Manonmaniam Sundaranar University

Directorate of Distance and Continuing Education
Tirunelveli – 627012, Tamil Nadu.

M.A.ECONOMICS
(First Year)

Economics of Climate Change
(SECE22)

Prepared by

Dr.K.AJITHA
Assistant Professor of Economics
Manonmaniam Sundaranar University
Tirunelveli – 627 012.

SEMESTER - II

ELECTIVE – IV

ECONOMICS OF CLIMATE CHANGE

UNIT I: INTRODUCTION

Science of climate change; global and regional climate predictions; uncertainty in science; physical impacts of climate change – agriculture, sea level rise, health, extreme events; policy debate.

UNIT II: CLIMATE CHANGE POLICY - MITIGATION

Efficiency, public goods, externalities; environmental policy instruments – emissions trading, carbon tax, emission trading versus tax; stock pollutants and discounting; decisions under risk and uncertainty;

Unit III: INTEGRATED ASSESSMENT

Costs and benefits of greenhouse gas mitigation; integrated assessment models; simulation exercises based on DICE model and its variants; sensitivity and uncertainty analysis; Stern review.

UNIT IV: CLIMATE CHANGE POLICY - ADAPTATION

Climate change impact assessment – applications for agriculture, sea level rise and health; vulnerability assessment; economics of adaptation; measurement of adaptation cost; issues in financing adaptation.

UNIT V: CLIMATE CHANGE NEGOTIATIONS AND EQUITY

Criteria for distribution of emission reduction burden; distribution criteria for adaptation fund; inter and intra-generational equity issues; discounting in climate change context.

Reference:

- F. Ackerman, E. Stanton: Climate Economics: State of the Art. Routledge (2013)
- W. Nordhaus: A Question of Balance. Yale University Press (2008)
- D. Acemoglu, P. Aghion, Leonardo Bursztyn, D Hemous. (2012). “The environment and directed technical change,” American Economic Review, 102(1): 131-166.

Table of Content

UNIT – I

ECONOMICS OF CLIMATE CHANGE

1.1. Introduction

Climate change will affect the basic elements of life for people around the world access to water, food production, health, and the environment. Hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms. Using the results from formal economic models, the Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global Gross Domestic Product (GDP) each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more. In contrast, the costs of action reducing greenhouse gas emissions to avoid the worst impacts of climate change can be limited to around 1% of global gross domestic product each year. The investment that takes place in the next 10 to 20 years will have a profound effect on the climate in the second half of this century and in the next. Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes. So prompt and strong action is clearly warranted. Because climate change is a global problem, the response to it must be international. It must be based on a shared vision of long term goals and agreement on frameworks that will accelerate action over the next decade, and it must build on mutually reinforcing approaches at national, regional and international level.

1.2. Climate change could have very serious impacts on growth and development: If no action is taken to reduce emissions, the concentration of greenhouse gases in the atmosphere could reach double its pre-industrial level as early as 2035, virtually committing us to a global average temperature rise of over 2°C. In the longer term, there would be more than a 50% chance that the temperature rise would exceed 5°C. This rise would be very dangerous indeed; it is equivalent to the change in average temperatures from the last ice age to today. Such a radical change in the physical geography of the world must lead to major changes in the human geography where people live and how they live their lives. Even at more moderate levels of warming, all the evidence from detailed studies of regional and sectoral impacts of changing weather patterns through to economic models of the global effects shows that climate change will have serious impacts on world output, on human life and on the environment. All countries will be affected. The most vulnerable the poorest countries and populations will suffer earliest and most, even though they have contributed least to the causes of climate change. The costs of extreme weather, including floods, droughts and storms, are already rising, including for rich countries. Adaptation to climate change that is, taking steps to build resilience and minimise costs is essential. It is no longer possible to prevent the climate change that will take place over the next two to three decades, but it is still possible to protect our societies and economies from its impacts to some extent for example, by providing better information, improved planning and more climate-resilient crops and infrastructure. Adaptation will cost tens of billions of dollars a year in developing countries alone, and will put still further pressure on already scarce resources. Adaptation efforts, particularly in developing countries, should be accelerated.

1.3. The costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly:

The risks of the worst impacts of climate change can be substantially reduced if greenhouse gas levels in the atmosphere can be stabilised between 450 and 550ppm (parts per million) CO2 (carbon dioxide) equivalent (CO2e). The current level is 430ppm CO2e today, and it is rising at more than 2ppm each year. Stabilisation in this range would require emissions to be at least 25% below current levels by 2050, and perhaps much more. Ultimately, stabilisation at whatever level requires that annual emissions be brought down to more than 80% below current levels. This is a major challenge, but sustained long-term action can achieve it at costs that are low in comparison to the risks of inaction. Central estimates of the annual costs of achieving stabilisation between 500 and 550ppm CO2e are around 1% of global GDP, if we start to take strong action now. Costs could be even lower than that if there are major gains in efficiency, or if the strong co-benefits, for example from reduced air pollution, are measured. Costs will be higher if innovation in low-carbon technologies is slower than expected, or if policy makers fail to make the most of economic instruments that allow emissions to be reduced whenever, wherever and however it is cheapest to do so.

1.4. Action on climate change is required across all countries, and it need not cap the aspirations for growth of rich or poor countries: The costs of taking action are not evenly distributed across sectors or around the world. Even if the rich world takes on responsibility for absolute cuts in emissions of 60-80% by 2050, developing countries must take significant action too. But developing countries should not be required to bear the full costs of this action alone, and they will not have to. Carbon markets in rich countries are already beginning to deliver flows of finance to support low-carbon development, including through the Clean Development Mechanism. A transformation of these flows is now required to support action on the scale required. Action on climate change will also create significant business opportunities, as new markets are created in low-carbon energy technologies and other low-carbon goods and services. These markets could grow to be worth hundreds of billions of dollars each year, and employment in these sectors will expand accordingly. The world does not need to choose between averting climate change and promoting growth and development. Changes in energy technologies and in the structure of economies have created opportunities to decouple growth from greenhouse gas emissions. Indeed, ignoring climate change will eventually damage economic growth. Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries.

1.5. A range of options exists to cut emissions; strong, deliberate policy action is required to motivate their take-up: Emissions can be cut through increased energy efficiency, changes in demand, and through adoption of clean power, heat and transport technologies. The power sector around the world would need to be at least 60% decarbonised by 2050 for atmospheric concentrations to stabilise at or below 550ppm CO_2e, and deep emissions cuts will also be required in the transport sector. Even with very strong expansion of the use of renewable energy and other low carbon energy sources, fossil fuels could still make up over half of global energy supply in 2050. Coal will continue to be important in the energy mix around the world, including in fast-growing economies. Extensive carbon capture and storage will be necessary to allow the continued use of fossil fuels without damage to the atmosphere. Cuts in non-energy emissions, such as those resulting from deforestation and from agricultural and industrial processes, are also essential. With strong, deliberate policy choices, it is possible to reduce emissions in both developed and developing economies on the scale necessary for stabilisation in the required range while continuing to grow. Climate change is the greatest market failure the world has ever seen, and it interacts with other market imperfections. Three elements of policy are required for an effective global response. The first is the pricing of carbon, implemented through tax, trading or regulation. The second is policy to support innovation and the deployment of low carbon technologies. And the third is action to remove barriers to energy efficiency, and to inform, educate and persuade individuals about what they can do to respond to climate change.

1.6. Climate change demands an international response, based on a shared understanding of long-term goals and agreement on frameworks for action:

Many countries and regions are taking action already: the European Union, California and China are among those with the most ambitious policies that will reduce greenhouse gas emissions. The United Nation Framework Convention on Climate Change and the Kyoto Protocol provide a basis for international co-operation, along with a range of partnerships and other approaches. But more ambitious action is now required around the world.

Countries facing diverse circumstances will use different approaches to make their contribution to tackling climate change. But action by individual countries is not enough. Each country, however large, is just a part of the problem. It is essential to create a shared international vision of long term goals, and to build the international frameworks that will help each country to play its part in meeting these common goals.

Key elements of future international frameworks should include:

♦ **Emissions trading**: Expanding and linking the growing number of emissions trading schemes around the world is a powerful way to promote cost-effective reductions in emissions and to bring forward action in developing countries: strong targets in rich countries could drive flows amounting to tens of billions of dollars each year to support the transition to low-carbon development paths.

♦ **Technology cooperation**: Informal co-ordination as well as formal agreements can boost the effectiveness of investments in innovation around the world. Globally, support for energy R&D should at least double, and support for the deployment of new low-carbon technologies should increase up to five-fold. International cooperation on product standards is a powerful way to boost energy efficiency.

♦ **Action to reduce deforestation**: The loss of natural forests around the world contributes more to global emissions each year than the transport sector. Curbing deforestation is a highly cost-effective way to reduce emissions; large scale international pilot programmes to explore the best ways to do this could get underway very quickly.

♦ **Adaptation**: The poorest countries are most vulnerable to climate change. It is essential that climate change be fully integrated into development policy, and that rich countries honour their pledges to increase support through overseas development assistance. International funding should also support improved regional information on climate change impacts, and research into new crop varieties that will be more resilient to drought and flood.

1.7. SCIENCE OF CLIMATE CHANGE

Climate change is usually discussed as a global issue. But understanding how climate change will affect children who live through it requires a narrower focus one that pushes directly against the limitations of that global view. Geographic variation in climate change's effects over time, uncertainty stemming from scientific complexity, and, more than anything, the inherent impossibility of forecasting future human behaviour combine to make climate change's eventual impacts on children both very different from place to place and extraordinarily difficult to predict with any certainty.

Climate change will influence children's lives in few "global" ways. Rather, during the coming decades, children will face myriad interactions between changes in the climate and social, economic, and cultural forces.

The terms climate and weather are sometimes confused with each other, and that confusion can have serious implications. Weather denotes the actual behavior of earth's oceans and atmosphere over a given short period; the term weather refers to the temperature, precipitation, wind, storminess, and so forth that we experience during any given day, week, month, or year. Climate, on the other hand, refers to the behaviour of weather over longer periods, such as decades, from a statistical perspective (for example, annual mean temperature or mean daily maximum temperature, averaged for a geographic region). Climate change thus refers to an increase in average global temperature, along with all of the ways such an increase affects the characteristics of climate and weather.

1.8 Physical Impacts of Climate Change

Concern about climate change has grown over the past 25 years. Today, thousands of climatological scientists and researchers across related fields are conducting research on topics ranging from the specifics of obscure climate processes to the likely impacts of climate change on everything from alpine ecosystems to financial markets. The pace of discovery and the growth in understanding have been sufficiently rapid, the breadth of impacts sufficiently wide, and the implications of social concern sufficiently broad that a major international organization was created to synthesize scientific evidence on climate change. The Intergovernmental Panel on Climate Change, or (IPCC), operates under the auspices of the United Nations Environment Programme and the world meteorological organization. Every six years or so, the panel publishes assessment reports that summarize the state of the research on climate change science, impacts, and policy. Many other organizations, too, have assessed aspects of the problems inherent in climate change, resulting in projects ranging from the 2007 Stern Review a UK government study emphasizing the economic benefits of early action against climate change to the 2014 philanthropically funded American Climate

Prospectus, which summarizes the expected economic risks of climate change in the United States.

Scientists are nearly certain that climate change is occurring and has the potential to be extremely harmful. Climate change nonetheless has several unique characteristics that combine to present a very challenging mix for policy makers. Climate changes both those already observed and those anticipated will affect different countries and different regions very differently. But, eventually, the changes will affect humans in every nation on the planet; in no place will climate remain unchanged. Moreover, every country's carbon dioxide emissions affect the climate in every other country because carbon dioxide's long lifetime means that it achieves a nearly uniform distribution in the atmosphere. Thus climate change is a global commons problem at the largest conceivable scale; the atmosphere is an easily damaged, open-access resource whose preservation will demand increasingly active coordination across the full complexity of human social interactions. Climate change's global nature thus distinguishes it from almost every other major environmental policy problem except, perhaps, the effects of ozone depletion or large-scale nuclear warfare. Another implication of carbon dioxide's very long lifetime is that a significant fraction (about 25 percent) of today's emissions will remain airborne even a millennium from now unless we invent a technology to affordably capture and bury the carbon dioxide, meaning that many expected changes are effectively irreversible. Furthermore, the huge mass of the oceans is absorbing a large portion of the climate's thermal energy as earth warms, and the resulting thermal inertia means that the effects of today's emissions will take several decades to appear.

Climate change science is also rife with uncertainty. Even though scientists are increasingly certain about the general characteristics of global climate changes under certain emissions scenarios, extensive uncertainties remain when it comes to details of how the climate will respond at time and spatial scales relevant to humans. The answers to such questions as how fast the sea level will rise are so uncertain that scientists can offer policy makers only a very limited basis for making decisions, much less tell them with confidence how high to build a seawall. When combined with the fact that, in the coming years, humans will change their emissions behaviours in response to changes in energy supply and economic development, uncertainty about what will happen becomes daunting.

1.8.1. Observed Global Changes

Earth's average temperature since the mid nineteenth century is known with fair precision. By that point, enough ground and ship-based thermometers were in place and readings were being reported with sufficient reliability that scientists today can retrospectively establish a credible record of global average temperature by using modern analytic techniques; that record is supplemented by satellite-based measurements beginning around 1980. Similarly, global sea level measurements using tide gauges go back to the late nineteenth century and are supplemented by satellite-based observations of sea surface height beginning around 1990.

1.8.2. Projecting Future Climate and Scientific Uncertainty

To the best of our understanding, climate change's impacts on humans have so far been small and subtle compared with variations in other environmental factors that affect human welfare. Under business-as-usual scenarios whereby we continue to emit vast quantities of carbon dioxide, however, the impact of climate change is expected to grow markedly, eventually becoming a significant drag on human wellbeing all over the planet. To understand the full scope of the problem, we need to predict climate change decades into the future. The most reliable tools for such predictions are climate-modelling computer programs called Atmosphere Ocean General Circulation Models (AOGCMs). These models solve complex systems of equations embodying the known physical and chemical laws that describe how the atmosphere and the oceans behave under the influence of sunlight, Earth's rotation, and changes in the chemical composition of the climate system, including emission of greenhouse gases. AOGCMs take as input the historical record of Earth's climate and make predictions subject to past constraints, thereby producing a long-term climate forecast not unlike weather forecasts provided daily by the world's meteorological organizations. Earth system models expand on AOGCMs (Atmosphere Ocean General Circulation Models) by adding descriptions of how the ocean, atmosphere, and climate interact with surface vegetation. Even the most advanced models can only approximate the climate's behavior, and they often disagree about specific aspects. That uncertainty stems from two sources. First, our understanding of the physical and biological world is incomplete and must be approximated in ways that compromise accuracy. Second, the equations that underpin AOGCMs must be solved numerically on computers with finite capacity, resulting in low (but rapidly improving) spatial and temporal resolutions on even the fastest computers. Together, those uncertainties mean that most models agree fairly well about large changes over long periods of time, but they disagree about smaller-scale changes. For example, projections of how mean temperature will change in an area the size of half of North America can be taken as fairly defensible— unlike projections of specific changes in a small area and a short time frame, such as the intensity of windstorms in Beijing in the winter of 2051.

1.8.3. Regime Shifts in Planetary Systems

Scientists see a significant chance that certain changes in the physical climate system could be so rapid, and their impact so widely distributed geographically, that they would radically alter human society. Examples include a multi meter sea level rise from the melting of ice sheets; a rapid release of methane (a potent greenhouse gas) from melting Arctic ocean sediments and permafrost, that would in turn produce several extra degrees of warming; a shift from moist tropical forest to savannah in the Amazon, causing large losses of ecosystems and species and substantial warming feedback from release of carbon dioxide from soils and biota; and shifts in precipitation and temperature large enough to drastically reduce agricultural productivity. These possibilities are relatively less likely than other, less extreme changes. But should they occur, their impact will be high. We likely won't face them in this century, but they are nonetheless plausible outcomes of extreme warming that policy makers should take into account. Low probability but high impact risks, such as those stemming from cancer causing chemicals, nuclear accidents, or geopolitical missteps are often viewed as threatening enough to require major shifts in policy. While the risk of a 4°C rise in global average temperature is low, it is not zero, and some estimates put the likelihood of even a 6°C rise in temperature at greater than one percent by the end of the century under a business-as-usual scenario. From a risk management perspective, the threat of less likely but extremely damaging regime shifts may thus be even more important than the threat of more likely but less damaging outcomes.

Scientists are nearly certain that climate change is occurring and has the potential to be extremely harmful. Climate change nonetheless has several unique characteristics that combine to present a very challenging mix for policy makers. Climate changes both those already observed and those anticipated will affect different countries and different regions very differently. But, eventually, the changes will affect humans in every nation on the planet; in no place will climate remain unchanged. Moreover, every country's carbon dioxide emissions affect the climate in every other country because carbon dioxide s long lifetime means that it achieves a nearly uniform distribution in the atmosphere. Thus climate change is a global commons problem at the largest conceivable scale; the atmosphere is an easily damaged, open-access resource whose preservation will demand increasingly active coordination across the full complexity of human social interactions. Climate change s global nature thus distinguishes it from almost every other major environmental policy problem except, perhaps, the effects of ozone depletion or large-scale nuclear warfare.

1.9. Sea Level Rise

Rising seas will increase both (1) long-term land loss, thus reducing the amount of land available for settlement, and (2) episodic coastal inundation. At current rates of sea level rise, for example, the portion of New York City at risk for a one hundred year flood will double under high emissions scenarios from just over 10 percent of the city today to 20 percent by 2100. Rising sea levels are also expected to increase erosion and to interact with tropical and extra tropical cyclones to worsen storm surges, all of which pose direct threats to children's wellbeing. Less directly, sea level rise will affect children by forcing coastal settlements to adopt expensive adaptive urban planning systems and infrastructure such as seawalls. Sea level rise will also increase the likelihood of large-scale migration and extremely costly relocation of urban centers.

1.10. Climate Change and Future Generations

It's easy to feel overwhelmed by the scope and scale of climate change as a problem. The uncertainty that stems from our incomplete knowledge about climate and our inability to forecast future human behavior suggests a practically unknowable future, in which potentially huge losses caused by climate change compete with technological advances, economic growth, and social and cultural shifts to determine children's welfare for the rest of the century. That said, history has demonstrated time and again that humans can tackle uncertain threats in times of need. The insurance industry exists to help us manage risks, and businesses in many industries perform risk analyses and adopt policies to reduce risks. On a larger scale, international frameworks are in place to manage global safety risks. International agreements adopted to reduce the risk of nuclear war constitute one such example; the Montreal Protocol prohibiting the manufacture of ozone layer destroying chemicals is another. Climate change has much in common with those uncertain but very real global threats. We must understand that scientific uncertainty about the specifics of a complex problem can go hand in hand with broad agreement about the overall riskiness of an outcome. At the heart of the climate change problem lies a tension that forces us to directly confront the value we put on future children's wellbeing. The long lag between the emission of a greenhouse gas and its eventual warming effect means that costly decisions to reduce emissions today will bring benefits largely through reduced harm to future generations born many years hence. There is much debate over the best way to approach decisions when costs and benefits are distributed over time, and many deep philosophical and ethical issues surrounding how we justify those decisions are not easily settled. In their article in this issue, economists William Pizer, Ben Groom, and Simon Dietz review discounting and intergenerational decision making. In the remainder of this issue, leading experts on the social effects of climate change examine issues relevant to climate change's impacts on children. In each case, readers can find ample cause for concern, as well as ample reason for hope that children's lives will continue to improve throughout the current century as they did during the previous one. Taken together, these reports make it clear that ensuring that children's futures are adequately protected from the hazards of climate change will require unprecedented effort, innovation, and coordination, suggesting that few of our decisions about any other issues will come close to having as strong an influence on children's lives.

1.11. Policy Debate

Climate change now appears unavoidable; an increasing number of scientists, indeed, believe that the signs of anthropogenic climate change are already rising above the noise of random weather and longer term cyclic fluctuations. The way in which the impacts of climate change are distributed carries strong implications for how the world should and will respond. Differential impacts, between regions and between groups, complicate the ethical and political issues. This section looks first at some of the broad distributional features of impacts and then considers specifically vulnerable groups, before considering some of the general implications. For some other areas of the world, the outlook appears unambiguously gloomy; and this applies particularly too many countries in the developing world. There are several reasons for this:

- Most developing countries are in tropical regions, and projected climatic changes seem unlikely to improve either the quality of the physical environment or their agricultural productivity.
- Developing-country economies are much more dependent upon agriculture and other aspects of natural resource flows.
- The institutional and social structure of developing countries tend to be weaker and hence less able to cope with change; they also have fewer financial resources for investing in more robust infrastructure.

