The Winners of the Blue Planet Prize

2009

Professor Hirofumi Uzawa (Japan)

Lord (Nicholas) Stern of Brentford (UK)

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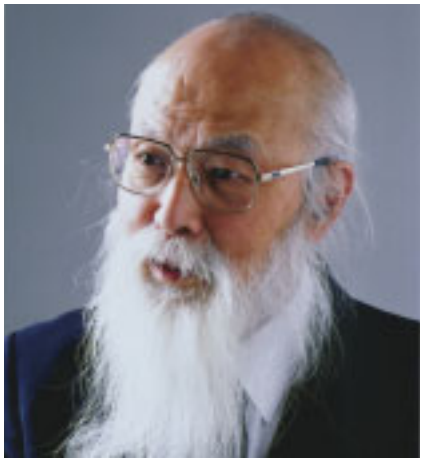
Member of The Japan Academy
Professor Emeritus, The University of Tokyo



Lord (Nicholas) Stern of Brentford (UK)

Professor, The London School of Economics

GIFT:
This Blue Planet we live on
Is blessed to hold life
In the universe full of stars brilliantly shining

We humankind
Are we spending the days by embracing from deep in our heart?
The happiness of being born on this blue planet of life

As a tiny life born on this planet
Caring other lives, cherishing each other
Are we pursuing in full, the meaning of our lives?
By truly giving our appreciation
To the blessings of the "planet of life" Earth

It is our great pleasure
If the film this time
Served you to think
About the happiness of living on this blue planet
By extending your thoughts
To the gifts from the "planet of life" Earth

Selected from the Slide Show Presented at the Opening of the Awards Ceremony

His Imperial Highness Prince Akishino congratulates the laureates

Their Imperial Highnesses Prince and Princess Akishino congratulate the laureates at the Congratulatory Party

The prizewinners receive their trophies from Chairman Seya

Professor Hirofumi Uzawa

Lord (Nicholas) Stern of Brentford

Dr. Hiroyuki Yoshikawa, Chairman of the Selection Committee explains the rationale for the determination of the year's winners

Hiromichi Seya, Chairman of the Foundation delivers the opening address

Professor Ichiro Kanazawa, President, Science Council of Japan (left) and Mr. David Warren, United Kingdom Ambassador to Japan, congratulate the laureates

Profile

Professor Hirofumi Uzawa

Member of The Japan Academy
Professor Emeritus, The University of Tokyo

Education and Academic and Professional Activities

1928	Born in Yonago, Tottori Prefecture
1951	Graduated from the Department of Mathematics, Tokyo University; Special research student from 1951 to 1953
1956	Research Assistant, Stanford University; Assistant Professor in 1959
1960	Assistant Professor, Department of Economics at the University of California, Berkeley
1961	Associate Professor, Department of Economics, Stanford University
1962	PhD in Economics (Tohoku University), Thesis: "Studies of the General Economic Equilibrium Theory of Léon Walras"
1964	Professor, Department of Economics, University of Chicago
1966	Fellow, Churchill College, Cambridge University
1968	Assistant Professor, Department of Economics, Tokyo University; Professor in 1969; Dean in 1980
1983	Person of Cultural Merit
1989	Appointed Professor at the Department of Economics, Niigata University after retiring from Tokyo University; Professor Emeritus at Tokyo University
1994	Professor, Department of Economics, Chuo University (retired in 1999)
1997	Order of Cultural Merit
1999	Full-time researcher, The Institute of Economic Research, Chuo University; Adjunct Professor, Institute of Advanced Studies, United Nations University
2000	Professor, Research and Development Initiative, Chuo University
2003	Director, Research Center of Social Common Capital, Doshisha University
2009	Senior Fellow, Keiyu International Institute of Medicine

(As of June, 2009)

In addition to the accomplishment of internationally cutting-edge research in the field of mathematical economics, Professor Uzawa has made a great impact from early on with his economics-based analyses and proposals for the issues on pollution and the environment. He has tackled the social cost of automobiles, urban problems, and global warming, and as a theoretical framework in confronting such issues he has advocated the concept of Social Common Capital, a pioneering and highly original achievement.

In addition, he has contributed to the peaceful resolution of the Minamata disease issue

and the Narita Airport construction issue, and has been consistent in his work as an economist who confronts the real world with a sincere outlook. Professor Uzawa continues to sound the alarm with respect to contemporary economics and civilization and remains a major influence on both the international stage and in Japan.

From Mathematics to Economics

Professor Uzawa graduated from the Department of Mathematics at the University of Tokyo in 1951 where he continued to work as a special research student until 1953. At that time, he discovered the true nature of economics in the words of John Ruskin, "There is no wealth, but life." which was featured in the foreword to *Tale of Poverty* by Hajime Kawakami, and set out to educate himself about economics.

In 1956, a paper on decentralized economic planning written by Professor Uzawa caught the eye of Professor Kenneth Arrow at the Department of Economics, Stanford University, who invited him to be a research assistant. After becoming Assistant Professor at Stanford in 1959 and in 1960 at the Department of Economics of University of California, Berkeley, he was appointed Associate Professor of the Department of Economics at Stanford in 1961, and in 1964 became Professor at the Department of Economics of University of Chicago. During this period, he researched the issue of optimum economic growth resulting in his remarkable paper *On a Two-Sector Model of Economic Growth*, which covered the production sectors of consumer goods and investment goods in manufacturing equipments. During his time at the University of Chicago, Joseph E. Stieglitz and George A. Akerlof, later Nobel laureates in economics, were among the students attending his seminars in mathematical economics.

Departing from Mathematical Economics to A Theory of Social Common Capital

In 1968, Professor Uzawa accepted a position as Assistant Professor of the Department of Economics at the University of Tokyo and returned to Japan as protests against the Vietnam War in the United States turned violent. Then, the words of John Ruskin came back to him and he started to think about the concept of Social Common Capital or "how to incorporate the natural environment and the social environment in economic theory," renewing his resolution to study the "economics that value the human spirit," which later became his consistent set of beliefs. Even though he realized that "it would be a full-frontal critique of the work I had done so far," he nevertheless criticized the status quo of mathematical economics (neo-classical economics) and sought to build a framework for economics with a solid foundation in the social environment, nature, education and healthcare.

In this period, he also turned his attention to the issues of pollution worldwide following in the wake of industrialization and urbanization, taking a strong interest in the Minamata disease and immersing himself deeply in pollution and environmental issues.

In 1972, he published for the first time the concept of Social Common Capital, which later became extremely important in thinking about global warming countermeasures. Social Common Capital refers to a natural environment and social infrastructure that enables the people living in a country or a specific region to enjoy a prosperous economy, develop a superb

culture, and maintain in a sustained and stable fashion a society that is attractive on a human level. It has a strong connection to human life and existence, one might even say that it is a way of thinking that attempts to socially manage common assets including resources, goods, services and systems that are important for a society to function smoothly. As a result, Professor Uzawa constructed the theoretical foundation that lies behind the concept of the commons. The following three elements constitute Social Common Capital:

1. The Natural Environment: the atmosphere, water, forests, rivers, lakes, oceans, coastal wetlands, soil etc.
2. Social Infrastructure: roads, transportation facilities, water and sewerage, electricity and gas etc.
3. Institutional Capital: education, healthcare, finance, the judiciary, public administration and other systems

Each category must be managed and operated by professionals in accordance with professional standards and based on specialist knowledge.

Building on ideas based on the concept of the Social Common Capital, Professor Uzawa became involved in the pollution problems, authoring *The Social Cost of the Automobile* in 1974, which turned the focus on the extent of pollution and damage caused to the natural environment and the social infrastructure of the Social Common Capital by the use of automobiles. Next, he attempted to calculate the social cost of automobiles. He measured the cost of creating ideal roads that do not infringe on the basic rights of the community by rebuilding roads which had numerous defects such as the lack of separation between pedestrians and cars. Setting this value as the index, he calculated the necessary cost of converting road structures and found that the social cost per automobile per year was at minimum two million yen.

The Economics of Global Warming

Professor Uzawa also put his attention to the issue of global warming from an early stage. As well as participating in the first conference of economists on the topic of global warming in Rome in 1990, he authored *The Economics of Global Warming* in 1991 where he focused on the implications of global warming on 20th century civilization and proposed preventative measures. His understanding on global warming was that it was caused by the mass consumption of fossil fuel and logging in the tropical rainforests. And the global environment came under great stress as a result of the insatiable pursuit of "affluence" and material comfort of advanced industrial nations that have turned waste habit into a virtue. In contrast, in developing countries where poverty dominates and economic development is nowhere in sight, people are forced into a predicament where they cannot but destroy nature and pollute the environment in order to survive. Consequently, Professor Uzawa pointed out that rich and poor countries equally destroyed the global environment, inflicting damage that cannot be undone by future generations. On the other hand, Professor Uzawa also turned his attention to carbon tax, in a broad sense an environmental tax, which was an initiative developed among economists as an effective policy for preserving the stability of the natural environment far into the future and for preventing global warming. Professor Uzawa stated that from the

viewpoint of fairness there were major problems with the intergovernmental terms for reducing total emissions of greenhouse gases by country, including the plan to reduce carbon dioxide emissions by 20% proposed at the international conference on atmospheric change held at the same time as the 1988 Toronto Summit in Canada. He has pointed out that, generally speaking, international agreements for stabilizing the atmosphere were extremely lucrative for developed countries and, moreover, that their character was antisocial to the extent that countries that consume fossil fuels profit from them. He is an advocate of the carbon tax system as a measure for stabilizing the atmosphere that could actually be put into practice. On the other hand, an uniform carbon tax system was not only problematic from the viewpoint of international fairness, but as there was a risk of nipping economic development in the bud in the majority of developing countries, he proposed a "proportional carbon tax" according to per capita income in each country.

In addition, there was an inherent risk that the carbon tax itself would deter economic progress in developing countries and, even if the system of a proportional carbon tax is adopted, Professor Uzawa thought that it was not an effective strategy in resolving the North-South problem. Accordingly, he devised the concept of an international fund for stabilizing the atmosphere that would eliminate the economic disparities between industrialized and developing countries and act as an effective deterrent to global warming while stabilizing the atmosphere.

The principle behind the concept is that every government donates a fixed percentage of the silviculture subsidy deducted from the proportionate carbon tax revenues to the international fund for stabilizing the atmosphere. The fund distributes the contributions from each country to developing countries where the allocation is used for measures to protect the global environment such as protecting tropical rain forests, sustaining agricultural communities or developing alternative energies.

Professor Uzawa's concept of a proportionate carbon tax and an international fund for stabilizing the atmosphere that would protect tropical rain forests and facilitate the prevention of global warming has won the backing of many economists as an international concept that considers intergenerational and regional disparities, but it has not been accepted as policy yet.

A Message to the Contemporary Society

In recent years, Professor Uzawa has turned his attention to movements that aim to "rehabilitate human beings," referring to the "urban and natural renaissance" that is taking place in Europe, and he is engaged in the research to spark this trend in Japan as well. He favors removing the concrete that covers riversides and returning to the meandering rivers of the past, planting the periphery with local trees and shrubs, and preventing floods not by building dams, but by creating rich woodlands in the upper reaches of the rivers, which social wisdom have long employed to control the waters by means of "green dams" that use the storage capacity of nature.

Professor Uzawa discloses his perception of the relationship between human beings and nature as a form of culture whereby society should communicate by going beyond the generations, saying "The culture of original human society prevented the depletion of natural

resources by means of a dialog with nature and accumulated knowledge about the natural environment within social norms designed for the survival of the society, and the culture (social system) also included transmission to the next generation."

Professor Uzawa points out that in modern times harmony between people and nature has collapsed and environmental destruction has advanced on a global scale because "modern science has played a major role in facilitating a lack of constraints on the exploitation of nature and ideas that place human beings in a position that is superior to nature." Global warming is a straightforward example. He stressed that we should recognize it is an extremely dangerous environmental change progressing on an unprecedented scale and that every effort must be made to tackle it now.

When considering institutional capital as social common capital, education and medical care assume the most important position. Education has the mission to promote both natural-born and acquired talent of each child as far as possible. On the other hand, medical care shall be performed based upon the professional medical knowledge to treat people who lose their regular functions through diseases or accidents. Those two functions are absolutely imperative to sustain the society that keeps each citizen to maintain dignity and to enjoy civil liberty. To live one's life in humane manner, I like to emphasize, those social common capitals play important part and shall never be controlled by mere market standards or bureaucrats.

A Paradigm Shift

In the latter half of the 1960s, Professor Uzawa felt "the emptiness and limitation of economics that advances enquiries based on abstract concepts such as capitalism or socialism" and stemming from this, he searched for a new framework, arriving at the idea of the Social Common Capital. The concept of the Social Common Capital offers an important foundation for institutional and political analysis in order to draft and select policies. It is viewed as an engine (mechanism) that creates measures that point to new directions for resolving a range of issues.

Social Common Capital provides a more honest answer than the economic point of view to the enquiry that is the ultimate goal of economics, "what should be done to bring about a sustainable and stable society?" When its social and institutional implications are considered, Social Common Capital furnishes a paradigm that opens the way to a new age.

