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Global Warming and Climate Change: A Review

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Abstract - Global warming, the gradual increase in Earth's temperatures and associated changes in global weather pattern, has had serious consequences in recent decades, constituting one of the major global issues of our time. This review highlights the sources of global warming, the country origins of Green House Gases (GHGs) emissions, the nexus between global warming and human activity, the costs of climate change drawing on findings on agricultural activity and, finally, policies to tackle global warming. The consequences of global warming still remain a subject of debate and speculation, but climate change studies hypothesize dire consequences for agricultural productivity and disease incidence globally, but especially for countries located nearer the tropics where temperatures are bound to rise higher.

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Global Warming and Climate Change: A Review

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I. Introduction

Global warming refers to the gradual increase in the Earth's temperatures and the associated changes in global weather pattern. Records show that the world's climate has barely changed since the Industrial Revolution in Western Europe which started in Great Britain in the late 1700s – that is, some two and quarter centuries ago. The world's temperature was reported stable throughout the 1800s, rose very slightly during the early 1900s, fell back in the 1950s through the 1970s, then started warming up again as from the 1980s. From the 1990s to the present (first decade of the 2000s), the world's temperature has risen by about 0.6 °C (= I . If) (The Economist 9th September 2006,; Noble and Watson 2006). It has been established that the earth has already warmed up by about 6 °C, since the first decades of the 1900s and is projected to warm up by as much as 5.8 °C by the first decades of 2100. Global warming has had serious consequences in recent decades, which have aroused international concern; some of these consequences include: a rise in sealevels; bleaching of coral reefs; thinning of sea ice; , retreating of glaciers; changes in precipitation patterns and growing seasons; changes in the frequency of pest and disease outbreaks; changes in the populations and geographical range of certain animal species; and changes in the cultivable ranges of certain animal species; and changes in the cultivable ranges of certain crops.

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However, the current concern is not much the rise in the earth's temperatures as the cause of that rise. Available evidence shows that whereas previous changes in the earth's climate were caused by variations either in the angle of the earth's rotation or in its distance from the sun, the current change is man-made originating in greenhouse gases (GHGs). The Economist 9th September 2006,; Noble and Watson 2006; Cline 2088; Mclean and McMillan 2003 pp.225-6). Beside, the observed rise in the earth's temperature is occurring at a rate hitherto not experienced. Although the long-term consequences of climate change remain a subject of among scientists and economists, climate change models predict deforestation, desertification, a pole-ward shift of vegetation and animal populations, rising sea levels, and decreased precipitations.

In this review, we highlight the sources of global warming, the country-origins or sources of Green House Gases (GHGs) emissions, the nexus between global warming and human (economic) activity, the costs (economics) of climate change drawing on findings on agricultural productivity, and, finally, policies to tackle global warming.

II. Causes of Global Warming

A phenomenon also known as 'climate change' or 'the green house effect', global warming is the process whereby solar radiation that has reflected back off the earth's surface remains trapped at atmosphere levels, due to the build-up of carbon dioxide ($C0_2$) and 30 0ther GHGs – e.g., methane, nitrous oxide (N_20), etc- which helps create a layer that prevents the heat from the sun from escaping into space, thus warming the earth's temperature.

Another factor is burning of fossil fuels (oil, coal, gas), which contain the carbon dioxide that the original plants breathed in from the atmosphere. Fossil fuels are formed from plants which breath in carbon dioxide ($C0_2$) (during photosynthesis) and release oxygen (O_2) in that process. Levels of carbon dioxide have increased from around 289 parts per million (ppm) prior to the 1700s (the Industrial Revolution century, when industrial gas emissions became significant) to around 380 ppm presently; that of methane, the second most important of the GHGs, from 750 parts per billion (ppb) to nearly 1,750 ppb; and that of nitrous oxide from about 265 ppb to about 312 ppb (Noble and Watson, op. cit.). How to reduce the heavy accumulation and, also, stop further increase in GHGs are key concerns of current international environmental policies, to which we return.

