate the ecological as well as the economic costs and benefits. Of course, the issue of uncertainty is central to cost-benefit analysis of climate change. Damage estimates tend to omit the possibility of the much more catastrophic consequences that could result if weather

disruption is much worse than anticipated. For example, if climate change causes severe hurricanes to become much more frequent, cost-benefit analyses would have to estimate the costs of destruction at a much higher level than they have done previously.

Economic studies dealing with cost-benefit analysis of climate change have come to different conclusions about policy. According to early studies by William Nordhaus and Colleagues (2000to 2008), the "optimal" economic policies to slow climate change involve modest rates of emissions reductions in the near term, followed by increasing reductions in the medium and long term, sometimes referred to as a gradual "ramping up" of climate policy.

8. ECONOMIC TRADE-OFFS BETWEEN ADAPTATION, MITIGATION AND CLIMATE DAMAGES

Policy responses to climate change can be broadly classified into two categories: adaptive measures to deal with the consequences of climate change and mitigation or preventive measure which are intended to lower the magnitude or timing of climate change (IPCC, 2007).

Adaptive measures include construction of dikes and sea walls to protect against rising seas and extreme weather events such as floods and hurricanes; shifting cultivation patterns in agriculture to adapt to changing weather conditions; creating institutions that can mobilize the needed human, material, and financial resources to respond to climate–related disasters. While mitigation measures include reducing emissions of greenhouse gases by meeting energy demands from sources with lower greenhouse gas emissions; reducing greenhouse gas emissions by increasing energy efficiency; enhancing natural carbon sinks. Carbon sinks are areas where carbon may be stored and this includes soils and forests.

Adaptation policies are essential to keep the costs of climate change impacts as low as possible. These include direct government intervention where necessary, e.g., for large-scale infrastructure projects, as well as facilitating market-driven adaptation by private actors, e.g., to overcome information barriers and moral hazard issues. The effectiveness of adaptation notwithstanding, mitigation policies are needed to limit climate change and thus avoid much of the damages especially in the long-run, limit the risks and avoid tipping points. Avoiding the long-run consequences of emissions requires immediate policy action. Justification for such mitigation actions cannot be based directly on the time profile of damages as they arise. Ideally, they should be based on the full stream of future avoided damages stemming from current emission reductions, plus a premium to manage the risks of non-market damages, catastrophic events and crossing irreversible tipping points.

The literature identifies many restrictions to adaptation and without appropriate policies, adaptation is expected to fall short of the societal optimal amount (UNEP,2014). Assuming that all adaptation options are readily available to firms and households and will be implemented without government intervention will hence result in lower residual damage estimates than are likely to occur, specifically without targeted adaptation policies. In principle, the central projection should include all adaptation efforts that are driven by market forces, where as actions which require government intervention should be excluded.

9. INTERACTIONS BETWEEN ADAPTATION AND MITIGATION POLICIES

In the absence of mitigation action adaptation measures play an important role in limiting the damages from climate change. Adaptation and mitigation are both powerful instruments to

limit climate damages, especially when the other instrument is locking. In terms of cost minimisation, however, both policies partially substitute each other. The least–cost policy package will consist of both measures, but adaptation cannot be a perfect substitute for mitigation. If only adaptation policies are available, damages are substantially larger than when only mitigation policies are available especially in the first half of the century. By the end of the century, the total climate change costs are roughly equal when optimal mitigation policies are available; regard less of the availability of adaptation. But even with optimal mitigation, adaptation can significantly reduce the costs of climate change.

10. CONCLUSION

The Climate change is an issue that embodies issues of externalities, common property resources, public goods, renewable and non-renewable resources and the discounting of costs and benefits over time. It has economic, political scientific and technological dimensions. The Least Developed Countries (LDCs) and Small Island Developing States (SIDS) are at the frontline of climate change effects, but they remain on the margin of the current debate on climate change. Adaptation to climate change in LDCs and SIDS is not only a sustainable development challenge, but also in some cases a survival issue.

Higher temperatures, sea level rise and extreme weather events linked to climate change are having a major impact on the earth, harming its economies, natural and physical assets and compounding developmental challenges including poverty, food and energy security and health. The economics of climate change offers critical insights into the costs and benefits of both inaction and action on climate change. Regardless of the progress made in mitigation efforts by the global community over the coming decades, climate change is already occurring. Adapting to climate change is, therefore, essential. Striking the right balance between mitigation and adaptation investments is an ongoing challenge for policy makers, especially in the Asia-Pacific region. Adaptation efforts can take several forms—altering farming practices and crop varieties, building water reservoirs, enhancing water use efficiency, changing building codes or constructing sea walls.