Today, when it is said anew that social stability is important, the concept of Social Common Capital is an important starting point for economics even as we consider what stability is and what should be done. The concept is a form of social management based on social standards and a way of thinking that emphasizes management systems on a foundation of professional ethics. It is a great achievement on the part of Professor Uzawa to have consistently advocated this concept, and based on the unshakeable conviction that social problems including environmental issues are "the issues that economics should be tackling," to have shown such vigor in protecting the fundamental rights of the citizenry, issuing warnings on global warming and proposing measures and policies. In the future, Professor Uzawa will surely continue to have a great impact both in Japan and on the international stage.

Lecture

Social Common Capital

Professor Hirofumi Uzawa

Rerum Novarum Inverted: The Abuses of Socialism and The Illusions of Capitalism

In his historic 1891 Encyclical *Rerum Novarum*, Pope Leo XIII identified the most pressing problems of the times as "the abuses of capitalism and the illusions of socialism". He called the attention of the world on "the misery and wretchedness pressing so unjustly on the majority of the working class" and condemned the abuses of liberal capitalism, particularly the greed of the capitalist class. At the same time, he vigorously criticized the illusions of socialism, primarily on the ground that private property is a natural right indispensable for the pursuit of individual freedom. Exactly 100 years after *Rerum Novarum*, the *New Rerum Novarum* was issued by Pope John Paul II on May 1, 1991, identifying the problems that plague the world today as "the abuses of socialism and the illusions of capitalism" (John Paul II, 1991, and Uzawa, 1991a, 1992c).

Contrary to the classic Marxist scenario of the transition of capitalism to socialism, the world is now faced with an entirely different problem of how to transform a socialist economy to a capitalist economy smoothly. For such a transformation to result in a stable, well-balanced society, however, we must be explicitly aware of the shortcomings of the decentralized market system as well as the deficiencies of the centralized planned economy.

The centralized planned economy has been plagued by the enormous power that has been exclusively possessed by the state and has been arbitrarily exercised. The degree of freedom bestowed upon the average citizen has been held at the minimum, whereas human dignity and professional ethics have not been properly respected. The experiences of socialist countries during the last several decades have clearly shown that the economic plans, both centralized and decentralized, that have been conceived of by the government bureaucracy, have been inevitably found untenable either because of technological deficiencies or in terms of incentive incompatibility. The living standard of the average person has fallen far short of the expectations, and the dreams and aspirations of the majority of the people have been left unfulfilled.

On the other hand, the decentralized market economy has suffered from the perpetual tendency toward an unequal income distribution, unless significant remedial measures are taken, and from the volatile fluctuations in price and demand conditions, under which productive ethics has been found extremely difficult to sustain. Profit motives often outrun moral, social, and natural constraints, whereas speculative motives tend to dominate productive ethics, even when proper regulatory measures are administered.

We must now search for an economic system in which stable, harmonious processes of economic development may be realized with the maximum degree of individual freedom and with due respect to human dignity and professional ethics, as eloquently prophesied by John

Stuart Mill in his classic *Principles of Political Economy* in a chapter entitled "Of the Stationary State" (Mill, 1848). The stationary state, as envisioned by Mill, is interpreted as the state of the economy in which all macroeconomic variables, such as gross domestic product, national income, consumption, investments, prices of all goods and services, wages, and real rates of interest, all remain stationary, whereas, within the society, individuals are actively engaged in economic, social, and cultural activities, new scientific discoveries are incessantly made, and new products are continuously introduced still with the natural environment being preserved at the sustainable state. [Regarding Mill's stationarity state, one may be referred to an excellent discussion by Daly (1977, 1999).]

We may term such an economic system as institutionalism, if we adopt the concept originally introduced by Thorstein Veblen in his classic *The Theory of Leisure Class*, (Veblen, 1899) or *The Theory of Business Enterprise* (Veblen 1904). It has been recently reactivated as a theory of institutions by Williamson (1985) and others, where institutions are defined by the rules of games that specify the incentives and mechanisms faced by the members of the society engaged in social activities. We would like to emphasize that it is not defined in terms of a certain unified principle, but rather the structural characteristics of an institutionalist economy, as symbolized by the network of various components of social common capital, are determined by the interplay of moral, social, cultural, and natural conditions inherent in the society, and they change as the processes of economic development evolve and social consciousness transforms itself correspondingly. Institutionalism explicitly denies the Marxist doctrine that the social relations of production and labor determine the basic tenure of moral, social, and cultural conditions of the society in concern. Adam Smith emphasized several times in his *Wealth of Nations* (Smith, 1776) that the design of an economic system conceived of purely in terms of logical consistency inevitably contradicts the diverse, basic nature of human being, and instead he chose to advocate the merits of a liberal economic system evolved through the democratic processes of social and political development. It is in this Smithian sense that we would like to address the problems of the economic, social implications of social common capital and the analysis of institutional arrangements and policy measures that ensue the processes of consumption and accumulation of both social common capital and private capital that are optimum in terms of a certain well-defined, socially acceptable sense.

Social Common Capital

Social common capital provides members of a society with those services and institutional arrangements that are crucial in maintaining human and cultural life. It is generally classified into three categories: natural capital, social infrastructure, and institutional capital. These categories are neither exhaustive nor exclusive, but they merely illustrate the nature of functions performed by social common capital and the social perspectives associated with them.

Natural capital consists of the natural environment and natural resources such as forests, rivers, lakes, wetlands, coastal seas, oceans, water, soil, and above all the earth's atmosphere. Social infrastructure is another important component of social common capital. It consists of roads, bridges, public transportation systems, water, electricity, and other public utilities, communication and postal services, among others. Social common capital may also include

institutional capital such as hospitals and medical institutions, educational institutions, financial and monetary institutions, cultural capital, judicial and police systems, public administrative services, and others. They all provide members of a society with those services that are crucial in maintaining human and cultural life, without being unduly influenced by the vicissitudes of life.

Social common capital in principle is not appropriated to individual members of the society, but rather is held as common property resources to be managed by the commons in question, without, however, precluding the private ownership arrangements. Nor is it to be controlled bureaucratically by the state. Thus, a problem of crucial importance in the theory of social common capital is to devise the institutional arrangements that result in the management of social common capital that is optimum from the social point of view. The theory of social common capital provides us an analytical framework in which economic implications of social common capital are fully examined and explored the conditions under which the intertemporal allocation of scarce resources, including both social common capital and private capital, is optimum from the social point of view.

Natural Capital

Natural capital consists of the natural environment and natural resources such as forests, rivers, lakes, wetlands, coastal seas, oceans, water, soil, and the earth's atmosphere. They all share the common feature of being regenerative, subject to intricate and subtle forces of the ecological and biological mechanisms. They provide all living organisms, particularly human beings, with the environment to sustain their lives and to regenerate themselves. However, the rapid processes of economic development and population growth in the last several decades, with the accompanying vast changes in social and natural conditions, have altered the delicate ecological balance of natural capital to such a significant extent that their effectiveness has been lost in many parts of the world.

The sustainable management of natural capital may be made possible when the institutional arrangements of the commons are introduced, as indicated by the historical and traditional experiences of the commons, with a particular reference to the fisheries and forestry commons, as in detail discussed by McCay and Acheson (1987) and Berkes (1989).

However, processes of industrialization themselves, together with the ensuing changes in cultural, social, and political conditions, have made the survival of the commons extremely difficult. Only a handful of the commons now remain as viable social institutions in which economic activities are effectively conducted with natural capital prudently sustained.

Social Infrastructure, Institutional Capital, and Cultural Capital

Social infrastructure is another important component of social common capital. It consists of roads, bridges, public mass transportation systems, water, electricity, and other public utilities, communication and postal services, and sewage, among others. Social common capital may also include institutional capital such as hospitals and medical institutions, educational institutions, judicial and police systems, public administrative services, financial and monetary institutions, and so on.

Cultural capital may also be regarded as an important component of social common capital, as extensively examined in particular by Throsby (2001). Cultural capital comprises those capital assets in society that yield goods and services of cultural value, including artworks, historic buildings, and so on, together with intangible assets such as language, traditions, and others.

Social Capital

A word of caution may be necessary regarding the concept of social capital, originally introduced by James Coleman, Robert Putnam, and others. The standard reference is Putnam (2000) and an extensive discussion is reported in Dasgupta and Serageldin (2000). Social capital refers to intangible social networks and relationships of trust that exists in communities. It means the connectivity of the social network each individual is embedded in, and facilitates the exchange of information and encourages reciprocal altruism. It is an interesting and fascinating concept, molded in the traditional framework of sociology and political science, though in good contrast with that of social common capital as envisioned in this book. [See also Arrow (2000) and Solow (2000).]

Sustainability

Social common capital is held by the society as common property resources to be managed by social institutions of various kinds that are entrusted on a fiduciary basis to maintain social common capital in good order and to distribute the services derived from it equitably. Social common capital is in principle not appropriated to individual members of the society, without, however, precluding the private ownership arrangements. Nor is it to be controlled bureaucratically by the state. Thus, a problem of crucial importance in the theory of social common capital is how to devise the institutional arrangements that result in the management of social common capital that is optimum from the social point of view.

The concept of sustainability is formally defined as the efficient pattern of intertemporal allocation of private capital and social common capital for which the imputed price of social common capital is assumed to remain at the stationary level at each time. As the imputed price of social common capital expresses the subjective value of social common capital each generation inherits from the past, the concept of sustainabililty thus defined may be regarded as expressing in formal terms the concept of the stationary state as envisioned by John Stuart Mill. It is closely linked to that introduced by Pezzey (1992), in which the utility remains constant over time. On the other hand, it is not apparent to see the link with Page's concept of sustainability which emphasizes maintaining life opportunity from generation to generation (Page, 1997).

Externalities

One of the intricate problems inherent in social common capital concerns the phenomenon of externalities. Since the classic treatment of Pigou (1925) and Samuelson (1954), the economists were always puzzled by the phenomenon of externalities, but it was put aside as peripheral and not worthy of serious consideration. Concern with environmental issues, however, has changed

this habit of economic thinking, and a large number of contributions have appeared where the issue of externalities occupies a central place, both from theoretical and empirical points of view. The analytical treatment of externalities in the theory of social common capital is adopted from that introduced in Uzawa (1974a, 1974b, 1974c, 1975, 1982, 1992a), in which two kinds of externalities, static on the one hand, and dynamic on the other, are recognized with respect to the services derived from social common capital. Static externalities occur when the levels of marginal products or utilities of individual economic units are affected by the aggregate amount of services of social common capital used by all members of the society, assuming that the stock of social common capital is kept at a constant level. Dynamic externalities, on the other hand, are observed when the conditions of production and consumption for each individual economic unit change over time due to changes in the stock of social common capital, either accumulation or depreciation, that occurs today.

The Commons

The natural environment, or rather natural capital, has been subject to an extensive examination in the literature, particularly with respect to the fisheries and forestry commons. The analysis of the fisheries commons was initiated by Gordon (1954) and Scott (1955), and was later extended to the general treatment within the framework of modern capital theory by Schaefer (1957), Crutchfield and Zellner (1962), Clark and Munro (1975), and Tahvonen (1991), among others. The simple dynamic model of the natural environment introduced in Uzawa (2003) that has the case of the fisheries commons primarily in mind belongs to the lineage of their approach. It is an extension of the analysis developed by Uzawa (1992b), where it is used to examine critically the theory of the tragedy of the commons, as advanced by Hardin (1968).

The model of the natural environment developed in Uzawa (1992b) may be applicable to the dynamics of the forestry commons as well. As with the fisheries commons, the dynamics of the forestry commons has been extensively analyzed in the literature. Indeed, it was made a central issue in economic theory by Wicksell (1901), who developed the core of modern capital theory with the analysis of forests as the prototype. The most recent contribution to forestry economics was made by Johansson and Lögren (1985).

The theory of social common capital provides us with the theoretical framework within which the role of institutional arrangements concerning social, cultural, and natural environments in the processes of resource allocation and income distribution may be effectively analyzed. Social common capital is generally composed of those scarce resources that are in principle neither privately appropriated nor subject to market transactions. Social common capital or the services derived from it play a crucial and indispensable role for each member of the society in concern to conduct at least the minimum level of human and dignified life. The management of social common capital thus is entrusted on a fiduciary basis to autonomous social institutions, to provide the environmental framework within which all human activities are conducted and allocative mechanism through market institutions work. The analysis of social common capital, as introduced by Uzawa (1974a, 1989, 1991a, 1991b) and recently developed in Uzawa (1998, 2003, 2005), may be applied to discuss some of the difficulties arising out of the tragedy of the commons phenomenon. Particularly, the institutional

arrangements whereby the sustainable use of resources in the commons may ensue are examined in terms of the concept of imputed price of social common capital.

The society generally allocates a significant portion of scarce resources for the construction and maintenance of social common capital, particularly social infrastructure, and one of the central issues in the dynamic theory of social common capital is to find the criteria by which scarce resources are allocated between investment in social common capital on the one hand and production of goods and services which are transacted on the market on the other.

