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Chapter V

CLIMATE CHANGE MITIGATION AND DEVELOPMENT

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CLIMATE CHANGE MITIGATION AND DEVELOPMENT

A. Introduction

The warming of the global climate system as a result of increasing greenhouse gas (GHG) concentrations in the atmosphere has become a major concern worldwide. Climate change is manifest in higher average global temperatures, rising global mean sea levels, melting ice caps and an increased intensity and frequency of extreme weather events. Most scientific research suggests that the consequences of unabated climate change could be dramatic. And while doubts remain about some of the concrete impacts, it seems clear that global warming will significantly increase the risk of a severe deterioration of the natural environment, with attendant effects on human well-being. It is virtually impossible to reasonably quantify the impact of unabated climate change in economic terms, as this involves a very long time horizon and highly subjective judgments. But because of the large risks and uncertainties, and the potential for severe economic repercussions, strong and early action to mitigate climate change is advocated (Stern, 2006; Weitzman, 2007). Looking at long-term climate change mitigation from this risk-management perspective is not primarily an economic issue but an ethical imperative.

Climate change mitigation has much in common with other processes of structural change in which new economic opportunities arise.

A certain degree of global warming and its related impacts have already become unavoidable and will require adequate adaptation measures. Adaptation is therefore an important issue, which is mainly related to addressing natural disasters in developing countries that suffer the most from the negative effects of climate change. This necessitates substantial financial and technical support for the poorer among the countries affected. A different, though related issue is that of mitigating further climate change by shifting global production and consumption patterns towards the use of more climate-friendly primary commodities, production equipment and consumer goods than the current GHG-intensive ones. This chapter focuses on some of the economic and development policy implications of climate change mitigation.

There is broad agreement that the scale of emission reductions needed to reduce global warming to more acceptable levels requires global action, and that developed countries have to make a major effort in this regard. They are mainly responsible for the current levels of GHG concentration, and they have greater financial and technological capabilities to take the necessary GHG abatement actions. However, developing countries, where GHG emissions are growing rapidly, cannot afford to remain as passive bystanders. Climate change mitigation is as much in their interests as in those of developed countries; it would considerably improve their prospects for development and poverty reduction. The possible linkages or trade-offs between developing-country policies for climate change mitigation and policies geared towards their development and poverty reduction objectives are therefore of central importance for their development path.

Historically, growth has been associated with increasing emissions, which gives the impression of an inevitable trade-off between growth and mitigation. In this chapter, it is argued that efforts directed at climate change mitigation can be compatible with faster growth. However, stronger political will is needed to make emissions regulation and control more stringent and to internalize the hitherto external costs of production and consumption. Furthermore, the wider dissemination of existing technologies and the development of new technologies and more climate-friendly modes of production and consumption cannot be left to market forces alone; they also require strong and internationally coordinated government action.

This chapter shows that developing countries have many options for contributing to climate change mitigation, which deserve to be pursued vigorously with the support of the international community. The economic approach to climate change mitigation has been dominated by calculating the costs of such mitigation and exploring mechanisms for attaining mitigation targets in the most cost-effective way. This chapter takes a different perspective: it argues that climate change mitigation should be associated with a process of global structural change, the parameters for which should be set politically by international agreements and national decisions on desirable reductions of GHG emissions. In the course of this process, demand will shift from GHG-intensive modes of production and consumption to more climate-friendly ones, causing losses and adjustment costs for many economic agents, but also generating new income for others. In this sense, climate change mitigation has much in common with other processes of structural change in which new economic opportunities arise in both developed and developing countries, especially as a result of the rapid growth of new markets.

From this perspective, the challenge for developing countries will be not only to adjust their modes of production and consumption to the requirement of reducing GHG emissions, but also to seize new growth opportunities created by new and fast growing markets. The process of structural change at the global level offers new opportunities for output growth because it may bring with it a revalorization of certain natural comparative advantages, and because the fast growth of domestic and international markets for what is sometimes called "environmental goods" is providing new possibilities for value-added creation.

Section B, which follows, summarizes findings on the economic implications of climate change for different groups of countries. Section C reviews policy measures that have already been introduced or are under discussion in the context of climate change mitigation. Section D elaborates on the notion of viewing climate change mitigation as a process of structural change, and consequently suggests a new interpretation of the economic costs of mitigation policies. In the subsequent section, the interaction between growth and development, on the one hand, and climate policies, on the other, is discussed. This is followed by an examination of specific options for GHG abatement in developing countries. The case is made for integrating GHG abatement policies with development policies. This not only offers considerable potential to generate synergies between climate change mitigation and development, it can also help developing countries gain from global efforts directed at GHG emission reductions, rather than losing out. Section F revisits, from a developing-country perspective, the emerging global framework for climate change mitigation, and the final section summarizes the conclusions of this chapter.

B. Greenhouse gas emissions and the global impact of climate change

Climate modellers expect that by the end of this century accumulated GHG emissions could cause a rise in the average global temperature of up to 6ºC from the mean temperature of 1980–1999, if the current upward trend in GHG emissions is not reversed in the coming decades (IPCC, 2007a, table SPM-2). This global warming trend is a stock-pollutant problem. The emissions of carbon dioxide (CO_2) and other GHGs discharged into the atmosphere are causing relatively little harm by themselves; the main problem arises from the progressive accumulation of these gases over many decades.

There is a strong scientific consensus that most of the increase in the mean global temperature since the mid-twentieth century can be attributed to the progressive rise in atmospheric concentrations of GHGs resulting from human activities since the beginning of industrialization in the eighteenth century (IPCC, 2007b). The main determinants of GHG emissions are economic growth, population growth and technological progress. But there is no mechanical link between these factors and the levels of those emissions; rather, their current levels have been influenced largely by the behaviour of consumers and producers. There are very different levels of emissions for similar levels of development: for example, CO_2 emissions per capita in the United States are more than twice the level found in European countries or Japan, which are at similar levels of development (table 5.1). Efforts to reduce such emissions will therefore also need to focus on encouraging more environment-conscious behaviour among households, firms and public administrations. Accordingly, policies to mitigate climate change by reducing GHGs need to encourage not only the development of cleaner technologies, but also the wider adoption of existing and new, cleaner technologies by consumers and producers.

The rise in GHG concentrations is mainly due to CO_2 resulting from the use of fossil fuels, especially for power generation and transport in developed countries. Another important source of CO_2 emissions is change in land use, mainly deforestation (chart 5.1). Together with emissions of methane and nitrous oxides, which originate primarily in the agricultural sector, CO_2 accounts for nearly 99 per cent of global GHG emissions.

Developed countries account for most of the historical GHG emissions, especially the energy-related ones since 1900, and they are therefore largely responsible for the problem of global warming (IEA, 2008b). They also have much higher current per capita emissions than developing countries. On the other hand, most of the growth in total GHG emissions over the past four decades has taken place outside developed countries. Thus their share in total current GHG emissions fell considerably over the past 35 years. This tendency is expected to persist in the coming decades, primarily on account of the strong economic growth projected for developing countries, especially for the largest economies, China and India. This means that action in developed countries alone will not be sufficient to achieve a reduction in emissions by the amount necessary for obtaining a significant degree of climate change mitigation.

The impact of the accumulation of GHGs is felt not only in global warming, but also through related symptoms, such as changing rainfall patterns, receding glaciers, melting ice caps and rising sea levels. According to most scientific studies, climate change will also result in a higher frequency and intensity of extreme weather events (e.g. droughts, floods and storms), declining water resources, increased transmission of vector-borne diseases (e.g. malaria) and loss of biodiversity.

Table 5.1

CO_2 EMISSIONS RELATIVE TO POPULATION, GDP AND ENERGY CONSUMPTION, 1980–2006

(Tons of CO_2 equivalent)

	1980	*1990*	*2000*	*2006*	*Percentage change 1980–2006*
			Emissions per capita		
World	4.2	4.1	3.9	4.4	3.6
Developed countries	11.1	10.6	11.1	10.9	-1.2
Europe	8.7	7.9	7.6	7.6	-12.6
Japan	7.5	8.7	9.4	9.5	26.7
United States	20.5	15.6	16.0	15.2	-25.7
Transition economies	11.2	12.0	7.3	8.1	-28.3
Developing countries	1.1	1.4	1.7	2.3	105.3
Africa	0.9	1.0	0.9	1.0	17.6
Latin America	2.0	1.8	2.1	2.2	8.6
West Asia	3.8	4.4	5.9	6.8	78.9
Other Asia, excl. China	0.6	0.8	1.1	1.3	133.3
India	0.4	0.7	1.0	1.1	165.1
China	1.5	2.1	2.4	4.3	185.5
			Emissions per $1 000 of GDP[a]		
World	0.7	0.6	0.5	0.5	-32.9
Developed countries	0.7	0.5	0.5	0.4	-39.7
Europe	0.6	0.4	0.4	0.3	-44.1
Japan	0.5	0.4	0.4	0.3	-24.4
United States	0.9	0.7	0.6	0.5	-44.0
Transition economies	1.4	1.7	1.8	1.3	-3.6
Developing countries	0.5	0.6	0.5	0.5	-9.3
Africa	0.4	0.4	0.4	0.4	2.6
Latin America	0.3	0.3	0.3	0.3	-6.7
West Asia	0.4	0.8	0.9	0.9	102.3
Other Asia, excl. China	0.4	0.4	0.4	0.4	-7.9
India	0.4	0.4	0.4	0.3	-8.1
China	1.7	1.2	0.6	0.6	-63.6
			Emissions per ton of oil equivalent[b]		
World	2.5	2.4	2.3	2.4	-4.4
Developed countries	2.6	2.5	2.4	2.3	-11.5
Europe	2.7	2.4	2.2	2.2	-20.4
Japan	2.6	2.4	2.3	2.3	-9.8
United States	2.6	2.5	2.5	2.5	-4.7
Transition economies	2.9	2.8	3.1	2.8	-3.1
Developing countries	1.9	2.1	2.1	2.4	21.1
Africa	1.5	1.4	1.4	1.4	-5.4
Latin America	1.9	1.7	1.9	1.8	-1.6
West Asia	2.6	2.6	2.5	2.5	-4.3
Other Asia, excl. China	1.5	1.8	1.8	2.0	32.5
India	1.4	1.8	2.1	2.2	57.9
China	2.4	2.6	2.7	3.0	26.8

Source: UNCTAD secretariat estimates, based on IPCC reference approach.
Note: CO_2 emissions based on IPCC reference approach.
a Calculations are based on constant 2000 dollars and purchasing power parities.
b An oil equivalent is the common unit of account for energy commodities. It is defined as 10^7 kilocalories (41.868 gigajoules); this quantity of energy is approximately equal to the net heat content of 1 ton of crude oil.

The overall impact will depend on the extent to which the mean temperature rises, but this is non-linear. Thus, there is a risk that critical thresholds ("tipping points") will be exceeded, which could cause irreversible damage to ecosystems and the inability to prevent potentially catastrophic impacts. The latter makes the measurement of the economic impact of climate change very difficult. Estimates in this regard have a large margin of uncertainty because of the long time horizon involved, but they are also highly sensitive to subjective assumptions. Most of the effects are "priceless" in that they are not reflected in any private or national accounting systems (Ackerman and Finlayson, 2006). The impact is often estimated in terms of material wealth lost, for example as a result of the increased frequency and intensity of natural disasters and loss of land due to rising ocean levels, as well as GDP foregone, mainly due to lower agricultural output. According to some such estimates, the cost of inaction in the face of global warming could reach 8 per cent of GDP annually by 2100 (Ackerman and Stanton, 2006; Kemfert 2005; Watkiss et al., 2005).

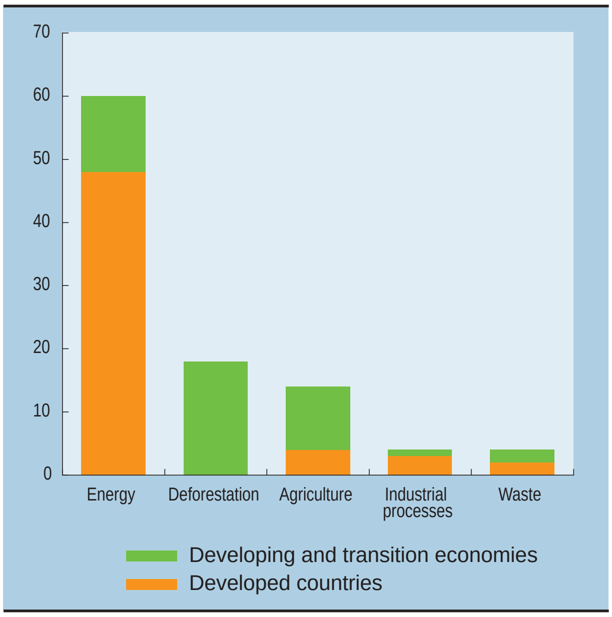
The extent to which the consequences of global warming will affect human life in the future largely depends on the success of environmental and economic policies in limiting GHG emissions through their influence on the patterns of production, consumption, and research and development (R&D). A target that seems viable, both scientifically and politically, is to limit the temperature increase to 2–2.5ºC by 2050 (Stern, 2006; IPCC, 2007b). If this target is reached, a large proportion of the potential damages from, and economic costs of, climate change may be avoided. But even a mean global temperature rise of this order is expected to have significant adverse impacts.

Even though climate change is a global phenomenon, there are large differences in the vulnerability of different geographical regions and individual countries to its symptoms. Climate models that gauge regional impacts of global warming show that developing countries are more vulnerable to climate change than developed countries (table 5.2). Assuming global warming is in the order of 2–2.5ºC, such estimates suggest that Africa, South Asia and West Asia would likely be the worst affected. In developing countries, the costs of climate change reflect mainly their geographical location and their greater reliance on agriculture, forestry and fisheries, which are particularly climate-sensitive. Moreover, the impact of climate change on human health will

Chart 5.1

SOURCES OF CURRENT GHG EMISSIONS

(Per cent of total GHG emissions)



Source: von Braun, 2008.
Note: Agriculture excludes land use changes.

