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Climate Change, Growth and Human Development

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Abstract

This paper surveys the evidence on the ways in which economic development and policies aimed at advancing human development have contributed and currently contribute to greenhouse gas emissions and global warming. It also examines the feedback effects that such warming and the resulting climate change can have on growth and human development, especially in the developing countries of the Asia-Pacific region. It discusses, *inter alia*: (i) the evidence of a nonlinear relationship between income growth and emissions, especially CO_2 emissions; (ii) the relative contributions of different kinds of activities to GHG emissions; (iii) the inter-country differences in the relationship between development, GHG emissions and global warming; and (iv) the constraints to adaptation to climate change faced by poorer countries and socially disadvantaged groups. This provides the basis for identifying the national and global strategies needed to address global warming and its consequences, with special reference to Asia-Pacific.

Key words: Human development, greenhouse gases, CO_2 emissions, global warming, climate change, deforestation, industrialisation, Agriculture.

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Climate Change, Growth and Human Development

Introduction

By all indications global warming and climate change are among the least tractable challenges confronting mankind today. While there is considerable agreement that the science does point to global warming induced by human activity and to adverse climate shifts following from this, not enough is being done as of now to stall and reverse this tendency. Unfortunately this occurs when for a majority of the world's population, even threshold levels of human development are yet to be realised. Since, under "business-as-usual" scenarios, the growth required to generate the wherewithal for advancing human development is likely to exacerbate global warming, efforts at mitigation (defined as action to reduce radiative forcing[1]) and adaptation (defined as action aimed at increasing tolerance to global warming and its climate change effects) are imperative.

From a human development perspective there are, *inter alia*, five questions relating to the debate on global warming and climate change that are of particular significance. The first of these is whether there is robust evidence that anthropogenic factors, or human activities on planet earth, are contributing to greenhouse gas (GHG)[2] emissions and to a rise in global temperatures to an extent where they are having significant climate change effects? Second, to what extent are these emissions the result of activities that contribute to the improved "well-being" of the already rich, the improvement in standards of living of the poor and the fact that poverty forces the poor to adopt certain practices and engage in certain activities? Third, and as a corollary, within the hitherto revealed trajectory of technology, how far are growth and human development dependent on activities that result in the emission of greenhouse gases and contribute to global warming? Fourth, would the policies for mitigation and adaptation currently being discussed and adopted at the national and international levels impact on growth and human development in the developing countries, including those in Asia-Pacific? And, finally, which mitigation and adaptation policies would not place the burden of adjustment on the poor?

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[1] The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007a) defines "radiative forcing" as "a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism."

[2] The most important of these are carbon dioxide (CO_2), methane, nitrous oxide and sulfur dioxide, ozone, chlorofluorocarbons and water vapour. Water vapour, which is contributed only in small measure by human activity, is the world's most prevalent greenhouse gas and is estimated to account for around 95 per cent by volume of these gases. Of the others, carbon dioxide is the most prevalent, amounting to an estimated 76 per cent of the GHGs other than water vapour in the Earth's atmosphere. However, the significance of a gas is determined not just by its prevalence, but by the strength of its greenhouse effect. While estimates vary, water vapour is seen as responsible for anywhere between 36 and 66 per cent of the green house effect, and together with clouds for between 66 and 85 per cent. CO_2 contributes between 9 and 26 per cent and ozone and other minor GHGs for around 7 and 8 per cent respectively. See Gavin (2005).

Global warming

Typically, the "Greenhouse Effect" results from the fact that GHGs form a blanket in the Earth's atmosphere. Shorter wavelength solar radiation penetrates through this blanket and heats the Earth's surface. A part of this absorbed heat is radiated back in the form of longer wavelength infrared rays, some of which are absorbed by these gases. This traps heat under the GHG blanket and warms the Earth's atmosphere. If the presence of greenhouse gasses is such as to keep the temperature of the Earth's surface roughly constant, there is no problem. But if excess green house gas emission and accumulation lead to an increase in temperatures over time, the effects on climate would be significant and potentially adverse from a human development point of view.