In the theory of social common capital, we formulate an analytical framework in which economic implications of social common capital of various kinds are examined and explore the conditions under which the intertemporal allocation of social common capital and privately owned scarce resources is optimum from the social point of view. It may be regarded as the general equilibrium versions of those formulated in Uzawa (1992b), where, however, the phenomenon of externalities is not explicitly discussed. In the dynamic models of social common capital introduced in Uzawa (2005), the phenomenon of externalities, both static and dynamic, is incorporated in the construct of the model and their implications for the processes of resource allocation, including both social common capital and privately managed scarce resources, are fully explored. The sustainable allocation of scarce resources occurs when the imputed prices associated with the accumulation and use of social common capital are used as signals in the allocative processes. Privately owned scarce resources and goods and services produced by private economic units are allocated through the mechanism of market institutions.

In the dynamic models concerning the accumulation of social common capital referred to above, the technological conditions are assumed to remain largely constant, independent of the accumulation of the stock of social infrastructure. Technological progress induced by the availability of social infrastructure and the accompanying increase in investment activities in the stock of privately owned scarce resources may be regarded as the central issue in the theory of social infrastructure, particularly within the context of developing nations, also examined in detail by Hirschman (1958) in terms of the concept of social overhead capital. Social overhead capital as defined by Hirschman comprises those basic services without which primary, secondary, and tertiary productive activities cannot function. In its wider sense, social overhead capital includes all public services from law and order through education, public health to transportation, communications, power and water supply, as well as agricultural overhead capital such as irrigation and drainage systems. Thus the theory of social common capital introduced in Uzawa (2005) may be regarded as an extension of Hirschman's concept of social overhead capital, in which natural resources are included in addition to social infrastructure and institutional and cultural capital.

The theory of social common capital may also be regarded as an extension of the two-sector models of capital accumulation originally introduced by Uzawa (1962, 1963, 1964). Similarly, the problems of designing institutional framework in which the optimum allocation of both social common capital and privately owned scarce resources may be realized are crucial in any attempt toward practical implementations of the theory of social common capital.

When we include all components of social common capital in a particular nation, the social institutions entrusted on a fiduciary basis with their management constitute the public sector in the broadest sense of the word. The aggregate expenditures incurred by all these social institutions are nothing but the governmental expenditures, either on the current account or on the capital account. Thus, the problem we address may be interpreted as that of devising an institutional framework in which the ensuring governmental activities are optimum from the social point of view.

Environmental Problems

In the last several decades, we have observed a significant change in the nature of environmental problems and the economic, social, and cultural implications that the degradation of the natural environment has brought about. During the 1960s and in the early 1970s, our primary environmental concern was with the disruption of the environment and the ensuing hazard to human health that were caused by the rapid processes of industrialization and urbanization, both of which were taking place at an unprecedented high pace in many parts of the world. The environmental damages were mainly caused by the emission of chemical substances such as sulfur and nitrogen oxides that themselves are toxic and hazardous to human health. In recent years, however, we have become increasingly aware of the extensive degradation of the global environment, as exemplified by such phenomena as global warming, the extensive depletion of tropical rain forests, with the accompanying loss of biodiversity, and pollution of the oceans. The global environmental problems are primarily caused either by the imprudent use and excess depletion of the natural resources or by the emission of those chemical agents such as carbon dioxide in the case of global warming which by themselves are neither harmful to human health nor hazardous to the natural environment, but, on the global scale, they contribute to the atmospheric instability and global disturbances.

As for the industrial pollution and similar environmental problems that were rampant and wide spread in the 1960s, the causal relationships were fairly easy to recognize, both from the social and scientific points of view, and the remedial measures were not too difficult to take, both from economic and political points of view, although one has to be aware of a significant number of major environmental problems in the 1960s such as the case of the Minamata disease that left a state of extreme social injustice for the victims.

On the other hand, the global environmental problems concern the degradation and destabilization of the natural environment covering an extensive area, with a large number of people involved. They not only affect the current generation, living in developing as well as in developed countries, but also all future generations are irreversibly involved as exemplified by the phenomena of global warming, the loss of biodiversity, and pollution of the oceans.

The global environmental problems are also noted for the intricate and subtle interrelationships that exist between human activities, both economic and cultural, and the ecological and biological processes in the natural environment. Traditional economic theory has not paid sufficient attention to the damages and threats to the natural environment, particularly with respect the stability and resilience of regenerative processes, that are exerted by industrial, urban, and other human activities. Instead, it has treated the natural environment

simply as the stock of natural capital, from which various natural resources are extracted to be used as factors of production for the productive processes in the economy.

However, in the economic analysis of fisheries, forestry, and other agricultural activities, a large number of studies have been made, where the implications of economic activities for the stability and resilience of the natural environment, either in the fisheries ground or in forestry commons, are explicitly recognized, and the patterns of resource allocation that are dynamically optimum in terms of the intertemporal preference ordering prevailing within the society are analytically examined, as in detail described, for example, by Johansson and Lögren (1985), and Clark (1990).

When we examine the interaction of economic activities with the natural environment, one of the more crucial issues concerns the organizational characteristics of the social institutions that manage the natural environment, in conjunction with their behavioral and financial criteria, which realize those patterns of the repletion and depletion of the natural environment and the levels of economic activities that are dynamically optimum from the social point of view. The dynamically optimum time-paths generally converge to the long-run stationary state at which the processes of economic activities are sustained at those levels that are at the optimum balance vis- vis the natural environment, and the problem we face now concerns the organizational and institutional arrangements for sustainable economic development.

Such an organizational framework may be provided by the institutional arrangements of the commons, as have been shown in terms of a large number of historical, traditional, and contemporary commons documented, for example, in McCay and Acheson (1987) and Berkes (1989). The commons discussed by McCay and Acheson (1987) and Berkes (1989) refer to a variety of natural resources extending from fisheries, forestry, grazing grounds, to irrigation and subterranean water systems. The processes of industrialization, however, together with the accompanying changes in economic, social, and cultural conditions prevailing in modern society, have made these commons untenable both from economic and social points of view, and the survival of the majority of the traditional commons have become extremely difficult.

Agriculture and Social Common Capital

Agriculture concerns not only economic, industrial aspects, but also virtually every aspect of human life: cultural, social, and natural. It provides us with food and the raw materials such as wood, cotton, silk, and others that are indispensable to sustain our existence. It also has sustained, with few exceptions, the natural environment such as forests, lakes, wetlands, soil, subterranean water, and the atmosphere.

Agriculture made possible a harmonious and sustainable interaction between nature and mankind through the social institution of the rural community in many East Asian countries, particularly in Japan. This does not, however, necessarily imply that the traditional, conventional social institutions prevailing in most of the agricultural communities are justifiable or desirable.

The land ownership probably is the single most serious and complex problem in Japan. Japan is noted for a high population density and for a long history of agricultural development.

Land had been cultivated literally to the top of the mountains and forestry had been subject to myriads of property right arrangements. The modern Civil Law, enacted in 1898, adopted an extremely narrow definition of land ownership, voiding traditional forms of property ownership for villages as the commons to manage and control the natural resources to be directly or indirectly obtained from land, forests, and other natural environments. The conflict between the modern Civil Law and traditional institutions of the commons had occupied the majority of the legal suits brought before the Grand Court before the Second World War. The land reform measures implemented during the period occupied by the Allied Powers did not help resolve the dilemma either. The postwar Japan has seen a large number of conflicts, occasionally serious, between the State and citizens, mostly farmers, in the processes of land expropriation for the construction of infrastructure facilities.

The Narita Airport Problem is probably one of the thorniest problems Japan has faced since the end of the Second World War involving infrastructure construction, and brought with it a far more extensive damage to the society than the scope and magnitude of the infrastructure facilities originally planned would deserve. It began on July 4, 1966, when the Cabinet meeting decided to construct the New Tokyo International Airport at Sanrizuka in Narita, without prior consultation with the inhabitants in the community or the local authorities, and the thirty years of the conflict claimed close to ten thousand casualties on both sides, leading to a large number of human tragedies, unprecedented in peacetime Japan. The conflict was peacefully brought to an end on May 24, 1993, when the Minister of Transportation and the representatives of the Airport Opposition Alliance jointly declared that neither side would resort to any forceful measures and instead would cooperate in devising a comprehensive regional development plan, including the completion of the Airport, that would be acceptable to all those involved. As part of the peaceful resolution of the Narita Conflict, a commission was appointed to draw a blueprint for the Sanrizuka Agricultural Commons that would serve not only as the core organization for the comprehensive regional development plan, but also as the prototype of the organizational renovation to vitalize the Japanese agriculture.

Medical Care as Social Common Capital

When medical care is regarded as social common capital, every member of the society is entitled, as basic human rights, to receive the best available medical care that the society can provide, regardless of the economic, social, and regional circumstances, even though this does not necessarily imply that medical care is provided free of charge. The government then is required to compose the overall plan for the regional distribution of various types of medical institutions and the schooling system to train physicians, nurses, technical experts, and other co-medical staff to meet the demand for medical care that would result in the management of the medical care component of social common capital that is socially optimum. It is then required to devise institutional and financial arrangements under which the construction and maintenance of the necessary medical institutions are realized and the required number of medical professionals are trained without social or bureaucratic coercion. It should be emphasized that all medical institutions and schools basically are private and the management is supervised by qualified medical professionals.

The fees for medical care then are determined based on the principle of marginal social costs pricing, not through merely market mechanism. It may be noted that, the smaller the capacity of the medical component of social common capital, the higher are the fees charged to various types of medical care services. Hence, in composing the overall plan for the medical care component of social common capital, we must explicitly take into account the relationships between the capacity of the medical care component of social common capital and the imputed prices of medical care services. The socially optimum plan for the medical care component of social common capital then is one where the resulting system of imputed prices of various types of medical care services leads to the allocation of scarce resources, privately appropriated or otherwise, and the accompanying distribution of real income that are socially optimum, in the sense as will be in detail discussed in this chapter.

When, however, physicians provide medical care services to those whose health is impaired due to diseases or injuries, the very nature of medical care necessarily implies that the processes of diagnosis and curative treatment may occasionally involve the impairment, physical or mental, of patients, whereas the curative effects are not necessarily absolutely guaranteed. If an ordinary person were to perform such conduct, he or she would certainly be criminally prosecuted. Only qualified physicians and co-medical staff are immune from such prosecution, because not only are they licensed to practice medical care, but also they are supposed, as being trusted on a fiduciary basis the management of the medical care component of social common capital, to obey professional codes of conduct truthfully and to take care of patients with the best scientific knowledge and the highest available technical proficiency of the medical sciences today. For such presuppositions to be fulfilled, it is not only necessary that arrangements are institutionalized whereby the provision of medical care and the conduct of each physician are properly monitored, in terms of peers' review or some other means, but also it is required that an overall system of incentive mechanisms, in terms of social esteem and compensatory scheme, must be established whereby it becomes physicians' own self-interest to obey professional codes of conduct truthfully and to seek for the best scientific knowledge and the highest available technical proficiency of the medical profession.

Under such utopian presuppositions, total expenditures for the construction and maintenance of the socially optimum medical care component of social common capital then exceed, generally by a large amount, the total fees paid by the patients under the principle of marginal social cost pricing. The resulting pattern of resource allocation and real income distribution, however, is optimum from the social point of view. The magnitude of the deficits with respect to the management of the socially optimum medical care component of social common capital then may appropriately be regarded as an index to measure the relative importance of medical care from the social point of view.

Education as Social Common Capital

Education, together with medical care, constitutes the most important components of social common capital and, as such, may require the institutional arrangements substantially different from those for the standard economic activities that are generally pursued from the view point of profit maximization and subject to transactions on the market. Whereas medical care is

provided for those who are not able to perform ordinary human functions due to impaired health or injuries, education is provided to help young people develop their human abilities, both innate and acquired, as fully as possible. Both activities play a crucial role in enabling every member of the society in concern to maintain his or her human dignity and to enjoy basic human rights as fully as possible. If either medical care or education is subject to market transactions based merely on profit motives or under the bureaucratic control by state authorities, their effectiveness may be seriously impaired and the resulting distribution of real income may tend to become extremely unfair and unequal. Thus the economics of education and medical care may better be carefully analyzed within the theoretical framework of social common capital. The role of education as social common capital within the analytical framework of the theory of social common capital may be effectively analyzed.

In describing the behavior of educational institutions, we occasionally talk about the maximization of net value, it is used in the sense that the optimum level of education and the most efficient pattern of resource allocation in the provision of education are sought, strictly in accordance with professional disciplines and ethics.

We consider a society which consists of a finite number of individuals and two types of the institutions; private firms that are specialized in producing goods that are transacted on the market, on the one hand, and social institutions that are concerned with the provision of education as services of social common capital, on the other.

All social institutions are characterized by the properties that all factors of production that are needed for the professional provision of education are either privately owned, or if not, they are managed as if privately owned. However, the social institutions in charge of education are managed strictly in accordance with professional discipline and expertise knowledge.

Subsidy payments are made for the provision of education, with the rate to be administratively determined by the government and announced prior to the opening of the market. The fees paid to social institutions for the provision of education exceed, by the subsidy rate, those charged for the attainment of education. Given the subsidy rate for the provision of education, the two levels of fees are so determined that the general level of education provided by all educational institutions in the society is precisely equal to the total level of education attained by all individuals of the society. One of the crucial roles of the government is to determine the subsidy rate for education in such a manner that the ensuing pattern of resource allocation and income distribution is optimum in a certain well-defined, socially acceptable sense.