Table 5.2

ECONOMIC IMPACT OF A GLOBAL WARMING OF 2–2.5°C BY 2100, ESTIMATES BY REGION

(Percentage change of GDP)

	Mean	*Lower bound*	*Upper bound*
Developed countries			
North America	0	1	-2
Asia	-1	0	-3
Europe	-1	0	-3
Transition economies	1	0	2
Developing countries			
Africa	-4	-1	-9
Latin America	-2	0	-4
West Asia	-3	-2	-4
South and South-East Asia	-3	1	-9
China	-1	2	-5

Source: Burniaux et. al., 2008: figure 6.2.
Note: Mean temperature increase is measured against the pre-industrial level.

reduce the productivity of the workforce, and extreme weather events, with their attendant effects on physical infrastructure, are also likely to hamper economic growth. In addition, the adaptive capacity of most developing countries is limited due to their widespread poverty, weak institutional capabilities and financial constraints. By contrast, countries at mid- to higher latitudes, such as Canada, the countries of Eastern and Northern Europe and Central Asia, including the Russian Federation, may actually benefit from higher agricultural productivity due to a strong carbon fertilization effect.[1]

In analysing the tangible economic implications of global warming limited to 2–2.5ºC, it is common to distinguish between the needs for adaptation to the inevitable consequences of climate change, on the one hand, and those for managing the process of the structural change necessary to contain the temperature rise within this range on the other.

Adaptation to the adverse effects on ecosystems, biodiversity, fresh water resources, agricultural output, human health and desertification, and to the increased risk of major natural disasters, poses a major challenge and a heavy financial burden for the countries concerned. Although dealing with this challenge requires adaptation programmes that have to be tailored to the specific needs and circumstances of each country, the financial burden should be borne by the international community as a whole. At the same time, developed countries need to acknowledge responsibility for the impact of their emissions that have accumulated over many decades, and provide the necessary support, primarily in the form of aid.

The issue of managing the process required to achieve mitigation targets is distinct from that of adaptation to inevitable climate change; it relates to the need for structural change to reduce emissions. The remainder of this chapter focuses on the economic and developmental dimensions of this process, and on the policies urgently needed at the national and international levels to support and accelerate the process of structural change.

C. Policies for climate change mitigation: some general considerations

1. Correcting market failure

The problem of climate change has arisen as a result of a global market failure: part of the costs of using factors of production is borne by society, rather than by the economic agents that control the underlying activity and profit from it. Thus, GHG emissions are an "external" effect of production and consumption. The absence of mechanisms to make the emitters of GHGs pay a sufficiently high price has led to an overuse of the atmosphere.

The correction of this market failure requires government intervention in the form of policies that will create adequate incentives to deter emitters from producing too many emissions. However, so far governments have been unwilling to impose a carbon price or to introduce regulations that are sufficiently stringent to lead to a substitution of carbon-intensive modes of production and consumption with more climate-friendly ones.

Generally, a distinction is made between two main types of instruments for correcting market failures related to environmental pollution: market-based instruments that establish an explicit price for emissions, and regulations and standards, which create an implicit price for emissions. There is wide agreement that a progressive increase in the price of GHG emissions is a necessary condition for their sizeable abatement to required levels.

Carbon prices are also essential for inducing research and development (R&D) and the diffusion of technologies that are less carbon-intensive. But manipulating markets and introducing a price for future carbon emissions is only a starting point; it is equally necessary for governments to take action to strengthen research in carbon capture and storage technology, support innovation and the diffusion of new, low-carbon technologies, tighten standards for vehicle fuel efficiency and facilitate the transfer of climate-friendly technologies to developing countries (UNDP, 2007: 20, 21). Government intervention in these areas is necessary because the current patterns of production and consumption and the existing technological frontier reflect the lack of appropriate incentives for research on more climate-friendly technologies in the past. "Autonomous" technical progress cannot be expected to advance fast enough to contribute sufficiently to climate change mitigation. For example, solar energy appears to be a promising alternative source of energy, but the capability to capture, store and transport this energy is still woefully underdeveloped.

So far, governments have been unwilling to impose sufficiently stringent regulations that would encourage more climate-friendly modes of production and consumption.

The role of the price mechanism in stimulating R&D and technology diffusion is limited due to the positive externalities and other market failures associated with invention, innovation and technology diffusion. In many respects, the problem of introducing technologies that support climate change mitigation is similar to that of all innovation activities, which, in a dynamic economy, emerge from entrepreneurial spirit and the search for competitive gains. Such activities invariably take place within a system of incentives and disincentives, and within a framework of regulations that imposes or prohibits certain forms of production in line with public preferences. The introduction of more climate-friendly modes of production and consumption is increasingly becoming such a public preference, and therefore cannot be left to market forces alone. The public-good nature of low-carbon technologies and the urgency of reducing GHG emissions in light of the risks of unabated climate change for future generations calls for public support measures in the form of regulations, standard setting and financing. In any case, climate change mitigation will have to involve a mix of different instruments to guide a process of structural change, which depends also on country-specific circumstances. Some of these instruments are discussed next.

2. Carbon taxes, emissions trading and regulation

There are two main types of market-based policy instruments: price-based and quantity-based. A carbon tax is a price-based instrument, because it imposes a direct charge on the use of fossil fuels based on their carbon content. Given that the carbon content is proportional to emissions of these fuels, the carbon tax is equivalent to an emissions tax. In contrast, in a system of tradable permits, the regulator determines the maximum permissible aggregate emission level (the "cap"), and issues corresponding allowances for emission dischargers. Emission allowances can be auctioned, which generates government revenues, or freely distributed, for example in proportion to past emissions ("grandfathering"). Supply and demand for allowances in the emissions trading market then determine the carbon price. Emissions trading is therefore a quantity-based policy instrument.

Theoretically, a carbon tax can achieve the same result as a tradable permit system (Baumol and Oates, 1988), and both can lead to an equalization of the marginal costs of abatement among emitters (i.e. a given emission reduction is achieved overall at the lowest cost). However, in practice both systems have different sets of advantages and disadvantages. Price and quantity controls have different outcomes in the face of uncertainty about compliance costs (Weitzman, 1974).

The key feature of the tradable permit system is that the regulator establishes a target for emissions. The volume of emission reductions is therefore known ex ante, but the abatement cost is not. Carbon prices may be higher or lower than expected and they can also be quite volatile. Uncertainty about abatement costs of future GHG emissions results mainly from the difficulty in predicting the development of low-carbon technologies and baseline emissions. In contrast, an emissions tax, or carbon tax, determines the marginal abatement cost, but the resulting emissions reduction is uncertain: it could undershoot or overshoot the level implicitly targeted by the regulator.

A hybrid "cap-and-tax" system could combine the advantages of a tax (cost certainty) with the environmental advantages of a tradable permit system (emission certainty). Under such a scheme, the government would set an emissions limit, but at the same time would guarantee making additional allowances available at a certain maximum "trigger" price. This maximum price would act as a "safety valve" that would reduce firms' adjustment costs (e.g. in the presence of inelastic capital substitution). It is effectively a carbon tax that would allow emissions without permits. This would prevent companies from having to cut back on output, or even closing down or relocating to countries with less stringent policies. Besides a ceiling on the carbon price, the government could also fix a lower bound price level; if this were crossed, it would intervene by removing allowances from the market. The minimum price would effectively be a subsidy per unit of unused emission permits. The function of the minimum price is to prevent carbon prices from falling below a level that eliminates incentives for investments in low-carbon technologies by firms and households. In a more general way, such a hybrid scheme would be able to cope with unexpected shocks to economic growth and abatement costs. The safety valve function could also become operational in the event of a serious crisis in energy supply (Helm, 2008).

A progressive increase in carbon prices will be necessary to achieve strong emission reductions.

The regulator would need to make periodic adjustments to either carbon taxes or emission ceilings that have been set too high or too low. In any case, both tradable permit schemes and carbon tax schemes would have to be adapted over time to take into account new knowledge about required emission reduction needs and technological change. It is important to make these changes in a predictable way so as not to thwart incentives for R&D and technology diffusion. Given that stringent emission reductions will require a progressive increase in carbon prices over the coming decades, the major question is whether it would be easier for policymakers to adjust tax rates or emission caps (Nordhaus, 2008).

The main reason why cap-and-trade schemes have been the preferred solution in some cases is that they remove uncertainty about the level of emission reductions. Cap-and trade programmes that cover CO_2 emissions (mainly from energy-intensive sectors) are operational in the EU Greenhouse Gas Emission Trading System (EU ETS) and in some other European countries (Norway, Switzerland), as well as in 10 northeastern and mid-Atlantic states of the United States that participate in the Regional Greenhouse Gas Initiative and in some of the more industrialized provinces of Canada. In the United States, a national market-driven system of tradable emission allowances is part of the new American Clean Energy and Security Act.[2]

Viewed from an international climate policy perspective, quantity-based mitigation policies have the advantage that the commitments made by countries in terms of emission reductions over a given time period are widely known. The "targets and timetable" approach is in fact the major characteristic of the current international approach to climate change mitigation enshrined in the Kyoto Protocol (see box 5.1).

An international carbon tax would preclude the need to negotiate national emission target levels. However, it would not only be difficult to administer, but it also implies that the relative adjustment burden would be higher on developing countries that are trailing in energy efficiency. A global carbon market in the form of a cap-and-trade system, as called for in the Stern Review, appears to be a more viable solution (Stern, 2006, 2008a and b). Such a system could be designed in a way that would allow developing countries to sell emission rights that are not needed to cover domestically produced emissions. The amount of financing mobilized for developing countries through such a system would depend on the modalities of the initial allocation of permits.

The effectiveness of introducing a price for carbon, and its subsequent increases, depends on the price elasticity of demand for energy. Price incentives are quite effective in influencing changes in energy use and carbon emissions by industries, but not by households, because household demand for electricity is much less elastic. For both industrial energy use and electricity generation, there are alternative fuels that yield the same result with differing levels of carbon emissions. A higher carbon price would therefore cause a noticeable reduction in industrial energy demand and a relatively small reduction in household electricity consumption, but it would also lead to a shift towards the use of fuels with lower carbon content, such as replacing coal with natural gas.

Use of the price mechanism to influence demand for less carbon-intensive energy is central to market-based intervention ...

The picture is different in the transportation sector, where, so far, petroleum fuels have been practically the only choice.[3] The bulk of crude oil is used for transportation, and a portion of the remainder goes to non-fuel uses such as petrochemicals, where there are no close substitutes. The connection between petroleum and transportation is projected to grow even tighter: transportation is expected to account for about two thirds of the growth in oil demand to end-2030 (EIA, 2007; OPEC, 2007). Thus the oil/transport market is almost disconnected from the market for other fuels and end uses. The lack of alternatives to oil means that, in the short run, price elasticity will remain close to zero for many consumers, and an increase in oil prices is likely to lead to only a modest change in short-run oil demand while representing a heavy burden on consumers.[4] Its main effect will emerge over the longer term, as it will accelerate the transition to more fuel-efficient vehicles.

Use of the price mechanism to influence the demand is central to market-based intervention in favour of climate change mitigation, but it would have to be accompanied by intervention on the supply side of other sources of energy in order to avoid the move towards a low-carbon economy being stalled by unfavourable movements in relative prices. Managing supply adjustments and price formation for different sources of energy is necessary to prevent the prices for non-fossil, renewable sources from increasing in response to fast growing demand for them, while at the same time the prices of the more carbon-intensive types of energy fall. For example, the replacement of coal with gas could be jeopardized if the increasing demand for gas leads to a sharp increase in its price. Gas supply would then need to increase with rising demand, or the price of coal would have to be raised artificially in spite of lower demand for this source of energy. Similarly, cutting down on the demand for oil could lower its price if supply is not adjusted to the lower demand. Therefore, producers of different fuels need to get involved in the formulation and implementation of an international climate change mitigation policy.

... but it has to be accompanied by intervention on the supply side of other sources of energy.

In addition to changes in the incentive structure through the market mechanism, direct government intervention through the introduction of emission performance standards and strict regulations that prescribe specific modes of GHG abatement appears to be indispensable for achieving ambitious targets within the envisaged time horizon. Regulatory standards have already been widely used, notably in developed countries, to address various forms of environmental pollution. They typically prescribe either a specific abatement technology – so-called best-available technology – for limiting the amount of emissions discharged, or they set performance standards (such as maximum emissions per unit of output) while leaving the choice of technology to the emitter. While technology standards are easier to implement than performance standards, they do not provide any incentives for firms to develop more efficient technologies than required by the regulation. They are appropriate when the polluter does not have many options for reducing emissions, or when emissions are difficult to monitor and measure systematically (such as fugitive emissions from pipelines and methane emissions from agriculture). Performance standards, on the other hand, provide emitters with more flexibility for reaching a mandatory emissions target: they can respond, for example, by changing their production technologies, their product mix and/or the types of fuels they use.

Box 5.1

KEY FEATURES OF THE CURRENT MULTILATERAL FRAMEWORK FOR A GLOBAL CLIMATE CHANGE POLICY AND ITS FUTURE

The broad foundation for addressing climate change was established by the United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in 1992 and ratified by 192 countries. The central objective of the Convention is embodied in its Article 2, which provides for the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". But the treaty does not define what that level is. It establishes that climate change is a common concern of mankind, but it recognizes important historical differences in the contributions of developed and developing countries to this global problem. It also recognizes that there are differences in their respective economic, institutional and technical capacities to tackle it. In accordance with the principle of "common but differentiated responsibilities", the treaty calls on developed countries to "take the lead in combating climate change and the effects thereof" (Article 3, para 1). Annex I of the treaty lists the countries (developed countries and countries with economies in transition) that agreed to take on GHG mitigation commitments.

The Kyoto Protocol to the UNFCCC, which was adopted in 1997 but entered into force only in 2005, established for the first time legally binding economy-wide GHG emission targets (excluding emissions from international aviation and maritime transport) for the Annex I countries to the Protocol. Targets are country-specific, but on average Annex I Parties agreed to a 5.2 per cent reduction of aggregate emissions during the period 2008–2012 (the so-called first commitment period) compared with emission levels in 1990 (baseline year).