The kinds of severe impacts noted above, and the broader likelihood that climate change could exacerbate international inequalities, pose several thorny international issues. One concerns evaluation of how serious a problem climate change is. The potential suffering of the poorer regions of the world features negligibly in such calculations: since they have little wealth, they have little to lose. The unavoidability of some climate change raises the question of compensation, but it is extremely difficult for one state to prove before an international court or tribunal a direct causal link between another state's emissions and its own environmental damage. Although upon signature of the United Nation Framework Convention on Climate Change (UNFCCC) a number of small island countries indicated that they might rely on traditional rules of international law to address damage to their environments from climate change, it is widely recognized that it would be factually and legally difficult to use these rules successfully. In terms of general international law, to this author's knowledge little progress has been made. The first line of recourse in these circumstances is to consider more ad hoc compensation for those most adversely affected. The three years since Rio have seen limited progress towards implementation of this principle. Most effort has been made in the context of the Global Environmental Facility, from which developing countries have sought funding for adaptation measures. However, the GEF's (Global Environmental Facility) mandate restricts it to projects that carry global environmental benefits, on which grounds most adaptation measures do not qualify GEF's (Global Environmental Facility's) role under the Climate Change Convention. Developing countries have been encouraged instead to apply for support for adaptation planning as part of their national reports to the Convention, but this is hardly a basis for sharing of long-term adaptation costs or compensation. Developed countries argue that adaptation must be seen in the context of general national development and hence addressed through traditional ODA channels. Developing countries oppose this as potentially moving away from principles of new and additional assistance for climate protection measures.

Issues of who should limit future greenhouse gas emissions and by how much have already proven to be the focal point of the international political process in respect of climate change. This section sets out the way in which equity issues have entered the debate so far. The following section then considers the broader literature on the questions of how future emissions (or abatement efforts) should be allocated in the longer term, and who should pay for abatement.

Conclusions

The essence of the global environment problem, as I have sketched it, is that during the next century humanity will have to face the finite nature of the planet on which we live. That does not mean an end to development, but it does mean having to develop processes and criteria for resolving two fundamental distributional issues: * how to share out the responsibility for coping with the impacts of climate change, including issues of evaluating and potentially compensating for impacts on the most vulnerable; * how to share out the responsibility for keeping the collective environmental pressures of IO billion people including, and most specifically, CO_2 emissions within tolerable limits. The ethical basis for accepting some responsibilities regarding Tran's boundary impacts seems clear: one can hardly talk of global order if countries can knowingly and over long periods act in ways that impose environmental damage on others and not accept responsibility for helping victims to cope with those impacts. This is already acknowledged in the Convention; but actually taking institutional steps in the form of a climate fund or insurance pool is a different matter. The theoretical case for such steps is overwhelming and the literature on emissions accounting suggests some bases on which assessed contributions might be made. But the practical and political difficulties are such that such institutional advances may only emerge, painstakingly and bitterly contested, if and as attempts to pursue case law surrounding actual impacts make the issues inescapable.

In the need to establish international norms and responsibilities reflecting a wide diversity of national positions, indeed, there are some parallels with the processes of building nation-states. This was-for some, still is-a process spanning many centuries, in which peoples slowly developed shared values, perceptions and norms, and for the common good vested authority in societal institutions. Ultimately that is the challenge posed by climate change in the twenty-first century. And, just like the process of nation building, it will be an epic struggle between what power is, and what is fair.

****

UNIT - II

CLIMATE CHANGE POLICY - MITIGATION

2.1. Introduction

Worldwide observed and anticipated climatic changes for the twenty-first century and global warming are significant global changes that have been encountered during the past 65 years. Climate Change (CC) is an inter-governmental complex challenge globally with its influence over various components of the ecological, environmental, socio-political, and socio-economic disciplines (Adger et al. 2005; Leal Filho et al. 2021; Feliciano et al. 2022). Climate change is characterized based on the comprehensive long-haul temperature and precipitation trends and other components such as pressure and humidity level in the surrounding environment. Besides, the irregular weather patterns, retreating of global ice sheets, and the corresponding elevated sea level rise are among the most renowned international and domestic effects of climate change (Lipczynska-Kochany 2018; Michel et al. 2021; Murshed and Dao 2020). Before the industrial revolution, natural sources, including volcanoes, forest fires, and seismic activities, were regarded as the distinct sources of greenhouse gases (GHGs) such as CO_2, CH_4, N_2O, and H_2O into the atmosphere (Murshed et al. 2020; Hussain et al. 2020; Sovacool et al. 2021; Usman and Balsalobre-Lorente 2022; Murshed 2022). United Nations Framework Convention on Climate Change (UNFCCC) struck a major agreement to tackle climate change and accelerate and intensify the actions and investments required for a sustainable low-carbon future at Conference of the Parties (COP-21) in Paris on December 12, 2015. The Paris Agreement expands on the Convention by bringing all nations together for the first time in a single cause to undertake ambitious measures to prevent climate change and adapt to its impacts, with increased funding to assist developing countries in doing so. As so, it marks a turning point in the global climate fight. The core goal of the Paris Agreement is to improve the global response to the threat of climate change by keeping the global temperature rise this century well below 2 °C over pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5° C (Sharma et al. 2020; Sharif et al. 2020; Chien et al. 2021.

Furthermore, the agreement aspires to strengthen nations' ability to deal with the effects of climate change and align financing flows with low GHG emissions and climate-resilient paths (Shahbaz et al. 2019; Anwar et al. 2021; Usman et al. 2022). To achieve these lofty goals, adequate financial resources must be mobilized and provided, as well as a new technology framework and expanded capacity building, allowing developing countries and the most vulnerable countries to act under their respective national objectives. The agreement also establishes a more transparent action and support mechanism. All Parties are required by the Paris Agreement to do their best through "Nationally Determined Contributions" (NDCs) and to strengthen these efforts in the coming years (Balsalobre-Lorente et al. 2020). It includes obligations that all Parties regularly report on their emissions and implementation activities. A global stock-take will be conducted every five years to review collective progress toward the agreement's goal and inform the Parties' future individual actions. The Paris Agreement became available for signature on April 22, 2016, Earth Day, at the United Nations Headquarters in New York. On November 4, 2016, it went into effect 30 days after the so-called double threshold was met (ratification by 55 nations accounting for at least 55% of world emissions). More countries have ratified and continue to ratify the agreement since then, bringing 125 Parties in early 2017. To fully operationalize the Paris Agreement, a work program was initiated in Paris to define mechanisms, processes, and recommendations on a wide range of concerns (Murshed et al. 2021). Since 2016, Parties have collaborated in subsidiary bodies (APA, SBSTA, and SBI) and numerous formed entities. The Conference of the Parties functioning as the meeting of the Parties to the Paris Agreement (CMA) convened for the first time in November 2016 in Marrakesh in conjunction with COP22 and made its first two resolutions. The work plan is scheduled to be finished by 2018. Some mitigation and adaptation strategies to reduce the emission in the prospective of Paris agreement are following firstly, a long-term goal of keeping the increase in global average temperature to well below 2 °C above pre-industrial levels, secondly, to aim to limit the rise to 1.5 °C, since this would significantly reduce risks and the impacts of climate change, thirdly, on the need for global emissions to peak as soon as possible, recognizing that this will take longer for developing countries, lastly, to undertake rapid reductions after that under the best available science, to achieve a balance between emissions and removals in the second half of the century. On the other side, some adaptation strategies are; strengthening societies' ability to deal with the effects of climate change and to continue and expand international assistance for developing nation's adaptation.

However, anthropogenic activities are currently regarded as most accountable for CC (Murshed et al. 2022). Apart from the industrial revolution, other anthropogenic activities include excessive agricultural operations, which further involve the high use of fuel-based mechanization, burning of agricultural residues, burning fossil fuels, deforestation, national and domestic transportation sectors, etc. (Huang et al. 2016). Consequently, these anthropogenic activities lead to climatic catastrophes, damaging local and global infrastructure, human health, and total productivity. This review aims to highlight the effects of climate change in a socio-scientific aspect by analyzing the existing literature on various sectorial pieces of evidence globally that influence the environment. Although this review provides a thorough examination of climate change and its severe affected sectors that pose a grave danger for global agriculture, biodiversity, health, economy, forestry, and tourism, and to purpose some practical prophylactic measures and mitigation strategies to be adapted as sound substitutes to survive from climate change (CC) impacts. The societal implications of irregular weather patterns and other effects of climate changes are discussed in detail. Some numerous sustainable mitigation measures and adaptation practices and techniques at the global level are discussed in this review with an in-depth focus on its economic, social, and environmental aspects. Methods of data collection section are included in the supplementary information.

2.2. EFFICIENCY, PUBLIC GOODS, EXTERNALITIES

2.2.1. EXTERNALITY

An externality exists if some of the variables which affect one decision-maker's utility or profit are under the control of another decision-maker.

For example, a chemical works which pumps effluent into the stream will affect the cost of producing beer in a brewery industry downstream because of its choice of output level and input combinations and the amount of effluent which needs to be removed from the water before it can be used in beer production. In this case, the externality is detrimental, but in other cases, there may be beneficial externalities, as for example, when an apple grower is located next to a bee-keeper. The bees will cross-pollinate the apple trees, benefiting the apple- grower, and feed off the apple blossom, benefiting the bee-keeper as well. This is an example of reciprocal externality. In addition, there may be consumer externalities, producer-consumer externalities and consumer producer externalities. Let us see why externalities may lead to inefficiency. We consider again the example of the upstream chemical factory and the downstream brewery. The chemical factory will fix its output level to maximise its profits and will not take into consideration the effects of its pollution on the profits of the brewery industry.

But the brewery would be willing to pay the chemical factory to reduce the amount of effluent, because, this will reduce the costs of brewery industry. Such a reduction in effluent may reduce the chemical industry's profits, as the firm's output of chemicals and the effluents are in fixed proportions and any reduction of effluent, thus, requires a reduction in output of the chemical industry. If the reduction in the brewery industry's costs exceeds the reduction in the chemical factory's profit, there are potential gains from trade and the original level of effluent cannot have been efficient. This observation leads to a possible solution to the externality problem presented by Coase.

2.2.2. Coase Theorem:

Assuming that the chemical factory produces its output and the effluent in fixed proportions, we can write its profit as a function of effluent, which is x, as: B(x). The damage produced by the chemical factory downstream due to pollution is D(x). Fig. 2.1 shows the marginal benefit (MB) B '(x) and marginal damage (MD) D'(x) from polluting downstream. Assume that the profits of the two firms measure the social value of their outputs and that the effluent does not impose costs on any other individuals or firms, then the efficient level of pollution which maximises the profits of the two firms is given by x* which satisfies : $B'(x^*) - D'(x^*) = 0$........... (1)

Consider two possible legal situations, which will be determined by which firm sets up business first:

(a) Permissive:

Suppose the chemical firm has the legal right to discharge as much effluent as it wishes. Thus, it controls effluent, x, and would choose a level x^1, where $B'(x) = 0$. Here the level of pollution is inefficiently large as its effect on the brewery 'firm is ignored'.

(b) Restrictive:

The chemical firm has no legal right to discharge effluent and the brewery firm can obtain a court order to prevent it from doing so.

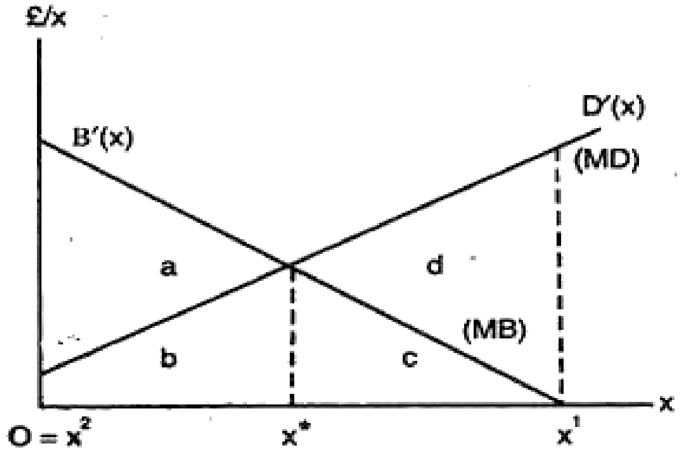

Fig.2.1. Negotiating Solution

In such a situation, it is the brewery firm which controls the level of pollution and chooses a level of $x^2 - 0$, where its costs from the effluent are minimised. A zero level of pollution is also inefficient since the brewery firm ignores the effect of its choice on the profit of the chemical firm.

Since x^2 and x^1 are inefficient, there are potential gains from trade, i.e., from a contract between the two firms to control the pollution level. Suppose the legal action considers a reduction of pollution to x* from x^1. The reduction in the chemical firm's profit is c and the reduction in the brewery firm's costs is c + d.

A payment by the brewery firm to the chemical firm of c + dQ ($0 < Q < 1$) in exchange for a reduction in pollution from x^1 to x* would achieve an efficient allocation of resources and make both firms better-off. The contract would generate a combined gain from trade of d. If the legal regime is restrictive, a contract in which the chemical firm paid the brewery Qa + b, in exchange for an increase in effluent from zero to x* would lead to an efficient level of pollution and make both parties better-off.

The payment to the brewery would more than compensate for the increase in costs b and the chemical firm's profit would increase by a + b which would more than cover the payment to the brewery. The contract would split the gains from trade between the two firms.

This result is known as Coase Theorem: "Bargaining can achieve an efficient allocation of resources whatever the initial assignment of property-rights." If the affected parties can contract with each other, the externality will be internalised and the party who has the legal right to control will take into consideration its effects on the other. The initial assignment of rights does affect the distribution of income. Under a permissive law, an efficient bargaining increases the polluter's profit by Qd and under a restrictive regime, an efficient bargaining increases it to Qa.

Despite private bargaining, inefficiency arising from externalities persist for a variety of reasons. In "small number" there may be failure to agree on the division of the gains from a move to a more efficient allocation.

In "large number" the absence of contracting between polluter and victims may arise. The free rider problem is likely to be important, because it will be difficult for the polluter to control the level of pollution for a particular victim. Reduction in pollution will tend to benefit all victims have in the area irrespective of whether they are willing to pay or not for a reduction in pollution. In addition, the legal situation may not be well-defined, so that it is not clear whether the polluter has the legal Tight to pollute, or his victims the legal right to protection from his pollution. Legal remedy is likely to be very costly.

Even if the market is established, it may not be competitive; a single polluter confronting many victims may act like a monopolist with respect to changes in the level of pollution. There is still interest in a solution to the externality problems which require public intervention.

2.2.3. Pigovian Taxes and Subsidies:

If the externality cannot be internalised via a Coasian bargaining, it may be possible to mitigate the inefficiency through government action. Prof. Pigou suggested that externalities should be internalized by a suitable taxes or subsidies policy. Suppose the legal regime is permissive, so that, a polluter would choose an inefficiently high level of pollution.

Imposing a tax of t per unit on the output of pollution would give the polluter a profit function of $B(x) – tx$ and the level of pollution chosen would satisfy $B'(x) – t = 0$. If the Pigovian tax rate was imposed on the marginal damage inflicted by the polluter then the efficient pollution level would be: $t = D'(x^*)$; the polluter would be allowed to choose the efficient amount of pollution, where

$B'(x^*) = t = D'(x^*)$ .... (2)

By making the polluter pay the marginal damage imposed by pollution the tax internalizes the externality:

Apart from the potential problems with Pigovian taxes, there are difficulties of obtaining the information necessary to calculate the correct rate of tax. If the parties can bargain about the level of externality, a Pigovian tax may not lead to efficiency.

Fig. 2.2 shows that the effect of the tax is to shift the polluter's marginal benefit (MB) curve down from $B'(x)$ to $B'(x)$ -1 and the polluter will maximise after tax profit by choosing x^*.

But, suppose, the chemical firm and the brewery can still negotiate. At x^*, the brewery still suffers positive marginal damage from pollution, whereas, the after tax MB to the polluter is zero. A bargain to reduce x to x^0 could make both of them better-off; but the governments' tax revenue would be reduced by $l(x^* -x^0)$, which is larger than the private gain from the bargain. The new allocation at x^0 is Pareto inefficient it would be possible to increase tax revenue and make both firms better-off if x was increased from x^0 to x^*. If private bargaining is possible, efficiency can be gained without Pigovian taxes. One justification for such taxes might be the achievement of better distribution of income only.

A tax on pollution could be combined with a subsidy to those who suffer from an externality to compensate for the damage. If such a subsidy is paid, it may not provide any incentive for private bargaining between the parties. Now, suppose, out of the proceeds of tax revenue, collected from the chemical firms, the brewery was paid a subsidy equal to the amount of damage it suffers from the effluent.

Thus, the combination of a Pigovian tax and subsidy leads to efficiency, even if the parties could bargain, provided the brewery can do nothing to change the damage that it suffers.

The magnitude of the effects of damage from externalities can be influenced by the actions of both parties, not just the party who causes the externality. For example, the brewery might be able to use a different production process which requires less water or sink a well to get less polluted water. Thus, efficiency requires that both parties mitigate the damage through a Coasian bargain. Instead, it can be shown that paying compensation to the brewery, when it can influence the costs imposed by the effluent, leads to inefficiency.

Suppose, the damage function is D(x, z) where z is the expenditure by the brewery to reduce the damage imposed on it by the chemical firm: $D_z < 0$. Let S (D) be the compensatory subsidy given to the brewery. The brewery will choose z to maximise S (D) -D -z and z will satisfy the Kuhn-Tucker condition:

$S'(D) D_z - D_z - 1 = D_z (x, z) [S(D) - 1] - 1 \leq 0, z \geq 0$.................... (3)

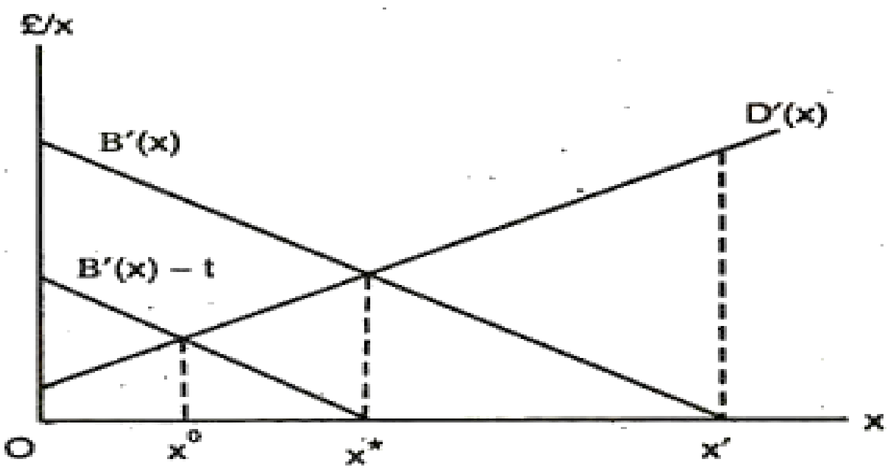

Fig.2.2. Pigovian Taxes and Subsidies

But, efficiency requires that $B(x) - D(x, z) - z$ is maximised which implies that $D(x, z) - 1 = 0$ .... (4)

(We assume that $D_z(x, 0) > 1$, if $x > 0$ so that it is always efficient for the brewery to undertake cost-reducing expenditure against effluent.) Comparing (3) and (4), we see that paying full compensation (S = D) to the brewery will eliminate its incentive to reduce the damage it suffers: If $S'(D) = 1$, the brewery will set $z = 0$.

In general, if the compensation varies with the amount of damage suffered ($S'(d) > 0$), there will be a less than efficient level of mitigation expenditure.

2.2.4. Common Property:

A common property resource is an asset whose services are used in production, or consumption and which is not owned by any one individual. Examples are ocean fisheries and common grazing land and public goods. We suggested earlier that common ownership can cause inefficiency and we will show this here.