Global Warming and Sustainable Development

The atmospheric concentration of greenhouse gases, particularly of carbon dioxide, has been increasing since the times of the Industrial Revolution, with an accelerated rate in the last three decades. According to the IPCC reports, it is estimated that, if the emission of carbon dioxide and other greenhouse gases and the disruption of tropical rain forests were to continue at the present pace, global average air surface temperature toward the end of the twenty-first century would be 3 - 6 C higher than the level prevailing before the Industrial Revolution, resulting in drastic changes in climatic conditions and accompanying disruption of the biological and

ecological environments.

The problems of global warming are genuinely dynamic. From past human activities we inherit an excess concentration of atmospheric carbon dioxide, and the choices we make today concerning the use of fossil fuels and related activities significantly affect all future generations through the phenomenon of global warming that is brought about by the atmospheric concentrations of carbon dioxide due to the combustion of fossil fuels today. Thus, we have to take into account explicitly the changes in the welfare levels of all future generations caused by the increases in the atmospheric accumulations of carbon dioxide.

In Uzawa (2005), we are primarily concerned with the economic analysis of global warming within the theoretical framework of dynamic analysis of global warming, as introduced in Uzawa (1991b, 2003). We are particularly concerned with the policy arrangements of the proportional carbon tax scheme under which the tax rate is made proportional either to the level of the per capita national income of the countries where greenhouse gases are emitted or to the sum of the national incomes of all countries in the world. We first consider the case where the oceans are the only reservoir of CO_2 on the earth, and then we explicitly take into consideration the role of the terrestrial forests in moderating processes of global warming by absorbing the atmospheric accumulation of CO_2, on the one hand, and in affecting the level of the welfare of people in the society by providing a decent and cultural environment, on the other.

The rate of anthropogenic change in the atmospheric level of CO_2 is determined by the combustion of fossil fuels and is closely related to the levels of production and consumption activities conducted during the year observed.

The impact index function $\phi(V)$ of the following form is postulated:

$$\phi(V) = (\hat{V} - V)^{\beta}, \quad 0 < V < \hat{V},$$

Where $\hat{V}$ is the critical level of the atmospheric accumulation of CO_2 and β is the sensitivity parameter ($0 < \beta < 1$). The critical level $\hat{V}$ of the atmospheric accumulation of CO_2 is usually assumed to be twice the level prevailing before the Industrial Revolution; that is, $\hat{V} = 600$ GtC. The impact coefficient $\tau(V)$ is given by

$$\tau(V) = \frac{\beta}{\hat{V} - V}.$$

Proposition. Sustainable time-paths (V_t) of the atmospheric accumulations of CO_2 are obtained as the competitive market equilibrium under the following system of proportional carbon taxes for the emission of CO_2 and tax-subsidy measures for the reforestation and depletion of resources of forests:

(i) In each country v, the carbon taxes are levied with the rate θ^v that is proportional to the per capita national income y^v:

$$\theta^v = \frac{\tau(V)}{\delta + \mu} y^v,$$

where $\tau(V)$ is the impact coefficient of global warming, δ is the social rate of discount, and μ

is the rate at which atmospheric CO_2 is annually absorbed by the oceans.

(ii) In each country v, tax-subsidy arrangements are made for the depletion of resources and reforestation of forests with the rate π^v that is proportional to the national income y^v, to be given by

$$\pi^v = \frac{1}{\delta}\left[\tau^v(R^v) + \gamma^v \frac{\tau(V)}{\delta+\mu}\right] y^v,$$

where $\tau^v(R^v)$, γ^v are, respectively, the impact coefficient and carbon sequester rate for forests in country v.

International Fund for Atmospheric Stabilization

The divergence in economic performance between developed countries and developing countries has steadily widened in the last several decades, and various institutional and policy measures that have been devised internationally or bilaterally have not had much impact in narrowing the gap between these two groups of countries. The introduction of the proportional carbon tax system as envisioned here, in spite of the implicit recognition of the equity aspect in its design, may tend to worsen the relative position of developing countries, at least in the short-run. It would be desirable, therefore, to supplement the carbon tax system with the international redistributive scheme that would have significant impact in narrowing the gap between the stages of economic development of various countries involved.

The International Fund for Atmospheric Stabilization is an institutional framework in which it is possible to combine an international arrangement to stabilize atmospheric equilibrium with a redistributive scheme to help developing countries to accelerate processes of economic development.

The International Fund for Atmospheric Stabilization presupposes that each country adopts the proportional carbon tax system under which emissions of carbon dioxide and other greenhouse gases are charged a levy evaluated at the imputed prices proportional to the per capita level of national income and a charge (or a subsidiary payment) is made for the depletion (or the afforestation) of terrestrial forests, again based upon the evaluation at the imputed prices of terrestrial forests that are proportional to the per capita level of national income, as in detail discussed in Uzawa (2003, 2005).

The tax revenues from the proportional carbon tax system are principally put into the general revenue account of each government, preferably to be partly earmarked for the purposes of restoring the natural and ecological environments, and for encouraging private economic agents to develop those technological and institutional knowledge that are crucial in restoring equilibrium conditions in the global environment.

Each country then transfers a fixed portion, say 5%, of the net revenue from the carbon tax system to the International Fund for Atmospheric Stabilization. The total amount transferred to the International Fund for Atmospheric Stabilization from individual countries then would be allocated to developing countries according to a certain predetermined schedule, properly taking into account the per capita levels of national income and the size of population.

Developing countries may use the amounts transferred from the International Fund for Atmospheric Stabilization for the purposes which they think appropriate, preferably for compensating those who would suffer from the phenomena of global environmental disequilibrium and incur the hardships by the implementation of the carbon tax system, for restructuring industrial organizations and social infrastructure, and for introducing substitutional energy sources and energy-saving technologies.

It is difficult to imagine that the International Fund for Atmospheric Stabilization or similar international arrangements on the global scale may be instituted in any immediate future. Whether such international arrangements may be effectively implemented or not depends to a significant extent upon the degree of awareness on the part of the general public concerning the enormous burden and costs future generations will have to suffer from the phenomena of global warming and other global environmental disequilibrium.

The strenuous effort by a large number of geo-scientists, ecologists, and other scientists to clarify the mechanism of global warming and to identify the specific implications of global warming and other environmental issues for ecological, biological, social, and cultural life on Earth has had a significant impact to the awareness and consciousness of the general public and the national governments. The numerous conferences and symposia organized by various international organizations, such as the 1991 Rio Conference and the Intergovernmental Panel on Climate Change, particularly the Kyoto Protocol of 1997, have substantially altered the perception of the international community as regards the plausibility and danger of global warming and other atmospheric disequilibria.

All these help the national governments involved to search for those policy and institutional arrangements that will make the practical implementation of the International Fund for Atmospheric Stabilization or similar international agreements feasible from economic, social, and political points of view. It would not be too optimistic to expect to have the International Fund for Atmospheric Stabilization or a similar framework to be instituted within a foreseeable period, though not in the immediate future.

A Hypothetical Case

A hypothetical case of the incidences of the proportional carbon taxes under the system of proportional carbon taxes for the emission of CO_2 and tax-subsidy measures for the reforestation and depletion of resources of forests are presented, all in terms of the statistical data of 2005 (in US$).

Table 1
Incidences of Proportional Carbon Taxes (2005) with the Coefficient of Proportion 0.01 Including All Radiative Forcing Agents (RFA)

Countries	National Income per capita [Dollars]	RFA Increase per capita (Ct)	Imputed Price Carbon Taxes [Dollars / ct] per capita [Dollars]	
USA	42,000	5.90	420	2,500
Canada	34,000	6.20	340	2,100
UK	32,000	3.00	320	950
France	31,000	2.20	310	680
Germany	31,000	3.20	310	980
Italy	28,000	2.20	280	600
The Netherland	35,000	3.60	350	1,200
Sweden	32,000	1.90	320	610
Norwey	48,000	1.60	480	760
Finland	31,000	2.00	310	610
Denmark	34,000	3.20	340	1,100
Indonesia	3,100	1.70	30	50
Japan	31,000	2.70	310	840
Korea	21,000	2.60	210	560
Malaysia	11,000	1.90	110	210
Philippine	3,200	0.30	30	8
Singapore	40,000	3.20	400	1,300
Thailand	6,900	1.20	70	80
India	2,200	0.30	20	7
China	4,100	1.10	40	40
Australia	33,000	7.10	330	2,300
New Zealand	23,000	3.50	230	790

Sources: UNFCCC, World Development Indicators, etc.

Table 2
Incidences of Tax-Subsidy Measures for the Reforestation and Depletion of Resources of Forests (2005)

Country	Forest and Woodlands [Million ha]	Net Annual Reforestation [1000 ha]	Imputed Price [Per ha]	Assessment	
				Total [Million Dollars]	Per Capita [Dollars]
USA	303	159	42,000	6,627	22
Canada	310	0	34,000	0	0
UK	3	10	32,000	321	5
France	16	41	31,000	1,264	21
Germany	11	0	31,000	0	0
Italy	10	106	28,000	2,929	50
The Netherland	0	1	35,000	35	2
Sweden	28	11	32,000	351	39
Norway	9	17	48,000	808	175
Finland	23	5	31,000	153	29
Denmark	1	3	34,000	102	19
Indonesia	88	−1,871	9,300	−17,120	−77
Japan	25	−2	31,000	−62	0
Korea	6	−7	21,000	−149	−3
Malaysia	21	−140	33,000	−4,679	−179
Philippine	7	−157	9,600	−1,507	−18
Singapore	0	0	40,000	0	0
Thailand	15	−59	20,700	−1,220	−19
India	68	29	2,200	64	0
China	197	4,058	4,100	16,678	13
Australia	164	−193	33,000	−6,319	−310
New Zealand	8	17	23,000	388	94

Tropical rain forest states: Indonesia, Malaysia, Philippine, and Thai
Source: World Resources Institute, etc.

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Profile

Lord (Nicholas) Stern of Brentford

Professor, The London School of Economics

Education and Academic and Professional Activities

1946	Born in U.K.
	Bachelor of Arts degree in mathematics at Cambridge (1967) , and Doctor of Philosophy in economics at Oxford (1971)
1970-1978	Lecturer in Economics, Oxford University
1978-1986	Professor of Economics at University of Warwick
1986-1993	Professor of Economics at London School of Economics
1994-1999	Chief Economist and Special Counsellor to the President of the European Bank for Reconstruction and Development
2000-2003	Chief Economist and Senior Vice-President of the World Bank
2003-2007	Second Permanent Secretary at H. M. Treasury, Head of the Government Economic Service, appointed to lead the writing of the Report of the commission for Africa 2004-5, conduct a review of the economics of climate change, which led to the Stern Review 2006: The Stern Review was released on 30 October 2006
2007-	I.G. Patel Professor of Economics and Government at London School of Economics, Director of the newly created India Observatory within the Asia Research Centre at LSE, and Chair of the Grantham Research Institute on Climate Change and the Environment
	Lord Stern of Brentford, cross-bencher in the House of Lords

(As of June, 2009)

Lord Stern released the Stern Review on the Economics of Climate Change on October 30, 2006, which discusses the effect of climate change and global warming on the world economy with the aid of recent scientific data and economic models, and has since published extensivery on the subject, including the Richard Ely Lecture at the American Economic Association (American Economic Review May 2008) and his recent book (entitled The Global Deal in the USA and A Blueprint For A Safer Planet, UK) To avoid the devastating effect of global warming, the Review made it clear that the world requires urgent action to implement global policies: cooperation from all countries is crucial. The Review stresses the concept of equity, including, both the responsibility of developed countries to developing countries and intertemporal considerations, the responsibility of the current generation to provide a sustainable planet for future generations.

The Review was discussed at the Conferences of the Parties to the United Nations Framework Convention on Climate Change in 2006 and 2007 (COP12 and COP13) and

received much public attention. Backed by the recent scientific data and economics, Lord Stern's work makes a significant contribution, not only through promoting the understanding of academic research, but also by informing the public about the potentially immense toll of global warming. The Review also had a significant impact on governments and policy makers by proposing viable policies to mitigate and adapt to climate change. Lord Stern continues to take every opportunity to discuss and influence policy makers across the globe, this includes assisting concerned parties to understand the consequences of global warming and understanding of the necessity of urgent action.

From Mathematics to Development Economics

Lord Stern was born on 22 April 1946 in London UK. He earned his Bachelor of Arts degree in mathematics at Peterhouse, Cambridge, and his Doctor of Philosophy in economics at Nuffield College, Oxford. His experiences in Mexico in 1964, Turkey and Iran in 1966 and Ethiopia in 1967 generated a lifelong interest in development economics, and particularly with poverty and the study of the development process in low-income countries. From 1969, early on his career, he began research in development economics, based first in Kenya and then in India, including the Uttar Pradesh village of Palanpur which he has visited regularly since 1974, researching the economic transformation of the village and the close relationship between overcoming poverty and environmental issues and climate changes have been key issues for his work, including in the Stem Review.