The Kyoto Protocol abolishes free use of the atmosphere by assigning each Annex I country a certain quota of emission rights based on the emission targets. Since the Protocol does not prescribe how commitments are to be met, there is considerable flexibility in identifying opportunities for GHG emission reductions in different economic activities and in the design of country-specific approaches to climate change mitigation. The Protocol has established three "flexible mechanisms" through which Annex I Parties can attain their emission targets. These are: (i) emissions trading among Annex I countries, (ii) the Clean Development Mechanism (CDM), and (iii) joint implementation.

The economic rationale for emissions trading (cap-and-trade system) is to exploit the differences in marginal abatement costs among emitters within and across Annex I countries. The CDM allows Annex I countries to earn certified emission reductions (CERs), or carbon credits, by investing in GHG abatement projects in developing countries, which can be counted against the national emission targets or traded in the carbon market. In most cases, however, only a limited percentage of emission reductions can be achieved through CERs. This limits the use that can be made of CDM (see box 5.2 below). Joint implementation is similar to CDM, but it is designed to allow an Annex I country to earn emission reduction units by investing in a project in another Annex I country (de facto, mainly transition economies).

It should be pointed out that the Kyoto Protocol puts the mitigation burden of a country only on its production activities, but not on the consumption of carbon-intensive products. This gives producers in developed countries the option to shift carbon-intensive production to developing countries, and/or consumers in developed countries the option to rely increasingly – in the aggregate – on imports of carbon-intensive goods for domestic consumption.

It could be argued that the environmental effectiveness of the Kyoto Protocol will be limited, given the short-term focus and the small magnitude of emission reduction commitments. Besides, the United States, the major emitter of GHGs at the time the Kyoto Protocol was adopted, has not ratified the Protocol, and no formal mitigation commitments are demanded of developing countries. However, the Kyoto Protocol provides a clear signal that climate change mitigation is no longer a concern only for a minority of the population that is particularly sensitive to environmental issues; rather, it is becoming a central parameter

Box 5.1 (concluded)

for public and private decision-making at all levels. Negotiations on the second commitment period of the Kyoto Protocol are currently under way, and are expected to be concluded at the forthcoming United Nations Climate Change Conference, the 15th Conference of the Parties (COP-15), in Denmark in December 2009.

To meet the emission reduction targets set by the Intergovernmental Panel on Climate Change in 2007 (IPCC, 2007a), it will be necessary for a successor agreement to the current Kyoto Protocol to set considerably more ambitious targets and involve a larger number of countries, including all developed and emerging-market economies, which contribute to a rapidly increasing share of the world's GHG emissions. In order to avoid cumbersome negotiations in the forthcoming meetings over which countries should be included in Annex I, it would be desirable to agree on a formula for determining their inclusion. A formula approach would automatically require countries that pass certain thresholds – for example in terms of the size of the economy, per capita income and/or carbon-intensity – to make formal commitments for GHG emission reductions.

3. Technology and innovation policies

While the wider dissemination of existing technology could go a long way towards reducing GHG emissions, climate change mitigation is an imperative that also requires faster creation and application of new technology. Carbon prices may provide a stimulus for accelerating the creation and application of appropriate cutting-edge technologies for carbon reduction compared to past decades. However, there is a high risk that the stimulus may not be strong enough to generate sufficient technological progress to keep up with the speed required to lower emissions, given that, owing to market failures and government lethargy in the past, GHG concentration in the atmosphere has reached a dramatic level. Current modes of production and consumption are shaped by "carbon lock-in", meaning that carbon-intensive technologies gained an early lead at a time when there was little, if any, concern about global warming (Unruh and Carrillo-Hermosilla, 2006). Today, the economic benefits of standardization and the low costs of imitating and replicating existing technologies keep the world locked into that same undesirable path.

In the past, there was considerable underinvestment in research aimed at the development of alternative sources of energy and cleaner production methods, as CO_2 emissions could be generated at no cost. Moreover, private R&D investment is often hampered by the existence of knowledge spillovers, whereby innovators are able to appropriate only a small proportion of the social benefits of their innovations. There are also market failures in the adoption and diffusion of new technologies resulting from learning-by-using, learning-by-doing, or network externalities. And incomplete information about the potential of new technologies frequently slows down their application in practice (Jaffe, Newell and Stavins, 2004; Fischer and Newell, 2004).

> There has been considerable underinvestment in research aimed at the development of alternative sources of energy and cleaner production methods.

A carbon tax, a cap-and-trade system, and more stringent regulations and standard setting will all help to promote the diffusion of climate-friendly technology and advance the technological frontier, but new technologies have rarely evolved independently of public policies. They are created through a process of what is often described as "learning curves" or "experience curves" (Ackerman, 2008; Abernathy and Wayne, 1974). The process of technological change is path dependent, in the sense that the current options available depend on past policies and actions, just as the available technological options in the future will depend on our actions and policies today.

In all countries technological change typically advances faster when it benefits from public support, which can take the form of publicly financed R&D, such as in nuclear power and, more recently, in wind power and ethanol production. Wind power became commercially viable only as a result of decades of government support in the EU, the United States and other countries, in the form of subsidies and support for R&D. The same will be true of other low-carbon energy technologies that will be needed for a sustainable resolution of the climate problem.

Climate-friendly technological change advances faster when it benefits from public support.

It is not merely the financing of research, but also the initial investments in the application of the new technology that help to make it a competitive choice for private enterprises, as prices fall with growing demand and larger scale production. Therefore, in both developed and developing countries, government procurement can play an important role in advancing climate-friendly technological progress, as it has done in other areas in the past. As pointed out by Ackerman (2008: 7): "Computers got their start with military purchases; the Internet grew out of a network sponsored by the United States Defense Department that was set up in the 1960s to connect military researchers around the country … if the world had waited for autonomous technical change or relied on getting the prices right, microelectronics might never have happened." Similarly, public sector initiatives are likely to be essential to ensure that the global economy moves along a climate-friendly path. Direct and indirect subsidies for the diffusion of new technologies and the use of alternative sources of energy can also be crucial. Examples are tax credits for energy-efficient equipment, and price support such as feed-in tariffs for solar- and wind-powered electricity.

As mentioned above, the level of carbon emissions is also determined by individual behaviour patterns at a given rate of growth and a given state of technology. These are influenced to a large extent by regulations and price incentives, but also by climate-related information and knowledge. With regard to energy efficiency, there is often a lack of information on the economic and environmental implications of using certain products, at both the firm and household level. Mandatory labelling pertaining to energy efficiency of consumer goods, including household appliances, cars and office equipment, could help promote more rational purchasing decisions by reducing transaction costs. There is also an important role for governments in raising environmental awareness through education and information campaigns, and demonstrating effective leadership in terms of application of stringent building and appliance standards.

D. Structural change for curbing global warming

In order to curb GHG emissions sufficiently to prevent a mean temperature rise beyond 2–2.5ºC, factors of production will partly have to be allocated to alternative economic activities, and capital accumulation will need to be geared, more than in the past, to the use of sources of energy and modes of production that generate fewer GHG emissions. This process may entail costs for producers and consumers, but efforts to measure the "costs of climate change mitigation" encounter serious conceptual and methodological problems. The economic implications of averting dangerous global warming cannot be adequately addressed within the framework of a traditional cost-benefit analysis, for various reasons. First, not enough is known about the resilience of the ecosystem to global warming, nor about the risks of discontinuous and irreversible changes caused by crossing "tipping points" that could have potentially catastrophic impacts with incalculable costs.

Second, there is little sense in adding up the costs that individual agents will incur in the coming decades by choosing climate-friendly modes of production or consumption instead of carbon-intensive ones. Effective mitigation policies imply structural change in response to the new public preferences. The whole process is comparable to the disappearance of telegraphs, telex machines and public fixed line telephones following the arrival of new communication technologies. More importantly, microeconomic costs on the demand side correspond to incomes generated on the supply side: the production of new technologies and equipment generates income and employment.

Third, these costs are sometimes measured by the input of capital, labour and land to processes that are required to achieve a certain volume of emission reductions, based on the assumption that these resources have to be withdrawn from other uses of value to a firm or society at large. This is a highly theoretical rationale, which assumes full employment of all factors of production in a static sense. In reality, economic activities that are associated with high GHG emissions will indeed be discontinued. Other activities that can be conducted in a more climate-friendly manner are created. Moreover, in the real world there is no full employment of labour, and fixed capital formation in support of one economic activity is rarely crowded out by investment in another economic activity. Rather, increased investment is a driver of overall economic growth and innovation.

Investment in activities that promote climate change mitigation can provide a stimulus for growth and employment creation.

To some extent, climate change mitigation may be achieved by reducing certain forms of consumption. But primarily it entails switching to or increasing expenditure on alternative types of energy, technology, production equipment and final goods. From this perspective, investment in activities that promote climate change mitigation is likely to create new income in addition to existing output, and implies a potential stimulus for growth and employment creation.

Official estimates of the economic costs of climate change mitigation do not reflect these macroeconomic dynamics of structural change, and should therefore be taken with cautions. These estimates are

Table 5.3

LOSS OF GDP FROM CLIMATE CHANGE MITIGATION: SELECTED ESTIMATES

	Stabilization of GHG concentrations		*Loss of GDP*	
	At CO_2 equivalent ppm[a]	*Target year*	*Per cent*	*Target year*
IPCC	445	2050	-5.5	2050
Burniaux et al./ OECD	550	2050	-4.8	2050
IMF	535–590	2100	-2.6	2040
Stern Review	550	2050	-1.0	2050

Source: IPCC, 2007a; Burniaux et al., 2008; IMF, 2008; Stern, 2006.
a Particles per million.

based on a comparison of two hypothetical future states of the economy: a baseline scenario, which projects economic developments and emissions in the absence of specific mitigation policies, and an alternative scenario that includes policies to achieve a certain volume of emission reductions. The results of such estimates depend on a host of assumptions concerning economic growth trends, future price levels of fossil fuels, substitution opportunities and the rate of technological progress.[5] They normally exclude the possibility of shifting preferences. The timing and location of mitigation measures influence the overall costs, because of the long-service life of energy-intensive capital stock and the costs of premature scrapping, as well as the fact that an equal reduction of emissions can be achieved at lower costs in countries that are relatively far from the existing technology frontier.

Official estimates along these lines suggest that accumulated global macroeconomic costs of mitigating climate change by limiting GHG concentrations to levels at which global warming can be expected not to exceed 2.5ºC could be in the order of 5.5 per cent of global GDP in 2050 (table 5.3). This corresponds to a reduction in the average annual rate of global economic growth in the order of 0.15 percentage point between 2010 and 2050. To put this in perspective, the same models typically assume that in 2050, the world's real GDP will be more than twice its current level. In developing countries, aggregate GDP is projected to increase, on average, by a factor of four by 2050. Moreover, these costs of mitigation would have to be compared with the costs of unabated climate change, which are impossible to quantify reasonably in terms of economic accounting, but which, according to many experts, could be much larger.

Thus, the standard model estimates suggest that the net costs of mitigation for the world economy as a whole would be fairly small, even though they assume exogenous technological progress. Yet decisive policy action in support of climate change mitigation is likely to spur not only the wider application of existing climate-friendly technologies, but also to accelerate the development of new technologies that favour cleaner modes of production, consumption and energy generation. This aspect is partly captured in models that allow for induced technological change and consequently show even lower macroeconomic costs than models that assume exogenous technical progress, if not overall benefits (Barker, Qureshi and Köhler, 2006).

> The macroeconomic costs of mitigating climate change may be negligible for the world economy as a whole, but they may differ considerably across countries …

However, while the macroeconomic costs of mitigating climate change may be negligible for the world economy as a whole, the net costs of adjusting production and consumption patterns to meet global mitigation target may differ considerably across regions and countries, depending on the extent to which climate-friendly technologies and environmental goods are available domestically or have to be imported from abroad. The latter aspect is of major importance for the international distribution of income generated by the production of more climate-friendly technologies, infrastructure, equipment and consumer goods. It is taken up in section E.4 of this chapter, which focuses on the design of development strategies that include climate change mitigation.

The potential economic opportunities arising from the transition to a low carbon economy may be illustrated by calculations of the International Energy Agency (IEA), based on a comparison of estimated future expenditures on low-carbon technologies for meeting a given projected increase in energy demand under specific emission constraints and hypothetical investment expenditures for traditional fossil-fuel-based technologies. These *incremental* expenditures during the period 2010–2030 will be within a range of $200 billion per annum for stabilizing GHG concentrations at a level that limits the increase in the mean global temperature to 3˚C, and $450 billion per annum to limit global warming to 2˚C (IEA, 2008a). This corresponds to 0.3–0.7 per cent of global GDP in 2008. About half of this additional capital expenditure will have to be made by developing countries, a large proportion by China and India. For individual economic agents, these investment costs will likely be offset to a large extent by fuel savings over time.

... depending on the extent to which climate-friendly technologies and products have to be imported from abroad.

The UNFCCC (2008a) has provided estimates of additional global financing needs, not only specifically for the energy sector but also for moving more generally to more climate-friendly products and processes. These estimates suggest that the worldwide annual additional expenditures involved in shifting towards more climate-friendly modes of production and consumption would amount to $440–$1,800 billion per annum up to 2030, equivalent to 0.7–2.1 per cent of world GDP in 2008. Between $180 and $500 billion of this world total would have to be borne by developing countries annually, corresponding to 1.1–2.9 per cent of their GDP in 2008 (and falling to 0.3–0.8 per cent of their GDP in 2030).

Against this background, major concerns have been raised that commitments of developing countries to GHG emissions reduction will jeopardize their development objectives. This issue is addressed in the next section.