The second biggest source of GHGs is deforestation (18°/$_o$), followed by industry (table1). Deforestation can be traced to poverty: poor rural households in developing countries depend on tropical forests for fuel-wood and new farmland. Around the global, 900 million people are known to live in absolute poverty in rural areas, dependent solely on the exploitation of natural products for food and income generation. The imperatives of short-term survival often force rural farmers in developing countries to resort to myopic agricultural practices of reduced fallow and increased acreage by encroaching on pasture and woodlands. This problem is worst in the high population density requires of Sub-Saharan Africa: Ethiopia, southern Malawi, southeastern Nigeria, Sierra Leone etc. Globally, African is reported to have suffered a net loss of forests exceeding 4 million hectares annually between 2000 and 2004, a result of conversion of forestland to agricultural use and dependence on fuel wood for energy. African foresland had declined from 656 million to 635 million hectares between 2000 and 2005.

Table 1 : World GHG Emissions by Sector (2000)

Sector	%
Energy generation (fossil fuels)	24.5
Deforestation	18.2
Industry (manufacturing)	13.8
Agriculture (livestock breeding etc.)	13.5
Transportation	13.5
Others	12.9
Waste	3.6

Source : The Economist, 2nd June, 2007, p. 4 (figure 1).

Table 1carries data on the 'sectorial Origins of World GHGs' sources of world GHG emissions. As already noted, energy generation is the major source (roughly 25%), followed by deforestation (18.2%) and m manufacturing (13.8%). The tendency to focus on fossil fuels explains why deforestation and even agriculture have not attracted deserved attention in discussions on sources of GHG emissions. For agriculture we should include especially livestock breeding: for instance, it has been found that every year the average sow and her piglets produce tonnes of carbon dioxide equivalent through the methane emissions from their effluent. In developing countries particularly the Pig-effluent collects in open lagoons which emit stench and gets infested with filies; sometimes it flows into nearby water systems.

Biofuels, produced from plants such as sugar cane, maize (corn), oilseed rape and wheat, are considered a promising way to reduce the amount of surplus carbon dioxide being pumped into the atmosphere by burning fossil fuels. The fact is that the plants from which biofuels are produced take up carbon dioxide during their growth, so that burning biofuels made from them should have no net effect on the amount of that gas in the atmosphere. Biofuels, it is claimed, should not contribute to global warning. There are however, studies disputing the practical application of this theory. The Paris-based International Council for Science (ICS) reports that the production of biofuels has aggravated rather than ameliorated global warming, reporting that most analyses had underestimated the importance to global warming of nitrous oxide, N_20, by a factor of between 3 and 5. The amount of N_20 released by farming biofuels crops such as maize and rape probably negates by itself any advantage offered by reduced emission of carbon dioxide.

Although nitrous oxide is not common in the earth's atmosphere, it is reported to be more potent GHG than carbon dioxide and it hangs around longer. The upshot is that, over the course of a century, its ability to warm the planet earth is almost 300 times that of an equivalent mass of carbon dioxide (**The Economist 11th April 2009**).

Nitrous oxide is made by bacteria that live in soils and water and, these days, their raw material is often the nitrogen-rich fertilizer that modern farming consumes, which has increased six-fold since the 1960s. Maize is said to be a contributor of nitrous oxide, emission but maize is one of the main sources of biofuels.

Country Origins of GHG Emissions

When it comes to contribution by individual countries and regions, the United States ranks the principal source of GHGs (24% of global GHGs), but China is projected to overtake the United States by the year 2025 (table 2). At present rich countries (The United States plus the European Union) emit more carbon dioxide than developing countries as a whole do. But developing countries will overtake rich countries within the next decade or so; China, the most populous of the emerging economies, will become the global leader in GHG emissions by the year 2015.

Table 2 : Greenhouse-Gas Emissions (Billion tonnes of carbon equivalent) by country

Country	Year 2000	Year 2025 (projected)
China	1.4	2.9
United States	1.9	2.6
European Union (EU-15)	1.05	1.25
Former Soviet Union	0.8	1.20
India	0.5	0.8
Brazil	0.4	0.6

Source : The Economist 9th September 2006A, p.16

Every year China is reported to build 60 gigawatts of power-generation capacity, almost as much as Britain's entire existing capacity. About 80% of China's power is coal-based, the dirtiest energy source.