Take the example of a lake in which all members of the community have the right to fish. For simplicity, let us assume that the total output or catch depends on the total time spent fishing by all individuals:

$q = f(L) = f(\sum L_i.)$................. (5)

Where q is the total output or catch, L_i is the time spent for fishing by the ith individual and $L = \sum L_i$. is total time spent fishing. f(L) is concave in L and attains a maximum at L in Fig. 2.3. The ith individual's catch, q_i, is:

$q_i = (L_i/L).f(L)$ ....(6)

It is assumed in equation (6) that everyone is equally skilful and can fish anywhere in the lake. Hence, the proportion of the total catch made by ith individual is the proportion of total fishing effort of labour input: $q_i/q = L_i/L$. Alternatively, catch per unit of labour input is q/L and, so, L_i hours spent fishing yield a catch of L_iq/L.

We also assume that variations of total output from the lake have no effect on the price of fish, p, and that variations in the total labour input have no effect on the wage-rate. They wish to maximise their individual profits: $\pi = pq_i - WL_1$ where π is i's profit.

Hence each sets L. so that:

$P[q/L + (L_i/L)(f'' - q/L)] - W = 0$ .... (7)

With this condition each individual is maximising profit and is, in fact, earning a positive profit which is: $pq_i - WL_i = (p.q/L - W).L_i$, which is positive, for $L_i > 0$, if $p.\ q/L - W > 0$.

If the marginal product declines ($f'' < 0$), marginal product $f' < q/L$.

The equilibrium total labour input, L^0, in Fig. 2.3 has the property that a reduction in total fishing effort, say to L, would actually increase total output. This occurs because the wage-rate is low enough for an intersection to take place in the range of negative marginal products.

The outcome, in this case, will be inefficient as long as the output of fish has a positive value and labour devoted to fishing has an opportunity cost. In order to generalize this result, we have to make some assumptions about the marginal social value of fish and the marginal social cost of labour.

We assume that these are, in fact, measured by the market prices offish (p) and labour (W), respectively. Hence net social benefit from fishing in the lake is: $pq - WL$, which is maximised when $pf' - W = 0$............. (8)

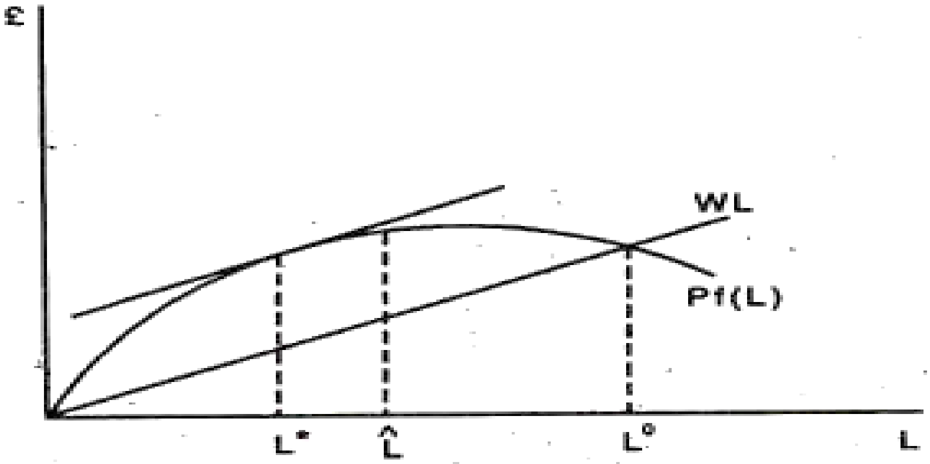

Fig.2.3.Common Ownership Causes Inefficiency

In terms of Fig. 2.3, the efficient level of L is L* where the vertical distance between the pq and WL curves is greatest. Notice that L* is always less than L° since $f' < q/L$: Free access always leads to overfishing if there are diminishing returns which means that the intersection of WL and pf(L) in the figure always occurs at a value of L greater than that at which their slopes are equal.

The efficient outcome could be achieved if all the individuals with fishing rights can agree to reduce their total labour to L*. Such an agreement may not be very likely if there are a large number of individuals with fishing rights or if it is difficult to police such an agreement because breaking the agreement would be profitable.

One solution could be to divide the lake among the individual fishermen and give each of them exclusive right to fish in that part of the lake. These rights will require policing and enforcing and this may be expensive.

An alternative solution would be to vest ownership of the lake in the individual. Since, on our assumptions, total profit from fish production from the lake is the net social benefit, maximisation of profit leads to efficient labour input.

Unrestrictive access leads to intensive use, but it may also lead to other kinds of inefficiency because it weakens the incentive of individual decision-makers to invest in improvements to the productivity of the resource, or to pay regard to the possibility of extinction of the fish stock through overfishing. Since a single individual cannot prevent others from using the resource; the benefits from investment or voluntary restraint will be spread over all other users.

Hence, it will not pay any single decision-maker to undertake the investment, or to restrict his catch, even though the total benefits exceed the cost. Even if the share of the benefits accruing to a single individual exceeds the cost of the investment, it may not be undertaken if each individual believes that he will benefit from the investment of other users. Because of non-excludability, investment by other users is a substitute for investment by any particular individual and if all individuals realize this, no investment may take place. The market fails in this case because no market can exist in the absence of well-defined and easily enforceable rights to exclude by any single individual. There is nothing which can be exchanged and no means which individuals can capture or be made to bear all the results of their actions.

2.3. PUBLIC GOODS:

The defining characteristic of a public good is that it is non-rival and non-exclusive: Consumption of it by one individual does not actually or potentially reduce the amount available to be consumed by another individual. Examples include radio and television broadcast and national defence. Any individual can listen to or watch the output of a broadcasting station, without preventing any other individual who possesses a radio or television receiver from consuming the same output. Any individual can increase his consumption of television broadcasts up to the total number of hours broadcast, without reducing any other individual's actual or potential consumption. Broadcasts are an example of an optional public good, in that, one can choose to consume any amount of output produced. Defence is a non- optional public good in that all inhabitants of the country consume the total quantity provided; and if one inhabitant is to be defended, all will be.

In the case of non-optional public goods, if we denote the total quantity produced by q and the total quantity consumed by the ith individual by q_1, i = 1 ………… n, we have $q_1 = q_2 = \ldots\ldots\ldots q_n = q$ ………… (9)

On the contrary, private goods are the goods which have the characteristic that with a given output, an increase in one individual's consumption of a private good reduces the amount available for consumption by other individuals.

Note that an increase in one individual's consumption of a private good need not actually reduce the level of consumption by any other individual, but only the amount available to be consumed by others.

For example, if I occupy a seat in an empty railway compartment, my consumption of the railway travel will not reduce that of anyone else's but it reduces the availability of consumption to one other since I have occupied one seat.

For private goods, the relationship between individual consumption x_i and output X is: $x_1 + x_2 + \ldots\ldots\ldots\ldots + X_n \leq x_p$ …………. (10)

Efficiency with Public Goods:

We derive the necessary conditions for Pareto efficiency in a two-person, two-good economy.

The preferences of consumer i can be represented by the quasi-linear utility function:

$U^i(x_i, q) = B_i(q) + x_i$

$B_i > 0$, $B''_I < 0$, $i = 1, 2$ .... (11)

Where q is the consumption of the non-optional public good by consumer i and x is consumption of the private good. The MRS of consumer i $MRS^i_{xq} = U_q / U_x = B'_i$, which is the marginal valuation of the public good by i in terms of the private good.

Notice that the assumption that preferences are representable by a quasi-linear utility function means that the marginal valuation of the public good is independent of the amount of the private good consumed. The production possibilities for the economy are shown in Fig. 2.4(a). The production possibility frontier, PP, is a straight line so that $MRT_{xq} = C$, indicating that we are assuming that the public good has a constant MC in terms of forgone private good output. We derive the efficiency conditions by maximising U^1 subject to individual 2 at least getting a specified level of utility U^2 and subject to the material balance constraints and technology.

In such an economy, the feasible output combinations are those on or below PP and material balance constraints. Since consumer 1 is non-satiated, the constraint on U^2 and the material balance constraint on the private good will bind as equalities in an efficient allocation.

The IC I_2 in Fig 2.4(a) shows combinations of x_2 and q which satisfy the utility constraint $U^2 (x_2, q) = U^2$. The vertical distance between PP and I_2 shows, for any level of q, the maximum amount of the private good which can be consumed by individual 1 given the technology of economy and the constraint that $U^2 = U^2$.

For example, when $q = q^0$, the maximum amount of private good available for individual 1 is $x^0{}_1 = x^0 - x^0{}_2$. Thus, since individual 1 will also be able to consume public good, his consumption bundle is $(x^0{}_1, q^0)$ when the public good output is q^0.

The curve g in Fig. 2.4(b) shows the vertical distance between PP and I_2 which gives the feasible consumption bundles of individual 1 provided that individual 2 has utility U^2. Utility of individual 1 is maximised at a* where his indifference curve is tangent to g. Since the slope of g is the difference between the slope of PP and the slope of I_2:

(MRT_{Xq} – MRS^2_{xq}) and the slope of I*1 is -MRS^2_{xq}, the efficient allocation is characterised by:

(MRS^1_{xq} + MRS^2_{xq})= MRT_{xq} .... (12)

Or, marginal benefit = marginal cost, which, in terms of single specification of preferences and technology,

$B'_1(q)+B'_2(q)=C$................ (13)

Because q is a public or non-rival and non-exclusive good, an increase in q by one unit increases all individuals' consumption of the public good by one unit. Hence, the marginal value of the additional unit of the public good, in terms of the private good, is the sum of all the individuals' marginal valuations of the public good.

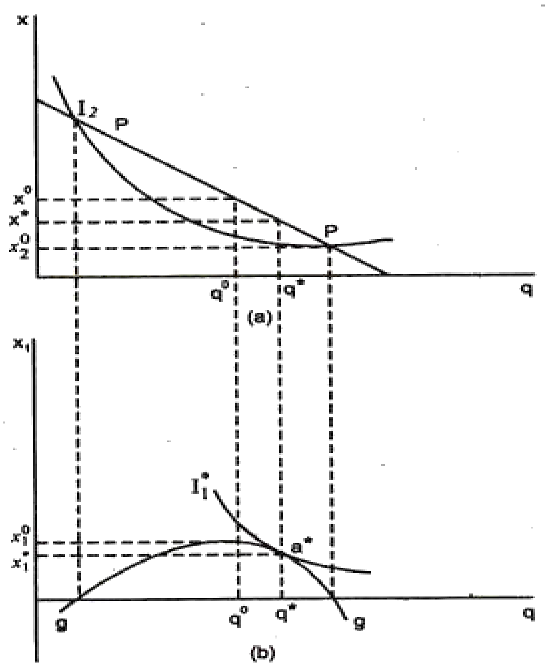

Fig.2.4. Efficiency with Public Goods

Efficiency requires that the amount of the private good the individuals would be willing to give up to acquire an extra unit of the public good (I.MRS must be equal to the amount by which production of the private good must be reduced to raise the output of the public good by one unit (MRT_{xq}).

A market economy is unlikely to satisfy the efficiency conditions for the supply of public good for two reasons first, many public goods are non-excludable. For example, defence and police services. If it is impossible to exclude non-payers from consuming a public good, firms may not be able to collect revenue to cover the cost of producing the public good.

If there are free riders because they cannot be excluded, the price that firms charge for supplying a public good may not be an adequate measure of the marginal benefit of the good and there will be a less efficient supply of the good.

Second reason is that the market may fail to provide an efficient amount of public goods even when they are excludable, arising from another characteristic of public goods: non- rivalry. Suppose, a good is excludable, transferable, there are many consumers and producers and also low information costs. In such a situation, if the good is private, the resulting market equilibrium allocation will be optimal.

Competitive market economy ensures that all consumers pay the same price, which will be equal to the marginal cost of the good in each of the firms. Consumers will compete for a given output of the good and no consumer will be offered or be able to force a sale at a price less than the market price.

By contrast, if the good is public, even if excludable, the opportunity cost of a unit sold to one consumer is zero when output q is given. Since the good is a public good, an additional unit consumed by one individual does not reduce the amount available for consumption by any other individual. This means that no consumer is competing against any other consumer for a particular unit.

The consumer, and, thus, the market is not competitive, despite the large numbers of buyers and sellers. If a consumer realizes that the marginal cost of his own consumption is zero, he may offer to the producer a very low payment for the right to consume the producer's output. If all consumers act in this way, the amount offered by consumers will be. Insufficient to cover the costs of production — and a zero output will be produced.

In a competitive market for a private good, consumers realise that they cannot affect the market price and, hence, they adjust their consumption until their marginal valuation of the private good is equal to its price.

Hence, all consumers' marginal valuations are equal to the price, and in a competitive market, P = MC, and the efficiency conditions for private goods will be satisfied. In a market for a public good consumers' marginal valuations of the good, will generally differ and, so, each should be charged a different price equal to his marginal valuation. The sum of these prices should then be equated to the MC of the public good. Consumers have no incentive to reveal correctly their marginal valuations of the public good since they do not regard the prices as unalterable, and, so, will not be satisfied.

2.3.1. Public Goods and Market Failure:

Suppose, we are deciding to introduce a mosquito abatement programme for the community. We know that the programme is worth more to the community than the private cost of £50,000 required to provide it. Can this programme be privately provided? We would probably break even if we can introduce a fee of £5 to each member of 10,000 households in our community.

But we cannot force them to pay the fee, let alone devise a system in which those households that value the programme the most pay highest fees.

The problem is that mosquito abatement is non-exclusive — there is no way of providing the service without benefiting everyone. Thus, households do not have the incentive to pay what the programme is really worth to them. People can act as free riders, understanding the value of the programme so that they can enjoy its benefit without paying for it.

With public goods, the presence of free riders makes it really difficult — or even impossible for markets to provide goods efficiently. Perhaps if few people were involved and the programme were relatively inexpensive, all households might voluntarily agree to share its costs.

However, when many households are involved, voluntary private arrangements are usually ineffective, and the public good must be subsidized or provided by governments, if it is to be provided efficiently.

Private Preferences for Government-Produced Public Goods:

Government provision of a public good is advantageous because the government can spend money from the revenue and increase taxes to pay for it.

But how can the government determine how much of a public good to provide when the free rider problem gives people the incentive to misrepresent their preferences? Here we discuss how to determine the private preferences for goods that the government provides and/or produces. Majority voting rule is commonly used to decide allocation questions.

Let us examine here how majority voting rule determines the provision of public education. Fig. 2.5 describes the preferences for spending on education of three citizens who are representatives of three similar groups of people in the school district.

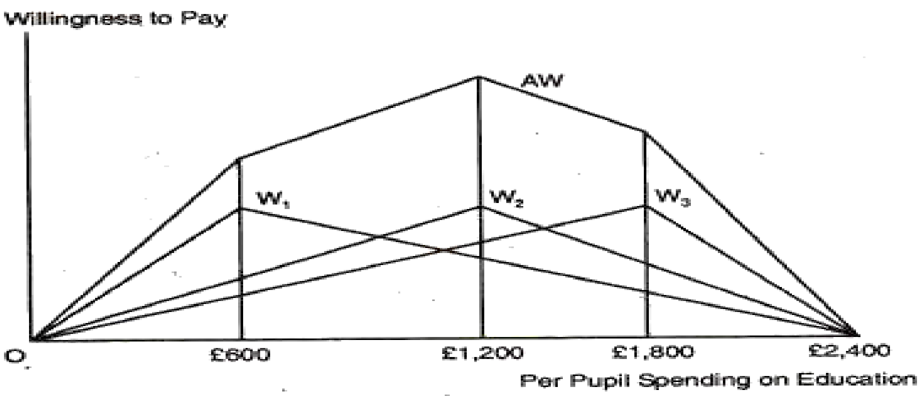

Fig.2.5. Private Preference for Public Goods

Curve W_1 gives the first citizen's (first group of citizens) willingness to pay for education, net of required tax payments. In general, the benefit from education increases as spending increases which requires increased tax payments as well. The willingness to pay curve initially slopes upward because the citizen places great value on low-spending levels.

However, when spending increases beyond £600 per pupil, the value on education increases at a diminishing rate, so the net benefit actually declines. Eventually, the spending level becomes so great (£2,400 per pupil) that the citizen is indifferent between this spending and no spending.

Curves W_2 and W_3, representing the second and third citizen's willingness to pay, are similarly shaped but reach maximum at £1,200 and £1,800 per pupil, respectively. The solid line AW represents the aggregate willingness to pay for education the vertical summation of the W_1, W_2 and W_3 curves. The AW curve provides a measure of the maximum amount that all three citizens are willing to pay to enjoy each spending level. As the figure shows, the aggregate willingness to pay is maximised when £1,200 per pupil is spent because this measures the benefit of spending net of tax payments required to pay for that spending and this also represents the efficient level of spending.

Will majority voting achieve the efficient outcome? Suppose the public is required to vote whether to spend £1,200 or £600 per pupil. The majority will vote for £1,200 per pupil (two against one) which represents the most preferred alternative of the median voter. Under majority rule voting, the preferred spending level of the median voter will always win an election against any other alternative. However, majority rule voting allows the preferences of the median voter to determine referenda outcomes, but these outcomes need not be economically efficient. Majority rule voting is not always efficient because it weighs each citizen's preference equally — the efficient outcome weighs citizens' vote by their strength of preference.

2.3.2. Public Goods:

We have seen that externalities create market inefficiencies that sometimes warrant government intervention and/or regulation. When should the government replace private firms as the producer of goods and services? Here we describe a set of conditions under which the private market either may not provide the good at all or may not price it properly once it is available. Public goods have two characteristics: They are non-rival and nonexclusive. A good may be regarded as non-rival, if, for any given level of production, the marginal cost of providing it to an additional consumer is zero. For most privately provided goods, the marginal cost of producing an additional good is positive. But for some goods, additional consumers do not add to cost. For example, a highway during a period of low traffic volume, because the highway already exists and there is no congestion, the additional cost of driving extra traffic (cars) on it is zero. Or, consider the use of public television. Once the television is in operation, the cost of providing it to one more viewer is zero.

Most goods are rival in consumption. For example, when we buy furniture, we rule out the possibility that someone else can buy it thus, the furniture is a rival good. Rival goods are required to be allocated among individuals, whereas non-rival goods can be made available to everyone without affecting any individual's opportunity for consuming them. A nonexclusive good is one if people cannot be excluded from consuming it. As a consequence, it is difficult, if not impossible, to charge people for using nonexclusive goods the goods can be enjoyed without directly paying for them. For example, national defence is a nonexclusive good.

Once it is provided, no one can be excluded from its benefit. Other examples of nonexclusive goods are public television, lighthouse etc. Some goods are non-rival but exclusive. For example, in periods of low traffic, travel on the bridge or highway is non-rival because an additional vehicle on the bridge or highway does not lower the speed of other vehicles. But it is exclusive because the authorities can keep people from using it.

A television signal is another example of a non-rival good. Once the signal is broadcast, the marginal cost of making the broadcast available to another user is zero, so it is non-rival. But broadcast signals can be made exclusive by scrambling the signal and charging for the code that allows it to be unscrambled, thus, a company can exclude users.

Some goods are nonexclusive but rival. Air is nonexclusive but can be rival if the emissions of one firm adversely affect the quality of the air and, thus, deny other people from enjoying it. A lake or ocean is nonexclusive, but fishing is rival because it imposes costs on others.

Public goods which are both nonexclusive and non-rival provide benefits to people at zero marginal cost, and no one can be excluded from enjoying them. For example, national defence is a public good which is nonexclusive and is also non-rival. The lighthouse is also a public good, because, it is non-rival and nonexclusive.

Many publicly provided goods may not be public goods but they are either rival in consumption, exclusive, or both. For example, school education is rival in consumption because there is a positive marginal cost of providing education to one more child. Similarly, charging tuition fee can exclude some children from enjoying education. Education is provided by the government because it entails positive externalities, not because it is a public good. Lastly, consider the management of a national park. Some people may be excluded from using the park by raising entrance fee. Use of the park is also rival because of crowded conditions.

2.4. ENVIRONMENTAL POLICY

The translation of existing or expected environmental problems into corrective or preventive environmental policy depends heavily on social and political factors at the national, and sometimes regional, level. Environmental problems within any nation are perceived, interpreted and given priorities in accordance with existing social preferences. Environmental quality is a matter of social choice and societies may differ, quite legitimately, in their views as to what constitutes an "acceptable" level of environmental quality. Societies afflicted with widespread malnutrition and disease, high infant mortality, low life expectancy, high illiteracy levels and endemic unemployment are not likely to place the same value on degradation of the natural environment as societies in which these kinds of problems have been overcome.