E. Climate change mitigation and the development imperative

1. *Emissions reduction, growth and development*

There is a commonly held belief that significant reductions in GHG emissions inevitably imply a trade-off with economic development. This perception is based on the understanding that the key to progress in development and poverty eradication is sustained economic growth, and that, since the beginning of industrialization, economic growth has been accompanied by a greater use of natural resources (notably fossil fuels), environmental pollution and the accumulation of GHG emissions. However, since more recent industrialization has also been accompanied by a reduction in current emissions relative to GDP, it may not be necessary for future development to repeat the experience of the past.

The overall impacts of economic growth on emissions such as CO_2 can be decomposed into three effects (Copeland and Taylor, 2004):

- A scale effect (i.e. additional emissions due to increasing production and consumption);
- A composition effect (i.e. the change in emissions due to a shift in the structure of production

and consumption towards activities and products with lower emissions intensity);

- A technology effect (which reflects the favourable impact of technological progress in terms of lowering emissions per unit of output).

Theoretically, an increase in emissions can be avoided if the scale effect of economic growth is offset by the composition and technology effects, but historically the technology effect has not kept pace with the scale effect. However, it should be noted that this has been the outcome of a major market failure: the use of the environment as a factor of production has not been included in cost and price calculations, resulting in its overuse. The relative importance of each of the three determinants for emissions, and the interactions between them, depend on how growth dynamics unfold over time in response to the pattern of relative prices and to legal and policy frameworks. They will be influenced by economic, environmental and technology policies, which can set appropriate incentives for economic behaviour that limits CO_2 emissions and appropriate disincentives for behaviour that continues to produce such emissions.

This means that, while slower economic growth based on given patterns of production and consumption could help reduce GHG emissions, it is not a precondition for climate change mitigation, nor is it a requirement for developing countries that are at relatively early stages of their industrialization. However, governments in both developed and developing countries need to influence the pattern of growth (i.e. the patterns of inputs and outputs) (Arrow and Bolin, 1995). This is not an entirely new challenge. Shaping structural change has been a key element in the design of successful development strategies that have focused on diversification away from a reliance on only a few export commodities and towards building comparative advantages in other areas of economic activity. Such strategies have given particular emphasis to industrialization in sectors that are expanding both nationally and internationally.

In many areas this structural change offers the possibility of synergies between the pursuit of mitigation and development objectives (Cosbey, 2009). The first reason why climate change mitigation has a positive impact on development is that in its absence there would be an increased risk of a significant slowdown in development progress. But there is also a potentially positive link between policies that favour climate change mitigation, on the one hand, and policies that support growth and development on the other. Considerable reductions in GHG emissions have already been achieved in both developed and developing countries as a by-product of policies that are primarily aimed at other objectives, such as raising overall productivity, diversification or increasing energy security. Conversely, many national policy measures in support of climate-friendly structural changes may also help achieve development objectives, including providing new employment opportunities and reducing poverty (UNCTAD, 2009a).

> Slower economic growth is not a precondition for climate change mitigation.

Beyond these possible synergies, the imperative of climate change mitigation also sets new parameters for development strategies: it implies a worldwide move towards new sources of energy, the development of new technologies and the production of equipment that embeds such technologies, as well as the adoption of more climate-friendly consumption patterns. This opens up new opportunities for creating value added in the markets for more climate-friendly energy, equipment and consumer goods. For some countries it may offer new possibilities to exploit natural comparative advantages that so far have been of minor importance economically, and for many others it may offer opportunities to build new dynamic comparative advantages.

2. *Options for climate change mitigation in developing countries*

(a) *Production and use of energy*

Energy supply is the largest single global source of CO_2 emissions, and, with current technology and sources of energy, growing levels of per capita income will lead to greater energy consumption in all major regions of the world in the coming decades. Thus production and use of energy are the priority areas of action for climate change mitigation. In these areas, developing countries face three major challenges. They need to: (i) satisfy the energy needs of their large number of rural poor, most of whom are not connected to any grid, while also increasing the provision of energy in urban centres to boost overall production capacity and accommodate rising household demand; (ii) switch from traditional to cleaner sources of energy, enhancing, in particular, the use of renewable energy from solar, wind, hydro or geothermal sources; and (iii) combine the increased total energy supply with measures to raise efficiency of production, dissemination and end use of energy.

About 2.5 billion people, or 40 per cent of the world's population, most of them in South Asia and sub-Saharan Africa, still experience energy poverty. They rely on traditional biomass fuels for cooking and heating, with associated ambient air pollution and adverse effects on health. And about 1.6 billion people have no access to electricity. Nevertheless, energy demand in developing countries has been rising sharply in all major regions in recent decades. Energy consumption during the period 1990–2006 in developing countries rose at an average annual rate of 4.1 per cent, compared to a world average of 1.8 per cent, reflecting robust economic expansion and associated growth in real per capita incomes. As a result, the share of developing countries in global energy demand increased to some 42 per cent in 2006, up from 29 per cent in 1990. China and India alone accounted for 21 per cent of global energy demand in 2006, compared with 13.6 per cent in 1990. This trend is expected to continue. Thus, although developing and transition economies consume much less energy per capita than developed economies at present (table 5.4), they will account for the bulk of growth in global energy demand by 2030 (IEA, 2008a). Again, China and India alone are expected to account for half of this increase.

> Developing countries need to combine an increase in total energy supply with a greater use of renewable sources of energy and higher energy efficiency.

With regard to energy use per capita, there is considerable variation in regional levels and trends. In Africa, there has been only a moderate upward trend since 1980, with levels only about one third of the world average in 2006. The past few decades have seen very little growth in energy use per capita in Latin America. However, in India there has been a steady upward trend, although its overall energy consumption per capita was less than one third of the world average in 2006 and about half of its population has no electricity supply. China's energy consumption per capita more than doubled between 1980 and 2006, but compared with consumption levels in developed countries it is still much lower (by nearly 70 per cent).

The strong growth in energy consumption has led to a sharp rise in CO_2 emissions. Developing countries accounted for 41 per cent of global energy-related CO_2 emissions in 2006, compared with some 26 per cent in 1990. By 2020, developing countries are expected to contribute to more than half of global energy-related CO_2 emissions and for an even larger share (56 per cent) by 2030. China's share in energy-related CO_2 emissions is projected to increase from about 20 per cent to nearly 30 per cent by 2030. China, India and West Asia combined are projected to account for more than 40 per cent of global CO_2 emissions in 2030, up from some 30 per cent in 2006. Similar to energy use, per capita CO_2 emissions in developing countries are on an upward trend, but have remained significantly lower than in developed countries (see table 5.1 above).

Although economic growth is generally associated with higher energy demand, the energy intensity of economic activity (i.e. energy use per unit of real GDP) can be expected to vary with the stage of development. In the process of industrialization, and with per capita incomes growing up to a certain level, developing countries' energy consumption intensity typically increases, but with greater affluence the structure of the economy tends to shift from heavy to light industry and services. This leads to a fall in the intensity of energy use (Hannesson 2002; *TDR 2005*, chap. II, sect. B). On average, the intensity of energy use has been on a slightly downward trend in developing countries over the past three decades. South, East and South-East Asia, where the intensity of energy use is quite similar to that in developed countries (table 5.4), have contributed strongly to this overall trend, even if China is excluded.[6]

A number of other developing countries have achieved considerable improvements in their intensity

Table 5.4

ENERGY USE RELATIVE TO POPULATION AND GDP, 1980–2006

(Tons of oil equivalent)

	1980	*1990*	*2000*	*2006*	*Percentage change 1980–2006*
	Energy use per capita				
World	1.63	1.66	1.65	1.80	10.43
Developed countries	4.22	4.33	4.71	4.70	11.37
Europe	3.18	3.26	3.40	3.49	9.75
Japan	2.96	3.59	4.15	4.13	39.53
United States	7.95	7.70	8.15	7.74	-2.64
Transition economies	4.26	4.80	3.09	3.87	-9.15
Developing countries	0.56	0.66	0.79	0.97	73.21
Africa	0.58	0.62	0.62	0.66	13.79
Latin America	1.01	0.97	1.10	1.17	15.84
West Asia	1.44	1.74	2.34	2.76	91.67
Other Asia, excl. China	0.36	0.45	0.61	0.63	75.00
India	0.30	0.38	0.45	0.51	70.00
China	0.61	0.77	0.88	1.44	136.07
	Energy use per $1 000 of GDP[a]				
World	0.29	0.26	0.22	0.20	-31.03
Developed countries	0.26	0.22	0.20	0.18	-30.77
Europe	0.22	0.18	0.16	0.15	-31.82
Japan	0.18	0.15	0.16	0.15	-16.67
United States	0.35	0.27	0.24	0.21	-40.00
Transition economies	0.48	0.61	0.57	0.48	0.00
Developing countries	0.28	0.27	0.23	0.21	-25.00
Africa	0.26	0.29	0.30	0.28	7.69
Latin America	0.16	0.17	0.16	0.15	-6.25
West Asia	0.17	0.30	0.35	0.36	111.76
Other Asia, excl. China	0.25	0.22	0.22	0.17	-32.00
India	0.26	0.23	0.19	0.15	-42.31
China	0.74	0.45	0.22	0.21	-71.62

Source: UNCTAD secretariat estimates, based on IPCC reference approach.
a Calculations are based on constant 2000 dollars and purchasing power parities.

of energy use as a result of policies to strengthen overall productivity, even without the explicit objective of contributing to reducing global warming. Brazil, China, India and Mexico have reduced their CO_2 emissions growth over the past three decades by some 500 million tonnes per annum – an amount that exceeds what the Kyoto Protocol requires of Annex I countries (IPCC, 2007b; Chandler et al., 2002).

There appears to be a huge potential for greater energy efficiency that could be exploited by wider dissemination of existing technologies in both developed and developing countries (UNCTAD, 2009a). The large difference in CO_2 emissions between the United States, Europe and Japan reflects, among other things, different degrees of application of existing technologies. For example, if Chinese coal power plants were to reach the average efficiency of Japanese plants, China would consume 20 per cent less coal (World Bank, 2007).

A large amount of GHG emissions could be prevented at the level of end users, through the introduction of efficiency standards and labelling, and by mandating the use of low-energy appliances and energy-efficient construction of new buildings. According to IEA estimates, a package of 25 energy efficiency measures could save up to one fifth of the global emissions projected for 2030 in a reference scenario (IEA, 2008b; Cosbey, 2009: 27). The timing of such efforts is important, not only from an environmental perspective, but also from an economic point of view: replacing or retrofitting an existing capital stock is much more difficult and generally more costly than mandating efficiency at an early stage. Power plants have a long service life, which can exceed 50 years. Therefore, the continued construction of relatively inefficient plants based on traditional fuels implies a risk of technology lock-in with associated high GHG emissions, even though in this case climate change mitigation could be achieved with the help of carbon capture and storage technologies (Gallagher, 2007).

A number of policies are already in place to encourage the development and deployment of low-carbon-emitting technologies in several developed countries, as well as in some developing countries, including Brazil, China, India and Mexico. Many developing countries have adopted targets for enhanced use of renewable sources of energy (table 5.5). Indeed, the share of developing countries in worldwide investments in energy efficiency and use of renewable sources of energy has risen steeply, from 13 per cent in 2004 to 23 per cent in 2007, partly as a result of improved policy and regulatory frameworks for clean energy investments, and partly in response to rising petroleum prices and concerns over supply constraints (UNEP, 2008). An outstanding example of these policies is Brazil's national ethanol programme for motor vehicles (PROALCOOL), which was launched in 1974 to reduce its dependence on oil imports. More recent policy measures in Brazil aim at the promotion of biodiesel and renewable energy technologies (PROINFA).

Table 5.5

SHARE OF RENEWABLES IN ENERGY CONSUMPTION IN 2006 AND TARGETS FOR 2020

(Per cent of total energy consumption)

	2006	*2020 target*
Developing countries		
Argentina	8.2	..
Brazil	43.0	..
China	8.0	15.0
Egypt	4.2	14.0
India	31.0	..
Indonesia	3.0	15.0[a]
Jordan	1.1	10.0
Kenya	81.0	..
Mali	..	15.0
Mexico	9.4	..
Morocco	4.3	10.0[b]
Republic of Korea	0.5	5.0[c]
Senegal	40.0	15.0[a]
South Africa	11.0	..
Thailand	4.0	8.0[c]
Developed countries		
Canada	16.0	..
European Union	6.5[d]	20.0
Japan	3.2	..
United States	4.8	..

Source: REN21, 2008, table R.7.
a 2025.
b 2010.
c 2011.
d 2005.

In energy-intensive industries, such as iron and steel, non-ferrous metals, chemicals, petroleum refining, cement, and pulp and paper, the main options for CO_2 abatement include improved energy efficiency and fuel switching. Many facilities in these sectors are relatively old and inefficient in terms of energy use, but there are also a number of others in developing countries that are new and already operate with the latest technology and use less energy. As these industries are expanding faster in developing countries than in developed countries, there are also greater opportunities for CO_2 abatement when developing countries invest in additional production capacities. This points to the need for strengthening regulatory standards to accompany the development of these industries in developing and transition economies, not least to discourage the relocation of production associated with high GHG emissions from countries with stronger environmental regulations to countries where such regulations or their enforcement are lax or non-existent.

In the construction industry, CO_2 abatement can be achieved mainly by improving energy efficiency in new and existing buildings. Among the major instruments are building codes that establish stringent energy efficiency standards, and strict product standards for lighting and electrical appliances. CO_2 emissions can also be significantly reduced even with existing mature technologies for energy efficiency. To support the use of such low-cost abatement opportunities it is important to improve the dissemination of public information on the possible microeconomic gains from energy efficiency measures, alleviate financing constraints, and eliminate subsidies for energy use based on fossil fuels (McKinsey Global Institute, 2007).

The development of energy-efficient industries should be accompanied by strengthened regulatory standards.