China has currently 40% of global stocks of coal-more than the United States, the EU and Japan put together. These analyses suggest that global policies to find solutions to GHG emissions should take the United States, China and the EU on board. As well, their sectoral targets should be energy, deforestation, agriculture and transportation.

III. Global Warming and Human Activity

It is clear that global warming is directly linked to human activity: emission from human activity provide the sources of GHGs. The first person to observe that link was the 19th –century Swedish Scientist Svante Arrhenius, who speculated that emissions from industry could double carbon dioxide levels in 3000 years, thus warming the earth. In 1938 Guy Calendar, a British engineer, in a talk to the Royal Meteorological Society, posited that the earth was warming, but his claims was dismissed as that of an eccentric.

As suggested earlier scientists speculated about global warming till the last decades of the 1900s, when 'the idea of global warming was retrieved from the bin and turned into one of the biggest arguments of our time'. (The Economist, September 9th 2006A pp 3-4). Scientific research has produced data, though often contradictory and speculative, to the effect that the earth is hotting up-eg. Artic Sea ice is melting unexpectedly fast at 9% a decade; glaciers are melting surprisingly swiftly; and a range of phenomena, thought to be unconnected to climate damage, are now linked to it.

Not all changes connected to global warming will be bad for all countries of the world. For instance, a rise in temperatures (warming) would benefit countries located in the cold regions e.g. Russia, Finland, Iceland, Canada, etc- by making parts of these countries that ate currently uninhabitable comfortable to live in. Let us note that some 25% of the world's undiscovered oil and gas reserves are located in Russia's cold, ice-covered regions, which could with global warming become easier to get at[1].

Among the most certain effects of climate change is rising sea levels caused both by thermal expansion of sea water and by partial melting of the vast sheets of ice in the polar region. Noble and Watson (2006 op. cit.). report that already the mean global see level has risen by between 10 and 25 centimeters. The Intergovernmental Panel on Climate Change (IPCC 2001), set up by the United Nations, forecasts an additional rise of between 8 and 88 centimeters by 2100[2]. Small island states – e.g. Maldives- stand threatened in their very existence by a rising ocean; as well, low-lying alluvial regions, such as the heavily populated delta of the Ganges and Brahmaputra Rivers. It is important to note, also, that many of the world's largest cities, including many of the developing world's most important, are built on coastlines. Such cities can only avoid being submerged by building costly protective infrastructure. Finally, rising see levels threaten the existence of a variety of biologically rich and economically important ecosystems such as coral reefs, mangrove forests, and other wetlands.

IV. The Economics of Climate Change

As pointed out above, not every change in climate change will be considered bad: countries in the cold regions, for instance, could benefit immensely from rising temperature; in contrast, the later will make Africa and India for instance, yet hotter, which will hurt agricultural productivity. However, Cline (2008) disagrees with this proposition, arguing, instead, that global warming will lead to a toiling off of agricultural productivity across the global

Table 3 : If Carbon Emissions Continue Unabated, By 2080s, Land And Farm Area Temperatures Will Rise Sharply.

Base Levels	Land Area	Farm Area
temperature[1]	13.15	16.20
precipitation[2]	2. 20	2.44
the 2080s		
temperature	18.10	20.63
precipitation	2.33	2.51
…and agricultural productivity will tail off across the global but most sharply in developing countries. (percentage change in agricultural output potential).		
World	Withont CF[3]	With CF[4]
Output weighted	-16	-3
Population weighted	-18	-6
Median by country	-24	-12
Industrial countries	-6	
Developing Countries[5]		
Median	-26	-15
Africa	-28	-17
Asia	-19	-7
Middle East & North Africa	-21	-9
Latin America	-24	-13

[1]Temperature is average daily in °C
[2] Precipitation is measured in millimeters per day
[3]Assumes no benefit to crop yields from increased carbon dioxide in atmosphere (carbon fertilization, CF).
[4]Assumes a positive impact in yields from carbon fertilization.
[5]Excludes Europe
Source: Cline (2008, table 1, p. 24).