This means that identical objectively perceived environmental damage may be accorded quite different social weights in different countries. These relative social weights then enter into the political process, where their transformation into policy action depends on the structure, representativeness, accessibility, prevalent ideology and other features of the national political system. Differences in interest group pressures and in the existing political machinery will often lead to differences in the assessment and selection of feasible policy alternatives. Since policy structures among nations are both heterogeneous and imperfect, this means that identical social weights applied to the same environmental issue in different countries may not in fact result in the same selection of policy alternatives.

Implementation of the policy framework will involve the selection, development and use of different kinds of environmental policy instruments. Nations typically will use some combination of prohibition, standards, charges, tax schemes, land use controls, clearance requirements, subsidies, hearing procedures, and the like in their at- tempts to carry out environmental policy. Such controls provide incentives and disincentives for decision makers at the operating level of the economy "carrots and sticks" that serve to guide the choice of inputs, processes, and outputs of environment-affecting activities, thus coming back full circle to economic activities.

2.4.1. Environmental policy instruments

We discuss the policy instruments for environmental protection.

(A) The Polluter Pays Principle (PPP):

For the last two decades, many economists have suggested that firms discharging polluting effluents to the environment should somehow be made to pay a price for such discharges related to the amount of environmental damage caused. OECD has suggested the Polluter Pays Principle (PPP) as a general basis for the environmental policy. It states that if measures are adopted to reduce pollution, the costs should be borne by the polluters.

The OECD Council defines the Polluter Pays Principle thus. "The principle to be used for allocating costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment is the so called Polluter Pays Principle." The essential concern of this principle is that polluters should bear the costs of abatement without subsidy.

The Polluter Pays Principle, as interpreted by the Supreme Court of India, means that the absolute liability for harm to the environment extends not only to compensate the victims of pollution but also the cost of restoring the environmental degradation. Thus, it includes environmental costs as well as direct costs to people or property.

Remediation of the damaged environment is part of the process of sustainable development and as such the polluter is liable to pay the cost to the individual sufferers as well as the costs of reversing the damaged ecology. The application of this principle depends upon the interpretations, particular cases and situations. This principle has brought more controversial discussions during the Rio Earth Summit 1992. The South has demanded more financial assistance from the North in combating the environmental degradation in the South. There are practical an implication on the allocation of economic obligations in relation to environmentally damaging activities, particularly in relation to liability and the use of economic instruments.

(B) The User Pays Principle—(UPP):

It is considered as a part of the PPP. The principle states that all resource users should pay for the full long run marginal cost of the use of a resource and related services, including any associated treatment costs. It is applied when resources are being used and consumed.

(C) The Precautionary Principle (PP):

The main objective of the precautionary principle is to ensure that a substance or activity posing a threat to the environment is prevented from adversely affecting the environment, even if there is no conclusive scientific proof of linking that particular substance or activity to environmental damage. The words 'substance' and 'activity' are the result of human intervention. The Rio Declaration in its Principle 15 emphasizes on this principle wherein it is provided that where there are threats of serious or irreversible damage. Lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation.

2.5. EMISSIONS TRADING

Emissions trading cleverly solves an economic efficiency problem with a traditional performance standard. Regulators may employ uniform performance standards for an entire industry, applying the same pollution reduction requirement to each plant in an industry. Uniform performance standards, however, do not imply uniform cost. Implementation of the same pollution reduction requirement throughout an industry may generate very high costs at some facilities and very low costs at others, because plants have different equipment and configurations. This implies that uniform performance standards regulate inefficiently.

For example, imagine an industry with just two facilities in it. (This is an unrealistic assumption, but it facilitates explanation). The regulator requires 100 tons of reductions from each facility. But these reductions cost $20 a ton to generate at one facility (call it Cheap) and $50 a ton to generate at the other facility (call it Expensive). A uniform standard would impose a cost of $7,000 for 200 tons of total reduction: (100 X $20) + (100 X $50). Suppose, however, that instead Cheap made all 200 tons of the required net reductions. This would reduce the cost of realizing the 200-ton total reduction to just $4,000 (200 X $20). In other words, a rearrangement of pollution reduction obligations could meet the same environmental goal at lower cost. Regulators, however, usually lack detailed marginal control cost information for each facility, so that government tailoring of regulate realize least cost abatement would prove very difficult or impossible. Emissions trading works around this informational problem by using a market in emission allowances to realize cost-effective pollution abatement. The regulator establishes a pollution limit, just as she would in establishing a traditional regulation, but she authorizes polluters to trade their obligations among themselves. If the regulator applied the same 100 ton limit to each of the two facilities discussed above through a trading program, Expensive's owner would likely pay Cheap's owner to over comply. Cheap makes 200 tons of reduction, 100 tons to satisfy its reduction obligation and another 100 tons to sell to Expensive's owner. Expensive's owner does not reduce Expensive's emissions, but instead complies with the purchased credits reflecting the extra reductions made at Cheap. Thus, a trading program authorizes polluters to trade their pollution control obligations in order to realize cost-effective abatement.

The United States Environmental Protection Agency (EPA) began experimenting with trading through the offset programs of the late 1970s and 1980s. These offset programs authorized polluters to forego otherwise required pollution abatement at one source if they purchased or realized extra reductions from another source not subject to a mass-based cap. These programs saved polluters a lot of money, but often did so by facilitating evasion of emission limits. Often polluters could not show that they had made reductions that they claimed credit for. In other cases, they claimed credits for activities that would have reduced pollution anyway from unregulated sources. The happenstance of an emissions reduction somewhere in the economy could allow a regulated polluter to avoid a required reduction, even if a state still needed that required reduction meet pollution reduction goals. The modern trading literature refers to the vice of relying on emission reductions that would have happened anyway to avoid an otherwise required emission reduction as a problem of "additionality”. Adding to the woes that this additionality problem created, these programs applied to volatile organic compounds, which defied reliable measurement. In 1990, however, Congress created a cap-and-trade program to address acid rain. Most of the sulfur dioxide emissions causing acid rain came from electric power plants. So, Congress capped the sulfur dioxide emissions of these plants, limiting the tons of sulfur dioxide each could emit in a year. But it made these allowances tradable, meaning that owners of electric power plants who over complied could sell the extra allowances to polluters who under complied. Because of rigorous monitoring requirements (which were technically possible for sulfur dioxide) and because Congress confined all trades to capped sources, this program succeeded in delivering significant environmental benefits, and did so at much lower than anticipated cost. Encouraged by the acid rain program's success, the U.S. government pushed hard to include trading in the international regime addressing global climate disruption. As a result, the Kyoto Protocol to the Framework Convention on Global Climate Change (Kyoto Protocol) the first international agreement to reduce greenhouse gas emissions authorizes broad international environmental benefit trading.

Although most observers refer to trading programs addressing climate disruption as "cap - and- trade" programs, these programs conform to model combining some of the features of the successful acid rain cap and trade program with features of the failed offset programs. These programs apply a mass-based cap to the emissions of targeted source the acid rain program had), but authorize the capped sources to trade outside the cap i.e., to purchase offset credits from uncapped sources to satisfy some or all of their obligations (like the failed offset programs). The trading programs enacted under the Kyoto Protocol have not always performed well, but governments have improved them over time. The European Union (EU) pioneered trading under the Kyoto Protocol with its ETS. The ETS produced few emission reductions, mostly because member states established insufficiently stringent caps for their sources. The offset credits used in the program also exhibited the same sorts of additionally problems that had plagued the early offset programs in the United States. The EU, however, has tightened the cap recently and made other improvements that create some hope of success in the future.

The first climate trading program in the United States, the Regional Greenhouse Gas Initiative (RGGI), an initiative of north eastern states, also suffered from an inadequate cap, which the regulating authority has recently revised. In spite of this problem, the regulated electric utilities significantly reduced emissions, partly because cleaner natural dirty coal during RGGTs first phase and RGGI states used allowance revenue (realized by auctioning pollution allowances) to fund energy efficiency and renewable energy (both of which reduce emission. Trading programs addressing greenhouse gas emissions have across the globe. In the last few years, China the world's largest of greenhouse gases completed pilot trading programs in seven ci provinces. All of these programs use the hybrid trading model, thereby potentially authorizing credits from a wide variety of unregulated pollution sources to substitute for compliance by the targeted sources (mostly large industrial facilities, including power plants). Thus, emissions trading provides for cost-effective abatement. It has a mixed track record suggesting that environmental performance depends heavily on design variables primarily the stringency of the cap, the role of offsets, and the strictness of monitoring requirements.

2.6. CARBON TAX

A pollution tax, like emissions trading, facilitates cost effective abatement. To see this, imagine that a regulator imposes a $100 per ton tax on a pollutant. Those facility owners who can make pollution reductions costing less than $100 per ton will likely reduce pollution in lieu of paying the entire tax. Those facility owners facing abatement costs exceeding $100 per ton will likely choose to pay the tax rather than reduce pollution. Hence, a pollution tax encourages cost-effective abatement by only encouraging abatement that costs less than the tax rate. The standard theory recounted here about the efficiency of pollution taxes and emissions trading depends heavily on a narrow understanding of efficiency. The standard theory focuses on the cost effectiveness of reducing a single pollutant i.e., the least cost method for achieving specified pollution reduction goal. The climate that one can stretch this efficiency definition a little market-based mechanisms' claim to efficiency. Addresses the principal "greenhouse gases" causing global climate disruption collectively. Accordingly, the trading programs authorize inter pollutant trading based on the relative global warming potential of greenhouse gases. So, the efficiency claim for market mechanisms in the climate context requires a minor adjustment. Market mechanisms cost- effectively reduce greenhouse gases as a group. This efficiency claim focuses on the means of environmental protection, not its ends. Market mechanisms achieving cost-effective abatement, however, often fail to achieve economic efficiency defined more broadly as allocative efficiency. Economists define measures that balance costs and benefits at the margin as allocative efficient. Allocative efficiency therefore measures the economic optimality of a goal, not the cost effectiveness of a chosen means of meeting a goal. Market mechanisms only prove allocatively efficient under very restrictive conditions, and other mechanisms also prove allocatively efficient if they meet those conditions. Thus, an emissions trading program will prove allocatively efficient if the cap underlying the program equalizes costs and benefits at the margin. But a traditional regulation equalizing costs and benefits at the margin will likewise prove allocatively efficient. And a carbon tax set to equal the social cost of carbon - the dollar value of the harms that carbon dioxide emissions cause - will provide for optimal carbon reductions, as only polluters with control options costing less than the social cost of carbon will choose to reduce emissions. But if the carbon tax is set at a lower or rate than this, it will not prove allocatively efficient. Similarly, a cap not to equalize costs and benefits at the margins does not lead to allocatively efficient reductions. Market mechanisms not aiming for optimal reductions will still, however, cost-effectively reduce emissions. Furthermore, economic theory associates allocative efficiency with balance of total costs and benefits. Many changes that abate greenhouse gas emissions reduce or increase other types of pollution and trigger additional safety, environmental, or health problems or benefits. So, example, most measures reducing emissions of carbon dioxide - the principal greenhouse gas also reduce urban smog. This implies that an emissions trade where a polluter foregoes carbon dioxide reductions and purchases credits reflecting additional reductions of some other greenhouse gases foregoes potentially important local air quality benefits. In China, for example, where urban air pollution causes more than a million deaths per year, such a trade may carry substantial environmental costs. Conversely, if a trading program authorized credits for nuclear power, credits realized through construction of nuclear power plants might create a risk of nuclear accidents that could be avoided by choosing other means of reducing greenhouse gas emissions. For that reason, the ETS disallows credits for nuclear power generation, even though nuclear power reduces direct greenhouse gas emissions to zero. A claim about the allocative efficiency of market-based mechanisms' carbon reductions does not necessarily imply that those mechanisms are allocatively efficient in terms of total benefits and costs. But several advanced countries have used pollution taxes to attack environmental problems. Many carbon taxes have been less effective than they might be, because they exempt carbon intensive industries. Still, carbon taxes, such as the carbon tax in British Columbia, have sometimes proven quite successful.

2.7. Stock pollution

Pollutants, towards which the environment has low absorptive capacity are called stock pollutants. Examples include persistent organic pollutants like PCBs, non-biodegradable plastics and heavy metals. Stock pollutants accumulate in the environment over time. The damage they cause increases as more pollutant is emitted, and persists as the pollutant accumulates. Stock pollutants can create a burden for the future generations, bypassing on the damage that persists well after the benefits received from incurring that damage, have been forgotten. Scientists have officially deemed that the planetary boundaries safe chemical pollutant levels (novel entities) have been surpassed. Stock pollutants are unwanted emissions that accumulate through time in the environment. While the distinction between flow pollutants, whose impacts quickly diminish, and stock pollutants, whose impacts accumulate, is a matter of degree, it can be useful to think of them separately. Some examples of stock pollutants include GHGs, mercury, and nuclear waste. Accumulation of stock pollutants that persist for long periods of time has the property that the per-unit level of damages increases with the accumulation of the pollutant in the environment, but damages do not change significantly from one year to the next. Credit systems should be designed to recognize this. That means that large year-to-year price fluctuations that can cause economic disruption should be avoided as this is largely unrelated to the actual impact of yearly emissions. Thus, banking and borrowing provisions and trigger prices need to be considered especially for stock pollutants.

Perhaps the most important policy area in which risk and uncertainty come into play is with respect to environmental risks. Health and safety hazards of course arise with respect to products and jobs as well, and financial risks pose potentially large welfare losses also. However, in these contexts there is usually some kind of functioning market that will foster incentives for safety and efficient outcomes. These market operations may be imperfect, and the incentives they engender may be inadequate, but the risk is nevertheless the result of some kind of market transaction. In instances in which these transactions are flawed, there are often ex post remedies in the form of legal liability for injuries, such as when the injurer is negligent. The characterization of environmental risks is quite different. These hazards typically are the result of public exposures to risks, not voluntary market-based transactions. Even in situations in which market forces come into play, as in the case of a person who purchases a less expensive house in a polluted area, there is usually no transmittal of an incentive to the polluter, who generally is not a party to the transaction. Similarly, in the absence of specific laws or regulations prohibiting pollution, there is no duty on behalf of the polluter that would lead to legal liability for the pollution.

****

UNIT - III

INTEGRATED ASSESSMENT

3.1. INTRODUCTION

Although academic research has driven economics and natural science forward, academics are often poorly suited to address complex problems like climate change involving a host of disciplines. Faculty tends to be narrowly organized into disciplines with few incentives to work with other disciplines. Each discipline has an important contribution to make to understand the chain of events that greenhouse gas emissions set in motion, but no single discipline has the breadth of knowledge to understand all the links between actions taken to limit greenhouse gases and the final consequences. Many individual disciplines have critical insights about specific phenomena, but they are often unaware of the insights of other disciplines. When a complex problem such as climate change appears, academics claim it is a “wicked problem” too difficult to solve but it may be simply too wicked for an individual discipline to solve on its own.

3.2. INTEGRATED ASSESSMENT MODELS

Since almost all the recent assessments of the economics of climate change have relied on "Integrated Assessment Models" - IAMs, focuses on enhancing our understanding of how those models typically calculate the net benefits and costs of mitigation over the next century. At the most general level, IAMs attempt to couple a representation of the world's economic systems to its energy- and land-use systems for about a dozen regions of the world in order to calculate how greenhouse gas emissions are likely to change as the magnitude and structure of the economy changes. The models then couple these projections of greenhouse gas emissions into the atmosphere, biomass, and oceans to simple climate change assessment models that yield likely temperature increases for any given future year.

There are two main aspects of existing climate IAMs:

(1) Their overall structure and level of technological disaggregation and

(2) The reasonableness of the input assumptions, both historic and future, for key parameters within these equations, including those that apply to new energy supply and end-use technologies. These topics are treated solely from

the perspective of how they affect the calculation of the net benefits and costs of mitigating climate change and the usefulness of these results to policymakers who are trying to significantly mitigate climate change.

To What Should the Costs of a Mitigation Scenario Compared?

To calculate the net benefits or costs of mitigating climate change, we must compare two scenarios. Most studies compare the net costs of a "reference" or "baseline" case to the net costs of a mitigation case, such as a scenario in which the global temperature increase is limited to 2°C by 2100. The construction of the reference case usually only assumes that no new climate-mitigation policies are implemented beyond those in place today. Conceptually, then, the reference case represents the costs to society that would actually result if the current level of climate change-mitigation policies were maintained. But there is a major problem with this approach. Integrated assessment modelers (and models) cannot forecast with reasonable accuracy what would actually happen to the trajectory of greenhouse gas emissions if no new mitigation policies were adopted worldwide over the next fifty to a hundred years. In particular, failing implementation new climate change-mitigation policies, there might be a major economic crisis resulting from climate change that causes the trajectory of GDP, or other economic indicators, to deviate substantially from the assumed projections. But integrated assessment modelers never model feedback between the amount of climate change and economic growth and would have an extremely difficult time doing so if they tried. The economy in a reference case could also begin to collapse because of the depletion of fossil fuel reserves, or because of a financial crisis. But even without considering climate change or resource depletion, no economist could possibly forecast the global economy for the next fifty to a hundred years with any reasonable accuracy for the purpose of policy-making. And because forecasting the future of the energy economy for the next fifty to a hundred years is impossible (not just difficult), there is no valid baseline emissions scenario which the costs of a mitigation scenario can be compared.

It is not surprising, then, that when different IAMs calculate the net costs or benefits of mitigating climate change, the models and modeling teams end up using a very wide range of greenhouse gas-emissions trajectories as their reference case (IPCC 2007, figure 3.8, 187). This reflects, in part, the tremendous uncertainty in making fifty- to a hundred-year economic and greenhouse gas emissions forecasts. The uncertainties reflect both the uncertainty in the underlying economic (GDP) forecasts as well as the uncertainties associated with how the assumed internal operating parameters and costs of dozens of energy supply and demand technologies will change over the long run in this scenario. Thus one cannot simply compare the net costs of mitigating climate change across different model results without explicitly accounting for the differing emissions trajectories of the reference cases. For example, if two models develop a mitigation scenario for the same level of temperature increase in 2100, but one model needs to reduce average emissions by 50 percent more than the other relative to their reference cases during the 2005-2100 period, then one would expect the net costs of mitigating this higher level of reference case emissions to be more than 50 percent higher in order to achieve the same final mitigation scenario.

3.3. GREEN HOUSE GAS EFFECT

The term 'Green House Effect' describes the warming of the earth and its atmosphere which occurs through the entrapment of energy by gases in the atmosphere. In essence, the atmosphere allows most sunlight (solar shortwave radiation) to enter and warm the Earth in a relatively unimpeded manner. As the surface of the Earth cools, it emits infra-red radiation, some of which is absorbed by the greenhouse gases in the atmosphere and re-radiated back to the Earth's surface, giving rise to additional warming. Without the greenhouse effect the Earth would be much colder. In fact, the ability of the greenhouse gases to absorb infra-red radiation ensures an equilibrium temperature higher than would otherwise be expected. In other words, the greenhouse effect makes the planet habitable for life. Options in the face of competition for limited government funding. Information from the national action plans can then be provided to the United Nations Framework Convention on Climate Change (UNFCCC) as part of a country's reporting requirements.

Most Asian and Pacific countries are well along in the process of developing an inventory of emissions of carbon dioxide (CO_2), methane (CH_4), and other greenhouse gases. Some countries have already undertaken studies to identify opportunities to reduce these emissions. Strategies to mitigate GHGs tend to focus on the use of fossil fuels, the source of most anthropogenic GHGs, and on forest management. Many countries have implemented energy-efficiency, reforestation, and other forest- related measures that were not initiated as part of a climate change strategy but, nonetheless, will result in GHG emissions reduction and/or carbon sequestration. Methane emissions from rice paddies, livestock, and coal mines constitute a significant portion of Asian GHG emissions, but the implementation of mitigation options for their reduction is just beginning. National policy-makers need information on the magnitude of the GHG reduction potential and the costs and benefits of mitigation options. Country studies' mitigation assessments can form the basis for the preparation of national action plans by identifying and evaluating policies and measures for reducing future GHG emissions. Policy-makers can then weigh the costs, benefits, and impacts of climate change mitigation and adaptation.