In transport, the main mitigation options are energy switching, introduction of fuel-efficiency standards, a modal shift from road to rail transport, and greater use of public transport systems. Growing transportation activity is part of economic development, and an appropriate transport infrastructure is a prerequisite for many economic activities. Thus the share of developing countries in transport-related CO_2 emissions is projected to grow rapidly in the coming decades. With current technology, transport relies predominantly on petroleum, which accounts for 95 per cent of the total energy used for transport worldwide. Today, transport is responsible for 18 per cent of global CO_2 emissions and it is one of the most rapidly growing sources of such emissions in both developed and developing countries. Road transport accounts for 72 per cent of transport-related CO_2 emissions (Baumert and Winkler, 2005). Shipping, on the other hand, which is the predominant means of global freight transport, is already one of the least energy-intensive transport modes; nevertheless, there appear to be relatively large opportunities for improving energy efficiency even in this sector (IPCC, 2007a).

The limited scope for substitution of petroleum has been a major reason for the highly price-inelastic demand for vehicle fuels. With “business as usual”, CO_2 emissions from road transport are expected to increase by almost 40 per cent until 2030 (IEA, 2008b; Cosbey, 2009: 31).[7] Under these circumstances, significant CO_2 abatement can only be achieved by large increases in fuel prices or taxes, or by introducing prohibitive measures. This can be a problem in rural areas with predominantly low-income populations, or in areas where public transport is often lacking or is not a sufficiently attractive alternative to private cars. But in urban areas, well-designed public policies and urban planning can make an important contribution to reducing emissions by influencing transportation choices.

Stringent efficiency standards for vehicles may help lower CO_2 emissions, but integrated urban planning that seeks to reduce the need for transportation and encourages commuting by offering attractive means of public transport is equally important.[8] This would not only cut down on energy use and CO_2 emissions, but would also improve the quality of life of the population and productivity. Examples of the implementation of eco-efficient transport networks are the cities of Curitiba in Brazil and Bogota in Colombia. Curitiba pioneered the idea of an efficient all-bus transit network, which inspired a similar approach (TransMilenio) in Bogota (Cosbey, 2009).

(b) Agriculture and forestry

Agriculture will likely be the worst-hit economic sector from global warming, particularly in developing countries. On the other hand, it is itself a major source of emissions, contributing 10–12 per cent of total global anthropogenic GHG emissions. Of the total agriculture-related emissions in 2005, 75 per cent originated in developing countries (UNFCCC, 2008b).[9] Moreover, projected population growth and changing diets with greater meat intake, associated with rising per capita incomes, particularly in developing countries, will lead to even larger increases in agriculture-related emissions.

In agriculture and forestry, rising current GHG emissions are mainly attributable to changes in land use. Adjustments in these sectors could contribute significantly to GHG abatement, without much technological innovation. They include, for example, improved crop and grazing land management, such as the restoration of organic soils that have been drained for crop production and restoration of degraded lands. In addition, soil carbon sequestration could contribute to 90 per cent of the mitigation potential of agriculture (representing between 11 and 17 per cent of the total mitigation potential). Improved water management and rice management,[10] as well as improved livestock and manure management, are other important options for developing countries. Indeed, 70 per cent of the mitigation potential of this sector could be achieved in developing countries (IPCC, 2007b). GHG emissions could also be reduced by substituting fossil fuels with agricultural feedstock for energy production.[11]

Slowing down deforestation is a high-priority mitigation option in tropical regions.

Sustainable agricultural production methods, including organic agriculture, can contribute to climate change mitigation and other improvements in the environment through the reduction or elimination of chemical pollutants, and water and soil conservation practices. Organic agriculture improves soil fertility and structure, thus enhancing water retention and resilience to climatic stress. It also mitigates climate change by utilizing less energy than conventional agriculture and by sequestering carbon (UNCTAD, 2009a and b).

Forests serve as sinks of GHG emissions, so that deforestation implies the loss of these important environmental sinks. Deforestation and forest degradation in developing countries are estimated to account for some 18 per cent of global GHG emissions. Their main objective is to gain land, in Africa for subsistence farming and in Latin America for the extension of large-scale cattle ranching and soy plantations. In South-East Asia, deforestation occurs mainly for timber production and for palm oil and coffee plantations (Stern, 2006, chap. 25). Reducing and reversing deforestation is believed to offer the highest potential of any sector to contribute to low-cost mitigation between now and 2030 (Enqvist et al., 2007). It should therefore be considered a high-priority mitigation option in the tropical regions of Africa, Asia and Latin America.

Important instruments in this area are programmes at the national and international levels to reward the avoidance of deforestation. Several countries in Latin America are already making efforts in this direction. Costa Rica and Mexico pay premiums to landowners for protecting forests, and Brazil has launched an international fund to attract financing for programmes that help preserve the Amazon rainforest, with an initial pledge of $100 million by Norway. While the principle of rewarding avoided deforestation is straightforward, several difficulties in verification and monitoring still have to be overcome. The terms "forest", and thus also "deforestation", are not easy to define, and there are problems arising from the possibility that one country's avoided deforestation might lead to accelerated deforestation elsewhere (Watson et al., 2000). Programmes that aim at avoiding deforestation have to be supported by strengthening national legal and regulatory systems as well as national capacity for resource management.

(c) Administrative and institutional capacity-building

Mitigation policies and strategies need reliable and comprehensive data for setting goals, monitoring policy implementation and elaborating plausible scenarios for future emissions. Designing effective mitigation strategies also requires reliable projections of future emissions. This not only depends on an accurate and comprehensive inventory of GHG emission sources and sinks, but also on a good understanding of the key economic drivers of emissions. The development of reliable GHG inventories is also necessary to enable firms to gain insights into their mitigation opportunities and GHG-related risks.

Developing countries should enhance their capabilities for effective participation in international climate policy negotiations.

The UNFCCC requires developed countries to submit such inventories on an annual basis, whereas reporting obligations are much less stringent for developing countries. In a 2005 UNFCCC compilation of national communications from developing countries on GHG emissions, most of the countries reported data for 1994 only (UNFCCC, 2005a,b; 2008c). For more than half of the countries, some important activity data were either lacking or not accessible. Major problems are the lack of institutional capacity for the collection, storage and management of the data needed for preparing a GHG inventory. This is an area where developing countries could benefit considerably from technical assistance. The GHG Protocol Initiative, for example,[12] has been promoting common standards and tools for GHG measurement, as well as capacity-building.

In order to reap possible development benefits from global climate change mitigation efforts, developing countries also have to enhance public sector capabilities for designing, implementing and monitoring climate policy measures, for effective participation in international climate change negotiations, and for effective use of international instruments such as the Clean Development Mechanism (CDM) (Willems and Baumert, 2003; Gallagher, 2007; see also box 5.2 below).

Clearly, this approach would have to be tailored to country-specific circumstances, but it involves institutionalizing a close dialogue between all key actors and institutions, including the relevant ministries, industries and research institutions. Such a forum could play a key role in managing the integration of efforts in support of climate change mitigation with those in pursuit of development objectives. This would include identifying synergies between climate change mitigation and development, and increasing participation in the markets for innovative, climate-friendly products and services. These are discussed in the next section.

3. Development opportunities arising from climate change mitigation

(a) Synergies

The effects of GHG abatement will not only be felt globally in terms of better climatic conditions conducive to economic and social progress in the developing world, compared to non-action; many effects will also be felt at the local level in the countries, regions or cities where efforts to mitigate climate change are undertaken, in the form of improved air, water and land quality, with attendant benefits for health and labour productivity. There are also concrete synergies between strategies for climate change mitigation and development (Cosbey, 2009; UNCTAD, 2009a). For example,

- There is broad agreement that the provision of energy to the poor constitutes developmental progress in its own right. In many cases, this objective can be pursued using energy from renewable sources at the micro level (e.g. biogas digesters, micro hydropower, solar cookers or photovoltaic panels can reduce the need for large energy infrastructure investments).
- In combination with measures for forest conservation, equipping poorer households with more climate-friendly energy sources will also lead to substantial benefits in terms of reduced indoor air pollution from inefficient biomass use and its attendant health problems.
- Increasing national energy efficiency generates considerable benefits for the national economy in terms of greater productivity and stronger international competitiveness of domestic producers.
- Efforts to achieve household energy efficiency will allow households, particularly the poorer ones, to switch their expenditures from heating and lighting to other purposes, including health and education.[13]
- Elimination of subsidies for traditionally produced energy can free substantial resources for use elsewhere, including public investment in more climate-friendly technologies and equipment.
- Efforts to restore forest cover or avoid deforestation or land degradation have important effects on development, as they help improve flood control in watersheds (Stern, 2006).
- Reducing the need for commuting through proper urban planning and providing attractive means of public transport would also improve the quality of life of the population and increase overall productivity.
- Switching to different sources of energy, in particular towards locally available renewable sources, would free foreign exchange for the purchase of capital goods, including equipment

that uses climate-friendly technology. It would also contribute to local employment generation, and thus to poverty reduction. For example, Brazil's ethanol programme, which seeks to replace petroleum as automobile fuel, has not only avoided 26 million tons of CO_2 emissions annually, it has also reduced energy import costs by almost $100 billion compared to a baseline scenario, and created hundreds of thousands of jobs for the rural population (Bradley and Baumert, 2005).

- A greater share of renewable sources of energy in the overall energy mix also enhances energy diversification and energy security, which are pursued as objectives in their own right. It thus helps to ensure smooth and continuous access to energy at affordable rates, and shields countries from the balance of payments impacts of fluctuations in global prices of fossil fuels (IEA, 2008c; Bacon and Mattar, 2005).[14]

(b) New market opportunities

More stringent climate-related standards and policies, in conjunction with increased consumer preferences for "green products" have already led to a rapidly growing global market for environmental goods and services. Private investments in energy efficiency and renewables rose from $33.2 billion in 2004 to $148.4 billion in 2007. New fixed investments in clean energy in 2007 were equivalent to 9.6 per cent of global energy infrastructure investment and 1 per cent of fixed capital formation (UNEP, 2008). Since dynamic growth in many developing countries has put enormous pressures on their national environments, policymakers in these countries are increasingly realizing that environmental pollution and inefficient use of raw materials entail huge costs. As a result, there is considerable potential for further growth of the market for energy from renewable sources and for equipment to generate such energy, as well as for energy-efficient cars, buildings and appliances. The overall size of this market is difficult to gauge, given that many environmental goods can also be used for purposes other than environmental protection. According to estimates by a leading private strategy consulting firm, the global market for environmental products and services may amount to as much as $1,400 billion (UNEP, 2008). Equipment that helps achieve climate change mitigation represents a significant share of this market.

Thus, there are considerable opportunities for income generation through increased participation in this market. Developing countries could seek such participation by integrating into international production chains, as many of them have successfully done in other fast-growing sectors. In addition, they themselves could contribute to innovation in climate protection processes and environmental goods based on specific local circumstances and comparative advantages. The development of "clean technologies" and early participation in the production of equipment embodying such technologies in the context of a rapidly expanding international market confers "first-mover advantages", given that other countries will eventually need to adopt these technologies as well. So far, the global export market for environmental goods is still clearly dominated by developed countries, which account for about 80 per cent of the total traded value of such goods. But developing economies such as Brazil, China, India, Indonesia, Malaysia and Taiwan Province of China already account for an increasing share of this market. China, for example, is already a major producer of equipment in the global wind power market, and it is among the world's largest producers of solar cells and lighting products. Brazil is the second largest global producer of biofuels, and India's photovoltaic production capacity has expanded rapidly in recent years (REN21, 2008; UNEP, 2009).

> Developing countries should seek to participate in the rapidly growing global market for environmental goods and services.

As environmentally sound equipment, consumer goods and sources of energy can be considered "sunrise" industries, developing countries could improve their prospects for growth and employment creation by directing their industrial and agricultural development in this direction (UNCTAD, 2009a). Initially, many developing countries will be mainly engaged in adapting these new technologies to their specific national and local contexts. But if integrated into a broader development strategy, these efforts could ultimately lead to the development of domestic supply capacities for exporting these adapted technologies to other countries with similar needs. This represents a growing potential not only for exports to developed countries but also for enhanced South-South trade.

Promotion of these technologies will require an appropriate framework for technology transfer. It will also require the development of mechanisms to promote domestic knowledge accumulation, technological learning and innovation in order to increase technological absorptive capacity. The level of domestic technological capabilities will determine to what extent developing countries could, where possible, move directly ("leapfrog") to the frontier technologies developed in industrialized countries, rather than merely imitating and adapting second-best technologies with a strong emphasis on end-of-pipe solutions.[15]

4. *Integrating climate change mitigation policies with development strategies*

Although responsibility for the already high levels of GHG concentrations in the atmosphere rests primarily with developed countries, developing-country governments should not remain passive. There are growing opportunities for their economies resulting from increasingly stringent policies for GHG abatement around the world. The most effective way forward is to integrate climate change mitigation strategies with more proactive national industrialization strategies. As in other areas of industrial policy, in order to benefit from these opportunities a set of coherent policies and effective institutional arrangements is needed that supports the process of economic restructuring and technological change. It will also be necessary to integrate the development and diffusion of climate-friendly technology, equipment and consumer products with wider national R&D, innovation and investment promotion policies (Rodrik, 2008; *TDR 2006*, chap. V).

Climate policies will involve a revalorization of comparative advantages and open new options for agricultural and industrial development. Relying on market forces to trigger adequate responses to the new challenges and opportunities would be risky in light of both objectives: achieving the desired limit of global warming and successfully integrating developing countries in the markets for climate-friendly energy, technology and equipment. Experiences with economic catch-up in mature and late industrializers (*TDR 2006*: chap. V; Amsden, 2001; Chang, 2002; Rodrik, 2006) have shown that the dynamic forces of markets that underlie structural change and economic growth can be, and often have to be, stimulated by targeted government policies.

The main reason for such policy support is insufficient information and associated uncertainty about the viability of new modes of production or the success of new products. This is particularly the case in countries and sectors where industrial development is at a relatively early stage and the scope for imitation is relatively limited. This uncertainty may discourage investment in new, low-carbon modes of production and the integration into markets for innovative, climate-friendly technologies, equipment and consumer goods. Supportive policies could help improve the information base for decision-making and thereby encourage the necessary investment, which in turn could lead to economies of scale. Such support should take into account both national needs for climate-friendly technologies and products, as well as the structural move towards their use at the global level that offers opportunities for strategic integration into the global market for these products.