Table 4 : How countries fare whether the impact of climate change is projected by economic or agronomic models, nearly all countries suffer

	Ricardian Model[a]	Crop model[a]	Weighted average without CF	with CF
Argentina	-4	-18	-11	2
Brazil	-5	-29	-17	-4
United States (Southwest plains)	5 (-11)	-16 (-15)	-6 (-35)	8 (-25)
India	-49	-27	-38	-29
China (South Central)	4 (-19)	-13 (-13)	-7 (-15)	7 (-2)
Mexico	-36	-35	-35	-26
Nigeria	-12	-25	-19	-6
South Africa	-47	-20	-33	-23
Ethiopia	-31	-31	-31	-21
Canada	0	-4	-2	12
Spain	-4	-11	-9	5
Germany	14	-11	-3	12
Russia	0	-15	-9	6

Note : Ricardian models statistically infer the contribution of temperature and precipitation to agricultural productivity by examining the relationship of land price to climate, whereas crop models relate farm output to land quality, climate, fertilizer inputs, and so on.
Sources : Cline. (op. cit., table 2, p. 25).

Table 5 : Illustrative costs of Emissions-reducing technologies relative to a marker (= the technology that would be displaced by the new technology).

Technology	Marker	Cost unit	Cost of marker	Cost of substitute Short-term[b]	Long- term
Nuclear	Natural-gas-combined-cycle power plant	US cents/KWh	3.5-4	6	5
Electricity from fossil fuels and carbon capture and storage	Natural- gas combined-cycle power plant	US cents/KWh	3.5-4	5	6
Wind	Natural- gas combined-cycle power plant	US cents/KWh	3.5-4	5	6
Photo voltaic [a]	Grid electricity	US cents/KWh	10	15	8
Biofuels	Petrol	$/gigajoule	12	15	15

(a) Solar input = 2000KWh/m^2
(b)10 years
*Source: **The Economist** 9th September 2006A (table 3) p. 14.*

Table 6 : Sources of Energy (% global energy supply)

Non- renewables (fossil- energy)	%
- Oil	34.3
- Coal	25.2
- Gas	20.9
Sub- Total	80.4

Renewables	
- hydo	2.20
- biomass	10.40
- tide	0.0004
- wind	0.064
- solar	0.039
- geothermal	0.410
	13.113

*Source : **The Economist** 2nd June, 2007, p. 20.*

Damage will be, generally, higher for countries located closer to the equator, where temperatures already tend to be close to crop tolerance level-and these countries are mostly located in Sub-Saharan Africa.

Economists have now accepted the view that geography, including temperature, has a profound development outcome (see, for instance, Gollup et al. 1969). The extremes of heat and humidity in the tropical regions contribute to deteriorating soil quality and the rapid depreciation of many natural assets. Such extreme tropical geographic conditions contribute, as well to the low productivity of certain crops, the weakened regenerative growth of forests, and poor health of both animals and human being leading to lower levels of productivity and efficiency.

Growth models now incorporated geographic factors, putting more weight on temperature, which raises estimates of the damage from climate change. Nordhaus (1994), for instance, estimates damage to the global economy of a 2.5 C temperature rise at 3% of global GDP. Table 5 displays data on estimates on the costs of climate change (loss in global GDP) and the costs of mitigating the effects of climate change. The problem here is that economists working on climate change face 'a cascade of uncertainties': how much carbon dioxide the world goes on emitting (which itself depends on whether governments pay attention to scientists' warnings); how past temperatures will increase in response to greater concentration of carbon dioxide (which depends on feedback loops'); what effect climate change will have on national economics (which depends on how people adapt to it); etc. (Bhargava 2006).