He was a lecturer at Oxford University from 1970 to 1977, and served as a Professor of Economics at the University of Warwick from 1978 to 1987. He taught from 1986 to 1993 at the London School of Economics, becoming the Sir John Hicks Professor of Economics. From 1994 until 1999 he was the Chief Economist and Special Counsellor to the President of the European Bank for Reconstruction and Development. He was the Chief Economist and Senior Vice-President of the World Bank from 2000 to 2003 where continued his work on the problems of world poverty.

In 2003 Lord Stern became Second Permanent Secretary at H. M. Treasury, initially with responsibility for public finances, and head of the Government Economic Service. He led the writing of the Report of the commission for Africa 2004-5 and in July 2005 he was appointed by the UK government to conduct a review on the economics of climate change, which led to the publication of the Stern Review on 30 October 2006. The Review gained global media attention for its stark assessment of climate change and examination of comprehensive policies to prevent the likely outcomes of unmitigated climate change. Lord Stern attended COP-13 in Nairobi in Kenya in 2006 and COP-14 in Bali, Indonesia (2007 United Nations Climate Change Conference) to promote the understanding of the Review worldwide.

In June, 2007 Lord Stern became the first holder of the I. G. Patel Chair at the London School of Economics and Political Science. In 2008 he was appointed Chair of the Grantham Institute for Climate Change and the Environment, and head of the newly created India Observatory within the Asia Research Centre at LSE. Sir Nicholas Stern became Lord Stern of Brentford in December 2007, appointed to the House of Lords.

Measures Proposed to Deal with Global Warming

The Stern Review is the most comprehensive review on the economics of Climate change. The Review analyses the economic costs of climate change, the costs and benefits of actions to reduce emissions, and considers policies to address climate change. The Review provides clear conclusions concerning the consequences of unmitigated climate change: if we take no action to control emissions and continue along a business as usual (BAU) pathway, we run severe risks of a transformation of the planet which would lead to large-scale migration involving hundreds of millions of people and global conflict. This is a challenge of risk management of the highest order of importance. Expressed in more narrow cost-benefit analysis terms the Review estimated total costs over next two centuries equivalent to at least 5% (up to 20%) of world GDP each year.[*1] Moreover, given the direct impact on the environment and human health, some recent scientific evidence suggests a disproportional share of the climate change burden will fall on the poor regions of the world.

By contrast, if we act now, the cost of action to avoid the most severe impacts of climate change are estimated at around 1% to[*2] of world GDP each year. New technologies and innovation can enable the world to avoid a climate disaster and maintain strong economic growth. Attempting to continue with high-carbon growth will not only severely damage the planet and humans and other life, it will stop or reverse growth.

To cope with the significant challenge of climate change, the Review concluded that a shared global perspective on the urgency of the climate change is required; long-term policy goals to address global warming, and an international approach based on multilateral frameworks and coordinated action, are essential to respond to the vast scale of the Challenge.

To control global warming, the Review examines national and international policies and indicates that four elements of policy are required. The first is carbon pricing policy worldwide, through taxation, emission trading or (an implicit price) regulation. The second is technology development policy, to encourage low-carbon and high-efficiency product technologies. Third is the policy to remove barriers to energy efficiency, and to inform and educate firms and individuals on possibilities. The fourth policy response is adaptation policy to deal with the climate change to which we are already committed.

An effective response to climate change will depend on creating the conditions for international collective action, for example effective policies to halt deforestation across the globe. After the release of the Review, Lord Stem has traveled extensively across the world to promote policy to curb emissions.[*3]

Lord Stern argues that developed countries are responsible for the bulk of the current stock of greenhouse gases in the atmosphere. They are also richer and have better access to technology. Therefore, they have a responsibility to lead efforts to reduce emissions and to find ways of sustaining development in a more hostile climate. They must do this directly through their own action and providing finance, directly or through trading for action in developing countries. In addition, given that developing countries will be responsible for the majority of the increase in greenhouse gas emission in the future, the sharing of low-carbon technology

between developed countries and developing countries is an essential requirement of any effective policy response.

Preservation of the global environment is indispensable to sustain the development of the world economy and the future welfare of society. It is the responsibility of the current generation to hand a safe and sustainable planet to future generations. Stern's work, including in The Stern Review, clearly defines what must be achieved to fulfill our responsibility for avoiding a major climate disaster. If disastrous climate change does occur, the developing countries and the world's poorest will be hardest hit; to prevent this tragedy the world must act with urgency. The clear messages in Lord Stern's work concerning developing countries coincide with his profound understanding of the severe situation of poor people in developing counties and his serious concern over the bleak future in the case of climate inaction.

As an economist, Lord Stern has engaged in studies of economic development, economic theory, tax reform, public policy, the role of the state, and the economic transition from command to market economies. In the year 1974 and 1975, he spent 8 months in a rural village in north east India; and he wrote books about development of tea plantations in Kenya and agricultural change in India. In addition, he has written books on crime and criminal statistics in UK, financial affairs, public development, "A strategy for development" 2002, "Growth & Empowerment: Making Development Happen" 2005, "A Blueprint for a Safer Planet" 2009, and over 100 published academic papers.

Lord Stern expressed the pressing situation of climate change as following:

"There is still time to avoid the worst impacts of climate change, if we act now, we act strongly and we act internationally." Already three years have passed since the Review was made public, urgent action to combat global warming is long overdue.

Notes

*1: After the Review was published, scientists concluded that the capacity of the planet to absorb CO_2 is less that the level assumed in the Review.
Considering this fact, Lord Stern now warns that the impact of climate Change is much larger than the review predicted.
Guardian 25 March 2008

*2: Lord Stern mentioned that the evidence now shows that climate change is happening faster than had been previously thought. Therefore emissions of greenhouse gases need to be reduced even more sharply. Owing to this increase in greenhouse gases, it will cost up to 2% of global GDP each year to address climate change.
Guardian 26 June 2008, New Scientist 21 January 2009

*3: Detailed policy. Developed countries to reduce their greenhouse gas emissions by at least 80%, in order for the world to achieve an overall reduction in global emissions of 50% by 2050.
Substantial trade between countries, including rich and poor countries, in greenhouse gas emissions, to keep down costs and help finance climate investment in developing countries.
A major reform of the Clean Development Mechanism, a Kyoto protocol mechanism that allows developing countries to sell emission reductions, but does not penalize them for emissions themselves.
A programme, $10-15bn per year, could stop up to half the deforestation. Urgent promotion of technologies such as Carbon Capture and Storage (CCS) is needed to curb the emissions from coal-fired electric power generation.
Rich countries honour 0.7% GDP in aid, by 2015 to developing countries for mitigating the impact of climate change.
Guardian 29 November 2007

Essay

Climate Change, Public Policy and a New Wave of Technological Change

Lord (Nicholas) Stern of Brentford

Science tells us that the problems created by the accumulation of emissions of greenhouse gases (GHGs) are potentially immense. Under anything approximating business-as-usual (BAU) there is a substantial probability (perhaps as high as 50%) that in a century or so global average temperatures could reach 5ºC above the 19th century, temperatures not seen on the planet for around 30 million years. The potential climate change associated with such temperatures would likely transform the lives and livelihoods of billions of people, including where hundreds of millions could live. Resulting population movements could lead to extended, severe and widespread conflict. These are the scale of the stakes that follow from the science.

The potential effects are subject to major uncertainties, they appear with long lags, and the effect of a kilogram of GHG emissions is independent of whom or where are the emitters (emissions are "public bads" in the language of economics). The combination of the magnitude, the uncertainty, the lags in the consequences, and the 'publicness' of the causes, all of which follow from the science, makes the politics and economics of policy supremely difficult (Stern, 2012).

It is hard for people to understand the scale of risk from climate change. More generally, misunderstanding of the meaning of uncertainty and how to respond are pervasive in both public and private decision-making. And the lags are compounded by ratchet effects and irreversibilities: once carbon-dioxide, the most important of the GHGs, is in the atmosphere, it is likely to stay for many decades. Further, capital equipment and infrastructure can last for a few decades, locking in high-carbon structures. Thus if decisions are postponed until the effects are very clear and the scale is demonstrated, it may be difficult, extremely costly, or impossible to extricate ourselves. Or we may have to consider very risky and badly understood alternatives such as geoengineering, which themselves may carry immense and potentially damaging consequences. The publicness of the cause may tempt people to leave action to others on the articulated grounds that each individual contribution is small or they may decline to act because they do not have confidence that others will act.

We have a problem of risk management and public action of immense importance whose scientific logic makes the formulation, decision-making, and implementation of policy extremely difficult. The policy challenge is, however, far from insoluble; indeed if it were, it is likely that the future for our children and grandchildren would be dire.

The building of the political will to take the radical decisions necessary will require the widespread and shared understanding of two fundamental propositions. So far, we as

scientists, social scientists, and communicators have not made sufficient progress in explaining and demonstrating these propositions. The two propositions concern first, the scale of the risks and the urgency of action and second, the nature and attractiveness of the new energy-industrial revolution which is required. They are the subject of the second and third sections of this brief paper. The remainder of this first section is devoted to the key elements of economic policy for the management of climate change and broader issues of sustainability beyond climate change.

Emissions of GHGs are not the only market failure relevant to the management of climate change. There are crucial market failures concerning: research, development and deployment; networks and grids; long-term risk and capital markets; property markets; and information more generally. Further, there are failures in the valuing and understanding of co-benefits of action on climate change (beyond the fundamental benefits of reducing the risks of climate change) and embedding these in policy. These arise especially around the valuation of ecosystem services and biodiversity issues which require close attention in their own right as well as being profoundly affected by action or inaction on climate change.[2]

Each of these requires careful attention: thus the problems of market failure associated with promoting action on GHGs go beyond the fundamental market failure of the unpriced "externality" of emissions. That market failure is indeed fundamental and is a first and crucial element of any policy foundation, but policy will fail to generate the scale and urgency of the response required if it stops there. The demonstration of ideas and new techniques helps others and thus should be fostered; networks depend on interaction and require government policy to work effectively and so on. Policy in relation to each of the failures described should be based on careful analysis of the origins of the failure itself and thus how it can best be tackled.

Scale of the Risks and the Dangers of Delay

Global GHG emissions are currently around 50 billion tonnes of carbon dioxide-equivalent (CO_2e) per annum and are growing strongly, mainly due to carbon intensive growth in the developing world. As the carbon cycle is unable to absorb all of the world's annual emissions, concentrations (stocks) of GHG emissions in the atmosphere have increased, to around 440ppm of CO_2e today. We are currently adding at a rate of around 2.5ppm per year. This rate is rising. Thus if we continue with something like BAU over the course of this century we would likely add at least 300 ppm, taking concentrations to around 750 ppm CO_2e or higher at the end of the century or early in the next. Such a path could bring somewhere in the region of a 50-50 chance of an eventual warming of more than 5ºC relative to mid-19th century levels[3]. A rise of 5ºC is immense: the planet has not seen these temperatures for more than 30 million years.

The world's current commitments to reduce emissions, as pledged in the Appendices to the Copenhagen Accord and confirmed in the Cancun agreement and recently at Durban, are consistent with at least a 3ºC rise (again with roughly a 50-50 chance of above or below). The world has not seen 3ºC for around 3 million years. *Homo sapiens* has experienced nothing like this, being present for only around 200,000-250,000 years, and our civilisations, in terms of arable farming, villages, towns and so on, have been here for only 8,000 or 9,000 years, since

the emergence from the last ice age, i.e. during the Holocene period, during which time average temperatures have fluctuated in a quite narrow range of between ±1ºC.

Such warming would likely cause disruption on a huge scale to local habitats and climates, for example through flooding, desertification, and water scarcity. Hundreds of millions of people, perhaps billions, would probably have to move, with the associated risks of severe and extended conflict. The great advances in development of the last few decades, which have seen hundreds of millions of people in developing countries rise out of income poverty, substantial improvements in health and life expectancy, large reductions in fertility rates, and major advances in education and literacy, would likely be put at risk.

The scale of the risks and the inherent uncertainty around these projections clearly imply that policy analysis of climate change must be framed in terms of risk-management. The potential risks are huge and the associated probabilities are not small.

The uncertainty present in these projections may suggest to some that delay whilst we learn more is the best response, rather than early and strong action to reduce emissions. That would be a profound mistake. First, the flow-stock process, from emissions to increasing concentrations of GHGs in the atmosphere, with CO_2, in particular, very long-lasting in the atmosphere, implies that we have a ratchet effect. Processes to remove emissions from the atmosphere or prevent solar energy reaching the earth, known as geoengineering, are undeveloped, largely untested and are also likely to involve significant risks. See the 2009 Royal Society report and Reekie and Howard (2012). Second, much of infrastructure and capital investment can result in technological "lock-in". With little action the long life times of much of the relevant high-carbon infrastructure and network investment could imply that the lock-in could last for many decades to come. Delay is clearly very dangerous: we are already at a difficult starting point in terms of concentrations of GHGs and weak action or inaction for a decade could make stabilisation of concentrations at levels that reduce the risks to acceptable levels, in particular 2ºC, very difficult.