The dynamic forces of markets that underlie structural change and economic growth often have to be stimulated by targeted government policies.

Many developing countries are likely to have natural comparative advantages – especially in the production of energy – that become more valuable in an era when the level of CO_2 emissions has to be sharply reduced. For example, solar, wind and hydro energy are likely to be highly valued substitutes for fossil fuels in domestic energy generation and consumption in a large number of developing countries. Their potential for exports may improve over time, once the problems of storage and transport of energy over long distances are solved through technological advances.

However, developing countries may also be well advised to evaluate to what extent they can acquire new comparative advantages in the growing market for environmental goods. These can be the result of an early establishment of an industry and the consequent acquisition of specialized knowledge or economies of scale or scope (Gomory and Baumol (2000: xiii). Such acquired comparative advantages play a particularly important role in medium- and high-technology-intensive industries such as those that contribute to climate change mitigation. Entry into such industries "is slow, expensive, and very much an uphill battle if left to free-market forces" (Gomory and Baumol, 2000: 5).

As in other industries, it may be possible for a developing country to start producing climate-friendly equipment by initially carrying out labour-intensive functions and thereafter progressively undertaking technological upgrading. Government support could serve to obtain dynamic scale economies, which requires both successive innovative investments and learning processes. Policy measures in support of industries that contribute to climate change mitigation may also include attracting FDI, particularly if it comes with a transfer of technology, organizational and managerial skills, and helps entry into international networks.

As with structural change policies more generally, specific policy measures depend on a country's particular initial conditions and its stage of economic development. However, there are several types of policy measures that may be relevant for different developing and transition economies in their efforts to combine global climate change mitigation with building domestic production capacity in the growing markets for environmental goods. Measures of relevance for industrial policy in a broader development context were discussed in greater detail in *TDR 2006* (chap.V). In the specific case of building domestic capacities for the provision of climate-friendly products and services, support could be provided, for example, by the following types of instruments:

> Industrial policy to promote the environmental goods sector is of particular relevance for forward-looking development strategies.

- Fiscal incentives, apart from those that may be provided for innovative GHG abatement activities, could aim at encouraging investment in developing capacities to produce or participate in the production of climate-friendly equipment and appliances.

- Direct public credit, possibly in the form of loans by development banks at preferential interest rates and with favourable repayment schedules, could facilitate the financing of investments for the purpose of creating capacities to produce climate-friendly equipment and appliances and for acquisition of such goods produced locally.

- Subsidies could be allocated to those firms which show the greatest potential capacity to facilitate the use of locally available renewable sources of energy and to strengthen the country's position in the market for environmental goods.

- Venture capital institutions could play an important role in providing risk capital for firms engaging in the production of equipment and appliances that can substitute to more carbon-intensive ones. Since such organizations themselves often face financing constraints, development banks and other public actors that are motivated by social returns and externalities, rather than by private profit, could play a crucial role.

- Research and development (R&D) activities in support of technology upgrading and local adaptation of technology for the production of climate-friendly equipment and appliances could be carried out by public institutions, or private institutions and firms could be given public grants for this purpose. In this case, budgetary constraints could be alleviated through royalty payments by the private users of public research output commensurate with their profits, or by common-project-financing through regional cooperation agreements. Such measures may be complemented by according favourable treatment to FDI that is associated with spillovers of climate-friendly technologies and know-how.

- The creation and expansion of firms involved in the development of climate-friendly technologies and the production of related equipment and appliances could be supported by public procurement schemes (see also section C.4 of this chapter). This could help the domestic firms reach the economies of scale necessary for making their environmental goods competitive relative to those of external suppliers. It could even help domestic firms take the lead in certain subsectors.

- Specific policy measures may also be relevant for the purpose of strategic integration into the global market for environmental goods, such as the creation of export processing zones that offer preferential tax and customs treatment. Measures such as selective liberalization through differentiated tariff and non-tariff barriers and granting duty drawbacks for imports of certain capital and intermediate goods have been successfully employed in the past for the development of specific industries in many countries. However, in recent years their use has become more difficult, and in many cases impossible, as a result of multilateral and bilateral regional trade agreements. While trade liberalization may help in the diffusion of climate-friendly technologies, it may render the exploitation of comparative advantages in markets for renewable energies more difficult. It may also hamper the development of domestic capacities for the production of climate-friendly technologies, equipment and appliances. While it is important, from a development perspective, to arrive at an appropriate balance between these two objectives in multilateral trade negotiations (see section F below), developing countries need to identify what policy space is still available to them in support of domestic climate-friendly industries. They should also avoid commitments in regional or bilateral agreements with developed countries that would circumscribe this policy space more narrowly than multilateral trade agreements have done.

Industrial policy with a special focus of using comparative advantages and creating new ones in environmental goods is of particular relevance in the context of forward-looking development strategies. This is not only because of the growing size of the market for such products, but also because the policy space for support measures in this area is less narrowly circumscribed by multilateral agreements than in other areas. According to Article 8 of the WTO Agreement on Subsidies and Countervailing Measures (SCM), specific subsidies for research or for the pursuit of environmental objectives are classified as non-actionable.[16] Subsidies are permitted for the "promotion of adapting existing facilities to new environmental regulations". They are also permitted for R&D, including the financing of venture capital funds and for the provision to the private sector of technologies and innovations developed in government research laboratories. Also included in this category is public procurement policy in support of the proliferation of domestically defined standards for particular technologies. Moreover, in order to support a shift in economic activity to new products or to the use of new technologies, activities can be subsidized as long as they are in the pre-competitive phase (i.e. before they result in the production of goods that are exported or subject to significant import competition).

In the climate-friendly goods sector policy space for support measures is less narrowly circumscribed by multilateral agreements than in other areas.

The practical relevance of subsidies that fall under Article 8 of the SCM Agreement becomes very clear from the assistance measures that many developed countries have adopted in response to the current recession in support of their ailing automobile firms. Due to their subsidy elements, these measures could be challenged as violations of the subsidy rules under that Agreement. However, if assistance is tied to new fuel-efficiency and environmental standards, they are likely to fall under the exemptions from WTO subsidy discipline for environmental reasons. Another example concerns China's granting of about $1.5 billion in research subsidies to bolster its automobile industry by encouraging the development of more environmentally friendly cars. This move is designed to encourage Chinese auto-makers to focus on electric-vehicle technology (Shirouzu, 2009).

Several types of these support measures have an impact on the public budget. It may therefore be difficult for developing countries, particularly the poorest, to implement such measures. This constraint applies to domestic development policies in general, and has to be addressed in the broader context of strengthening public finances in developing countries. However, it may be easier to gain access to external financial support for the specific area of climate change mitigation than for other areas of industrial policy, given the possibilities arising from the emerging international framework for climate policies. For example, a strengthened CDM or a global carbon market in the form of a cap-and-trade system (Stern, 2008a and b) would allow developing countries to sell emission rights that they do not need to cover domestically produced emissions.

F. Towards an effective international climate policy framework

1. The broad agenda

Decisive action to reduce GHG emissions is required by national governments, especially those of developed and emerging-market economies that are responsible for the bulk of current GHG emissions. At the same time, because of the global nature of climate change and the risks involved, this action needs to be coordinated and organized within an international framework that includes all countries. International cooperation started with the establishment of the UNFCCC in 1992. Since the UNFCCC entered into force in 1994 there have been annual Conferences of the Parties (COPs) with the aim of strengthening the international climate policy framework. A further step in this direction was the adoption of the Kyoto Protocol on Climate Change at COP-3 in 1997, which entered into force in 2005 (see box 5.1 above).

Given that the Kyoto Protocol expires at the end of 2012, a new global agreement is needed to deal with climate change mitigation thereafter. A first step towards a post-Kyoto Protocol agreement was taken in December 2007 with the adoption of the Bali Action Plan adopted by COP-13. It defines four main building blocks of a new agreement, which will be presented for endorsement at COP-15 to be held in Copenhagen in December 2009. These are mitigation, adaptation, technology and financing. There was also agreement on the need to develop a shared vision for long-term cooperative action, including a long-term goal for global emission reductions.

The negotiations will have to address the need for "enhanced national/international action on mitigation of climate change" by both developed and developing countries. This primarily involves determining the extent of mitigation commitments to be made by Annex I Parties. But in addition, negotiations will also have to extend to "nationally appropriate mitigation actions" by developing countries. Without their effective participation, it will not be possible to ensure stabilization of GHG concentrations at relatively "safe" levels, in the light of past and projected future regional trends in economic growth and associated GHG emissions.

The negotiations will also have to agree on main policy approaches to achieve emission reductions, including the future role of the CDM, which so far has been the main vehicle for involving developing countries in the international framework for climate policy (box 5.2). An important issue to be resolved pertains to policy approaches and incentives for reducing emissions from deforestation and forest degradation in developing countries. Other key issues are how to support adaptation in developing

Box 5.2

THE CLEAN DEVELOPMENT MECHANISM: LARGE POTENTIAL BUT UNDERUTILIZED

The Clean Development Mechanism (CDM)[a] is based on the recognition that since GHG emissions are a problem at the global level, it does not matter where emission reductions are achieved. The same amount of additional emission reductions can be achieved more easily and at a lower cost in developing countries, which tend to operate at a greater distance from the world's technological frontier, than in developed countries. The CDM offers investors from Annex I countries (see box 5.1 above) the possibility of earning carbon credits – or CERs – if they undertake projects in developing countries that help these countries prevent or reduce GHG emissions.

Interest in CDM projects has grown rapidly in recent years. In July 2009, there were more than 4,400 projects in the "CDM pipeline", up from 534 at the end of 2005. Of these, 1,725 projects had been approved by that date. The UNFCCC expects the approved projects to reduce emissions by a cumulative 1.6 billion tons of CO_2 equivalent by the end of 2012, or by an annual average of 308 million tons. This indicates that CDM has considerable potential to contribute to a reduction in global GHG emissions, which totalled 41 billion tons in 2005.[b] The value of CDM projects by investors from Annex I countries amounted to $7.4 billion in 2007, up from $5.8 billion in 2006 (World Bank, 2008). This corresponds to about 1.3 per cent of total direct investment flows to developing and transition economies (UNCTAD, 2008).

So far, CDM projects have been concentrated in only a few activities, including hydro power, and in a small number of countries. In July 2009, China and India accounted for nearly two thirds of all CDM projects in the pipeline and for 70 per cent of all expected CERs by 2012, the end of the first commitment period of the Kyoto Protocol. China alone is expected to supply some 55 per cent of these carbon credits. Besides China and India, the two other major players in the CDM market are Brazil and Mexico, but the gap with China and India in terms of both the number of projects and CERs is considerable. By contrast, the share of the least developed countries (LDCs) is only about 1 per cent, which is even lower than their share in FDI to all developing and transition economies. This may reflect not only a limited number of potential projects that can generate GHG emission reductions relatively easily, but also the limited administrative capacity of these countries to participate in the mechanism.

Wider participation of developing countries in CDM has been encouraged through the Nairobi Framework launched in November 2006. This cooperation agreement, initially concluded among six multilateral agencies (UNDP, UNEP, UNFCCC, the World Bank, the Asian Development Bank and the United Nations Economic Commission for Africa), which UNCTAD joined in May 2009, aims at building capacity in developing countries, especially in sub-Saharan Africa, to develop CDM projects and benefit from access to carbon finance.

Although CDM can make a substantial contribution to climate change mitigation, its potential remains underutilized to date, for various reasons. The absolute amount of investment in CDM projects will be higher the more restrictive emission limitations become as cap-and-trade systems evolve. The role of the CDM is also circumscribed by the possibility of Annex I countries to limit the share of their domestic GHG emissions that can be offset through CERs. Just as it does not matter for global warming where GHGs are emitted, it does not matter for climate change mitigation as to where those gases are reduced. Considering the urgent need to reduce GHG emissions in the coming years, it is desirable that all "quick wins" possible in developing countries be utilized, and that low-cost abatement opportunities in those countries be exploited. On the other hand, the larger the scope for counting emission reductions achieved through the CDM in developing countries against commitments made by developed countries, the lower will be the incentive for clean technology innovations in developed countries. Therefore, a strengthening of the CDM should be accompanied by tighter emission restrictions, as well as greater government support for R&D and for wider application of innovative technologies in developed countries.

The effectiveness of the CDM also depends on the capacity of the CDM Executive Board to expedite approval and implementation of CDM projects. Judging by the backlog of projects, this capacity appears

Box 5.2 (concluded)

DISTRIBUTION OF CDM PROJECTS, BY REGION AND SELECTED COUNTRIES, 2009

	CDM projects in the pipeline (as at 1 July 2009)		*CERs expected by 2012*	
	Number	*Per cent*	*Million*	*Per cent*
Africa	105	2.35	81	2.92
of which:				
Egypt	12	0.27	16	0.59
Nigeria	7	0.16	28	1.00
South Africa	29	0.65	20	0.72
Latin America	797	17.84	392	14.20
of which:				
Brazil	346	7.75	175	6.32
Mexico	154	3.45	65	2.36
Chile	69	1.54	40	1.44
West Asia	49	1.10	34	1.21
Other Asia and the Pacific	3 470	77.68	2 237	81.00
of which:				
China	1 754	39.27	1 534	55.52
India	1 127	25.23	424	15.34
Republic of Korea	63	1.41	103	3.72
Viet Nam	71	1.59	22	0.78
Europe and Central Asia	46	1.03	18	0.67
Total of 76 countries	4 467	100.00	2 762	100.00
Memo item:				
Least developed countries	45	1.01	26	0.94

Source: UNEP, Risø CDM Pipeline Analysis Database, at: http://www.cdmpipeline.org/overview.htm (accessed 1 June 2009).

to be low at present. The approval process could perhaps be accelerated by simplifying and streamlining the criteria for approval. At present, CDM projects submitted for approval have to pass a counterfactual test: the emission levels associated with a project have to be below those that would occur under a "business-as-usual" scenario. It has been observed that "the projects that have made it through the CDM project cycle have tended to be those that are the simplest to quantify [in terms of GHG-emissions reductions] and not necessarily those with the greatest benefits in terms of co-benefits or sustainable development" (Schmidt et al., 2008: 2; Cosbey et al., 2005). Promoting co-benefits of CDM projects is also an important objective in the ongoing negotiations on the future climate mitigation framework (Kinley, 2009). Depending on the project, co-benefits may include, for example, the elimination of a health hazard or the generation of local employment. Such co-benefits are highly desirable, but it is also important to avoid too much emphasis on such co-benefits in the evaluation of CDM project submissions so as not to further complicate and retard the approval process.