As climate change continues to progress and extreme weather events become more frequent and more severe, the need for adaptation finance for developing countries also continues to grow. Adequate carbon pricing and the integration of long-term policy framework for the low carbon transition into national planning and budgeting will be important elements to support climate investments. Financial regulation will also play an important role in easing the risks for private investors thereby unlocking private finance, as will green bonds. The least-cost policy package may consist of measures, but adaptation cannot be a perfect substitute for mitigation. Of course, with optimal mitigation, adaptation can significantly reduce the costs of climate change. Economic analysis alone cannot adequately respond to a problem of this scope, but economic theory and policy have much to offer in the search for solutions. An effective response to the climate change problem requires much more sweeping action on a global scale than anything so far achieved. Economic policy patterns that have the power to alter patterns of energy use, industrial development and income distribution are essential to any plan for mitigating or adapting to climate change.

REFERENCES

1. Adger, W. Neil (2006), Vulnerability, Global Environmental Change, Vol.16, No.3.

2. Agrawala, S and Others (2003), Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans, Environmental Directorate and Development Cooperation, Directorate, OECD, Paris.
3. Bretschger, L. and S. Smulders (2001), Explaining Environmental Kuznets Curve: How Pollution induces Policy and New Challenges, Revised Version of Centre Discussion Paper, No.2000.95, Tilburg University, Netherland.
4. Calzadilia, A., F. Pauli and R. Roson (2007), 'Climate Change and Extreme Events: An Assessment of Economic Implications', International Journal of Ecological Economics and Statistics, Vol.7, No.7.
5. Christensen, J.H.and others (2007), 'Regional Climate Projections' in S.Solomon and other(eds),Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.
6. Cline, W.R. (1994), 'The Costs and Benefits of Greenhouse Gas Abatement: A Guide to Policy Analysis', The Economics of Climate Change, OECD, Paris.
7. Cook, J.et al (2016), "Consensus on Consensus: A Synthesis of Consensus Estimates on Human-Caused Global Warming", Environmental Research Letters, Vol.11, No. 4, April.
8. Cooper, R.N. (2000), 'International Approach to Global Climate Change', The World Bank Research Observer, Vol. 15, No.2, pp.145-172.
9. Cooper, R.N. (2020), International Approaches to Global Climate Change, The World Bank Research Observer, Vol.15, No.2.
10. Cubasch, U and R. Cess (1990), 'Process and Modelling', in Scientific Assessment of Climate Change, IPCC, UNEO.
11. Dell, M.B.; F. Jones, and B.A. Olken (2008), 'Climate Change and Economic Growth: Evidence from the Last Half Century', Working Paper, No. 14132, National Bureau of Economic Research, Cambridge, MA.
12. EPA (2015), "Ecosystems: Climate Impacts in Ecosystem", Website article, United States Environmental Protection Agency, March, 2015.
13. Fankhauser, S. and R.S. Tol. (2005), 'On Climate Change and Economic Growth', Resource and Energy Economics, Vol.27, No. 1, pp.1-17.
14. Fankhauser, S. and R.S. Tol (2005), 'On Climate Change and Economic Growth', Resource and Energy Economics, Vol.27, No.1.
15. FAO (1998), Climate Change, Forests and Forest Management-An Overview, (Forestry Paper), Food and Agriculture Organization, UNO.
16. Gilbreath, J. (2004), Climate Change: Global Warming Kills, Environmental Health Perspectives, Vol. 112, No.3.
17. Gregory, P.J., J.S.I. Ingram, and M. Brklacich (2005), Climate Change and Food Security, Philosophical Transactions, Biological Societies, Vol.360, No.1463.
18. Grossman, G.M. and A.B. Krueger (1995), Economic Growth and Environment, The Quarterly Journal of Economics, Vol.55, No. 2, pp.353-377.
19. Hope, C.W. (2006), 'The Marginal Impact of CO_2 from PAGE2002: an Integrated Assessment Model incorporating the IPCC's five reasons for concerns', Integrated Assessment Journal, Vol.6, No.1, pp.19-56.
20. Houghton, J.T. (1991), Scientific Assessment of Climate Change: Summary of the IPCC Working Group I Report, Proceedings Second World Climate Conference, Cambridge University Press, Geneva, Switzerland.
21. IPCC (2007), Climate Change 2007: The Physical Science Basis, Cambridge University Press, New York.