Excess emission of GHGs, especially of CO_2, has indeed resulted in such a tendency. In the "natural" world, the amount of carbon dioxide in the atmosphere is regulated by the carbon cycle. Elements of the living world, such as plants, algae, bacteria and animals, directly (through photosynthesis, which uses light energy to convert carbon dioxide into organic matter, for example), or indirectly (through consumption, for example), extract carbon from the non-living world and return it to the atmosphere and water (as CO_2), through processes such as burning and decay. This, however, tends to be a closed carbon cycle in which the emission of CO_2 and its absorption are likely to be closely matched, resulting in a degree of stability in GHG concentration in the atmosphere. "Excess" emission is largely the result of anthropogenic activity, or the contribution of various forms of human activity to GHG emission that cannot be absorbed and results in an increase in GHG concentration. As a result of the contribution made by human activity at the margin, the carbon dioxide concentration in the atmosphere has increased. According to one estimate, the "levels of several important greenhouse gases have increased by 40 per cent since large scale industrialization began around 150 years ago".[3] The GHG concentration in 2005 was 425 ppmv (parts per million by volume) in terms of CO_2 equivalent (CO_2e) and the current rate of increase is 2-3 ppmv per year. According to the IPCC (2007c), the CO_2, methane and nitrous oxide concentrations in the atmosphere have increased from 280 ppm, 715 ppb (parts per billion) and 270 ppb respectively in 1750 to 379 ppm, 1774 ppb and 319 ppb respectively by 2005. The IPCC Special Report on Emissions Scenarios projects an increase of global GHG emissions by 25 to 90 per cent (CO_2-eq) between 2000 and 2030.[4] The difficulty is that once concentrations increase they are a legacy that has lasting effects, particularly in the case of CO_2, on surface temperatures and climate over time.

The available scientific evidence as reported in the Fourth Assessment Report (AR4) of the Inter-Governmental Panel on Climate Change is that average global surface temperatures rose by 0.74 °C over the hundred year period ending 2005.[5] What is more pertinent is the evidence that the pace of global warming has been accelerating and the incidence of warmer temperatures over time is rising. According to the World Meteorological Organisation, the year 2010 tied with 2005 and 1998 for the warmest year on record and the ten warmest years after temperatures have been instrumentally measured starting in 1854 have been during the period since 1998.[6] The AR4 argued that in case GHG emissions continue unchecked, there will be a rise in global atmospheric temperature by at least 0.2°C per decade over the next

[3] United States Energy Information Administration 2012.
[4] See IPCC 2007b.
[5] Such estimates are probabilistic and normally given in terms of a range, which in this case is [0.56 to 0.92 °C]. See IPCC 2007a.
[6] See *The Hindu* 2011.

two decades. The "best estimate" under various emission scenarios point to temperature changes (relative to 1980-99) varying from 1.8-4 °C by 2090-99.[7] Some see estimates such as these as conservative because they are based on optimistically low projections of the extent of GHG emissions and do not fully capture the uncertain feedback effects that initial warming would have, leading to further warming.

Global warming and climate change

The extent of warming is uneven across the globe making its effects and their intensity uncertain. The oceans and tropical coastal regions are expected to see the least warming, the high latitudes particularly around the poles the most, with the mid-latitudes falling in between. Yet, the geophysical consequences of this warming are expected to be near omnipresent and manifold. To start with, it could result in a rise in average sea levels, threatening low-lying islands and coastal regions with submersion. Satellite data suggest that since 1993, the sea level has been rising at a rate of around 3 mm per year, which is seen as significantly higher than the average during the previous half century. According to the IPCC's Special Report on Emission Scenarios (SRES), there is one scenario (A1B) in which the global sea level could rise by 0.22 to 0.44 metres above 1990 levels by the mid-2090s.[8] Secondly, it could result in the melting of polar icecaps, the retreat of mountain glaciers and loss of snow cover in lower altitude mountain peaks, leading to changes in river flows, flooding and other disruptive consequences. Third, the rise in temperature could lead to an increase in the frequency and intensity of unpredictable extreme weather events such as heat waves, tropical storms, cyclones, hurricanes and extreme rainfall events. Fourth, patterns of precipitation are expected to change substantially, with substantial temporal and spatial variations in these changes. And, finally, the severity of droughts and intensity of floods are likely to increase.