The cost of mitigating the costs of climate change depends principally on three factors. The first is how far energy demand can be reduced by relatively cheap energy-efficient technologies. Currently, global dependence on non-renewable fossil energy sources ranges up to 93% (table 6). The International Energy Agency (IEA) estimates that there are abundant cheap energy-efficient measures – e.g. new buildings, for instance, can be made 70% more efficient than average existing ones, reckoning that by the year 2050 energy-efficient technologies can reduce emissions back to 2000 levels at moderate cost.

The second factor is how fast the price of renewable energy technologies will fall. The gap between some of them and the fossil-fuel-based energy should shrink (table5), as technologies mature and manufacturing volumes rise: e.g. the cost of windpower, has come down from 8-10 cents to 3.5-4 cents per KWh since 1990 because of better-designed turbines and higher volumes.

The third factor is how fast emissions are reduced. Economists, in contrast to scientists, recommend a gradual approach; they point out that, as carbon dioxide hangs around in the air for up to 200 years, a tonne produced now is not much worse than a tonne produced in 20 years' time; that cutting emissions gradually is a great deal cheaper than doing it quickly, because machinery can be replaced with new, lower-emission varieties at the end of its life-cycle instead of being written off prematurely.

V. Environmental Policies on Climate Change

These policies can be categorized into two for purposes of the present analysis: national and global (international). The former refer to policies adopted by individual governments to attempt to address environmental problems peculiar to their countries; the latter, on the other hand, are socalled because they are targeted at environmental problems that transcend national boundaries – e.g. the threat to the ozone layer

from chlorofluorocarbons (CFCs) and global warming leading to climate change. Global environmental policies are formulated and implemented collectively by national governments who accede to the multilateral treaties which usually form the basis for implementing global policies such as, for instance, the Kyoto Protocol on climate change drawn up in 2001.

a) National Policies

For this purpose, we draw solely on the experiences of the countries of the Organization for Economic Cooperation and Development (OECD) as well as those of East and Central Europe and former Soviet Union to illustrate the nature of, and problems relating to, national policies, given that systematic data on developing countries, especially Sub-Saharan African countries, are sparse, if not totally lacking (see also Sinn 2007; Stern 2009; Stern et al. 2007; Tol 2004; Weitzman 1974; World Bank 2006; Jones et al. 2008).

i. *Pollution Taxes*

In Europe as a whole policies have been targeted on energy, transport, agriculture, and economy. As energy is a major source of both pollution and tax revenue in the OECD economies particularly, attention has been focused on restructuring of energy pricing as a starting point in integrating environment and economy. (see, for instance, Portier 1996). Air pollution is a key environmental problem in the OECD; strategies here include pollution (emission) taxes, direct control or legislation, etc.

Pollution taxes are aimed to reduce damage to the environment by cutting emissions of products such as methane gases or carbon dioxide (CO_2). The rationale for a pollution tax, therefore, is to compel polluting producers to include in their prices the full social costs of production. In the OECD, pollution taxes, also known as eco-taxes, are an a affirmation of the 'polluter-pays principle' adopted way back in 1974 and ratified by the European Community (now European Union) in 1975.

The 'polluter-pays principle; which, essentially, allows pollution to occur but taxing it, derives from Arthur Cecil Pigon's 1932 classic **The Economics of Welfare**, which focused on problems of maximization of social welfare under neoclassical perfectly competitive equilibrium conditions Pigon argued that the neoclassical social welfare proposition was hampered by two factors: monopoly and externalities, both factors discounted in neoclassical general equilibrium economics. The notion of externalities came to be introduced in neoclassical economic theory to reflect-for the first time, indeed-the inherent contradiction between the interests of the private agent (firm or individual driven purely by private gain) and those of society as a whole. Let us recall that externalities, generally, refer to the effects of the activities of private agents which fail to be captured by market prices but which could impose costs on (in the case of negative externalities or diseconomies such as pollution) or yield benefits for (in the case of positive externalities) the society as a whole[3].