3.3.1. GREEN HOUSE GAS EMISSIONS INVENTORIES AND MITIGATION STRATEGIES IN THE ENERGY SECTOR

Carbon emissions from the combustion of fossil fuels constitute the largest source of greenhouse gases from the Asia-Pacific region. The region includes three large, heavily populated countries: China, India, and Indonesia. China and India rely on coal, the most carbon-intensive fossil fuel, as their primary source of energy. Annually, these two countries jointly produce and use about 1.5 thousand million tonnes of coal. Oil use is significant in the other Asian countries. Gasoline and diesel are used for transport in equal proportion, and kerosene and LPG are used for household cooking in virtually every country of the region. With the increased transport of Liquefied Natural Gas (LNG), its use has spread to Northeast Asia (S. Korea, Japan, and Taiwan (China)), where it is used increasingly for electric power generation as well as space heating in S. Korea and Japan. Mitigation options for reducing carbon emissions from the energy sector fall into two categories: (i) improving the efficiency of energy use; and (ii) substituting less carbon-intensive energy sources for more intensive ones. In the region, improving energy efficiency has been the theme of many government programs over the last two decades. Program success has varied across countries, depending on the level of commitment. Fuel substitution has also occurred in many countries, particularly with the introduction of natural gas. However, the introduction of renewable energy sources has been limited by high capital costs and other barriers.

3.3.2. Implementation of Mitigation Options

The purpose of mitigation assessments is to provide information that will be useful in designing plans and implementing policies that address the increasing atmospheric concentrations of GHGs. The assessment process includes identification of strategies and policies, as well as barriers and incentives for the implementation of mitigation options. Some of the barriers discussed were country-specific, while others were common among countries.

Barriers to the implementation of projects include: -

- Lack of updated databases on forest resources; -
- Lack of tenurial arrangements for peasants who depend on the forest for their livelihood;
- General lack of education and information about the role of forestry, GHGs, and climate change. This is most limiting when such ignorance is found among the national, regional, and local forest resource managers who are responsible for designing and implementing mitigation policies. This lack of information also influences the actions of the peasants and farmers who have a very intimate and functional interaction with the forest;
- Reluctance of private landowners to invest in forestry due to the long-term nature of the investment;
- Presence of extreme ideological or religious groups in forest areas. For example, the situation in parts of the Philippines makes these areas unattractive for investment;

- Lack of institutional and financial capacity to implement mitigation options; Low profitability of forest management, especially in the temperate Asian regions, which makes forestry an unattractive investment unless subsidies and incentives are available;
- Inadequate legal framework to guide forest utilization;
- Inappropriate tax and pricing incentive systems that under- value wood and encourage excessive exploitation.

Incentives for the implementation of mitigation policies include:

- Provision of soft loans for establishing forest plantations by private individuals, landowners, and industry;
- Assistance in increasing the value of the forest estate through enhanced marketing of various non-timber forest products;
- Provision of technical assistance, including the selection of appropriate species for different options;
- Provision of extension services to farmers and forest users, and promoting people's participation in social/community forestry options to increase the chances of success for the option;
- Revision of the tenurial arrangements to give some level of ownership and control to those who use the land, subject to some minimum resource management restrictions;
- Reduction of taxes on private lands devoted to forestry and increase in taxes on idle private lands (a proposal to adopt this incentive is currently being considered by the Philippines Congress);
- Joint implementation with other parties such as OECD countries, who may have more abundant resources and obligation to invest in mitigation options;
- Reduction of subsidies and tax breaks that induce excessive harvesting; this would force loggers to be more efficient and reduce emissions, especially in countries such as Indonesia and Malaysia where production forestry is a very large part of the national economy;
- Provision of alternative opportunities for earning a livelihood that do not depend on undesirable forest exploitation (possibly by increasing agricultural productivity).

3.3.3. Policies and Institutions

Enforcing existing laws and regulations such as those stipulated under concessions is a good starting point in mitigating GHG emissions. The development planning bodies should be encouraged to consider climate change issues when formulating a national or integrated development plan. For mitigation options to be translated into various activities, appropriate policies must be formulated, together with a legal framework to support their implementation. The need for effective institutions to design, oversee, and manage the implementation process is critical. Each country has different institutions which are responsible for the various kinds of mitigation options and policies suggested. A common requirement in all the countries is the need for strengthening horizontal and vertical link ages among national government agencies, such as departments of environment, and other participants such as the private sector, NGOs, and community organizations. A careful separation between the implementing agencies and monitoring institutions is essential for checks and balances. For example, in Mongolia, the former could be the Ministry of Agriculture and Food, while the latter is the National Development Board. In most countries, there already exists a national body that can monitor mitigation activities. Implementation is then left to the appropriate institutions depending on the nature of the mitigation option in question. An intermediate institution, in charge of day-to-day coordination of mitigation options, may be designated by the monitoring agency, if necessary.

3.3.4. Conclusions: Recommendations for Future Action

The design of mitigation options is currently in its initial phase in the region. The task is challenging, given the lack of funding for demonstration projects and only partial integration of global climate change concerns into government institutions. The next steps taken to encourage implementation of effective mitigation projects include: (i) establishment of criteria for selecting mitigation options; (ii) promotion of institutional awareness; and (iii) acquisition of funding for mitigation projects. These steps are discussed below. After the potential benefits and costs of projects have been identified, countries should establish criteria that allow them to rank projects in order of overall feasibility. A new model could be developed to rank projects according to overall costs and benefits; alternatively, existing general models could be adapted to reflect methane mitigation options. Models aside, the following criteria are listed in order of importance: (i) the cost effectiveness of the project; (ii) the GHG mitigation effect; (iii) social acceptance; (iv) potential for replication both nationally and regionally; and (v) the existence of important secondary benefits such as improved safety, cleaner local air and water, and creation of a local energy source. Cost-effectiveness is the over ridding concern in the region. As a result, policy-makers require that mitigation projects be cost-effective above all other factors. Each nation should focus on the sectors that emit the most CH4 and attempt to implement the most cost-effective mitigation options for those sectors. It is important that scientists become cognizant of the economic costs and benefits of CH4 mitigation options, so that they can better communicate these benefits to important government and financial experts. In addition, when mitigation projects are being promoted among governmental institutions, the focus must be on the secondary benefits of these projects (e.g., improved yield from rice paddies and livestock, creation of a local energy source, improved profit, improved safety, and fewer environmental impacts). One way for countries to proceed is to assemble a team of in- country experts, including scientists, policy-makers, financiers, and people from the private sector. This team can identify a list of mitigation projects, perform economic feasibility studies on them, and come up with a group of projects that have the most promising economic returns. International financial institutions and donor governments can then be approached with this list to obtain funding. Joint implementation is also an option, where appropriate.

3.4. DICE MODEL

DICE model (DICE is an acronym for Dynamic Integrated model of Climate and the Economy). While the DICE model is only a single model, the basic structure of the analysis is similar in other integrated assessment models. The DICE model views climate change in the framework of economic growth theory. In a standard neoclassical optimal growth model known as the

Ramsey model, society invests in capital goods, thereby reducing consumption today, in order to increase consumption in the future (Ramsey 1928; Koopmans 1965). The DICE model modifies the Ramsey model to include climate investments, which are analogous to capital investments in the standard model. The model contains all elements from economics through climate change to damages. The geophysical equations are simplified versions derived from large models or model experiments.

Revisions from Earlier Versions of the DICE and RICE Models

There are several large and small changes in the DICE model compared to earlier versions. The prior complete documented version of the DICE model is Nordhaus (2008), while the last complete version of the regional (RICE, signifying the Regional Integrated model of Climate and the Economy) model is in Nordhaus 2010). The first revision is that the time step has been changed from 10 years to 5 years. This change is taken because improvements in computational capacities allow the model to be easily solved with a finer time resolution. A second change is the projection of future output growth. Earlier versions of the DICE and other Integrated Assessment Models tended to have a stagnations bias, with the growth rate of total factor productivity declining rapidly in the coming decades. The current version assumes continued rapid total factor productivity growth over the next century, particularly for developing countries. A third revision incorporates a less rapid decline in the CO2-output ratio in several regions and for the world, which reflects the last decade's observations. Earlier trends (through 2004) showed rapid global decarbonization, at a rate between 1.5% and 2% per year. Data through 2010 indicate that decarbonization has been closer to 1% per year. The new version assumes that, conditional on output growth, uncontrolled CO2 emissions will grow at 0.5% per year faster than earlier model assumptions. A fourth assumption involves the damage function. The most recent versions of both DICE and RICE used the impact estimates from the 2000 RICE model (Nordhaus and Boyer 2000). There has been significant further work on damages since that time. Tol's central estimate is that damages are about 3% of global output at a temperature increase of 3°C. However, current studies generally omit several important factors (biodiversity, ocean acidification, and political reactions), extreme events (sea-level rise, changes in ocean circulation, and accelerated climate change), impacts that are inherently difficult to model (catastrophic events and very long-term warming), and uncertainty (of virtually all components from economic growth to damages). I have added an adjustment of 25% of the monetized damages to reflect these non-monetized impacts. We have estimated the DICE model for several alternative scenarios. These reflect differing assumptions about policy, damages, and discounting.

We list the scenarios briefly and describe them in more detail below.

1. The first is the "baseline" scenario, which uses the standard DICE model and assumes no changes in climate change policy from 2010 levels.
2. The second is the "optimal" climate policy scenario, which uses the standard DICE-2013R model and optimizes the time path of emissions reductions and investment.
3. A third run modifies the damage function in the standard DICE model so that the optimal path leads to a limit on temperature increase to 2°C above the 1900 level.
4. The fourth run is a variant of run 3 and assumes that the 2°C limit is an average rather than an annual or decadal maximum.
5. The fifth run examines the impact of a near-zero discount rate on the SCC.
6. The sixth run is a variant on the fifth that calibrates other parameters to keep real returns on capital in the lower-time-preference scenario equal to the rate of return in the baseline scenario.
7. A final run is a high-discount-rate sensitivity analysis that raises the pure rate of social time preference to 3.5% per year.

3.5. The Stern Review and Its Meta-Analysis of Integrated Assessment Models Net Cost Results

The famous 2007 Stern Review relied solely on the results from other research team Integrated Assessment Models regarding the net cost of mitigating climate change. The review lists many requirements of an adequate Integrated Assessment Models methodology for computing the net costs and benefits of mitigation (Stern 2007). It says that a broad assessment of net costs "requires a thorough modelling of consumer and producer behavior, as well as the cost and choice of low-GHG [greenhouse gas] technologies". It goes on to say,

"Models should cover a broad range of sectors and gases, as mitigation can take many forms, including [reducing] land-use and industrial process emissions. Most models, however, are restricted to estimating the cost of altered fossil-fuel combustion applied mostly to carbon, as this reduces model complexity. Although fossil-fuel combustion accounts for three-quarters of developed economies' carbon emissions, this simplifying assumption will tend to over-estimate costs, as many low-cost mitigation opportunities in other sectors are left out. (Stern 2007)"

The Stern Review then lists the key model comparison studies carried out in, or recently before, 2006 and comments that "the wide range of model results reflects the design of the models and their choice of assumptions, which itself reflects the uncertainties and differing approaches inherent in projecting the future". The Stern critique of typical inadequacies in Integrated Assess Managements, with which we agree describes, therefore, a major methodological problem with its own reported results, as seen below.

To get a better sense of the kinds of additional future uncertainties that even the Stern Review fails to address, we will refer the reader to a lengthy technical critique we have published elsewhere of the meta-analysis of IAM-generated cost projections carried out by Barker, Qureshi, and Koehler, which the Stern Review itself commissioned and on which it relied (Barker et al. 2006; Rosen and Guenther 2014). This meta-analysis seems to have provided the primary basis for the Stern Review's conclusion that the net costs/benefits of mitigating climate change (on a present-value basis) by 2050 probably lie in the range of a cumulative (not annual) loss of GDP of 1 percent, plus or minus 3 percent, by 2050. At first, this appears to be quite a wide range compared to the central value, and it allows for the possibility that GDP growth could be at least as high as 2 percent more in the mitigation scenario as in the reference case, or 4 percent lower. But, on the other hand, since even +2 percent in cumulative GDP growth over forty to forty-five years is only about +0.05 percent per year, on average, we see that the entire range of results cited by both Barker et al. (2006) and Stern (2007) is, in fact, extremely small relative to average historical global GDP growth rates, which were in the range of 2-3 percent per year. Anyone who is aware of typical inaccuracies in making economic forecasts, even over the short run, would assume that the cumulative uncertainty in such estimates in the long run would be vastly greater than the average annual value of 0.05 percent in the results cited in the Stern Report (Stern 2007), (Paul Krugman [2014] recently characterized such a small annualized figure as a "rounding error"). Consequently, then, the Barker meta-analysis was not a valid basis on which the conclusions of the Stern Review could appropriately rest.

Conclusion

How much and how fast should the globe reduce greenhouse gas emissions? How should nations balance the costs of the reductions against the damages and dangers of climate change? The Stern Review answers these questions clearly and unambiguously: we need urgent, sharp, and immediate reductions in greenhouse gas emissions. The Review's radical revision of the economics of climate change does not arise from any new economics, science, or modelling. Rather, it depends decisively on the assumption of a near-zero time discount rate combined with a specific utility function. The Review's unambiguous conclusions about the need for extreme immediate action will not survive the substitution of assumptions that are more consistent with today’s marketplace real interest rates and savings rates. Hence, the central questions about global-warming policy? How much, how fast, and how costly? Remain open. The Review informs but does not answer these fundamental questions.

****

UNIT - IV

CLIMATE CHANGE POLICY – ADAPTATION

4.1. INTRODUCTION

The increase in greenhouse gas concentrations in the atmosphere has led many scientists to conclude that the earth's temperature will increase by several degrees over the next century (Houghton et al. 1992, NAS 1992, Wigley & Raper 1992, Mitchell et al. 1995). Some are beginning to conclude that the anthropogenic effect of increased greenhouse gas concentrations on global climate is already evident (Thomson 1995). To stabilize concentrations of greenhouse gases at current levels, thus reducing the risks of future warming, draconian cuts of 60 to 80% in anthropogenic emissions of carbon dioxide would be required (Houghton et al. 1990). Given that the Frame work Convention on Climate Change seeks only to stabilize emissions from developed countries (UNEP/ WMO 1992), it appears likely that atmospheric concentrations of greenhouse gases will continue to rise. If they do, warming of the climate is highly likely. If climate change is inevitable, then it is probably inevitable that the sea level will rise, agricultural production will change, runoff and water supply will change, and the location of forests and other terrestrial vegetation will shift pole ward and to higher altitudes (Tegart et al. 1990, Smith et al. 1995). Society will have to adapt to these and other changes.

4.2. CLIMATE CHANGE IMPACT ASSESSMENT

There are two fundamental types of adaptation: reactive and anticipatory (Smith in press). Reactive adaptations are measures taken as a response to climate change. For example, a farmer may notice that droughts are becoming more persistent and may switch to more drought tolerant varieties of crops. Anticipatory adaptations are measures taken in advance of climate change. These are taken to minimize or offset the effects of climate change. One of the first steps in responding to climate change is to identify the policy options available to address the adverse effects of such change. This article describes a number of government policies that could be implemented in anticipation of climate change to reduce its potential adverse effects. The policy options are divided into 5 climate-sensitive sectors: water resources, coastal resources (sea-level rise), forests, ecosystems, and agriculture. The 5 lists of anticipatory adaptation options presented here represent the range and type of policies that should be considered; however, the lists are not comprehensive. These lists are meant to provide policy makers with ideas about possible adaptation measures and to stimulate the identification of other adaptation measures.

4.3. CRITERIA FOR ANTICIPATORY ADAPTATION OPTIONS AND ORGANIZATION OF POLICY LISTS

All anticipatory adaptation policies should satisfy at least 2 criteria: flexibility and the potential for benefits to exceed costs. The regional impacts of climate change are highly uncertain. If adaptation measures only addressed one type of climate change, such as increased flooding due to wetter conditions, they might leave the sector vulnerable to another type of climate change, such as drought from drier conditions. To address the broad range of uncertainties, anticipatory adaptation policies should be flexible. The objective in selecting an anticipatory adaptation policy should be to enhance the ability to meet stated objectives under a wide range of climatic conditions. As such, a policy may be either robust, meaning it allows the system to continue functioning under a wider range of conditions; or resilient, meaning it allows the system to quickly adapt to changed conditions. In addition to being flexible and having the potential for benefits to be greater than costs, anticipatory adaptation options that meet the following criteria should be implemented now to address climate change.

• **Net benefits independent of climate change:** Some adaptation options may yield net benefits even if cli mate change does not occur. Many of these options involve changing plans for responding to particular cli mate events such as floods or droughts or allowing greater flexibility in response to current climate variability. For example, implementing market based system for allocating water would result in more efficient allocation of water under the current climate and would allow for a more rapid and efficient response climate change than would more rigid schemes f water allocation (Frederick & Kneese 1990).

• **High priority:** Some adaptation options need to be implemented in anticipation of climate change because they would be significantly less or not effective if implemented as reactive policies.

Adaptation options that fall into the following **sub-categories** may be considered high priority:

Irreversible or Catastrophic Impacts: These options are policies concerning potentially irreversible or catastrophic impacts of climate change; for example, loss of life or of species, extensive loss of property, or destruction of resources may be irreversible or catastrophic. Such policies warrant consideration because reactive measures will probably be unsuccessful in mitigating the impacts of climate change.

Long-term Decisions: Decisions on many long-term issues, such as the construction of dams, reservoirs, and bridges, have long useful lifetimes and may be affected by climate change. Policies affecting the construction of such structures warrant consideration because the initial costs of making the structures less vulnerable to climate change are likely to be significantly less than the costs of adapting the structures after climate changes (NAS 1992).

Unfavorable Trends: Certain trends in growth or resource use may make some types of adaptation more difficult; for example, the fragmentation of habitats is a trend that is unfavorable to wildlife. As climate changes, fragmentation could become an even greater problem as species need to migrate to cooler areas. Policies affecting such trends warrant consideration before climate change, because adaptation may be more difficult in the future or because opportunities to implement low-cost or politically feasible options may be lost (Smith in press). The following sections of this article list anticipatory adaptation options that increase flexibility and have benefits greater than costs. Each individual anticipatory adaptation option is described and we indicate whether the option has net benefits independent of cli mate change or is of high priority. If the option is of high priority, we indicate whether it is high priority because it has irreversible or catastrophic impacts, is a long-term decision, or has unfavorable trends. All of the options listed below meet the general criteria of being flexible and having the potential for a favorable benefit-cost analysis. Where appropriate, we have cited examples of implementing these policies in Africa.

This unit covers the following topics:

- General policy options for adaptation to climate change,
- Policy options for adaptation of water resources,
- Policy options for adaptation to a rise in sea level,
- Policy options for adaptation of forests,
- Policy options for adaptation of ecosystems, and
- Policy options for adaptation of agriculture.

This list of anticipatory adaptation options is meant to be useful to all regions of the world. Whether and how these policies are applied in specific regions and countries depends on local circumstances and such matters as whether it is institutionally, culturally, or socially feasible to implement these changes. Thus, the nature of actual adaptation measures may be different in Africa than in other areas.

4.4. POLICY OPTIONS FOR ADAPTATION TO SEA LEVEL RISE

Plan Urban Growth:

Redirecting growth away from sensitive lands and toward less vulnerable areas is one option to reduce the risks associated with a sea-level rise, and also to reduce vulnerability to severe coastal storms that happen under current climate conditions. This option may be particularly useful in decisions to site large capital facilities or facilities that would pose significant hazards if subject to flooding (Wang et al. 1995). This option receives high-priority consideration because of unfavourable trends. Net benefits are independent of climate change.

Decrease subsidies to develop sensitive coastal lands:

Limit government subsidies or tax incentives to develop land sensitive to sea-level rise, such as barrier islands, coastal wetlands, estuarine shore lines, and critical wildlife habitat. Such policies would include ensuring that any government subsidies for flood insurance reflect the current risks of developing in coastal areas and on floodplains and would possibly include prohibiting new insurance policies in risky locations. Additionally, insurance and banking industries may be encouraged to factor risks of climatic variability into investment decisions and thereby reduce reliance on government-subsidized insurance and disaster relief. Such policies would allow markets to reflect the true risks of developing or living in sensitive coastal areas (Warren 1992, Canadian Climate Program 1993, OTA 1993a). This option receives high-priority consideration because of unfavourable trends. Net benefits are independent of climate change.

Use set-backs for coastal development:

Set-backs for coastal development buy some time to avoid the destructive effects of sea-level rise. The buffer zones enable sea level to rise up to a point without threatening coastal development. Beyond that point, response measures will need to be taken. For example, French et al. (1995) recommended incorporating buffer zones between the shore and new coastal development in Nigeria. This option receives high-priority consideration because of unfavourable trends.