[a] For a more detailed review of the CDM, see UNCTAD, 2009c.

[b] UNFCCC, CDM statistics online, at: http://cdm.unfccc.int/Statistics/index.htm (accessed 10 June 2009). The European Commission Joint Research Centre shows worldwide GHG emissions growing faster (http://ec.europa.eu/dgs/jrc/index.cfm?id=2820&obj_id=341&dt_code=HLN&lang=en, accessed 25 May 2009).

countries as well as their transition to low-carbon economies through technology transfer and financing. The challenge is to carefully balance commitments and entitlements across the four proposed pillars between developed and developing countries, taking into account their diverse socio-economic conditions and vulnerabilities to climate change.

The widely varying socio-economic conditions across countries suggest that it will be necessary to adopt a multi-track framework involving different degrees of commitments and/or national policy measures for different groups of countries based on their level of development. In addition, new mechanisms for financial and technological support will need to be established, depending on the development stages of countries and their contributions to the climate change problem (Bodansky and Diringer, 2007). There is considerable GHG abatement potential in developing countries, which can be exploited at much lower costs than in industrialized countries. It is therefore in the interest of the developed countries to strengthen cooperation with developing countries in the pursuit of climate change mitigation. The CDM is a promising starting point for mutual action in that direction, even though it does not by itself lead to additional emissions abatement at the global level.

2. Involvement of developing countries

In order to reach a new climate agreement, it will be necessary that all parties view the distribution of responsibilities as sufficiently fair or equitable. The challenge is to secure a commitment to GHG reductions not only by developed countries, but also by emerging-market economies, which in recent years have drastically increased their GHG emissions.

Commitments have to vary for different categories of countries and over time.

The principle of common but differentiated responsibilities is a starting point for defining the type and scale of mitigation actions to be undertaken by developed and developing countries. In accordance with this principle, several studies have proposed that, since the GHG emissions of developed countries peak earlier than those of developing countries, the developed countries should reduce their emissions at a more rapid rate than developing countries (Stern, 2006: 495; UNDP, 2007: 7; IPCC, 2007b: 748).

A promising approach to reducing GHG emissions would be to extend the coverage of existing cap-and-trade systems and increase their effectiveness. Ideally, all developed and developing countries that have made reduction commitments would trade under the same system so as to discourage double standards and ensure fair competition. However, in order to ensure the participation of developing and transition economies in the same international cap-and-trade system, it will be indispensable to allow different levels of commitments and target dates for different categories of countries, and, accordingly, to find acceptable criteria for the distribution of emission permits amongst all participating countries.

Proposed criteria include, *inter alia*, per capita GDP, per capita emissions, emissions per unit of GDP, current emissions, historical emissions and population size.[17] One possibility would be to use a sequence of formulas for dynamic emission target setting within a cap-and-trade framework that would be determined by a combination of historical emissions, current emissions, population, income, and possibly some other country-specific indicators. This could also involve indexing emission targets to economic growth (Frankel, 2007). Similarly, a graduation index has been proposed that combines a country's per capita income and per capita emissions for determining emission thresholds, which would oblige developing countries to take on emission reduction commitments (Michaelowa, 2007).

For the time being, several developing countries, in particular low-income and least developed countries, may be exempted from formal reduction commitments. But in order to avoid larger adjustment burdens at later stages, these countries should nevertheless begin to work early on, and with the support of the international community, towards developing capabilities to introduce climate-friendly modes of production and consumption.

There are a number of proposals for progressively engaging developing countries in climate change mitigation. A major focus has been on the sectoral approach that targets emission reductions for a range of energy-intensive industries, such as power, iron and steel, and cement. The thrust of these approaches is to achieve large volumes of emission reductions, while also mobilizing, via carbon trading credits or other mechanisms such as CDM, sufficient funds for the deployment and diffusion of clean technologies. The sectoral approach could also serve as a stepping stone for developing countries towards adoption of economy-wide emission limitation goals in the medium term. The longer term goal would be to increasingly integrate developing countries into international cap-and-trade systems (Bodansky, 2007; Jackson et al., 2006).

Reducing deforestation has the highest potential to contribute to low-cost mitigation, but ...

This sectoral approach could be incorporated into a modified CDM, or organized outside the CDM. A sectoral CDM would involve the reduction of emissions below a specified baseline for a predetermined time period, with a corresponding supply of carbon credits. Incorporating a sectoral approach into the CDM would help counteract a growing trend towards fragmentation of mitigation efforts and thereby facilitate uniform standards and monitoring. However, establishing a sectoral mechanism outside the CDM appears to be simpler in many ways. First, it would preclude the need to demonstrate additionality and compliance with an increasing number of conditions, which at present make approval of projects extremely cumbersome, lengthy and costly. Second, it would enable the emission baseline to be negotiated directly between developing and developed countries within the framework of the UNFCCC. In both cases, emissions below baseline would generate carbon credits, but failure to reduce emissions below baseline would not lead to penalties that would require developing countries to purchase corresponding emission allowances. This approach is therefore known as the "sectoral no-lose target" (SNLT).

… the present international climate policy framework does not address deforestation.

A variant of SNLT has the main objective of providing additional specific incentives – in the form of financial support and transfer of cutting-edge technology – to major emitting developing countries to enable them to reduce emissions in a given sector by a certain agreed amount below the initial no-lose target baseline. Given the additional support provided, only emissions below this more stringent target would be credited. The emission baseline established under SNLT would be based on a country's past emission trends, and would assume the implementation of policies and measures aimed at reducing emissions below the SNLT baseline. It has been proposed (Schmidt et al., 2008) that a more ambitious reference path for emissions than that of the SNLT approach could be achieved with additional external financial and technological support for domestic abatement measures.[18]

Sectoral agreements could require considerable financial transfers from developed countries to specific sectors. But such transfers may not be forthcoming for agreements that cover major competitors in internationally traded goods sectors. The sectoral approach may therefore be best suited for domestically oriented sectors that have only a few major emitters, such as electricity generation (Bradley et al., 2007). However, sectoral agreements need not be limited to carbon crediting schemes; they could also focus on technological standards similar to the vehicle emission standards of the EU, or they could mandate the use of specific technologies or alternative sources of energy, or proscribe heavily polluting equipment.

Reducing emissions from deforestation and forest degradation is an example of a sectoral approach that could make a significant contribution to climate change mitigation. Although reducing and reversing deforestation has the highest potential of any sector to contribute to low-cost mitigation between now and 2030 (Enqvist et al., 2007), emissions from this source are not addressed in the existing international climate policy framework. The Bali Plan of Action has therefore emphasized the strategic importance of slowing deforestation, which is a high-priority mitigation option in the tropical regions of Asia, Africa and Latin America. One option for international support in the prevention of deforestation could be to establish an explicit carbon crediting mechanism. But this would have to overcome considerable methodological challenges of establishing credible baselines, accurately measuring emissions, and ensuring that local emission reductions are permanent. There has also been a proposal to establish a dedicated fund under the UNFCCC to support voluntary engagement of countries in reducing emissions from deforestation. Some funds designed to support a slowdown in the rate of deforestation are already operational (UNFCCC, 2008a). Moreover, "positive incentives" could be provided by developed countries to build institutional capacities for reducing illegal logging and fire outbreaks, and banning imports of illegal timber.

Agriculture, particularly in developing countries, also has a significant potential to mitigate climate change at a relatively low cost. However, existing financing mechanisms under the Kyoto Protocol enable only a very small fraction of the mitigation potential of agriculture to be realized (Martino, 2009). For instance, soil carbon sequestration, which accounts for most of the mitigation potential in agriculture, is outside the scope of the CDM. It would therefore be desirable to include the issue of GHG emission reduction in agriculture on the agenda of the forthcoming climate change negotiations (see also FAO, 2009; IAASTD, 2009).

Developing countries have implemented a host of measures that focus primarily on promoting priority national development goals, but which also contribute to global GHG abatement as a "by-product". These policies and measures fall in the wider category of sustainable development policies and measures (SD-PAMs). It has been proposed that in the post-Kyoto climate regime, developing countries should have the possibility of unilaterally pledging implementation of specifically tailored policies with a development focus that have climate-friendly co-benefits as a major characteristic (Baumert and Winkler, 2005). This would allow them to gain formal recognition for their contribution to GHG abatement and help overcome the perception that countries without emission targets do not contribute to climate change mitigation. Implementation of SD-PAMs would allow developing countries to accumulate knowledge about the mitigation potential of the economy, and related economic, social and environmental costs and benefits. It could also contribute to increasing the capacity of domestic institutions for effective policy integration. To encourage SD-PAMs, developed countries could offer to provide financial and technical assistance. But linking SD-PAMs with carbon crediting mechanisms is unlikely to be feasible given the difficulty in establishing "additionality" and credible emission baselines (Bradley et al., 2007).

3. External financing, trade and technology transfer

The effective participation of developing countries in global GHG abatement depends to a large extent on their utilization of climate-friendly technologies. The issue of technology development and transfer is therefore high on the agenda of the climate policy negotiations. The incremental investment costs of introducing clean energy technologies in developing countries are estimated at several hundred billion dollars per annum over the next few decades.[19] As discussed in the previous section, participating in the production of equipment and appliances that embed such technologies, and contributing to further technological progress in this sector, are important aspects of industrial development that should become major elements in the design of development strategies for the coming decades. The poorer developing countries may require additional foreign direct investment (FDI) and official development assistance (ODA) if they need to import the technology and equipment for helping GHG abatement.

The funds available through the UNFCCC (from the Global Environment Facility (GEF) Trust Fund, the LDC Fund and the Special Climate Change Fund) are very small compared to the size of resources required to cover the external financing needs of developing countries, particularly those that will not benefit from a revalorization of comparative advantages in the production of energy, or will not be able to build relevant new dynamic advantages. Various other multilateral financial mechanisms exist that rely on developed-country contributions for promoting GHG abatement in developing countries, such as the World Bank Climate Investment Fund and the Clean Technology Fund (CTF). In addition, a number of new financing options have been proposed, including a World Climate Change Fund, based on financial contributions by all countries, except the LDCs, to scale up financing for climate change mitigation and adaptation.

An international carbon market in the form of a cap-and-trade system could be a source of income for many developing countries. If designed in a manner that takes into account the responsibility of the industrialized countries for the existing GHG concentrations in the atmosphere, on the one hand, and the need for developing countries to contribute to global climate change mitigation, on the other, such a system might go a long way towards meeting their requirements for the financing of imports of the technology and equipment necessary for GHG abatement. For example, if population size were to be given an important weight in the initial allocation of permits across countries, many developing countries would be able to sell their emission rights because they would be allotted considerably more permits than they need to cover domestically produced emissions.

Access of developing countries to clean energy technologies could also be promoted through bilateral, regional and international cooperation agreements, such as the Asia-Pacific Partnership on Clean Development and Climate Change (APP). This agreement, launched in 2005, comprises Australia, Canada, China, India, Japan, the Republic of Korea and the United States. These countries have agreed to work together, along with private sector partners, to meet goals for energy security, national air pollution reduction and climate change mitigation by accelerating the development and deployment of clean energy technologies. In addition to renewable energy, the APP focuses on GHG emission reductions in industries such as steel and cement. Another example is the EU-China Partnership on Climate Change, formed in 2005. It aims to: promote the development and deployment of "zero emissions" and carbon capture and sequestration technologies; lower the costs of major clean energy technologies to enhance their diffusion and use; and support the mutual goal of improving energy efficiency.

In addressing climate change, it would be appropriate for the international community to consider support measures for developing countries that combine GHG abatement with the promotion of development objectives (Cosbey, 2009). From this perspective, it is regrettable that developed countries have been resisting liberalization of imports of agricultural products, including ethanol, while subsidizing their own biofuel production. Yet ethanol from sugar cane is currently considered by many experts as a very efficient biofuel in terms of cost, energy balance and GHG abatement. The reductions obtained from the use of biofuels based on feedstocks that are used in Europe and North America are much smaller than those from ethanol, and their supply and use are being supported by sizeable government subsidies. These subsidies, which are projected to rise from $11 billion in 2006 to $25 billion per year by 2015, correspond to $960 to $1,700 per ton of CO_2 equivalent saved (OECD, 2008). If the same fiscal expenditure were to be allocated for emission reduction projects in developing countries, a much larger abatement effect could be obtained, while respecting their comparative advantages in biofuel production.

> An international cap-and-trade system could be a source of income for many developing countries.

Another potential obstacle for developing countries to contribute to climate change mitigation and at the same time grasp the opportunities provided by fast growth in the market for environmental goods is the protection of intellectual property rights. Typically, technology transfer is either associated with FDI or it is organized on the basis of licensing. The WTO Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS Agreement for short) severely restricts reverse engineering and other forms of imitative innovation, since it upholds the private rights of patent holders. As a result, it tends to limit the access of developing countries to proprietary knowledge. This implies an asymmetry that favours the producers and holders of protected intellectual property – mainly in developed countries – at the expense of those trying to gain access to protected intellectual property, mainly in developing countries (*TDR 2006*, chap.V). Exceptions are limited to very specific cases, such as access to medicines in developing countries. This exception is made for humanitarian reasons, but it can also have a positive impact on the development of pharmaceutical industries in developing countries.