Pigou first formulated the socalled tax-subsidy solution to internalizing externalities, the idea that externalities should be corrected by government policy interventions in the form of imposing taxes on negative externalities and granting subsidies on positive externalities to adjust and supplement the operation of the private market mechanism. On this basis, Pigou evolved the concept of social cost to account for not only the direct private costs, but also the externalities. As noted already, Pigou's work did serve as the starting point for 'a new economic theory of welfare' whose main idea is the maximization of social welfare.

By the 1970s on wards, Pigou's theory began to attract attention in view of the new approach to economic growth based on the 'quality of life' concept. Contemporary concern with greenhouse gases (GHGs), polluted environment, etc.-i.e., with social costs not captured in private market prices-are the modern illustrations of Pigou's separation of divergences between marginal social and private benefits (and costs).

In several European countries direct coal subsidies began to be reduced as from the 1980s to 'force change to different fuels'. By reducing domestic coal subsidies (and importing coal from South Africa, Australia or Central Europe) West European countries had sought to reduce their volumes of methane and carbon dioxide (Co_2) emissions. Methane emission would be lower because imported coal primarily comes from open-cast mines and not, as in European mining regions, from deeper mines that generate large amounts of methane gases. Eco-taxes also began to be imposed, generally, meant to raise the prices of products which create pollution as they are manufactured, or disposed of e.g. lubricants, fertilizers, pesticides, non-returnable containers, mercury and cadmium batteries, 'feedstock' chemicals and packaging materials. By imposing the tax, the demand for the product will be reduced, which will induce the producers (firms) to take account of the external costs that their production activity imposes on society (see also Solsbery and Wiederkehr 1995).

ii. *Legislation*

Also known as the 'communal and control approach', legislation attempts to introduce direct controls, which may involve specifying minimum environmental standards on air and/or water quality, for example, or imposing complete ban on use of particular inputs. For example, the effluent form a refinery or chemical plant may be permitted (by legislation) to a

'specified' level of a particular pollution. In some cases, legislations may require the installation of specific types of anti-pollution equipment. At the consumer level, for instance, new automobiles in the European Union, as from the early 1990s, have to incorporate catalytic converters.

To be effective, legislations setting minimum environmental standards, apart from setting of inspectorates to monitor compliance, must make sure that the monitoring agencies possess knowledge of what the Pareto optimal level of pollution should be in the products being regulated. For the standard setting approach to be completely effective, the inspectorates must have knowledge of the marginal net private benefit (MNPB) curve and the external marginal cost, EMC, curve in order to determine the Pareto level of output and associated level of pollution. It is quite unlikely for such a situation to obtain in reality. Bedside, when standards are set across the board to all firms the process does not take account of the marginal cost of reducing pollution associated with individual firms.

iii. *Tradeable Emission Allowances*

In this approach, also known as tradable permits, the relevant government agency sets a global target for a reduction in a particular type of pollution. In the United States, for instance, under the 1990 Clean Air Act, the United States Environmental Protection Agency (USEPA) set a target for United States power states to cut annual emissions of sulphur dioxide from an average 19 million tons in 1980-1985 down to 9 million tow by the year 2000. it is important to note that the policies differ substantially in cost of implementation and effectiveness. Broadly, these approaches can be collapsed into two: regulatory and market-based.

The Regulatory Policies (comprising the legislation and tradeable emission allowances approaches) are used extensively in both industrial and developing countries. They are best suited to situation involving a few public enterprises and uncompetitive private firms. This is particularly true when the technologies for controlling pollution or resource use are relatively uniform and can easily be specifies by regulators- as in the case of Cubatao, Brazil, where (ETESB(the Brazilian State regulatory agency), to address serious pollution from particulates and sulphur dioxide, forced the larger polluters (public sector and multinational firms) to install precipitators and switch to low sulphur oil.