Incorporate Marginal Increases in the Height of Coastal Infrastructure:

In building coastal infrastructure, such as bridges or seawalls, marginal increases in the height of the structures may be included to offset a sea-level rise. For example, outflow from sewage treatment plants could be several feet higher to offset a sea-level rise. Such additions are less expensive to make while construction is in progress than after the initial work is complete (NAS 1992). This option is high priority because of long-term decisions.

Preserve Vulnerable Coastal Wetlands:

Efforts should be made to maintain coastal wetlands that are more likely to withstand a sea-level rise. Wetlands are valuable natural areas that are difficult to re-create; therefore, current and future efforts are warranted to protect the areas. In setting priorities for protecting wetlands, the likelihood of surviving a sea-level rise or migrating landward should be considered. Protecting wetlands will also improve water quality, flood control and fish and wildlife habitat under current climate conditions (Warren 1992, Canadian Climate Program 1993). This option receives high-priority consideration because of irreversible or catastrophic impacts. Net benefits are independent of climate change.

4.5. POLICY OPTIONS FOR ADAPTATION OF AGRICULTURE

Develop new crop types and enhance seed banks:

Seed banks that maintain a variety of seed types provide an opportunity for farmers to diversify, allowing them to both counter the threat of climate change and develop a profitable specialization. Development of more and better heat- and drought-resistant crops will help fulfil current and future world food demand by enabling production in marginal areas to expand. Improvements will be critical because the world population continues to increase, with or without climate change (NAS 1992, OTA 1993a). This option receives high-priority consideration because of irreversible or catastrophic impacts.

Avoid monoculture and encourage farmers to plant a variety of heat- and drought-resistant crops:

Growing of single crops such as maize increases farmers' vulnerability to climate variability. If the probability of droughts and heat waves increases with climate change, such vulnerability can increase. One adaptation option is for farmers to plant a wider variety of crops to reduce the risks of crop failure. Through its agricultural extension service, the government of Malawi has been advising farmers to grow drought resistant food crops such as cassava, millet, sorghum, etc. (Theu et al. in press).

Avoid tying subsidies or taxes to type of crop and acreage:

Commodity support programs or tax policies may discourage switching from one cropping system to another that is better suited to a changed cli mate. Therefore, efforts to stabilize farm supply and to maintain farm incomes should avoid disincentives for farmers to switch crops, rotate crops, and use the full acreage normally planted. This policy approach will increase the efficiency of current farming practices and will also increase the ability of the system to quickly recover from climate change (Lewandrowski & Brazee 1993).

Increase efficiency of irrigation:

Many farming technologies, such as efficient irrigation systems, provide opportunities to reduce direct dependence on natural factors such as precipitation and runoff. In evaluating an improvement to irrigation systems, the additional benefit of reducing vulnerability to climatic variations and natural disasters should be considered. Improvements allow greater flexibility by reducing water consumption without reducing crop yields. This will also help in adapting water resources.

Disperse information on conservation management practices:

Many practices, such as conservation tillage, furrow diking, terracing, contouring, and planting vegetation to act as windbreaks, will protect fields from water and wind erosion and can help retain moisture by reducing evaporation and increasing water infiltration. Using management practices that reduce dependence on irrigation will reduce water consumption without reducing crop yields and will allow greater resiliency in adapting to future climate changes (Easterling 1993). Net benefits are independent of climate change.

Liberalize agricultural trade:

Lowering trade barriers will result in higher levels of global agricultural production both under the current climate and under climate change scenarios. Farmers will receive information on changes in global market conditions faster than if trade barriers were not lowered (Rosenzweig & Parry 1994). Net benefits are independent of climate change.

Promote agricultural drought management:

Encourage management practices that recognize drought as part of a highly variable climate, rather than treating drought as a natural disaster. Farmers can be given information on climatic conditions, incentives can be offered to adopt sound practices of drought management, and farmers can be discouraged from relying on drought relief. This type of policy is particularly useful if farm disaster relief and other government subsidies distort the market and encourage overly risky expansion of farming into marginal lands (OTA 1993a).

4.6. POLICY OPTIONS FOR ADAPTATION OF HEALTH

Health Climate is expected to make three changes that could affect human health: Vector borne diseases, heat stress and ozone formation (IPCC, 2007b). All of these threats to human health already exist. Climate change will simply exacerbate the problem. Vector-borne diseases change because the animals that carry the disease can move into new territories. For example, warming and precipitation increases can expand the territory of harmful mosquitoes or biting flies. As these territories expand, additional human populations can be infected with the disease. Abnormal increases in temperature are known to cause heat stress which raises acute mortality rates. People in relatively cool climates seem particularly vulnerable. Finally, warmer temperatures increase the rate at which nitrogen oxides and volatile organic compounds form into ozone, increasing human exposure to ozone. There are currently many effective strategies to deal with each public health problem. Vector borne diseases can be controlled with public health measures (Ebi, 2008). For example, vectors that carry disease can be controlled as with tick or mosquito spraying. People can take preventive measures to avoid exposure by using mosquito netting or wearing insect repellants. Finally, the disease can be treated once it is contracted with antibiotics and other medical responses. Heat stress deaths can be limited by warning systems, limiting strenuous behavior during a heat wave, and providing threatened individuals with protective shelter that is adequately cooled (Ebi et al., 2004). Higher ozone concentrations can be prevented by controlling the precursors to ozone: Nitrogen oxides and or volatile organic compounds. Unfortunately, there are few economic analyses of the costs and benefits of these alternative responses to the threat of climate change. A great deal of the literature has simply predicted potential deaths assuming no adaptation whatsoever

4.7. VULNERABILITY ASSESSMENT

Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report observed that the earth's climate system, when com- pared with the pre-industrial era, has demonstrably changed at both global and regional scale. Further the report notes that the global mean temperature may increase anywhere between 1.4 and 5.8 degree Celsius by 2100. This unprecedented increase is expected to have severe impacts on various aspects of the climate system including changes in the global hydrological system, sea level increase and changes in crop production. A country's vulnerability to climate change is decided by the presence of appropriate mitigation and adaptation options. It is now widely recognised that developing countries are particularly vulnerable to the impact of climate variability and change especially when compared to developed countries. This is because in developing countries ecological environments are fragile, the susceptibility of economic systems to risks is high and the low income levels of most citizens constrain their ability to cope. The initial circumstances of each country in terms of its climatic conditions, socio economic setting and growth prospects will also partly determine the scale of the social, economic and environmental impacts of climate change (Stern 2007). Climate change is likely to impact all the natural ecosystems as well as socio- economic systems in India as shown by the National Communication Report of India to the United Nations Framework Convention on Climate Change (UNFCC). Different sectors like water resources, forests, agriculture, and coastal zones are projected to have several potential impacts. It will bring changes in hydrological cycles, rain-fall as well as the magnitude and timing of its run-off. However, the distribution of the incidences of climate change will also vary within the geography encompassed by India. Some sectors and regions in India are considered highly susceptible to current climate variability and the projected impacts of climate change. To minimise the potential harm associated with global changes, people and places need an assessment of vulnerability of the human-environment systems in which they live, associated adaptation opportunities and constraints. However, the field of vulnerability assessment to climate change is fragmented. Much debate remains in - conclusive around how to characterise vulnerability. This article attempts to assess the work on vulnerability to climate change, with particular reference to India.

Vulnerability: Different Meanings

Within the field of climate change, the reports of the IPCC have become the most authoritative source which act as a legitimising device for research, IPCC's fourth assessment report defines vulnerability as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. However, this concept of vulnerability has been criticised for not taking into account the richness and diversity of findings on the causes and consequences of vulnerability to climate change and climate risks (Adger 2006). For example, IPCC argues that developing countries are most vulnerable to climate change because of their lack of "institutional capacity" to cope. At the same time there is evidence from regions like the Sahel suggesting that communities and countries have, within their local knowledge and experiences, a latent capacity to adapt to variability. Despite criticisms, the IPCC's conceptualisation of vulnerability has been widely accepted and followed in climate change research. Vulnerability is a multidimensional concept associated with different conceptualisations and there remains a high degree of uncertainty in its measurement and classification. This concept has been used by various research communities in different ways based on the objectives to be achieved and the methodologies employed. These differences limit the possibility of having a universally accepted definition of vulnerability. The ordinary use of the word vulnerability refers to the capacity to be wounded, i.e., the degree to which a system is likely to experience harm due to exposure to a hazard. Historically, the concept was introduced as a response to a purely hazard oriented perception of disaster risk in the 1970s. These risk hazard approaches to understanding vulnerability have evolved from the extensive natural hazards literature in geography. This approach incorporates mainly physical elements of exposure of a unit and the probability and impacts of hazards.

Another important conceptualisation of vulnerability can be found in the well-known pressure and release model (Blaikie et al 1994) where physical hazards represent one pressure and characteristic of vulnerability, but there are other pressures like local geography and social differentiation which together "create" the disaster. This approach successfully captures the essence of both the physical hazards as well as the political economy perspectives on vulnerability.

Looking at the diversity of studies on vulnerability at the climate change and the contending definitions, a challenging task lies ahead to develop a common conceptual framework to assess vulnerability to climate change.

Vulnerabilities in India

Among the most significant potential impacts of climate change on India are changes of climate change on India are changes in the monsoon pattern. Several studies have shown that in general, the mean monsoon intensity and variability is expected to increase (Ashrit et al 2001; Chung et al 2006; Kumar et al 2006). However, each study arrives at this conclusion through different modelling and is not necessarily specific about how much the monsoon will increase. A 20% rise in all India summer monsoon rainfall and further rise in total rainfall is projected over all the states, except Punjab, Rajasthan and Tamil Nadu which shows a slight decrease. Thus climate change is likely to increase the variability and uncertainty in monsoon patterns.

Agriculture and allied activities provide employment to two thirds of India total workforce and contribute nearly 20% of the country gross domestic product. However, Indian agriculture continues to be fundamentally dependent on weather which makes it sensitive to climate induced effects. Any changes in the climatic factors like temperature, precipitation, carbon dioxide concentration, changes in the soil moisture will affect Indian agriculture. The productivity of different crops will be affected. Rice and wheat yields could decline considerably due to climatic changes (IPCC 1996; 2001). Agriculture in the coastal regions of Gujarat, Maharashtra and Karnataka is found to be the most negatively affected. Small losses are also indicated for the major food grain producing regions of Punjab, Haryana and Western Uttar Pradesh. This means agricultural production will be affected and food security can be adversely impacted, particularly among small farmers and rural populations. On the other hand, West Bengal, Orissa and Andhra Pradesh are predicted to benefit to a small extent from warming. Various global circulation models have given contradictory predictions about the impacts of climate change on cyclones and it is not certain what can be expected. Yet it is possible that warmer sea surface temperatures may increase the frequency and intensity of cyclones in the Indian Ocean region.

Significant portions of India landmass near the coastline is at sea level or only a few metres higher. These areas also have some of the highest population densities. The IPCC (2007) has projected a mean sea level rise of 0.18 to 0.59m by 2090, relative to the 1980 – 1999 level. Under a range of climate change scenarios, the frequency and intensity of extreme precipitation events are expected to increase. This will put many more millions of people at risk due to flooding associated with extreme precipitation impacting both their lives and livelihoods. Climate change will also put millions more at the risk of vector borne diseases. Projections show that the incidence of malaria will increase. Given weak public health infrastructure this implies increased health care spending and decreased standard of living especially for the poor. Vulnerability to climate change in India, they have perhaps paid less attention to the ground realities of the vulnerable people. Looking at this may help develop adaptive capacities of the people to deal with the risks of climate change in India.

Despite considerable advances in the methodologies for assessing vulnerability to climate change, ambiguities and uncertainties still remain. Vulnerability research is facing challenges in three areas. First, climate change is not the only stress that society faces, multiple stressors operate in all the human-environment systems. It is, therefore, a challenging task for researchers to identify and evaluate those stressors most relevant for assessing climate change vulnerability. Second, vulnerability assessment requires characterisation of the future in terms of socio-economic and bio-physical variables. However, uncertainties about the future make vulnerability assessment that much more difficult and challenging. Third, the apparent lack of consistency in the use and meaning of the variety of concepts employed in vulnerability research contributes to increasing confusion in this area. Research in India on vulnerability to climate change is still underdeveloped. Further research is urgently required in several areas. This research has to base itself on an understanding of the regional and micro level aspects of climate change to properly address the vulnerability of people with more accuracy.

4.8. ECONOMICS OF ADAPTATION

Theory of Efficient Adaptation

1. **Private adaptation**: If the consequences of an adaptation decision affect only the decision maker, we define these actions as “private adaptation”. With both firms and households, many adaptation decisions involve only their own welfare; they are private adaptations. The costs and the benefits of private adaptation accrue just to the firm or household. Because the decision makers are interested in maximizing their own welfare, the only adaptations they will

choose are ones that make them better off. Firms and households will choose efficient adaptations. Of course, this assumes access to markets, private property rights, no externalities and good information, all of which we discuss further in the chapter.

2. Household adaptation: In order to understand how households will respond to climate, one must first understand how climate directly affects household decisions. Let us begin with a simple model of the direct effects of climate on households. We imagine a utility function (U) that entails goods (X) but also contains climate (C). The individual maximizes utility subject to a budget constraint determined by income (Y):

$$\text{Max } U(X,C) \text{ s:t: } Y = PX, \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Where P is a vector of prices. Using Roy's Identity, we can identify a set of demand functions for this individual:

$$X1 = D1\ (P, Y, C),$$

$$X2 = D2\ (P, Y) \quad \ldots\ldots\ldots \qquad (2)$$

For a vector of goods, X2, C will not play any role. The desire for many goods such as transport or staples may not be climate sensitive. Households will purchase the same amount of these goods (given a market price and their income) no matter what the climate is. However, for another vector of goods, X1, C will shift the demand function. For example, households may want more water to drink or lighter clothing in a warmer climate. Given the price of water or clothing, they will decide to buy more or less of these goods as climate changes. This change in behavior due to climate is adaptation. If it makes the household better off, it is an efficient adaptation. Presumably, households will engage in efficient adaptations precisely because the changes increase the utility of the household. Of course, if households do not know that a new behavior will make them better off, they may not engage in it. However, it is likely that households will quickly learn whether they want to change their behavior as they experience a new climate. One suggestion in the insurance companies can provide insurance for households against climate change. Whereas insurance for weather events is a common feature of many insurance contracts, none of these contracts are long–term climate contracts. Insurance companies renegotiate contracts for weather each year. As weather changes over time, premiums also change. To eliminate the climate uncertainty facing households, insurance contracts would have to be written for decades, not a single year. Companies would have to promise to make payments every year for climate outcomes into the distant future to eliminate the risk to the household of climate uncertainty. However, unlike weather events, which will vary from one household to another, climate uncertainty is correlated across many households. In the extreme, the entire earth will experience a certain amount of warming. The uncertainty for the insurance company is not a set of small independent risks but rather one very large risk. The insurance industry is simply not large enough to offer such policies.

3. Public adaptation: With some decisions, however, many people are affected by a choice. For example, building a sea wall across a coastline protects everyone behind it. Saving an endangered species benefits everyone who cares about biodiversity. Building a road gives everyone along the road access. Protecting property rights gives everyone in a society an incentive to invest in capital. Because such decisions affect many beneficiaries, we define them as "public adaptations". The optimal amount of public adaptation equates marginal cost with the sum of marginal benefits across all individuals. As with all public goods, markets can handle public adaptations only if they can effectively collect revenues from multiple consumers (Samuelson, 1954). There are some special cases where consumers have similar demand functions, where markets can effectively deliver public goods (e.g., clubs). However, when consumers are heterogeneous, it is difficult to coordinate collective payments and public goods are underprovided. Markets are not effective at providing public adaptations. They have difficulty collecting payments from the disparate beneficiaries. Governments consequently have a critical role to play in adaptation to make sure that public adaptations are done efficiently. Governments can coordinate across heterogeneous citizens to create an "aggregate demand" for a service. Governments are needed to encourage public adaptations. In theory, the very incentives that make private actors want to engage in only efficient adaptation applies to local government as well. By backing all projects whose benefit exceeds the cost, the government can work efficiently for their citizens.

However, with public goods, there is not a perfect match between who pays for a good and who benefits. It is therefore possible for citizens who get more of the benefit to want to have too much of the service provided and for citizens who pay too much of the cost to want too little. There is no guarantee or even a good track record that governments will be efficient at providing public goods. Therefore there is no particular reason to believe that governments will suddenly be efficient with respect to public adaptations. This is one of the reasons why it is critical that more research be done on public adaptations. Governments need advice concerning how they should proceed. There is a reason to be especially concerned about public adaptation in developing countries. Many developing countries have weak governments that do not serve the citizens at large. Weak governments are not likely to be effective at public adaptations either. They are likely to over-adapt to benefit a few chosen citizens and under-adapt to benefit everyone else. They are likely to be less informed about their choices and the ramifications. There may be a strong need for international governmental organizations to assist local and national governments in developing countries to design and implement public adaptation.

4. Development as climate adaptation: For developing countries, another effective adaptation strategy is development itself (Schelling, 1992). One of the reasons developing countries are particularly vulnerable is that they have a large share of their economy in climate-sensitive sectors, namely agriculture. Development can encourage a more robust economy by developing service, manufacturing, and other sectors of the economy. The more wealth and income is in sectors that are insensitive to climate, the more climate-resilient is the economy. Development is also generally helpful because it raises incomes. As people become wealthier, they will pay more for the provision of nonmarket services. That is, richer citizens will pay more for public adaptations to climate. Another side benefit of development as an adaptation strategy is that it can be an effective compensation scheme. Development can lift people out of poverty in the long run. Of course, helping countries develop would likely increase their energy demand, which would make mitigation more difficult. But mitigation policies that are based on keeping the world's poorest people in poverty could well be just as harmful as climate change itself.

4.9. MEASUREMENT OF CLIMATE CHANGE

This paper describes best practices for how and when to carry out economic evaluations of proposed climate change adaptation activities, focusing primarily on Cost Benefit Analysis (CBA). Within the overall framework of CBA, many different analytical methods and tools can be used to assess the value of specific impacts of climate change, specific benefits offered by effective adaptation, or specific costs of implementing those adaptation strategies. These methods and tools span much of the spectrum of economic and financial analysis and modelling, but are all inputs into a unifying framework provided by Cost Benefit Analysis.

COST-BENEFIT ANALYSIS

The basic concept of Cost Benefit Analysis (CBA) is simple. An activity is proposed to address a problem, which can be anything from the construction of a new road, to the introduction of new seed varieties, to the widespread dissemination of a preventive health tool. The CBA assesses the total costs of implementing the activity and the total benefits, and then compares them. If the benefits exceed the costs, then the activity is considered to have "passed" the test. CBAs within the realm of climate change adaptations take the same broad approach:

1. Climate change will have an impact on lives and livelihoods. First we need to measure that impact. What will the specific impacts be? Who will be affected? And how can we place a value on that impact in monetary terms?
2. A proposed adaptation activity (or portfolio of activities) reduces negative impacts. We need to assess how much each activity will reduce harm in both physical and monetary terms.
3. The activity (or portfolio of activities) will cost something to implement. We need estimates of the cost of adaptation activities. Again, if the benefits exceed the costs or if the benefit to cost ratio is greater than one the activity may be considered worthwhile from an economic perspective. If we were to choose among a number of activities purely based on economic criteria, this approach could lead us to rank them by benefit-cost ratio and to begin implementing

them in order of their place on the list. In practice, of course, the devil is in the details. There are different ways to estimate the costs and benefits of a proposed activity, ranging from the very simple to very complex, each of which has its own embedded assumptions. In many cases, a more complex analysis may give more reliable results; however, they also require more time, more skill, and more reliable data. Complex analyses typically cost more to carry out, which means that the cost of a CBA - Cost Benefit Analysis could exceed the cost of the adaptation activity itself. The most significant difference between CBA in general and Cost Benefit Analysis for climate change adaptation has to do with risk and uncertainty. Unlike CBAs carried out in the past, when changes were relatively predictable and could be incorporated into the analysis, CBAs now must factor in how climate change will affect baseline conditions. For some development challenges, that might require Cost Benefit Analysis to evaluate appropriate interventions; climate change may not be particularly important, so this will not be a major constraint. However, for activities related to agriculture, infrastructure, urban development, coastal management, and other geographic and sectoral areas, climate change is likely to have significant impacts that must be integrated into the design of development interventions and into Cost Benefit Analysis of potential activities. For activities whose core purpose is to build resilience and to adapt to climate change, of course, the nature of those impacts will be of primary importance to the design both of the activity and of the CBA. Even in cases where we know that climate change will impact a sector, predicting the magnitude and frequency of impacts is inherently filled with uncertainty. Factoring this uncertainty into Cost Benefit Analysis and into project design is one of the major challenges of climate change adaptation.