To embark on strong action now, if the science turns out to be wrong and the risks are small, would leave us with a more energy efficient and bio-diverse economy and new technologies, even though ex post we might have wished there had been somewhat smaller investment in these areas. On the other hand, if the science turns out to be right, and we ignore the risks, we would be in an extremely difficult position from which it would be very hard to extricate ourselves. Given this logic, basic decision theory or common sense points to strong action, particularly since the science is very likely to be right. To argue for weak or delayed action involves claiming to be pretty sure the risks are small—an extraordinary position given 200 years of cumulative scientific analysis—and/or that delay has only modest downside.

Size of the Response and the New Energy-industrial Revolution

Most nations now agree, as expressed in the current global negotiations (the agreement at Cancun at the UNFCCC meeting of December 2010), that limiting the rise in global temperature to 2ºC is necessary in the sense that levels above this are (sensibly) regarded as dangerous. To achieve this goal, with a 50-50 probability, global emissions would need to fall from current levels to pass well below 35 billion tonnes of CO_2e in 2030, and well below 20

billion tonnes of CO_2e in 2050. These "global constraints" should be at the heart of discussions and of the understanding of action.

Reducing absolute emissions levels by a factor of at least 2.5 in 40 years would require a reduction in emissions per unit of output by a factor of around 8 if the world economy grows over 40 years by a factor of around 3 (equivalent to an annual world GDP growth rate of around 2.8%). Emissions reductions on this scale should surely be regarded as a new energy-industrial revolution. The transition to low-carbon growth and the energy-industrial revolution represent a far more attractive path than the high-carbon, dirty and environmentally destructive path that has gone before. The transition is likely to be a period of innovation, creativity and growth, and will involve substantial investment across the economy. And low-carbon growth is likely to be cleaner, safer, quieter, more energy secure and more bio-diverse. Low-carbon growth is the genuine growth option; an attempt at high-carbon growth will self-destruct.

The study of past periods of economic/technological transformation has much to teach us here. Past industrial revolutions, e.g. steam and the railways, and much more recently the information, communications and technology (ICT) revolution, which continues (Figure 1), involved a transformation that saw two or more decades of strong innovation and growth, with investment flowing to those pioneer countries and businesses that showed leadership and embraced the transition (see, for example, Perez, 2002 and 2010). Such transformations involve periods of 'creative destruction' (in the tradition of the economist Joseph Schumpeter), where new firms and ideas drive out the old, generating a dynamic period of innovation, opportunity, employment and economic growth. Countries and states such as China, Korea, Germany, the Scandinavian countries, and California are leading the transition with the size of their low-carbon markets growing strongly. The costs of low-carbon technologies, such as solar PV and off-shore wind power have declined rapidly over recent years and similar cost reductions are expected in the future as their deployment accelerates.

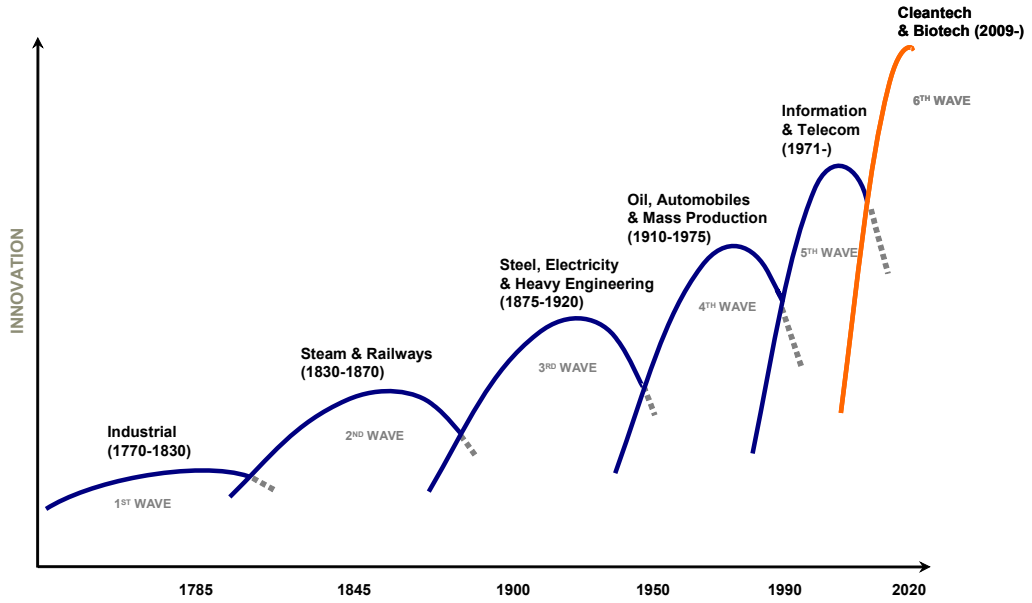

Figure 1
Waves of Innovation

Source: DONG Energy (2009); diagram based on Perez (2002) drawing on report by Merrill Lynch (2008) (schematic not precise quantitative vertical axis).

The transition will require strong action to reduce emissions across all countries and all economic sectors. Energy efficiency will be central to the response, as will the introduction of new low-carbon technologies and strong and determined action to slow and halt deforestation. This will involve the implementation of transparent, long-term and credible public policies (to address the market failures) and public investments that create a positive environment for innovation and change. They should take careful account of and be integrated with policies to protect ecosystems and biodiversity.

As this transformation progresses the world must also be prepared to adapt to the climate change to which we are already committed from past and future emissions. We have to manage the unavoidable as well as avoiding the unmanageable. We are already outside the temperature range of the Holocene period when our societies developed. Another 1-1.5ºC which appears very likely will require major adaptation to changing weather and climate patterns. There should be close intertwining with mitigation and development—indeed it is a mistake to separate them excessively in terms of organization and implementation. Much of irrigation and water management should combine mitigation, adaptation and development, similarly buildings, city management, power and so on. The stronger the emissions reduction, the less the necessary scale of adaptation but given what we have already done and are doing on emissions the scale of adaptation will have to be large.

We are already starting to see emissions reduction policies introduced in many countries. But action will have to be stronger and more rapid, more coordinated, and extend more broadly across the many relevant market failures if the level of investment and pace

of change necessary to avoid dangerous climate change are to be achieved. Delay is dangerous and now is the time to accelerate. The world economy risks a prolonged slow down as a consequence of the financial and economic crises of the last few years. Low-carbon growth is the only sound basis for a sustainable recovery.

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Notes

1. I am very grateful to James Rydge for his guidance and support.
2. The Rio+20 conference of June 2012 rightly places strong emphasis on these bio-diversity issues. See The Economics of Ecosystems and Biodiversity (TEEB) Volumes.
3. See, for example, Bowen and Ranger (2009).

Lecture

Creating a Global Agreement on Climate Change: Responsibilities and Opportunities

Lord (Nicholas) Stern of Brentford

Introduction

Avoiding dangerous climate change and overcoming global poverty are the two defining challenges of the 21st century. The global responses to these challenges must be carefully designed, but if strong action is taken now, they will be both manageable and affordable.

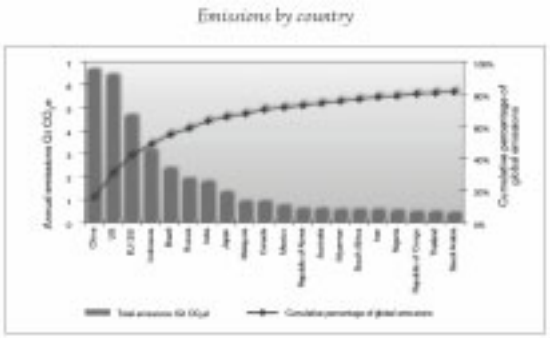
Rich countries are largely responsible for the causes of the current climate crisis, but it is developing countries that are being hit earliest and hardest by the consequences. Thus, rich countries must take strong action now and provide significant mitigation and adaptation assistance to developing countries. Developing countries must also play a leading role in designing and implementing a global deal. However, it is reasonable that developing countries place strong conditions on the performance of rich countries both in cutting their emissions drastically and in providing financial and technological support to developing country action; with such performance they could provide a "commitment to commit" to emissions reductions. Rich country support can and should start now with substantial help with finance for the climate change action plans which developing countries are now constructing.

I begin by briefly discussing the problem of climate change and what it implies for targets to reduce emissions of greenhouse gases. This leads to a discussion and analysis of how to achieve emissions targets and the likely costs involved. I conclude with the main elements that must be part of any global deal negotiated in Copenhagen in December 2009. If that global deal is to be built and sustained it must be effective, efficient and equitable.

From People to Emissions

The rate of growth of economic activity in the industrialising parts of the world accelerated dramatically from the mid-19th century onwards, while the form of that activity (the rise of industry and the relative decline of agriculture, for example) became much more hydrocarbon-intensive. These three effects-growth, industrialisation and hydrocarbon use-combined to increase greenhouse gas emissions. The second half of the 20th century saw a sharp increase in the rates of growth of emissions as the world recovered from the Great Depression and the Second World War, and more countries industrialised.

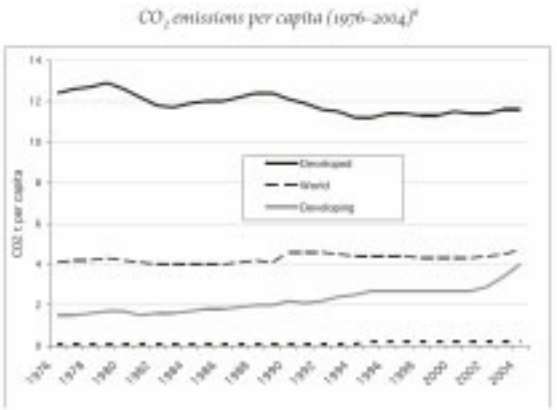
- The combined effects of growth, industrialisation and hydrocarbon use substantially increased flows of greenhouse gas emissions: thus concentrations of stocks have grown from 285ppm in the mid 19th-century to over 430ppm CO_2e today.



Source: Garnaut (2008), UNFCCC (2007) 2004 data for US, EU (25), Russia, Japan and Canada; Department of Climate Change (2008) 2004 data for Australia (using UNFCCC accounting); and World Resources Institute (2008) for other countries (2000 data except for CO_2 emissions from fossil fuels, which is for 2004).

Figure 1
From People to Emissions 1

- Over the next 20 years developing countries will play an increasing role in driving growth in overall emissions.
- Per capita emissions for rich countries are much higher.



Source: Climate Analysis Indicators Tool (CAIT)

Figure 2
From People to Emissions 2

From Emissions to Temperature

As a result of this hydrocarbon-intensive growth, the world has been emitting carbon dioxide and other greenhouse gases at a faster rate each year than the planet can absorb, especially during the rapid and energy-intensive growth of the last 60 years.

Concentrations of greenhouse gases in the atmosphere have grown from 285 parts per million (ppm) in pre-industrial times to over 435 ppm of carbon-dioxide-equivalent (CO_2e) today, and we are adding at a rate of over 2.5 ppm per year (and if there is little or weak action this is likely to accelerate to around 3 ppm per year or higher over the coming decades). As a result, continuing with 'business-as-usual' (BAU) is likely to take us to over 750 ppm CO_2e by the end of the century.[1]

This level of concentration, even if there were no further increase, would result in a significant probability, around 50% or more, of an eventual temperature increase of more than 5ºC compared with the pre-industrial era (our benchmark for temperature increases unless otherwise stated). The planet last experienced such temperatures more than 30 million years ago, long before the appearance of humans, 100 to 200,000 years ago. The most recent warm period was around 3 million years ago when the world experienced temperatures 2ºC or 3ºC higher than today. Humans have never experienced temperatures anywhere near a 5ºC increase.

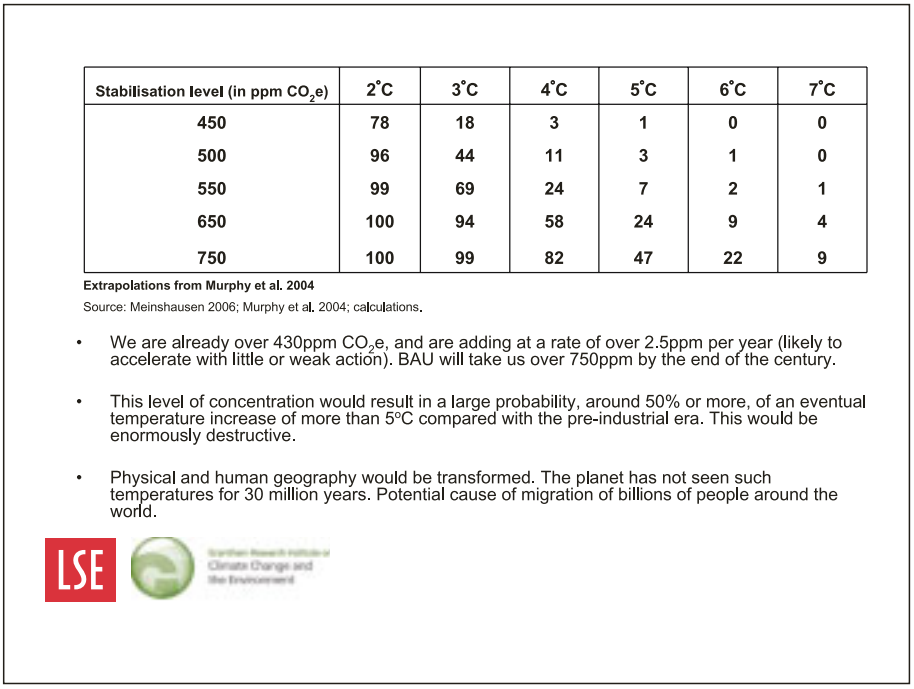
From Temperature to Climate Change and Impacts on People

Thus 'business-as-usual' emissions of greenhouse gases would profoundly change the climate of the planet. Global sea level would rise by several metres and many low-lying coastal areas, such as much of Bangladesh, would be inundated. Many areas, probably including southern Europe would turn into deserts. The physical and thus human geography (where we can live and how we live our lives) would be transformed, leading to the migration of hundreds of millions of people, and intense competition for scarcer resources, such as water.[2] This would probably lead to intense and prolonged international and national conflicts. The stakes are immense: we are essentially gambling the planet.