Market-based Approaches, if effectively implemented, will frequently be less costly in meeting environmental goals than regulatory alternatives. With market-based approaches, all polluters or resource users are faced with the same price and must choose their degree of control. In market-based approaches, each agent decides either to use fewer resources or pay for using more. Market-based policies that price environmental damage affect all polluters, which means that such approaches provide the right long-term signals to resource users. The polluter or resource user has the incentive to use whichever technologies most cost-effectively reduce environmental damage. However, price-based approaches will be effective only to the extent that polluters and resource users are sensitive to them, which depends on three factors: ownership, competition, and differences among users.

iv. *Environmental Financing*

How are revenues generated from eco-taxes used? Who finances environmental investment? In the OECD countries eco-taxes are ear-marked for specific environmental purposes- e.g. water and waste management? For one thing, ear-marking will help to bring political acceptability and support for otherwise politically unpopular taxes.

In Eastern Europe, as in developing countries, the public sector plays the role of key provider- sometimes the sole provider of finances for environmental investments. In the OECD countries, in contrast, the private sector and households shoulder a large part of the burden for spending on pollution control and environmental infrastructures (Gillespie 1996). In the East European countries, the institutional framework for environmental financing has been strengthened in a number of countries by the establishment of environmental funds capitalized by environmental taxes and charges which are then reallocated to support important environmental investments in air and enforcement mechanisms. Several other measures to strengthen environmental financing institutions have been put in place- e.g. 'green' equity schemes, to provide equity to projects and companies investing in environmental improvements- such as, for example, the Nordic Environmental Finance Corporation (NEFCO) provides a model of such schemes in the Baltic region.

b) International Policies

As noted above, this category of policies transcend national boundaries. Here we consider policies on global warming. Several international agreements have drawn attention to the need to manage the global environment. The Montreal Protocol, reached in 1987 to reduce the production and consumption of chlorofluorocarbon (CFCs) and halon substances which deplete the ozone layer in the upper atmosphere. The Montreal Protocol was amended in 1990 to target the phasing out of CFCs and halon by 2000. The agreement also provides for trade bans on CFCs and CFC-using products; the latter are inert and non-toxic substances, CFCs being widely used in refrigeration, foams, aerosols, and dry-cleaning processes, and halon in fire extinguishers. The Montreal Protocol has been relatively successful, having made it possible to replace those CFC-using and halon elements by less ozone-destroying and halon in fire

extinguishers. The Montreal Protocol has been relatively successful, having made it possible to replace these CFC-using and halon elements by less ozone-destructive products.

As noted earlier, serious global efforts to address climate change began with the Earth Summit-formally known as the United Nations Conference on Environment and Development in Rio de Janeiro in 1992-which produced the United Nations Framework Convention on Climate Change (UNFCCC), a treaty aimed explicitly at limiting climate change by reducing emissions of GHGs. The UNFCCC, however, did not produce mandatory emission ceilings or enforcement provisions; instead, it provided for the signing of protocols under the treaty's auspices that would contain such mandates.

The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) was negotiated at Kyoto, Japan, in 1997 and amended in 2001 and it is to expire in 2012[4]. However, it did not enter into force until 2005, after it had been ratified by the requisite number of countries. By 2006, 163 countries, including the European Union, had ratified the protocol, the major outstanding countries still obtaining being Australia, and the United States. The latter complained that, in its own view, the costs of compliance were excessive, the exclusion of developing countries will render the undertaking ineffective, and the scientific uncertainties surrounding climate change remain too significant to warrant the actions taken.

Under Kyoto, most of the developed countries agree to reduce their GHG emissions by an average of about 5% from 1990 levels between 2008 and 2012 when the treaty is due to expire. However, the negotiated emissions limits are differentiated according to countries and regions, ranging from a reduction of 8% to an increase not to exceed 10%. Developing countries are exempt from such firm commitments under Kyoto. Core elements of Kyoto includes rules for compliance; land-use, land-use change, and forestry (LULUCF) provisions; and mechanism which give countries some flexibility to achieve their GHGs emissions reductions commitments. Kyoto recognizes that LULUCF (whose essential role is development and preservation of carbon sinks) can play a vital role in achieving the ultimate goal of stabilizing Co_2 concentrations.

The second mechanism is the socalled Joint Implementation (J1), which permits legal entities in one country that has an emission commitment to earn credit towards that commitment by undertaking emissions reductions project in another such country. Countries facing relatively high costs for emissions reductions can reduce their costs of compliance by earning such credits in countries where the costs are lower.