22. IPCC (2013), Climate Change 2013: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, U.K.

23. IPCC (2014), Climate Change 2014: Impacts, Adaptation and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

24. IPCC (2014), Climate Change 2014: Impacts, Adaptation and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

25. Lacocq, F. and Z. Shalizi (2007), 'How might Climate Change Affect Economic Growth in Developing Countries? ', Policy Research Working Paper, No. 4315, World Bank, Washington, D.C.

26. Lecocq, F. and Z. Shalizi (2007), How might climate change affect economic growth in developing countries? Policy Research Working Paper, No. 4315, Washington, D.C.

27. Lucas, R.E. and S. Valente (2011), 'Climate Change and Uneven Development', The Scandinavian Journal of Economics, Vol.113, No. 4.

28. Mankiw, N.G., D. Romer, and D. N. Weil (1992), 'A Contribution to the Empirics of Economic Growth', The Quarterly Journal of Economics, Vol.107, No.2.

29. Mendelsohn, R.and A. Dinar (1999), Climate Change, Agriculture and Developing Countries: Does Adaptation Matter? World Bank Research Observer, Vol.14, No.2.

30. Mortens, P. and others (1999), Climate Change and Future Population at risk of Malaria, Global Environmental Change, Vol.9, No.1.

31. Nicholls, R. J. and R.S.J. Tol (2006), Impacts and Responses to Sea Level Rise: A Global Analysis of the SRES Scenarios over the Twenty-First Century, Philosophical Transactions of the Royal Society, Vol.364, No.1849.

32. Nordhaus, W. (2007), "The Stern Review on the Economics of Climate Change", http://nordhaus.econ.yale.edu.

33. Nordhaus, W. (2008), A Question of Balance: Weighing the Options on Global Warming Policies, Yale University Press, New Haven.

34. Nordhaus, W. (2013), The Climate Casino, New Haven; Yale University Press, London.

35. Nordhaus, W.D. (1991), 'To Slow or not to Slow: The Economics of the Greenhouse Effects', Economic Journal, Vol.101, No.407, pp.920-937.

36. Nordhaus, W.D. (1991), 'To Slow or not to Slow: The Economics of the Greenhouse Effects', Economic Journal, Vol.101, No.407.

37. O' Brien, K.L., L. Sygna and J. E. Haugen (2004), 'Vulnerable or Resilient? A Multiscale Assessment of Climate Impacts and Vulnerability in Norway', Climate Change, Vol.64, No.1-2.

38. OECD (2001), Multifunctionality: Towards an Analytical Framework, OECD Publishing, Paris.

39. OECD (2015), Climate Change, Risks and adaptation: Linking Policy and Economics, OECD Publishing, Paris.

40. Parry, M and other(ed) (2007), Climate Change 2007: Impacts, Adatation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

41. Parry, M. and others (eds) (2007), Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

42. Revesz, R., K. Arrow et al (2014), "Global Warming: Improve Economic Models of Climate Change", Nature, April 4, http://www.nature.com.
43. Ricci, F. (2007), Channels of transmission of Environmental Policy to Economic Growth: A Survey of the Theory, Ecological Economics, Vol.60, No.4.
44. Stern, N. and others (2006), Stern Review: the Economics of Climate Change, HM Treasury, London.
45. Stern, N. and others (2006), Stern Review: The Economics of Climate Change, HM Treasury, London.
46. Stommel, H. and E. Stommel (1983), Volcano Weather, Seven Seas Press, Newport, USA.
47. Tol, R.S.J. and S. Wagner (2010), "Climate Change and Violent Conflict in Europe over the last Millennium", Climate Change, Vol.99, No.1-2, pp.65-79.
48. Tol, R. S. J. (1995), The Damage Costs of Climate Change toward more Comprehensive Calculations', Environmental and Resource Economics, Vol.5, No.4.
49. U.S. Global Change Research Programme (2014), Third National Climate Assessment, Overview and Report Findings
50. UNEP (2014), The Adaptation Gap Report 2014, United Nations Environment Programme, Nairobi.
51. USGCRP (2009), 'Global Climate Change Impacts in the United States', in United States Global Change Research Programme, Cambridge University Press, New York.

52. WHO (2012), Atlas of Health and Climate, World Health Organization and World Meteorological Organization, Geneva.
53. World Bank (2010), World Development Report 2010, Washington, D.C.
54. Zhang, D. and others (2007), "Climate Change and War frequency in Eastern China over the last Millennium, Human Ecology, Vol.35, No.4, pp.403-414.
55. Zhang, D.and others (2007), 'Climate Change and War Frequency in Eastern China over the Last Millennium', Human Ecology, Vol.35, No.4.