The Fourth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC) in 2007 includes a review of recent research on the impacts of climate change in Japan. Average temperature in Japan increased by about 1ºC in the 20th century and by 2ºC to 3ºC in the largest cities. This is consistent with evidence of an increase in the number of days over 35ºC and a decrease in extremely low temperatures. There is also evidence of increased extreme rainfall events over the past 100 years, including serious flooding in 2004 which was the result of 10 typhoons. Migration of plants and animal species has also been reported, the flowering date of the cherry has changed and alpine flora in Hokkaido have decreased.

The IPCC also reports that heatwave conditions and extreme precipitation will increase over Japan as atmospheric moisture content increases. Significant decreases in rice production are also predicted; an atmosphere with carbon dioxide concentrations that are double those of pre-industrial times (i.e. around 560ppm CO_2e) could decrease rice yields in irrigated lowland areas of central and southern Japan by up to 40%. Sea level rise will also have powerful impacts on Japan. Over 4 million people could be at risk from a rise in sea level of 1 metre.

But remember that 'business-as-usual' will imply far higher concentrations than 550 or 560ppm CO_2e. The consequences for Japan both in terms of direct effects and migration of 550ppm CO_2e would be very unpleasant; for 650ppm CO_2e or more they are likely to be devastating.



Stabilisation level (in ppm CO_2e)	2°C	3°C	4°C	5°C	6°C	7°C
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

Extrapolations from Murphy et al. 2004

Source: Meinshausen 2006; Murphy et al. 2004; calculations.

- We are already over 430ppm CO_2e, and are adding at a rate of over 2.5ppm per year (likely to accelerate with little or weak action). BAU will take us over 750ppm by the end of the century.
- This level of concentration would result in a large probability, around 50% or more, of an eventual temperature increase of more than 5°C compared with the pre-industrial era. This would be enormously destructive.
- Physical and human geography would be transformed. The planet has not seen such temperatures for 30 million years. Potential cause of migration of billions of people around the world.

LSE

Figure 3
From Stocks to Temperature

What our Emissions Targets Should Be

In order to reduce the risk of climate change the world must act together and commit to targets for emissions reductions. Most assessments of sensible risk management imply that we should hold greenhouse gas concentrations at or below 500 ppm CO_2e, and try to reduce them from there. Holding concentrations below this level would expose the planet to a probability of global average temperature rising by 5ºC or more of around 2% or 3% compared with a huge 50% or more under 'business-as-usual'.

Looking longer term, we should recognise that holding concentrations below 500ppm CO_2e and bringing down to 450 ppm or below, would still carry a serious risk of passing a number of potential tipping points, like the destruction of rainforests and the release of methane from thawing permafrost. It makes sense, therefore, to interpret 'holding concentrations below 500 ppm' as eventually allowing a very long-term stabilisation markedly below that level. The learning we have to do to hold levels below 500 ppm will tell us much about how to go further. Just where around 500 ppm CO_2e, and then lower, we should aim is

a matter of balancing the costs and the avoided risks. As the scientific evidence accumulates the risks look ever larger; on the other hand the technology of emissions reductions is already moving so quickly that costs of action and the benefits of new technologies may look even more attractive.

Annual global emissions of greenhouse gases were about 40 gigatonnes (Gt) CO_2e in 1990; they are over 50 today. If the world is to hold concentrations below 500ppm CO_2e and then try to reduce from there, then we must ensure annual global emissions peak within the next 10 years and reduce to half 1990 levels, or about 20 Gt CO_2e at most, by 2050. As the global population will probably be around 9 billion in 2050, this would be equivalent to emissions of around 2 tonnes CO_2e per capita. Given that there will be very few countries with actual emissions below this level there can be very few above.[3]

At the Italy summit (L'Aquila) in 2009, G8 leaders for the first time acknowledged the importance of avoiding an increase in global average temperature of more than 2ºC compared with pre-industrial times. They also agreed a goal for developed countries of reducing their annual emissions of greenhouse gases by at least 80% or more by 2050 compared with 1990. This would take actual emissions in Europe and Japan to around 2 tonnes per capita, the maximum sustainable for any major country as argued above.

In addition to these distant objectives, explicit intermediate targets for 2020 and 2030 are necessary now for the rich countries and very soon for all countries. The immediacy of the problem allows no delay, and businesses, markets and developing countries require strong signals now and powerful examples of what is possible. The longer we delay, the more difficult and more costly it will be to stay below 500 ppm CO_2e.

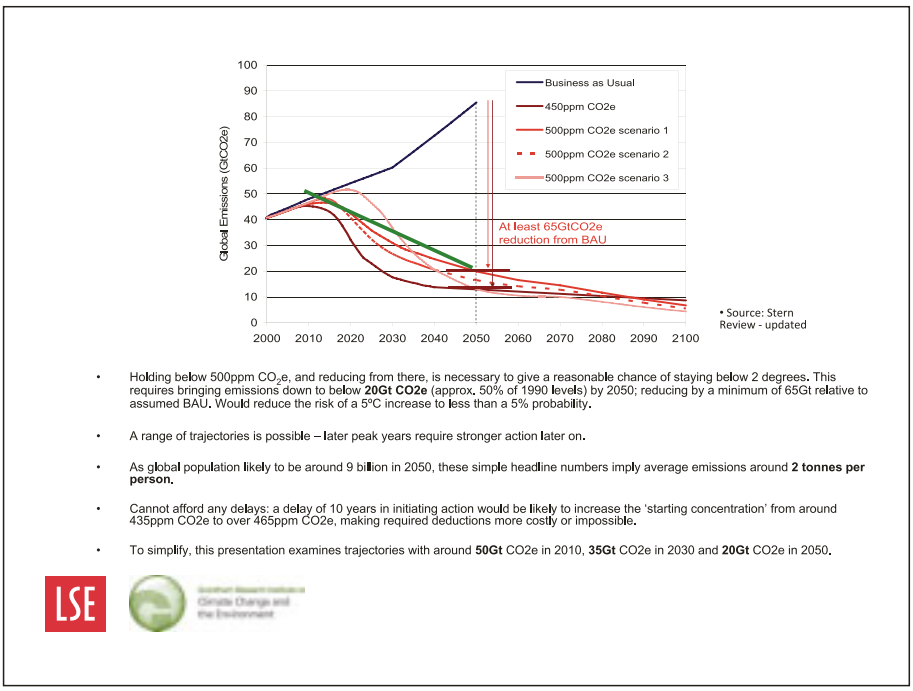


Figure 4
What our targets should be.

How to Achieve the Targets and Costs Involved

To be on a path to halve annual global emissions by 2050 from 1990, and allow eventual stabilisation at 450 ppm CO_2e, total world emissions in 2030 would have to be around 35 Gt CO_2e. Table 1 outlines six scenarios that demonstrate the extent of cuts necessary to achieve this interim 2030 target.

The scenarios focus on five nations or regional groups: USA, EU/Japan, China, India and the Rest of the World.[4] I have put the EU and Japan together since they start with similar emissions per capita and have similar emissions per unit of output. For all scenarios the overall economies grow at 2.5% for the USA and EU/Japan and 7% for each of China and India. The scenarios then look at different assumptions concerning emissions per unit of output. In the first block of 3 scenarios we have both the US and EU/Japan halving emissions per unit of output and in the second block, dividing by 4.

Within the blocks, the scenarios vary according to different assumptions concerning emissions per unit of output in India and China: India and China both constant; India constant and China halving; India halving and China dividing by 4. The assumptions concerning India relate to her much lower emissions per unit of output in 2010 (close to 2 tonnes versus around 6 for China) and to her lower standard of living (also her 'starting' emissions per unit of output are substantially lower than China's).

The table shows that only scenario 6 has any plausibility in terms of implications for the 4.3 billion people in the Rest of the World in 2030. Even that scenario would imply that the per capita emissions of the USA, EU/Japan and China would substantially exceed those of the 4.3 billion in the Rest of The World by 2030. Scenario 6 would require China to have peak emissions around 9 or 10 tonnes per capita with a peak around 2020 and India to peak at around 4 or 5 tonnes per capita well before 2030. Rich countries would have to reduce drastically starting now.

The architecture is clear: unless the USA, EU/Japan and China reduce emissions per unit of output by a factor of 4 it will not be possible to reach the goals that sensible risk management requires. The alternatives would be to cut growth or be reckless with the climate. Surely the right answer is to cut right back on emissions per unit of output. No major country, least of all a rich one, can claim to have good reason to 'contract out'. We must do this together.

Table 1: Emissions Scenarios Consistent with Global Emissions of 35 $GtCO_2e$ in 2030

Scenario for emissions (em) change to 2030	Emissions in 2030									
	USA		EU 27 & Japan		China		India		Rest of the World	
	tCO_2e per capita	Total ($GtCO_2e$)	tCO_2e per capita	Total ($GtCO_2e$)	tCO_2e per capita	Total ($GtCO_2e$)	tCO_2e per capita	Total ($GtCO_2e$)	tCO_2e per capita	Total ($GtCO_2e$)
Scenario 1: Overall growth: India & China 7%, US, EU27 & Japan 2.5%. em/output: India & China constant; US, EU27 & Japan halving.	16.6	6.2	9.9	6.2	20.8	31.3	5.3	7.9	-3.8	-16.5
Scenario 2: Overall growth: India & China 7%, US, EU27 & Japan 2.5%. em/output-India constant; China, US, EU27 & Japan halving.	16.6	6.2	9.9	6.2	10.4	15.6	5.3	7.9	-0.2	-0.9
Scenario 3: Overall growth: India & China 7%, US, EU27 & Japan 2.5%. em/output-India halving, China decrease by factor of 4; US, EU27 & Japan halving.	16.6	6.2	9.9	6.2	5.2	7.8	2.6	4.0	2.5	10.9
Scenario 4: Overall growth: India & China 7%, US, EU27 & Japan 2.5%. em/output: India & China constant; US, EU27 & Japan decrease by factor of 4.	8.3	3.1	4.9	3.1	20.8	31.3	5.3	7.9	-2.4	-10.3
Scenario 5: Overall growth: India & China 7%, US, EU27 & Japan 2.5%. em/output-India constant, China halving; US, EU27 & Japan decrease by factor of 4.	8.3	3.1	4.9	3.1	10.4	15.6	5.3	7.9	1.2	5.3
Scenario 6: Overall growth: India & China 7%, US, EU27 & Japan 2.5%. em/output-India halving; China, US, EU27 &Japan decrease by factor of 4.	8.3	3.1	4.9	3.1	5.2	7.8	2.6	4.0	4.0	17.1

Assumptions:	**Population (bn)**		**Emissions per capita (CO_2e)**	**Total emissions ($GtCO_2e$)**
	E2010	**E2030**	**E2010**	**E2010**
China	1.4	1.5	6.0	8.1
India	1.2	1.5	1.7	2.0
USA	0.3	0.4	25.1	7.5
EU27 & Japan	0.6	0.6	12.1	7.5
Rest of the World	3.4	4.3	7.8	26.8

Source: UN 2008 World Population Prospects

Sources: Climate Analysis Indicators Tool (CAIT) & Global Carbon Budget Project.

There will of course, be other countries such as the USA, Canada, Australia which must bring emissions down much more strongly than Japan or Europe-these 3 countries are currently well over 20 tonnes CO_2e per capita. In terms of technology and geography however Japan is much closer to Europe and the fact that others have still farther to go is no excuse for major and technologically advanced countries like Europe and Japan, and Japan is the world's second largest economy, to fail to take a strong lead. If a poor country like China, with much lower emissions per capita than Japan, is likely to have to cut emissions per unit of output by a factor around 4 in 20 years, it is hard to argue that Japan cannot also cut emissions per unit of output by a factor 4 and thus halve its per capita emissions to around 5 or 6 tonnes in the next two decades.

We should not be rigid about the precise figures for annual emissions in 2030 or any other particular year. There could be a little more emissions in one year and a little fewer in another. But the limits imposed by the overall arithmetic for total emissions over the next few decades are very real and give a very powerful indication of the scale of action required.