Multilateral rules on proprietary knowledge aim at protecting the interests of the innovating firms in gaining an adequate profit. However, they also have to strike a balance between these interests and global public interests. The Doha Declaration explicitly recognized the flexibility within TRIPS to grant compulsory licences, and clarified the need to interpret TRIPS from a public health perspective. Given the global public good character of climate change mitigation, and that it is in the interest of developed countries to involve developing countries in global efforts to reduce GHG emissions, similar flexibility as that applied to medicines appears to be justified for proprietary rights in the field of climate-friendly technologies.

Another means for enabling developing countries to enhance their own production of equipment and appliances that help reduce global warming would be for developed countries and/or multilateral institutions to provide them with financial support for the acquisition of the appropriate licences. In this spirit, China and India have recently proposed the establishment of a Technology Acquisition Fund, to be financed by Annex I countries, to enable the purchase by developing countries of international property rights for low-carbon technologies.

G. Conclusions and policy recommendations

The impact of unabated global warming is the most severe in developing countries. Past and present GHG emissions, the bulk of which have been produced by developed countries, are commonly considered to be the main cause of global warming. But in developing and transition economies, especially in the largest and fastest growing among them, such emissions are now on a steeply rising trend. This trend will continue unless vigorous action is taken to change the energy mix and modes of production and consumption.

Developed countries need to lead global action to mitigate climate change by adopting strong policy measures, not only in their own interest, but also for ethical and economic reasons. They need to assume responsibility for the accumulation of emissions affecting the global climate, which have resulted from their past actions, particularly as they have greater economic, technological and administrative capacity to shift rapidly to a low-carbon economy. It is equally in the interests of developing and transition economies to contribute to global mitigation efforts in line with the principle of common but differentiated responsibilities, because current trends in their GHG emissions are not sustainable. And developed countries have an ethical obligation to support developing and transition economies in their efforts.

Climate change is the outcome of a gigantic market failure, and mitigation efforts now require strong government action at the national and international level. The international framework for a climate policy is still weak. If strengthened, many of its elements could contribute to more effective global GHG abatement efforts and to the greater participation of developing countries in those efforts. These elements include, *inter alia*, the promotion of carbon trading, and the two project-based mechanisms of the Kyoto Protocol – the Clean Development Mechanism and Joint Implementation – as well as the prevention of deforestation.

Climate change is the outcome of a gigantic market failure, and mitigation efforts require strong government action at the national and international level.

Putting a price on emissions, in the form of taxes or tradable emission permits, and thereby changing the incentive structure for producers and consumers, could help set in motion a process towards establishing low-carbon economies. Measures that increase the demand for less carbon-intensive or carbon-free sources of energy are central to market-based intervention in favour of climate change mitigation, but these measures also need to be accompanied by intervention on the supply side of energy from other sources. Managing supply adjustments and price formation for different sources of energy is necessary in order to prevent prices of non-fossil, renewable energy from increasing – relative to the prices of the more carbon-intensive types of energy – as demand for them grows. Therefore, producers of different fuels need to be involved in the formulation and implementation of an international climate change mitigation policy.

There is considerable scope for developing economies to gain from the structural change towards climate-friendly modes of production and consumption ...

In addition to changes in the incentive structure through the market mechanism, direct government intervention in the form of emission performance standards and strict regulations that prescribe specific modes of GHG abatement is indispensable in order to achieve ambitious targets within the envisaged time horizon. Also, more proactive policies to advance technological progress are required, because innovation towards low-carbon modes of production has become a necessity, unlike innovations in most other areas. Leaving this process to the market mechanism alone carries the risk that it may not provide a sufficiently strong stimulus for accelerating the development and application of appropriate cutting-edge technologies for carbon reduction to reach the required targets. This is partly because there has been considerable underinvestment in research aimed at the development of alternative sources of energy and cleaner production methods in the past, so that current modes of production and consumption are shaped by "carbon lock-in". In many cases, private firms may be reluctant to increase R&D investment sufficiently, because knowledge spillovers may prevent them from fully reaping the profits from their innovations. In the case of technology and know-how that advance more climate-friendly modes of production and consumption, such spillovers may even be desirable. Therefore, subsidies and public acquisition of patents could be ways to compensate private firms for possible losses resulting from such spillovers. Moreover, experience shows that technological change often advances faster when it also benefits from R&D in public institutions, and when the public sector takes the lead in applying new technologies in practice.

... but they need sufficient space for proactive industrial policies to promote the domestic development of renewable sources of energy, climate-friendly technologies and the production of low-carbon equipment and appliances.

The engagement of developing countries in climate change mitigation efforts will largely depend on how a global climate policy is designed. Such a policy should facilitate their access to clean technologies, to financing for emission reducing investments, and to compensation for income losses that certain countries may face, for example as a result of energy-switching or forest conservation. International emissions trading within the framework of a global cap-and-trade system with a distribution of emission rights that favours developing countries could serve as a new financing mechanism. This could complement increased ODA for public GHG abatement projects and additional FDI in low-carbon activities.

Climate change mitigation does not have to be at the expense of growth and development. Experiences from both developed and developing countries show that many synergies are possible between GHG abatement, on the one hand, and development objectives on the other. Similarly, action undertaken primarily in the pursuit of other social and economic development objectives can often also lead to GHG abatement as a by-product. More generally, in order to implement successful programmes to reduce GHG emissions, developing countries need the strengthened administrative and institutional capacity that typically comes with development.

Climate change mitigation is best understood as a process of structural change. This process certainly implies adjustment costs for many economic agents, but the time horizon for climate change mitigation is so long that it is difficult to estimate the total "costs of mitigation". Estimations of these costs may be misleading as they are subject to a considerable uncertainty and have to be based on highly subjective judgements. It is important to recognize that, as in other instances of structural change, this process also offers enormous new opportunities for product and process innovation, income growth and employment generation. From this macroeconomic perspective, climate change mitigation is likely to involve only negligible net costs in terms of lower global GDP; it may even have a growth stimulating effect in many countries. Economic development always implies a process of structural change. What is important is to guide this change in the direction that is compatible with public preferences (in this case the need to reduce the risks arising from global warming), and to design development strategies that take account of the new opportunities offered by this process.

It would be justified to allow compulsory licensing of patents for the production of climate-friendly equipment and goods that embed climate-friendly technologies.

In the years and decades ahead there is considerable scope for developing economies to gain from the opportunities that will emerge from the structural change towards renewable sources of energy, climate-friendly technologies, low-carbon equipment and appliances, and more sustainable modes of consumption. Successful participation in the new markets is largely a matter of reassessing natural comparative advantages, especially in the production of clean energy, and creating new dynamic comparative advantages through a proactive industrial policy. Such a policy should aim at the early creation of capacities to produce or participate in the production of such goods, and their subsequent upgrading.

Each developing and transition economy will need to define its own strategy for integrating into the emerging new markets for new products that help achieve GHG abatement objectives, taking into account both the local needs for specific "environmental goods" and the options for producing such goods for local, regional or global markets. Experience from developed countries and several emerging-market economies shows that a successful industrial policy may comprise, among other elements, public sector engagement in R&D, simplifying access to patents, fiscal and financial support for new production activities, information dissemination and FDI policies that favour integration into international production chains, government procurement and temporary protection of specific subsectors. A proactive industrial policy with a special focus on using existing comparative advantages and creating new ones in the environmental goods sector is of particular relevance in the context of forward-looking development strategies. This is because the policy space for support measures in this area is less narrowly circumscribed by multilateral agreements than in other areas.

The international community can support industrial development in this direction by allowing developing countries sufficient policy space in the context of relevant international agreements on climate change, trade, FDI and intellectual property rights. Given the global public good character of climate change mitigation, it would be justified to interpret the flexibilities of the TRIPS Agreement in a way that would allow compulsory licensing of patents for the production of climate-friendly equipment and goods that embed climate-friendly technologies, similar to the exemptions accorded for medicines in support of public health.

Notes

1 In general, agricultural output and productivity are expected to decline given an adverse carbon fertilization effect. The carbon fertilization effect is the potentially beneficial effect of rising GHG concentrations in the atmosphere on crop growth by stimulating photosynthesis and lowering water requirements. But in tropical regions, crops are already close to critical temperature thresholds. However, some parts of China may benefit from this effect due to moderate temperature increases (Stern, 2006, chap. 3). A study by Cline (2007) finds that a global mean warming of 3ºC will have a negative impact on global agricultural productivity in the longer run (by 2080), even in the presence of a carbon fertilization effect. The study suggests that the adverse impact on agricultural productivity will be felt first in developing countries, and they will suffer much more than developed countries.

2 The House of Representatives passed the American Clean Energy and Security Act on 26 June 2009 (for full text see: http://energycommerce.house.gov/Press_111/20090701/hr2454_house.pdf).

3 At the global level, the available supply of biofuels is too small to make a noticeable dent in the demand for oil.

4 Clearly, carbon pricing also has a distributional impact that is not negligible. An analysis of the distributional effect has to identify the social groups that finally have to bear the direct burden by paying higher prices for certain types of energy or goods, the production and consumption of which implies environmental costs that so far have not been accounted for in price calculations. This is relatively easy, but it is only part of the analysis, which also needs to take account of a number of other factors. It is true that the final consumers will have to pay the price, and consumption patterns across income groups are such that the share of energy in total consumption is higher among lower income groups. Thus, the direct effect of the introduction of instruments, such as carbon prices or taxes, on income distribution is regressive. However, the overall distributional effect of policies for climate change mitigation is also influenced by the use of revenues from carbon emission reduction policies and the distribution of income from production based on new technologies and more environment-friendly goods compared to that of production based on traditional technologies and goods. Since there are likely to be considerable differences in each of these variables, depending on the different policy instruments chosen, the actual impact on income distribution could only be assessed based on concrete policy choices. For this reason, the distribution and equity effects of climate change mitigation policies in general are not pursued further in this chapter.

5 Global integrated assessment models such as those used by the IMF (2008) or the OECD (2007) employ a least-cost approach, involving equalization of marginal abatement costs across sectors and countries based on internationally harmonized carbon taxes or global emissions trading. In these models, the shift to low-carbon technologies is driven by assumptions about exogenous technological change and endogenous substitution away from carbon-intensive inputs in response to higher carbon prices (see also Burniaux et al., 2008).

6 In China, there was an exceptionally large reduction in intensity of energy use as a result of the country's dramatic structural change after 1980 (see *TDR 2005*, chap. II). This decline bottomed out during the period 2000–2006, but the Government's 11th five-year plan for 2006–2010 specifies the objective of a reduction of energy consumption by 20 per cent in 2010 from its 2005 level. This reflects its concern about the sustainability of the rapid growth in energy demand in view of the potential adverse economic and environmental consequences (see People's Republic of China, State Council Information Office, 2008).

7 In many fast-growing developing countries, where private automobile transportation is expanding rapidly, estimates are much higher: based on data

from IEA (2004). Baumert and Winkler (2005) have estimated an increase in CO_2 emissions from road transport by 2020, in China of 143 per cent, in India of 67 per cent, in Indonesia of 122 per cent, in Mexico of 71 per cent and in West Asia of 68 per cent.

8 Locating residences close to places of work and other destinations is probably the most effective policy option. This option is of particular relevance for urban centres that are expected to expand in the future, but less so for urban areas that have already been built.

9 UNFCCC (2008c) presents an in-depth discussion of the challenges and opportunities emerging from climate change mitigation in agriculture, along with case studies.

10 As rice is the major crop grown in developing countries, improving water and rice management is considered an important option for methane abatement in developing countries, notably in South-East Asia.

11 In sectoral carbon reduction accounting, such substitution would be counted in favour of the sectors using the energy.

12 For details, see www.ghgprotocol.org.

13 Cosbey (2009) found that household energy efficiency projects scored higher than all other types of projects in terms of "development dividend", as calculated for the assessment of projects under the Clean Development Mechanism.

14 On the other hand, the search for energy diversification does not necessarily imply a move towards a more climate-friendly energy mix, since it can also imply the development of a conventional source of energy, such as domestic coal, at the expense of other fossil fuels, such as imported oil.

15 End-of-pipe systems are used for the treatment of emissions where these cannot be avoided in the first place. This traditional approach still plays an important role in many industries, and will continue to do so as long as carbon-intensive technologies remain in use. The sensible environmental and developmental option is to minimize the need for such treatment and to maximize the use of cleaner solutions upstream in the production process, especially when new productive capacities are built.

16 Formally, these subsidies became actionable following a review of the initial provision in 2000 and the failure to reach agreement over its extension. However, in practice no action has been taken in this regard. In order to qualify for the initial provision, subsidies for research must be for activities conducted by firms or research establishments on a contract basis with firms, on the condition that the assistance covers not more than 75 per cent of the cost of industrial research or 50 per cent of the cost of pre-competitive development activity. Regarding environmental objectives, subsidies are permitted for the "promotion of adapting existing facilities to new environmental regulations". The Doha Ministerial Conference took "note of the proposal to treat measures implemented by developing countries with a view to achieving legitimate development goals, such as regional growth, technology research and development funding, production diversification and development and implementation of environmentally sound methods of production as non-actionable subsidies, and agrees that this issue be addressed ... [as an outstanding implementation issue]. During the course of the negotiations, Members are urged to exercise due restraint with respect to challenging such measures" (WTO, 2001: 6). In the meantime, however, the issue of Article 8 subsidies seems to have been eclipsed by negotiations on other issues.

17 For an overview, see Bodansky, 2004.

18 This would imply that emission reductions below the initial baseline but above the more ambitious new reference path would not be credited any more. Instead, they would be permanently "retired from the atmosphere" as a mitigation contribution of developing countries.

19 According to UNDP estimates, developing countries will need to undertake investments of about $44 billion per annum by 2015 for "climate-proofing" existing infrastructure, in addition to investments for adaptation to climate change. A similar amount is considered necessary for adapting poverty reduction programmes to climate change (e.g. support for public health, rural development and community-based environmental protection). A further $2 billion per annum will be needed for strengthening disaster response measures (UNDP, 2007: table 4.3).

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