These changes in climate in turn directly and indirectly affect the development prospects of poorer countries, including in the Asia-Pacific region. The most obvious direct effect is increased exposure to natural calamities due to extreme weather events and their fallout such as floods. There is already evidence of increased extreme weather events, though the science directly linking these to global warming is underdeveloped. Consider the Asia-Pacific experience during 2010 for example. Pakistan experienced its worst flooding in its history after exceptional monsoon rains, which left more than 1,500 dead and displaced more than 20 million. Temperature at Mohenjo-Daro in Pakistan touched 53.5 Celsius, which was a national record and the highest temperature in Asia since at least 1942. Other highs included 52 degrees Celsius in Jeddah and 50.4 in Doha.[9] The heat wave also triggered forest fires and drought that led to crop failures. Floods and landslides killed more than 1,400 people in Gansu province in China. Heavy rains in Australia made it the third wettest year on record, with the country also experiencing devastating floods in early 2011. And large parts of Australia and Indonesia suffered heavy rains from May 2010, linked to a La Niña event that cools the Pacific Ocean.[10]

There have in recent times been a significant number of natural disasters worldwide. In 2009, hydrological disasters were the most common (53.7 per cent of total reported), followed by

[7] IPCC 2007c.
[8] See Bindoff et al. 2007.
[9] Reuters 2011.
[10] Reuters 2011.

meteorological disasters (25.4 per cent). But the number of victims in meteorological disasters was high (50.6 million). This was mostly due to typhoon 'Morakot' (Kiko) that hit Taiwan, Province of China, and the Philippines, typhoon 'Pepeng' (Parma) and tropical storm 'Ondoy' (Ketsana), mainly in the Philippines and Viet Nam, cyclone 'Aila' in Bangladesh and India, and a major snowstorm in China.[11]

Figure 1 – Top 10 countries by damages in 2009 and distributed by disaster type

Country	Disaster distribution	Damages (US$ Bn.)	Country	Disaster distribution	% of GDP
United States		10.8	**Samoa**		28.7
China P Rep		5.2	**El Salvador**		4.4
France		3.2	**Tonga**		3.6
India		2.7	**Lao P Dem Rep**		1.9
Italy		2.6	**Burkina Faso**		1.9
Indonesia		2.4	**Fiji**		1.6
Spain		1.9	**Mongolia**		1.2
Australia		1.5	**Viet Nam**		1.2
Japan		1.4	**Honduras**		0.7
Viet Nam		1.1	**Costa Rica**		0.7

Climatological Geophysical Hydrological Meteorological

Source: EM-DAT: The OFDA/CRED International Disaster Database (www.emdat.be), Universite Catholique de Louvain, Belgium, cited in Vos et al. 2010.

The Centre for Research on the Epidemiology of Disaster (CRED) estimated that in 335 natural disasters reported worldwide in 2009, 10,655 persons were killed, 119 million others affected and economic damages valued at $41.3 billion caused (Figure 1).[12] Asia reported the largest number of disasters (40.3 per cent), and accounted for 89.1 per cent of the victims and 38.5 per cent of total reported damages.

These and other events do seem to be signals that the climatic effects of global warming are already with us. Though it is extremely difficult to establish direct linkages, scientists are not ruling out a link between some of these events and the increase in GHGs. The direct damage and consequences that such extreme events have for livelihoods and human development indicators are well known. Not surprisingly, the global ambition, even if as yet not the commitment, is to stabilise GHGs at around 450-550 ppm CO_2e, so as to limit global warming to around 2°C.

[11] Vos et al. 2010.
[12] Vos et al. 2010.

To the extent that natural shocks of the kind noted above are related to climate change, their adverse implications for the effort to advance human development should be obvious. They are likely to result in the loss of livelihood opportunities, exacerbate nutritional deprivation and disrupt capability-building activities like schooling for children. Further, crop losses resulting from such climatic events can result in food price increases that are an additional damaging consequence. Thus, in what is seen as partly the result of idiosyncratic weather and natural disasters, wheat prices in Asia-Pacific rose by close to 50 per cent between July and September 2010, the price of corn by 25 per cent and the price of soybeans by 12 per cent.[13] But the impact of unusual and extreme weather events is not just immediate and short-term. They can have long-term consequences through the shock-induced distress sale of land and other assets held by the poor and vulnerable, for example. These would undermine the long-term ability of the poor to cope with and benefit from processes of development.

Climate change vulnerability in Asia-Pacific

The Intergovernmental Panel on Climate Change (2001) traces the vulnerability of a system to (i) the nature and extent of exposure to climate variation to which a system is exposed; (ii) its sensitivity, or "the degree to which a system is affected, either adversely or beneficially, by climate variability or change"; and (iii) its adaptive capacity. Based on a combination of indicators related to each of these, the Asian Development Bank (ADB) and the International Food Policy Research Institute (IFPRI) (2009) have identified Afghanistan, Bangladesh, Cambodia, India, Lao PDR, Myanmar, and Nepal as the countries most vulnerable to climate change in Asia and the Pacific, while those seen as significantly vulnerable—because of low scores for two out of the above three features—include Bhutan, China, Indonesia, Pakistan, Papua New Guinea, Sri Lanka, Thailand, Timor-Leste, Uzbekistan, and Viet Nam. Thus vulnerability is widespread, even though the poorest of countries are seen as capable of adapting to significant extents if the requisite policies are adopted and investments made.