4.10. INTRODUCTION OF FINANCING ADAPTATION

The subject of climate finance has become increasingly critical in our collective efforts to combat the escalating impacts of climate change. As the world grapples with the urgency of addressing climate-related challenges, the availability, access and adequacy of adaptation finance support have taken centre stage. This paper delves deep into this crucial topic, shedding light on its significance and highlighting the pressing need for a more comprehensive understanding of the problem at hand. In an era where transformative climate finance is essential to drive sustainable development, build climate resilient societies and contribute to reducing the potentially massive loss and damage from climate impacts, a precise framing of the issues is paramount. By dissecting the complexities of climate finance, we can unearth the underlying gaps and needs, ultimately paving the way for more robust and effective approaches and avenues to tackling the climate finance needs. Adaptation finance plays a pivotal role in supporting projects and endeavours aimed at addressing the challenges posed by climate change. This critical financial resource pool encompasses both private and public funding streams, operating on various scales, from the local and national to the global level. Its primary purpose lies in providing essential support to countries, communities and individuals as they strive to adapt to the multifaceted consequences of climate change (Censkowesky, 2022). Developing countries bear the brunt of climate change effects disproportionately. Aspects like geographic position, socio-economic divides and underdeveloped infrastructure intensify their vulnerability. Furthermore, limited adaptive capacities in these regions magnify their climate risk exposure (Adger et al., 2006). This is attributed to numerous factors including economic status, wealth and income and expenditure. The importance of climate finance cannot be overstated. It underpins the transition to a low-carbon, climate-resilient future, affecting economies, livelihoods and ecosystems. Our imperative is understanding the nuances of the multifaceted challenges in financing climate action. Accurate framing allows us to identify shortcomings and inefficiencies, guiding us towards precise solutions that address the core issues. Correctly understanding the problem empowers policy-makers, stakeholders and the global community to make informed decisions and allocate resources judiciously, fostering a more equitable and sustainable world. In this paper we delve into the challenges faced in climate adaptation finance, looking at both the supply and the demand aspects. For clarity, by supply side we mean factors that are controlled by finance providers and intermediaries in a broad sense. These determinants of adaptation finance are understood and written about more substantively than the demand side challenges, which mainly relate to the systemic and operational conditions within finance-receiving countries that affect adaptation finance.

4.10.1. Issues in Financing Adaptation

The subject of climate finance has become increasingly critical in our collective efforts to combat the escalating impacts of climate change. As the world grapples with the urgency of addressing climate-related challenges, the availability, access and adequacy of adaptation finance support have taken centre stage. In an era where transformative climate finance is essential to drive sustainable development, build climate resilient societies and contribute to reducing the potentially massive loss and damage from climate impacts, a precise framing of the issues is paramount. By dissecting the complexities of climate finance, we can unearth the underlying gaps and needs, ultimately paving the way for more robust and effective approaches and avenues to tackling the climate finance needs. Adaptation finance plays a pivotal role in supporting projects and endeavours aimed at addressing the challenges posed by climate change. This critical financial resource pool encompasses both private and public funding streams, operating on various scales, from the local and national to the global level. Its primary purpose lies in providing essential support to countries, communities and individuals as they strive to adapt to the multifaceted consequences of climate change (Censkowesky, 2022). Developing countries bear the brunt of climate change effects disproportionately. Aspects like geographic position, socio-economic divides and underdeveloped infrastructure intensify their vulnerability. Furthermore, limited adaptive capacities in these regions magnify their climate risk exposure (Adger et al., 2006). This is attributed to numerous factors including economic status, wealth and income and expenditure. The importance of climate finance cannot be overstated. It underpins the transition to a low-carbon, climate-resilient future, affecting economies, livelihoods and ecosystems. Our imperative is understanding the nuances of the multifaceted challenges in financing climate action. Accurate framing allows us to identify shortcomings and inefficiencies, guiding us towards precise solutions that address the core issues. Correctly understanding the problem empowers policy makers, stakeholders and the global community to make informed decisions and allocate resources judiciously, fostering a more equitable and sustainable world. In this chapter we delve into the challenges faced in climate adaptation finance, looking at both the supply and the demand aspects. For clarity, by supply side we mean factors that are controlled by finance providers and intermediaries in a broad sense. These determinants of adaptation finance are understood and written about more substantively than the demand side challenges, which mainly relate to the systemic and operational conditions within finance-receiving countries that affect adaptation finance. We also examine the approaches available to tackle these challenges. We find that the language employed in narratives around challenges associated with climate finance in general tends to focus on supply-side issues. The subsequent section discusses solutions to address these challenges comprehensively. This includes analysing climate finance delivery based on commitments, such as the $100 billion target and doubling adaptation finance. Additionally, we explore discussions related to the processes within and outside the UNFCCC that can contribute to addressing climate finance challenges. This includes reform agendas within international financial institutions (IFIs), as well as bilateral and regional initiatives, alongside resilience partnerships that make significant contributions. Finally, we present some high-level policy recommendations based on the analysis.

4.10.2. Understanding the Challenges from the Supply of International Climate Finance

Gaining insight into the challenges posed by the supply side of international climate finance is instrumental in addressing the complexities in a structured manner. Examining the supply side brings to the fore issues related to the sourcing of financial resources for adaptation efforts. It highlights the constraints and limitations faced by various stakeholders, including governments, international financial institutions and private entities in providing adequate funds. In this section we discuss three pivotal challenges that underpin the complexities of climate finance: availability, accessibility and adequacy.

1. Availability of Finance:

The primary challenge in addressing climate adaptation finance revolves around the sheer scale of financial resources required and allocated for adaptation initiatives. Studies suggest that adaptation costs for developing nations might increase to $160–340 billion by 2030 and $315–565 billion by 2050 (United Nations Environment Programme, 2022). As the impacts of climate change become increasingly severe the costs of adaptation soar, making the gap significant between the demand for climate finance and the availability of resources. Accessing adequate adaptation finance from multilateral and bilateral climate finance mechanisms, such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), the Adaptation Fund, the World Bank, the International Monetary Fund (IMF) and wealthy countries, is the only way for developing countries, particularly the most vulnerable, to implement these initiatives that would include their adaptation priorities and needs. These needs could be presented in different forms within a national strategy or plan document including in the UNFCCC Nationally Determined Contributions (NDCs) or National Adaptation Plans (NAPs) or other national communications (UNFCCC). Finance requirements for identified priorities and needs are very high and will likely increase if mitigation action does not reduce the need for adaptation. Current global adaptation finance flows from bilateral and multilateral sources including the financial mechanism of the UNFCCC has been below the current needs of developing countries (United Nations Environment Programme, 2022). It is crucial to emphasise that there is no presumption or requirement for all climate finance to flow exclusively through the financial mechanism of the UNFCCC. However, these mechanisms do have a significant role in advancing global cooperation on climate finance. For example, the GCF, designed solely to channel climate finance for climate projects, is grappling with funding deficits against projected demand from developing countries as current pledges and replenishments significantly reduce. These delays in fulfilling commitments and meeting funding targets obstruct the timely flow of finance to adaptation action (Schalatek, 2023).

A critical aspect of assessing the availability of finance is the nature of the funding itself. A significant proportion of climate finance, as discussed in the section on adequacy, comes in the form of concessional loans rather than grants: between 2016 and 2020, 59% of total bilateral public climate finance and 84% of total multilateral public finance (OECD, 2022). Among multilateral public finance sources, multilateral climate funds were offering a higher proportion of grants (56%) in comparison to loans (39%), possibly a result of their sole purpose to focus on climate finance. In contrast, multilateral development banks (MDBs) primarily provided loans, accounting for 91% of their allocations (OECD, 2022). Bilateral and multilateral climate funds, although constituting a smaller portion of the climate finance landscape, allocated a more significant share of funds in the form of grants compared to MDBs (OECD, 2022).

Adaptation finance studies have shown that developed countries have fallen significantly short of their commitments. In 2019, developed countries pledged to at least double their adaptation finance commitments, increasing their funding to $40 billion (Lissner et al., 2022). According to ODI research, only 11 countries have fulfilled their share of adaptation requirements. Adaptation finance also falls far short of that programmed towards mitigation (Pettinotti et al, 2023). The private sector's involvement in addressing climate finance availability is gaining attention. However, limited data reveals that the private sector has not played a significant role in adaptation finance, with a stark contrast between the $300 billion directed towards mitigation and a mere $1 billion for adaptation (Buchner et al, 2021). This imbalance is largely due to the lower financial returns from adaptation projects, making private investment less appealing. Developing countries are cautious about relying heavily on the private sector, citing the urgent nature of climate challenges and the need for immediate solutions.

2. Accessibility of Finance:

In addition to availability, access to finance for adaptation is even more challenging compared to mitigation due to the complexities associated with adaptation projects. Mitigation measures are typically straightforward, while adaptation projects can be complex and time-consuming processes involving a meticulous assessment of climate rationale; the link between climate, climate impact, climate action and the societal benefit of a particular action, as compared to what would happen without the intervention. Developing countries, particularly least developed countries and small island states, face significant challenges trying to access climate finance. For example, GCF approval time for projects in Least Developed Countries (LDCs) is a median of 21 months, with some projects taking as much as five years (Djabare et al, 2021). Staffing issues and complex application procedures burden these nations as funding requirements include extensive documentation, detailed project proposals and adherence to specific guidelines. While the experiences of developing countries in securing financing, whether in the form of grants or loans, differ significantly, those reporting challenges often attribute these to compliance with procurement procedures and understanding donors' eligibility requirements and conditionalities, with demands for extensive technical details related to environmental and social safeguards, gender impacts and climate rationale, which can become cumbersome. It is important to ensure that projects address environmental and social impacts, including gender considerations, but concerns arise when these requirements become mere box-ticking exercises to meet donor demands, rather than genuinely strengthening these areas. This reflects an underlying lack of trust and patience in supporting the development of national governance structures and mechanisms. Furthermore, conditionality can arguably impact the flexibility and ownership of adaptation projects. Embracing soft conditionalities, such as requiring projects or programmes to demonstrate that they are participatory, consensus-oriented, equitable and inclusive, is increasingly seen as a norm (Schalatek, 2012). Conversely, hard conditionalities, like results-based payments, tend to be situation-dependent and contingent upon specific agreements regarding anticipated outcomes. Linked to demand-side challenges, discussed in the next section, macroeconomic factors in the country, such as inflation, debt ratings, security concerns and currency instability, compound existing weaknesses in public financial management, further complicating the accessibility and management of donor grants and finance. The internal mobilisation of financial resources is further complicated by economic instability and global market volatility.

3. Adequacy of Finance:

Adequacy in adaptation pertains to the sufficiency of financial resources allocated for adaptation action. This can be in terms of scale, type, predictability and timeliness. Ensuring that funds are disbursed in a predictable manner is imperative for the effective implementation of adaptation projects. Delays will result in missed opportunities and heighten the vulnerability of communities, especially in the face of extreme weather events and other climate-related emergencies. The issue of adequacy arises due to the disparity between the actual funding received and the costs involved in implementing comprehensive adaptation measures. Available adaptation finance does not match the magnitude and urgency of adaptation needs. Figures highlighted previously indicate that the requirement far exceeds the current level of climate finance – including for mitigation efforts – and it is beyond the unmet annual target of $100 billion. This limitation can impede the ability of these countries to execute transformative adaptation projects and initiatives and limit them to incremental progress. In addition, different forms of financial instruments, such as grants, concessional loans or equity investments, can have varying impacts on the adequacy of adaptation efforts. Grants, for instance, provide direct financial support without the burden of repayment, making them more accessible for countries with limited fiscal capacity. However, loans might also entail repayment with interest, potentially increasing the financial burden on already resource-constrained nations. Thus, determining whether the mix of financial instruments is adequate and aligned with adaptation priorities is a crucial aspect of the adequacy assessment.

4.10.3. Understanding the Challenges from the Demand of International Climate Finance

Climate finance in general typically lean towards the supply side – emphasising the availability of and access to financial resources from different sources. However, a comprehensive approach to climate finance should equally consider the challenges posed by the demand side. In this context, 'demand side' refers to recipients, or the countries and communities seeking financial support to adapt to and mitigate the impacts of climate change.

Countries rely not only on internationally mobilised resources for climate action domestic resources are as important, if not more so. In this section, we analyse the internal issues to the finance seeker associated with climate finance. Understanding these demand-side challenges is critical to achieving the goals of effective and equitable climate finance, and will help in recognising and addressing the challenges and barriers developing countries face when attempting to mobilise internal financial resources for climate adaptation, and attract and utilise internationally mobilised resources.

Economic fundamentals and capacity

Developing countries can face significant challenges rooted in their economic fundamentals. The fundamentals of an economy can be understood through indicators like the rate of economic growth, inflation rate and unemployment rate, which together paint a picture of a country's economic wellbeing and situation. A weak economic base characterised by low GDP, modest per capita income and limited resources restricts fiscal capacity. Such fragile economies find it hard to allocate significant funds for climate adaptation. Concurrently, systemic issues like unemployment, income disparity and under-developed infrastructure limit resource mobilisation and accentuate the impacts of climate change, making adaptation even more important. Economic fundamentals such as limited GDP, dependency on climate-sensitive sectors like agriculture and lack of economic diversification constrain nations from using national public finance resources for adaptation (Brown, 2015). Global market volatility, paired with domestic economic instability, often magnifies budgetary constraints (Brown, 2015). Budgetary constraints prevalent in many developing countries make it challenging to dedicate adequate resources for climate adaptation (Brown, 2015).

Immediate socio-economic priorities

Addressing social and economic issues while also prioritising climate change adaptation can be overwhelming. Developing countries often face a combination of pressing problems including poverty, unemployment and health crises. Poverty is widespread, with millions struggling to meet their needs. An estimated 7% of the global population – some 575 million people – will still be living in extreme poverty by 2030 (United Nations, 2023). Fragile social systems are further strained by health crises due to poor access to healthcare and sanitation. In these circumstances, allocating resources to climate change adaptation becomes extremely challenging. This is not to suggest that investments in climate change adaptation are somehow detached from broader investments in addressing social issues; in fact, they are interconnected and mutually reinforcing.

The success of adaptation financing is not merely about securing funds, but also about integrating adaptation into broader economic goals and strategies. Several strategies can be adopted to address these challenges.

- The more straightforward response would involve providing technical assistance and resources to help developing countries navigate the complex application process and help them progressively comply with the requirements of multilateral and bilateral climate finance mechanisms. While building technical capacity, there are possibilities to streamline procedures for developing countries to access multilateral funds. The harmonisation of procedures, including accreditation and access processes, would reduce the transaction costs associated with seeking financial support. For example, a collaborative effort in shaping a streamlined accreditation approach, like the Climate Investment Funds (CIF), coupled with standardised documentation and climate rationale justification across various funds like GCF and GEF, would prevent a situation where more time is spent on funding applications than on the actual implementation of projects.
- Integrating climate risks into macroeconomic planning and modelling economic scenarios represents a pivotal step in addressing demand-side challenges. Climate adaptation efforts, including how climate finance is channelled towards these efforts, should be integrated into national economic development strategies. The traditional approach to economic planning must evolve to account for the ever-growing impact of climate-related disruption. By aligning adaptation efforts with a country's broader economic goals, such as investment in climate resilient infrastructure, this ensures that adaptation becomes an integral part of a country's economic planning and decision-making processes. Such integration allows adaptation projects to serve dual purposes, not only enhancing climate resilience but also contributing to

economic development. This entails a need for a comprehensive assessment of how climate change can affect various sectors of the economy, usually undertaken through the national development planning process or through formulation of NDCs and NAPs. This assessment would consider the potential consequences of extreme weather events, shifting weather patterns and rising sea levels on industries such as agriculture, energy and transportation. By doing so, governments and policy-makers can better understand the vulnerabilities of their economies and develop strategies to mitigate these risks. This approach should go beyond simply identifying vulnerabilities and exploring economic opportunities. For instance, the transition to a low-carbon economy and the development of clean energy technologies represents significant economic opportunities. By emphasising the potential benefits of climate action, governments can align long-term climate strategies with economic growth and job creation. Such opportunities will pave the way for reducing reliance on fossil fuels and develop cleaner, more efficient technologies, they open doors to new industries, job markets and international collaborations. This, in turn, can lead to economic diversification and resilience, reducing dependence on sectors vulnerable to climate-related disruption.

• Improving governance and transparency is also a key response to addressing the demand side. Addressing corruption, improving governance efficiency and increasing transparency are prerequisites for effective adaptation financing. These steps are vital in ensuring that allocated funds are used for their intended purposes, that project proposals are properly evaluated, and that resources are distributed effectively. Corruption can divert funds away from their intended projects and initiatives. This misallocation of resources can lead to consequences when funds earmarked for climate adaptation are redirected elsewhere. Governance inefficiencies worsen the situation, with delays, lack of coordination and ineffective implementation of policies. Furthermore, the lack of transparency in transactions and decision-making processes creates an environment that can easily be exploited. To address these challenges effectively requires an approach that includes governance reforms, transparency initiatives and clear policy frameworks. It is through efforts to overcome these obstacles that developing nations can create an environment conducive to utilising adaptation financing effectively, while building resilience against climate change impacts.

• Improving and strengthening delivery channels and mechanisms in country is important. A critical component of delivery mechanisms is the governance arrangements for the flow and allocation of the money, including how planning is done and decisions are made, and by which actors and institutions. The quality of the governance and decision-making on how the finance is used is just as important as the quantity of finance flowing. Efforts are being made by LDCs for example under the flagship LDC Initiative for effective adaptation and resilience (LIFE-AR), to address such challenges through a finance delivery mechanism. LDCs have made a commitment to improving their systems at different levels starting from the national level and going all the way down to the local level.

It is important to bridge between domestic ability and international mobilisation needs. A core issue is the mismatch between the financial resources that developing countries can mobilise domestically and the substantial funding required for effective climate adaptation. This bridge between domestic financial capacity and international funding needs is where adaptation financing must find its place. International support, whether from developed countries, international financial institutions or private sector investments, plays a pivotal role in filling this gap. However, this must be done in a way that respects the sovereignty and priorities of each country, while promoting inclusivity.

4.10.4. Reforms outside the climate negotiation process

The need for financial reform has become increasingly urgent in light of the impact of the Covid-19 pandemic (Streimikiene and Kaftan, 2021). Many developing countries have suffered greatly from the effects of the crisis, leading to a growing recognition that significant changes are needed in the financial landscape. The economic downturn Financing Adaptation in Developing Countries: assessing demand and supply side challenges 19 caused by the pandemic, along with increased spending on disaster recovery, has put a strain on national finances. This has raised concerns about countries ability to manage their debt, sustain public expenditures and secure funding for future development initiatives. In response to these challenges there is a growing consensus that global financial reform is not only desirable, but also an urgent necessity. Such reform needs to consider measures to strengthen healthcare systems, build climate resilience and adaptive capacity, support economic recovery efforts and provide debt relief for nations burdened by high levels of debt. Additionally, there is a call for an equitable distribution of resources (i.e leaving no one behind or a concentration of support to certain countries) and international cooperation aimed at addressing the challenges faced by developing countries in the post-pandemic era. At COP27, developing countries expressed dissatisfaction with the status of climate finance, the significant portion of which is provided in the form of loans, which places further burdens on economically strained nations (Alayza et al, 2022). This dissatisfaction is not limited to the climate process and the negotiations on finance, but there is a growing recognition that global public financial systems, including development banks, need comprehensive reform. This recognition aligns with the increasing demand for expanded climate finance, acknowledging that debt issues hinder developing countries' efforts to address climate change.

To effectively address the demand aspect, countries must establish systems that promote transparency, accountability and efficient utilisation of climate finance resources. This includes establishing climate finance delivery systems and mechanisms for tracking and reporting on climate expenditures, ensuring that funds reach their intended beneficiaries and building local capacity to manage and implement climate projects effectively. Encouraging transparency and accountability of private sector actors through disclosure mechanisms and other relevant regulatory tools will also be important.