The third mechanism is the Clean Development Mechanism (CDM), whose importance lies in bringing developing countries into the Kyoto protocol. Under CDM, as in J1, developed countries may accrue emissions credits towards their reduction commitment by sponsoring carbon emissions reduction projects in developing countries. CDM not only gives the developed country an opportunity to meet its commitments at lower costs than otherwise, it also promotes sustainable development in the developing country at the same time it encourages the transfer of technology (Noble and Watson op.cit).

Among the developed world, the European Union (EU) has taken Kyoto most seriously; in 2003, it established a trading system, the European Emission Trading Scheme (EETS), in which each country receives a fixed number of Co_2 emissions allowances for its companies in energy-intensive industries such as electric power generation, refining, paper, steel, glass, and cement-these are the socalled 'dirtiest heavy industries'. The EETS works as follows: national governments decide how much carbon the 'dirtiest industries' in their countries may spew forth; they then allocate 'permits to pollute' to each company in that line of industry. If a firm wants to exceed its limits, it must buy 'pollution permits' from cleaner firms or credits from developing countries that have set up special projects to lower emissions-e.g. protection of the Amazon rainforests in Brazil. Penalties for non compliance are set at € 100 in 2008-12 period (see Noble et al. 2005).

The IPCC has produced estimates of the costs to individual countries of complying with the Kyoto Protocol: these range from 0.2 to 2% of GDP in absence of international carbon permit trading, and from 0.1 to 1.0% of GDP if such trading takes place. These costs could be reduced further by expanding the stocks of carbon sinks: a forestation, reforestation, and avoiding deforestation; and improved forest, cropland, and grassland management; implementing project-based emissions swapping between industrial and developing countries through the clean Development Mechanism, and reducing emissions of other GHGs, including methane and halocarbons.

c) The Role of the World Bank

The World Bank is involved in global efforts to mitigate and adapt to climate change mainly through two initiatives: the Global Environment Facility (GEF) and the Carbon Finance Portfolio (CFP).

The World Bank is the implementing agency for the GEF, which was established in 1991 to provide funding for projects to support biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants. Through the GEF, the World Bank disburses annually some $250 million for projects on energy efficiency, renewable energy, and sustainable transportation.

The World Bank was among pioneers facilitating carbon trading under the CDM and JI flexibility mechanisms of Kyoto. The Prototype Carbon Fund was

lunched in 1999 with a target of $180 million, and by 2006 the World Bank was managing nine funds with available funds to then value of about $2billion.

VI. Conclusion

Global warning constitutes one of the major global issues of our time. Although a long-standing phenomenon, the current concern with global warning arises from two distinct facts: it is caused by human activity; and it is occurring at an unprecedented rate. The consequences of global warning still remain a subject of debate and speculation, but climate change studies hypothesize dire consequences for agricultural productivity and disease incidence globally, but especially for countries located nearer the tropics where temperatures are bound to rise higher. Global warning has received national and international policy attention over the past thirty years, having constituted one of the key themes in the rise of 'green economics' and 'green politics' over this same period.

Note

[1]According to Yale University Professor, Robert Mendelssohn, a 2.5^0c increase in temperature would increase GDP in former Soviet Union by 11% (and 0.3% in North America). A less optimistic forecast by William Nordhaus (dubbed the father of climate change), predicts a reduction in the United States GDP of 0.5% (Nordhaus 1994).

[2]See IPCC (2001); Mayer (2000); Noble et al. (2005), and Smith et al. (2003).

[3]For Pigou the essence of externalities that create a wedge between private and social interests in production: '… is that one person A, in the course of rendering some service, for which payment is made, to a second person B, incidentally also renders services or disservices to other persons (not producers of like services), of such sort that a payment cannot be exacted from the benefited parties or compensation enforces on behalf of the injured parties' Pigou, op. cit, p. 183).

[4]This section relies on Noble and Watson 2006

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