The sensitivity and adaptive capacity of the Asia-Pacific region is influenced by three features. First, the region accounts for 68 per cent of the developing world's population and 64 per cent of its undernourished population.[14] This makes it extremely sensitive to adverse climatic changes as well as substantially reduces its coping capacity. Secondly, the region is home to countries that are already extremely disaster prone. Over the more than three decades during 1975-2006, Asia accounted for about 89 per cent of people affected by disasters worldwide, 57 per cent of total fatalities, and 44 per cent of total economic damage.[15] Finally, the region is already prone to extreme weather events, with the coastal areas periodically experiencing tropical cyclones and associated high winds, storm surges, and extreme rainfall events, and the influence of the El Niño Southern Oscillation subjecting the region to considerable volatility. While this is true of coastal regions in all developing countries, the problem is particularly acute, involving periodic drought and rising sea levels, in island economies such as those in the southwest Pacific.[16] Climate change could significantly alter the dynamic underlying these events and may increase their frequency and intensity. It is to be expected that low-lying countries, especially small islands, will face the highest exposure to rising sea levels.

[13] Chao 2010.
[14] FAO 2006.
[15] Sanker et al. 2007.
[16] Preston et al. 2006.

Vulnerability in the Asia-Pacific is the greater in the case of the Least Developed Countries (LDCs), which include Afghanistan, Bangladesh, Bhutan, Cambodia, Kiribati, Lao People's Democratic Republic, Myanmar, Nepal, Samoa, Solomon Islands, Timor-Leste, Tuvalu and Vanuatu. The LDCs are normally (though not always) among the poorest in the region and the world and tend to be more economically vulnerable. This vulnerability stems, *inter alia*, from the following: poor infrastructure facilities, in particular transport, which come in the way of an integration of the economy; a high degree of risk-exposure when faced with natural calamities; a lack of diversification of the economic structure; inadequate education and health facilities; and low savings rates, which make the task of economic and social transformation extremely difficult in the absence of substantial inflows of foreign assistance. Thus, for eight of the Asia-Pacific LDCs for which data are available from the World Bank's World Development Indicators (2011), the savings rate in 2006 was below 15 per cent in four, of which two had negative savings rates. In addition to this, many of these countries are characterised by major geographical handicaps inasmuch as they are either small, remote, landlocked countries, or remote island economies.

Infrastructural inadequacies are particularly important from the point of view of the small island developing states, which are especially vulnerable to environmental shocks. Seven of the 13 LDCs in the Asia-Pacific region are SIDs (Kiribati, Maldives, Samoa, Solomon Islands, Timor-Leste, Tuvalu, and Vanuatu). These are among the smallest and most remote countries on earth, together accounting for a land area of less than 60,000 square kilometres scattered across the world's largest ocean.[17]

Not surprisingly, all seven of the island LDCs in the Asia Pacific are very prone to external shocks such as those experienced during the global food, energy and economic crises in recent years. Simultaneously, all seven countries share a high degree of vulnerability to environmental disasters, that occur at regular intervals in the region, and whose numbers are expected to rise as a result of climate change. Adverse effects of the climate change-related sea-level rise are projected particularly for the Maldives, Tuvalu, and Kiribati, where a significant portion of the land mass is made up of low-lying atolls that do not reach more than a few meters above current sea level.[18] As former President Mohamed Nasheed (2009) of the Republic of Maldives noted, "For the Maldives, climate change is no vague or distant irritation but a clear and present danger to our survival. But the Maldives is no special case; simply the canary in the world's coal mine".

The extent of environmental vulnerability that characterizes these countries is highlighted by the Environmental Vulnerability Index developed by the South Pacific Applied Geoscience Commission (SOPAC), a regional organization in the Pacific. Based on several indicators, Kiribati, Maldives, Samoa and Tuvalu are rated as highly vulnerable to environmental shocks. The situation is less acute in Solomon Islands and Vanuatu; however, both countries are still rated as vulnerable.[19]

Vulnerability to natural disasters also threatens the tourism industry, an important form of economic activity in some of these countries. Even by 2000, international tourism receipts as a percentage of GDP amounted to 51.4 per cent in the Maldives, 22.9 per cent in Vanuatu and 17.7 per cent in Samoa. Data for 2005 shows a slight increase for Samoa but a decrease for