****

UNIT - V

CLIMATE CHANGE NEGOTIATIONS AND EQUITY

5.1. Introduction

Equity and responsibility in climate policy should become more than mere solutions for maximizing advantages and minimizing costs, or mere tools for attaining targets such as 'economic growth' or 'political stability' (Banuri et al. 1996). United Nations Framework Convention on Climate Change (UNFCCC) refers to equity in a subjective manner: 'the Parties should protect the climate system for the benefit of the present and future generations of humankind, on the basis of equity and in accordance with their common but different responsibilities in respect of capacities. As a result, the Developed Country Parties should take the initiative in combating climate change and its effects'. Discussions of equity at the UNFCCC included a variety of aspects, such as current or past responsibilities for the causes of climate change, future responsibilities for adaptation to climate change, 'the willingness to pay' for damages caused by climate change, equality of per capita emissions of gases into the atmosphere. The concept of responsibility is equally fundamental to climate change issues. It involves the idea that 'everything is related to everything else' and includes an appeal for a 'more ethical stance' (as if this were a concrete goal). It is important to avoid vague propositions, as well as the 'militant' aspects often associated with environmental discourse as a whole; this undermines the political credibility of the environmental agenda, which is often viewed as 'non-scientific' in academic circles. 'Equity or environmental issues continue to be treated as externalities to markets'.

Adaptation to climate change may also provide a viable route to sustainable development and go beyond mere risk minimisation and survival strategy for the poor, whose livelihood systems are increasingly exposed to extreme events (Jerneck and Olsson 2008). Since adaptation requirements are different over short, medium, and long terms, setting a framework that integrates short and long term measures for adaptation is crucial (Corfee-Morlot and Hohne 2003). Just like the global approach to climate change response under shared but differentiated responsibilities that enables the building of consensus around policies, strategies, and standards on a set of priorities, a similar approach should be used in guiding the planning and fund allocations for the implementation of adaptation at any level. This will require laying down some fundamental principles for the process to ensure fairness and equity.

5.2. Criteria for Distribution of Emission Reduction Burden

Policies under consideration within the Climate Convention would impose C02 controls on only a subset of nations. A model of economic growth and emissions, coupled to an analysis of the climate system, is used to explore the consequences of a sample proposal of this type. The results show how economic burdens are likely to be distributed among nations, how carbon "leakage" may counteract the reductions attained, and how policy costs may be influenced by emissions trading. We explore the sensitivity of results to uncertainty in key underlying assumptions, including the influence on economic impacts and on the policy contribution to long-term climate goals. At the First Conference of the Parties to the Framework Convention on Climate Change in 1995, nations reached agreement on the terms for negotiating a protocol on the control of greenhouse gas emissions. This so-called Berlin Mandate (United Nations, 1995) specifies that targets and timetables for control of emissions (what the text calls Quantified Emissions Limitation and Reduction Objectives, or QELROs)

We focus on four aspects of the possible economic and climatic effects of such policies. The first two concern the manner in which their effects would be mediated through the international trading system, influencing the distribution among nations of economic burdens and of carbon-emitting activity. Restrictions on carbon emissions are likely to involve costs for the country adopting the policy, but they also may have smaller but significant economic implications for other countries that have not accepted obligations under the Convention. This spill over will occur because QELRO-induced reductions in economic activity in one country lead to reductions in demand for the exports of others. Also the relative prices of different sources of energy will shift, with consequent effects on the prices of non-energy goods. These changes in relative prices will occur both within countries (leading to in-country substitution) and between countries (leading to trade adjustments), with the welfare effects extending to all countries. Some non-participants will lose and some will gain, depending on the circumstances. A second possible effect of any agreement that raises the costs of carbon emissions differentially across countries is so-called carbon "leakage." An important mechanism for such leakage is that countries not under restraint will experience changes in the cost of energy-intensive goods and services, and shifts in their international competitiveness in the manufacture of these items. As a result, they may emit more C02 than they would if there were no agreement under the Convention. If, in an effort to reduce costs, countries facing emissions restrictions adopted some form of trading in emissions rights, economic burdens would be reduced, and their distribution shifted. This response leads to the third of the effects considered below, finally, there is the issue of the likely contribution of proposed polices to longer-term objectives of the Convention. Many would argue that QELRO proposals currently under consideration are not in themselves a long-term response to potential climate change, but merely next steps on a path to emissions restraints by all Climate Convention signatories.

When a carbon constraint is accepted by some regions, the overall system of production, consumption and trade adapts, and the effects are felt in those countries taking direct action to reduce emissions and in countries assume no such obligation. The consequences for each region of the sample QELRO, measured in terms of the consumption-based welfare index. The EPPA distinguishes four OECD regions: the United States (USA), the European Community (EEC), Japan (JPN) and the Other OECD (OOE). Under the set of QELRO conditions imposed here, each of these OECD regions meets emissions target independently (the implications of emissions trading considered later). The depressing effect on the regional economies of the constraints, which force adjustments to a lower production frontier different composition of output, are clearly shown.

The distribution of welfare losses among the sub-regions of the OECD is notable. The costs to the United States, Japan and the Other OECD similar. The United States and the Other OECD are alike because, in Reference run, both regions make use of the carbon-liquids backstop technology, which is relatively carbon-intensive. If emissions restrictions are accepted relatively easy in this model to avoid emissions growth by foregoing development of this non-conventional carbon fuels industry.

The QELRO calls Quantified Emissions Limitation and Reduction Objectives restrictions simply accelerate the diffusion of a non-carbon backstop which is not far from being economic in Japan at the start of the analysis. In addition, the EPPA model's representation of the structure of the Japanese economy permits an easier substitution of electricity for other energy forms than is possible for other regions. The EEC fares somewhat worse that its companion regions because, lacking the necessary natural resource base, it does not use the backstop carbon fuel under Reference conditions with no policy. Also, the non-carbon electric backstop source involves a greater cost penalty than in Japan. As a result, reductions in their carbon emissions are achieved only with more drastic changes in resource allocation and consumption patterns.

5.2.1. Carbon Leakage

If one set of world regions constrains activities that produce C02, then the changes in relative prices and shifts in trade patterns may cause increases in carbon emissions elsewhere, partially offsetting the reductions achieved. This phenomenon is often referred to as the carbon "leakage" which may accompany restrictions that differ among world regions. For our sample QELRO, carbon leakage can be defined as that increase in C02 emissions in non-OECD regions (compared to the Reference case without restraints) stated as a percentage of the reduction in emissions in the OECD. Under this definition, the leakage from the AOSIS-type protocol under the Reference case is 6.8% for the period 2000 to 2100.

5.2.2. Potential Benefits from Emissions Trading

Meeting a commitment to reduce emissions by domestic actions alone is relatively expensive, and countries will seek efficiency by exploiting the cheapest opportunities for reducing carbon emissions, wherever they may be available. One approach is to engage in individual bilateral agreements that allow countries facing a constraint to undertake or fund C02 reduction measures in other countries. On a project-by-project basis such programs fall under the rubric of Joint Implementation (JI) or Activities Implemented

Jointly (AIJ). A comprehensive approach to the goals of JI and/or AIJ would be to set up a market for carbon emissions by allocating emissions quotas and allowing countries to engage in trading for those rights (see Tietenberg and Victor, 1994). There is no precedent for a market in emissions rights on such a scale, and the feasibility of involving a large number of nations in such a system remains to be explored. The transactions costs are unknown as well. Nonetheless, even idealized versions of such schemes can give important insight regarding the general magnitude of the economic benefits that a trading regime might offer. In our analysis of these trading systems we assume an allocation of emissions permits that is common to all cases considered. That is, each of the OECD regions is assumed to receive permits in the amount of the QELRO limit defined above, and each non-OECD region is credited with permits equal to its emissions under the Reference case. By this construction, leakage is constrained to zero, and thus the region-by-region burdens in the no-trading case differ slightly from those in Figure 3. If the permits are sold, the revenues are credited to the representative consumer, and adjustments come through both substitution and income effects.

By the period 2030 to 2050, the cost to the OECD is cut by 60% to 70%, compared to that with independent action. Non OECD regions also benefit, as shown in the lower part of the figure. They receive payments to compensate for emissions reductions they otherwise would not undertake, and they also gain because of trade effects stimulated by the improved economic health of OECD nations. It is worth noting that, stated as a fraction of the burden with no trading, the benefit of the trading regime to non-OECD regions declines over time, while the benefit to the OECD regions rises. This happens for a couple of reasons. In the early years of the analysis period the imposition of emissions trading helps to correct the adverse effects of energy price subsidies in non OECD regions (particularly in the Former Soviet Union, Eastern Europe, and China), but over time these subsidies are assumed to be removed. Also, over time there is an increasing gap between OECD emissions in the Reference case and those in the QELRO calls Quantified Emissions Limitation and Reduction Objectives case, leading to increasing gains from the ability to trade. On the other hand, the non-OECD regions are growing more rapidly than the OECD, so the permit sales and associated energy sector adjustments are declining relative to the total size of their economies. It also is important to point out that not all regions need participate in order for substantial gains to be achieved from a trading regime. With trading among the countries of the OECD only, for example, the benefits are very small, less than 5% of those shown for full global trading. The small benefit is explained by the fact that, despite their different access to backstop sources noted earlier, the OECD regions as defined in the EPPA model are similar enough in economic structure that carbon trading opportunities are limited.

5.2.3. Backstop Technologies and Distribution of Burdens

Assumptions about the availability and relative cost of the two backstop technologies have an especially significant effect on the distribution of burdens of the QELRO calls Quantified Emissions Limitation and Reduction Objectives restriction and on estimated leakage. To demonstrate this point, we formulate a case which is dramatically different from that in earlier sections. We hypothesize a world where all the conditions in the reference case remain the same, except that the backstop technologies do not exist (or, alternatively, that their costs are so high that they never enter substantial use). The stark comparison is particularly useful in illuminating the mechanisms that distribute the economic burden among regions. The carbon-free and carbon fluids backstops partially counteract one another. Thus the Reference case with no backstops implies total carbon emissions that total about 14% more than the Reference with both backstops (with no emissions limits in either case). The no- policy pattern of regional emissions is even more significantly different between the two worlds, owing to differences in penetration of the two backstops, as are the levels of Gross Domestic Product (GDP) and of our consumption-based welfare measure. Beyond the issues of economic burdens and carbon leakage, these results have another set of implications for current proposals for restrictions on emissions. By itself, the effort required by our sample QELRO proposal yields only a minor reduction in the magnitude of potential global warming. Indeed, predicted temperature changes depend more on what is assumed about economic growth, productivity improvement in energy use, and the relative costs of future technologies than it does on policy measures of the severity of the one studied here. Yet the uncertainty about these causal factors is great, so that over the wide range suggested by we do not know what the human contribution to atmospheric gas concentrations will be. To this economic uncertainty must be added the limits to our knowledge of the carbon cycle and the climatic response to these gases, and the severity of the economic and ecological consequences. In these circumstances, QELROs proposed for near-term agreement need to be designed so they can be easily adapted over time, as we learn more about these key influences. Further, given the limits on what can be achieved with restraints applied to only a subset of countries, negotiators must seek to identify policy designs that offer the prospect of attracting participation by all world regions.

5.3. CRITERIA FOR ADAPTATION FUND

The Adaptation Fund of the Kyoto Protocol was established as a financial instrument under the UNFCCC - United Nations Framework Convention on Climate Change to finance adaptation projects and programmes in developing countries that are particularly vulnerable to the adverse effects of climate change. It is financed by voluntary contributions and also from a two per cent share of the proceeds of the Certified Emission Reductions issued under the Protocol's Clean Development Mechanism projects. By 2017, the total commitments had reached close to US$438 million in 67 countries. The Fund is governed by the Adaptation Fund Board, which consists of 16 members and 16 alternates representing Parties to the Kyoto Protocol. A majority of members – about 69 per cent – represent developing countries. Its Secretariat is serviced by the GEF, which is operated by the World Bank, and its trustee is also the World Bank. Significantly, the Fund has been pioneering "direct access" funding arrangements which allow countries a simplified and accelerated way to access and manage funds without those funds having to pass through financial intermediaries. The Fund's implementing entities consist of national, regional and multilateral organisations which are selected through an accreditation process. This process is bolstered by a reaccreditation procedure that takes place every five years. These processes aim to ensure that the Fund's implementing entities are complying with the Fund's fiduciary standards, transparency, accountability, integrity and other standards, including environmental and social safeguards and a gender policy, as discussed in this assessment. These entities are eligible for project and readiness grants. Project finance amounts range between approximately US$700,000 and US$14 million, averaging at around US$6.7 million per grant.36 Readiness assistance of between US$10,000 and US$50,000 is provided for South– South cooperation and technical support is provided for environment, social and gender programmes.

5.4. INTER AND INTRA-GENERATIONAL EQUITY ISSUES

Intergenerational equity has been the bedrock of sustainable development and international policies surrounding climate change since time immemorial. While many international legal instruments most notably the Stockholm Declaration, Rio Declaration, United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement recognise and seek to preserve the rights and interests of future generations, intergenerational equity is usually undefined and often regarded as 'soft law' with the scope of interpretation to suit different circumstances.

A problem that we cannot ignore any longer is that climate change and its repercussions are wreaking havoc everywhere with extreme weather conditions, including increasing heat waves, catastrophic monsoons, roaring wildfires, severe droughts, and bone-chilling cold spells. Climate change is inherently an intergenerational problem affecting the present generations. It will cast an ominous shadow on the future (unborn) generation, mainly depending on the actions we choose to take today. Hence, present action to combat climate change may not result in immediate results but is an investment sought to be undertaken for the benefit of future generations.

The concept of 'intergenerational equity', initially conceptualised for sustainable development, has become even more relevant in light of climate change. As two sides of the same coin, intergenerational equity and sustainable development are rooted in the need to balance the short-term needs of today's generation (intergenerational equity) with the longer-term needs of future generations (intergenerational equity), all the while promoting prosperity and quality of life.

Aspects of intergenerational equity

International legal instruments, specifically in environmental law, often refer to intergenerational equity as the foundation for advocating for environmental protection and climate change mitigation and adoption policies.

India-specific approach

India has been at the forefront of recognising a clean and healthy environment as an integral part of the right to life under Article 21. It has advanced this fundamental right by enforcing the right to a healthy environment through specific legislation, a dedicated tribunal and judicial precedents.

Aspects of intergenerational equity

International legal instruments, specifically in environmental law, often refer to intergenerational equity as the foundation for advocating for environmental protection and climate change mitigation and adoption policies.

Climate change combat needs to prefer imaginative over evidence-based legal approach

Whether it is to clean and preserve Manila Bay in the Philippines, adhere to obligations ratified under the Paris Agreement, or recognise the role of the Amazon deforestation in accelerating climate change events— all have been interpreted unequivocally considering the rights and interests of future generations.

India-specific approach

India has been at the forefront of recognising a clean and healthy environment as an integral part of the right to life under Article 21. It has advanced this fundamental right by enforcing the right to a healthy environment through specific legislation, a dedicated tribunal and judicial precedents.

The Supreme Court of India has recognised and implemented principles of the precautionary principle, polluter pays principle, sustainable development and, importantly, 'intergenerational equity'.

India has contributed to developing the principle of 'intergenerational equity' by placing the obligation on the governments to take adequate and necessary steps to provide 'clean air' to protect the health of future generations (for example, in M.C. Mehta versus Union of India, 1987).

It has gone one step ahead and placed an affirmative duty on the governments of the present generations to adequately take measures, even if it means amending current legislation to make accommodations for the generations to come (in A.P. Pollution Control Board versus Prof. M.V. Nayudu, 2000).

The Supreme Court has also interpreted the principle for protecting carbon sinks and prohibiting large-scale deforestation (in K.M. Chinnappa versus Union of India, 2002 and Maharashtra Land Development Corporation versus State of Maharashtra, 2010).

Recently, it also regulated mining using this principle (in Goa Foundation versus Union of India, 2014) and in furtherance of wildlife conservation (in T.N. Godavarman Thirumulpad versus Union of India, 2010).

Why is Delhi's air much worse than you think?

These cases have led to the development of environmental jurisprudence in India and present an opportunity to develop the principle of intergenerational equity specific to climate change. It would also require the governments— both at the Union and the state level— to work in tandem to enforce the decisions of the Supreme Court.

Considering India's unique socio-economic vulnerabilities, intergenerational equity could also lead to enriching jurisprudence across the globe and the development of international climate change law.

The criticism of the principle of intergenerational equity lies in its anthropocentricity and the self-perpetuating cycle of climate vulnerability. Those facing socio-economic hardship and marginalisation are most severely impacted by climate change, adversely affecting their adaptive capacity. This presents a unique opportunity for India to be at the forefront of addressing these concerns in light of recent climate change events and provide a blueprint to similarly placed nations at comparable economic capacities and development indices. Another drawback of the modern judicial system is that if future generations (through representations) directly bring claims, they might be deemed non-existent.

So, how can they claim rights in the present when they do not exist? However, this issue has been dealt with by the Supreme Court of India effectively, as it has vastly expanded the scope of locus standi, mainly when it deals with violating fundamental rights such as life, health, livelihood and clean environment. All such rights stand endangered for the present and future generations if the current trajectory of climate change continues and mitigation policies are not adopted.

Future approach

The Supreme Court of India has been the torchbearer in the recognition of a healthy, clean environment as part of the enforceable fundamental right to life, especially with the need for balancing it with other competing fundamental rights, and can continue to pave the way for the protection of the climate system as well. In the context of Indian jurisprudence, it is up to the governments in tacit compliance with the judiciary to take charge in the fight against climate change, considering its unique circumstances. It is essential to recognise India's socioeconomic vulnerabilities while formulating climate change adaptation and mitigation policies and ensuring fairness between the generations. This process can start by targeting short-lived climate pollutants such as methane, black carbon, tropospheric ozone and hydro fluorocarbons by monitoring and focusing on their reduction through policy measures at the state and district levels. It can use the already existing mechanisms of pollution control boards to monitor the effective implementation of such policies. Climate change mitigation policies are the need of the hour and they require the positive and active involvement of States to protect the rights of future generations effectively.

5.5. DISCOUNTING IN CLIMATE CHANGE CONTEXT

What should be done about climate change? The debate is notoriously complex, involving a mix of difficult and uncertain science, the potent structuring of the energy, agricultural, and forestry sectors across the globe well as issues of national sovereignty, distributive justice, and corrective justice development. Specialists intensely disagree about the central issues the policies that are best, the level of resources to be devoted to the problem which nations should pay. Many of these disagreements are beginning to p role in domestic law, and they may well arise in the context of judicial interpretation of many environmental statutes. When readers pick up two of the most prominent recent books on topics, one by Sir Nicholas Stern written for the UK government, and American economist William Nordhaus, they find dramatically different recommendations. Stern argues for an immediate and dramatic response, very high carbon tax imposed immediately and increasing rapidly over the issue, according to Stern, is urgent. Nordhaus also favors an intern agreement, but he recommends modest and slow changes. In his view, changes impose costs that are far too large relative to the benefits, and he prefers a slow but steady change in the energy supply system.

Both authors, it turns out, make the some basic assumption about the effects of climate change, about most other parameters that might affect the debate. The major differences is one that at first seems entirely technical: the proper computation of the discount rate, which, as we will discuss, is simply the rate one uses to match cash flows in different periods. Stern argues for a low discount rate, while Nordhaus argues for a high one.

We explore the issue of discounting in the context of climate change. The central problem is that if the world cuts emissions immediately the beneficiaries of its action will be people living decades from now, not people living today. By contrast, the cost of emissions reductions will be paid mostly by current generations. At the core of the climate change problem, then is an ethical debate involving the allocation of resources across generations.

Defenders of discounting argue that it is necessary to ensure consistent comparisons of resources spent in different time periods. Critics of discounting begin with a principle of intergenerational neutrality. Discounting has generated a massive literature with strong views on various sides of the issue. Although there are many subtleties and complexities in these arguments, we break down the basic positions into two camps: the positivists and the ethicists. The positivists generally defend discounting at the market rate of return on the theory that only by evaluating projects at the market rate can we ensure the projects are worthwhile. If a project produces less than the market rate of return, there is a better return available by simply investing in the market.

The ethics respond the positivist approach is morally indefensible and unjust because it grossly undervalues the future in violation of a principle of intergenerational neutrality. It is easy to show that using any modest level of discounting, future generations count for essentially nothing. We show that this argument confuses the valuation of lives with the problem of discounting. We argue for discounting money, not lives.

****