The key areas of actions to reduce emissions will be (i) energy efficiency (ii) low-carbon technologies and (iii) halting deforestation. All will require investments which will have to start strongly now across the world in order to achieve the annual emissions reductions required by 2030. At the start of the process of stabilising atmospheric concentrations there is great scope for energy efficiency improvements. *Energy efficiency* varies across developed countries. In 2005 Japan consumed 1.94 kWh of energy per dollar of GDP, expressed in (2000) USD. The EU consumed 2.29 kWh per dollar of GDP (there is significant variation within the EU from 4.4 kWh in Bulgaria to 1.33 kWh in Ireland). In contrast, the US consumed 2.68 kWh of energy per dollar of GDP in 2005. While Japan is more energy efficient than the US and some EU states, other major developed economies have achieved similar (Germany, France) or better (UK) levels of energy efficiency.

Developing and deploying low-carbon technologies and activities will also be essential, and Japan is in an excellent position to lead. Japan has shown great technological leadership in the past; the Toyota Prius is a prominent and important example of 'green' innovation and leadership by a Japanese company. Another, less well-known, example is the development and deployment of home-use fuel cells by Tokyo Gas Company and Panasonic Corporation. The success of these technologies, especially hybrid drive technology, demonstrates the rewards and opportunities available to those who lead.

The global emissions reductions necessary require there to be many more examples like these. We need a rapid and widespread advance in the development and diffusion of a wide range of technologies. Technology policy is essential to achieve this and is a powerful stimulus. Japan has great experience in this area of policy.

As with all policy that creates the incentives to drive major change, it is important to avoid overconcentration on the many lobbyists and vested interests that will seek to delay and/or reduce the effectiveness of policy. The world needs Japan's proven track record of technological innovation. Japan has a significant opportunity to lead the world again, just as she did with the development of the semi-conductor during the 20th century.

Halting deforestation will require major advance in agricultural productivity and in

other parts of the economies of the regions where the trees stand. Governance and enforcement of laws on deforestation will require investment too. And peoples dependent on forests in various ways must have a strong and direct stake in their protection. Policies must be constructed by the countries where the trees stand but strong external support should be an obligation on us all. Japan is playing its role in helping to reduce deforestation. For example, it is an active participant in the Asia Forest Partnership (AFP) that aims to combat illegal logging and reduce forest loss and degradation. We all gain from avoided deforestation. We should be clear however that it will require substantial and sustained financial and other support.

The cost of stabilising at or below 450 ppm CO_2e (and implementing these different mitigation options), if the world acts now, is relatively small, compared to the cost of the damages avoided. Both the bottom-up and the top-down studies in the Stern Review, Chapters 9 and 10 respectively, arrived at mitigation costs in similar ranges-around 1% (between -1% and 3%) of world GDP for stabilisation below 550ppm CO_2e. With ever clearer evidence that risks from unmanaged climate change are even worse than was assumed by the Stern Review, it is clear that concentrations should be held below 500ppm CO_2e and eventually brought down to no higher than 450ppm CO_2e. The annual costs of mitigation over the next few decades might now be around 2% of world GDP.

Since the Stern Review was published there have been a number of new studies, both bottom-up and top-down. Significant examples of the former are those from McKinsey (Enkvist et al., 2007) and the IEA (2007), both of which indicated mitigation costs consistent with or lower than the Stern Review. Similar conclusions on costs of action are drawn in the Fourth Assessment Review of the IPCC (AR4, IPCC 2007).

These costs will mostly take the form of new investments and will appear, for a while, in terms of higher costs for energy to industrial and domestic consumers. But there will be potentially major savings from energy efficiency and the new low-carbon technologies, relative to those displaced, are likely to have strong benefits (energy security, cleaner air, less noise, etc.) beyond the reductions in emissions. Stopping deforestation carries great co-benefits too in terms of avoided soil erosion, silting and flooding and better watershed management, maintaining patterns of rainfall, bio-diversity and so on.

Thus, we should not see the route to the low-carbon economy merely or mostly in terms of cost and burden-sharing. There are investments and opportunities. The transition to the low-carbon economy over the next two or three decades is likely to be one of the most dynamic and exciting periods in economic history with strong discovery and growth. This will be wider and deeper in terms of technology and geography than the arrival of the railway and electricity in industrialising countries in the 19th and 20th centuries. And when low-carbon growth is achieved it will be more energy secure, cleaner, quieter, safer, and more bio-diverse than its predecessor; in other words much more attractive. High-carbon growth has no future: it will kill itself if we try to continue-first on high hydrocarbon prices and second and more fundamentally, on the very hostile physical environment it will create.

A Global Deal

The 15th Conference of the Parties (COP15) to the United Nations Framework Convention on Climate Change, to be held in Copenhagen in December 2009, will be decisive in determining the policies for the period beyond 2012 that succeed the Kyoto Protocol. The Copenhagen meeting will be the most important international gathering since the Second World War. The risks it must grapple with and the policies it agrees must be truly global. A delay in reaching an agreement would be dangerous. First, the relentless flow of emissions would continue to increase the stock of greenhouse gases in the atmosphere, taking us into ever more difficult territory and second, delay could undermine the market confidence that will be crucial for the necessary investments in the low-carbon economy.

It is important that the agreement in Copenhagen be guided by clear principles based on rigorous analytic foundations and a common understanding of the key challenges. The following provides a brief outline of a possible global deal based on the preceding analysis.[5] It also draws on intensive public discussion during the work of the Stern Review in 2005 and 2006 and on continual interaction internationally over the last three years.

Any global deal must be based on three basic principles:

Effectiveness-it must lead to cuts in emissions of greenhouse gases on the scale required to reduce the risks from climate change to acceptable levels;

Efficiency-it must be implemented in the most cost-effective way, with mitigation being undertaken where and when it is cheapest; and

Equity-it must take account of the fact that it is poor countries, with fewer resources and technologies, that are being hit earliest and hardest by the consequences of climate change, while rich countries have a particular responsibility for the cause through their past emissions.

Effectiveness

There are several requirements for 'effective' action:

- Global annual emissions to fall by at least 50% relative to 1990 levels by 2050, to at most 20 $GtCO_2e$;
- Global average per capita emissions that will need to be around two tonnes per year by 2050 (20 Gt divided by nine billion people);[6]
- Agreement by developed countries to take on immediate and binding national targets, and to commit to reductions of at least 80% by 2050 compared with 1990;
- Well before 2020, demonstration by developed countries that they can deliver credible reductions, without threatening growth, and that they can design mechanisms and institutions to transfer funds and technologies to developing countries;
- Subject to this and to strong support with finance and the sharing of technology, a formal expectation that developing countries would make a ‘commitment to commit’ to take on binding national targets of their own by 2020;

- All developing countries with or without immediate formal targets would require climate change action plans;
- A commitment by all countries, regardless of targets, to develop the institutions, data and monitoring capabilities to assess progress in a transparent way, and to put in place policies to avoid the locking-in of high-carbon infrastructure.

Efficiency

Only sound, measured and coordinated policy, and timely international collaboration, can deliver strong and clean growth for all at reasonable cost. The essence of efficiency is to get emissions reduced where the cost is lowest. If any mass sector, technology or country is left out, costs will rise. In principle, efficiency requires that the marginal cost of reducing emissions is the same everywhere.

Backed by very strong targets for cuts in emissions by developed countries, carbon prices can be maintained at levels which will provide incentives both for reductions at home and purchases from abroad, and will guide action towards the lowest cost options. The cheapest mitigation options often reside in developing countries, which should take advantage of carbon markets from the outset. The current structure of the Clean Development Mechanism (CDM) makes it difficult to create market flows to developing countries on the scale required. Moving from a project-based to a wholesale mechanism, perhaps based on sector-specific efficiency targets and credible sector decarbonisation plans, would permit scaling-up in a number of emissions and energy-intensive industries.

Equity

Any global response to climate change must be equitable; responsibilities and costs should be allocated in ways that take account of wealth, ability, and historical responsibility.

However, we start in a very difficult and inequitable position. The numbers are stark. Rich countries are responsible for around two-thirds of the existing stock of greenhouse gases in the atmosphere and their emissions per capita are much higher than those of poor countries. Therefore developing countries have a strong and understandable sense of injustice. They see rich countries having first relied on fossil fuels for their development, and thus being largely responsible for the existing stocks of greenhouse gases in the atmosphere, then telling developing countries to find another, and possibly more costly, route to development.

Given the inequities of the history of emissions, and the implications of climate change for future development, rich countries must demonstrate the feasibility of low-carbon growth and set an example for others. However, they should do much more than this. There is a strong imperative for the rich countries to provide more funds to developing countries, in addition to current development commitments, to fund the extra costs created by climate change.

Delivering additional funds on an appropriate scale is crucial. The long-standing target for development aid, set out in the Monterrey Consensus on Financing for Development in 2002 and reaffirmed in December 2008 in the Doha Declaration on Financing for Development, is for developed countries to provide at least 0.7% of GNP as Official Development Assistance (ODA). The EU gave itself, in June 2005, just before the G8 meeting at Gleneagles in the UK,

until 2015 to reach the target.

Adaptation to a more hostile climate, however responsible we are in cutting emissions, will increase the burden on developing governments. Therefore the targets for support from the public budgets of rich countries are likely to be closer to 1.0% of GNP than 0.7% for the coming two decades. With the private flows that could come with them and the growth and poverty reduction they could help foster, these flows of public funds would constitute very wise investments for the world as a whole, as well as the fulfilment of our duty as citizens of the world.

Developing countries should challenge the rich countries to commit to very strong cuts in emissions. They could place the following conditions on rich countries and, on condition of their fulfilment, the developing world should give a 'commitment to commit' to targets within 5-10 years:

(i) strong performance by the rich countries over the next decade towards meeting targets for 2020, 2025 and 2030, which are tough and fully consistent with a path to reductions in emissions of at least 80% by 2050 relative to 1990;

(ii) financial support through the markets and elsewhere for action in the developing world, and strong support in the battle against deforestation; by the 2020s the necessary flows to support reductions in emissions by developing countries are likely to be in the region of $100bn per annum.[7]

(iii) rich countries to develop new technologies for low-carbon economic growth, which should be shared with developing countries; and

(iv) substantial assistance in adaptation to those impacts of climate change which are now inevitable over the next few decades; by the 2020s the necessary additional support (over and above existing ODA countries) is likely to be in the region of $100bn per annum.[8]

This would be a framework where the developing world would explain to the rich world what is necessary and place the conditionality and performance requirements on them.

Conclusion

If the world allows climate responsibility on the one hand, and growth, development and the fight against world poverty, on the other, to become set against each other, the argument is lost from the start. The world has both the technology and the economic understanding to move forward strongly on both simultaneously. In other words the two defining challenges of our century must be tackled together. If we fail to manage climate change we will derail development and if we try to manage climate change by blocking development we will fail to build the global coalition necessary to reduce emissions.

Japan is in a strong position be in the vanguard on climate change. Japan has an enviable track record of leadership in technological innovation and the world looks to Japan to again demonstrate this leadership. Strong and effective climate change policy that sets a clear and instructive example for the rest of the world is crucial. If not the world will ask "if a country like Japan cannot do this, then how can we?" Japan is pivotal.

At Copenhagen in December 2009, leadership must come from the top; that means heads of government. The problems of climate change are too wide to be confined only to one

or two individual government departments, ministries or negotiators. It is vital that united and decisive leadership is displayed by heads of government. And if we learn to collaborate on the necessary scale in this fundamental area we will surely do much better in the many other important areas of international policy.

Rich countries must recognise their responsibilities, especially to developing countries and take strong action now. Developing countries should place conditions on rich countries, and on condition of their fulfilment, 'commit to commit' to substantial cuts in emissions of their own. The arithmetic is crystal clear, only a comprehensive agreement that involves both rich and developing countries can achieve the cuts in emissions necessary to avoid dangerous climate change.

Action is not led only from the top: it will be the individual understanding of citizens, communities, companies and NGOs that will drive forward this debate. The understanding and demands of members of the public are the most fundamental drivers of political change. It will be this voice that will carry us through to a more responsible future.

Notes

1. For references the reader may wish to consult my recent book "A Blueprint for a Safer Planet", published by Bodley Head in April 2009 (title in the USA is "A Global Deal" and published by Public Affairs), the Stern Review on "The Economics of Climate Change" published by Cambridge University Press in January 2007, or the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
2. Note that the effects of climate change operate mostly through water in some shape or form: storms, floods, drought, sea-level rise.
3. The base of 1990 for emissions reductions is not always stated-but it should be. The 20 Gt CO_2e upper limit in 2050 already involves substantial risk and should not be revised upwards.
4. EU refers to the 27 member countries of the European Union.
5. The reader may wish to consult my recent book "A Blueprint for a Safer Planet", for a detailed description.
6. We should note that this applies to actual emissions and there are strong arguments for rich countries to not only limit their actual emissions to these levels but also to fund emissions reductions elsewhere.
7. See, for example, "A Blueprint for a Safer Planet", Stern, 2009.
8. See, for example, the analysis of the Human Development Report 2007-08 which indicated costs around $85bn p.a. by 2015.

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