[17] UNESCAP 2009.
[18] FAO 2006.
[19] Timor-Leste is not covered by this index. For further details, see the Official Global EVI website at http://www.vulnerabilityindex.net/EVI_2005.htm

Maldives, resulting from the Indian Ocean tsunami in 2004. However, tourism receipts still accounted for almost 40 per cent of GDP.[20] The dominance of the tourism sector reflects the inadequate diversification of economic activity in these countries. In combination with their high vulnerability to natural disasters – as seen in the tsunamis of 2004 and 2009 that affected Maldives and Samoa respectively– the possibility of a drop in international tourism arrivals represents a concrete and major threat to overall economic development in these countries.

Global warming and economic growth

Climate change is also likely to severely affect individual sectors that are crucial from a human development point of view, particularly a sector like agriculture, the performance of which is critically dependent on soil and moisture conditions.[21] The combined and often conflicting effects of three consequences of GHG emissions are involved here: rising temperature, increased CO_2 concentrations and changes in rainfall patterns. The Stern Review (2007) argued that the impact of warming on agriculture was captured by a "hill function", with the location of the hill on the curve relating yields to temperature changes being dependent on geography. Thus in tropical regions, to which much of the Asia-Pacific belongs, even a 2˚C rise in temperature could result in a significant decline in yields. In higher latitudes, crop yields are expected to increase initially when temperature increases are moderate, and then to fall. Finally, significantly higher temperatures are expected to result in substantial declines in cereal production around the world, particularly if the carbon fertilization effect[22] is small, as argued by some.

Modelling studies discussed in recent IPCC reports indicate that moderate to medium increases in mean temperature (1–3ºC), along with associated CO_2 increases and rainfall changes, are expected to benefit crop yields in temperate regions. However, in low-latitude regions, moderate temperature increases (1–2ºC) are likely to have negative yield impacts for major cereals. Warming of more than 3ºC would have negative impacts in all regions.[23]

The effect tends to be greater on winter crops in tropical climates. However, these effects may not materialize in full or at all because of the potentially offsetting effects of increased atmospheric carbon dioxide concentrations.[24] Studies that attempt to simulate the effects of different combinations of temperature rise and increased CO_2 point to the probability of a small increase in rice yields, while the effect on wheat is unclear, varying from negative to positive.

[20] UNESCAP 2009.
[21] For a detailed review see Jayaraman 2011.
[22] Since plants absorb carbon dioxide from the air in their growth process, scientists have suggested that as CO_2 concentrations in the atmosphere rise, plant growth will increase. But while this consequence has been demonstrated under laboratory conditions, open air, field experiments reportedly point to smaller gains. See Cline (2007).
[23] Easterling et al. 2007.
[24] Carbon fertilization refers to the fact that higher concentrations of carbon dioxide promote plant growth by facilitating the production of carbohydrates and reducing water loss due to respiration. This effect is stronger in the case of the so-called "C3 crops" such as rice, wheat and legumes, as compared with the "C4 crops", such as maize, millets, sorghum and sugarcane. Earlier estimates of the effect of carbon fertilization were based on laboratory experiments. But subsequent studies based on so-called Free-Air Concentration Enrichment (FACE) experiments conducted on field crops in open air under agronomic conditions suggest that the effect of carbon fertilization is almost 50 per cent lower than indicated by laboratory studies for C3 crops and almost nil for C4 crops.

Similarly in the available science the effect of predicted variations in rainfall is uncertain. But it is to be expected that in primarily rain-fed agriculture, farmers dependent on rainfall for irrigation and farms inadequately provided with drainage and flood control protection are bound to be adversely affected by increased uncertainties in rainfall.

Agriculture is also likely to be affected from the cost side. Temperature increases are expected to adversely impact the response of crop output to nitrogenous fertilizers, necessitating larger application to sustain production. Further temperature and rainfall pattern changes may affect the type and intensity of vulnerability to pest attack, necessitating costly adaptation.

A detailed modelling exercise by ADB and IFPRI (2009) concluded that while climate change will cause yield declines for the most important crops in developing countries as a group, South Asia will be particularly hard hit. Even as far as irrigated crops are concerned, while climate change will have varying effects across regions, irrigated yields for all crops in South Asia will experience large declines.

William Cline's study (2007) predicted that under the IPCC's scenario A2, by the 2080s, global agricultural productivity would decline by about 3 per cent if the carbon fertilization effect was operative and by about 16 per cent if it was not. These losses are expected to be disproportionately concentrated in developing countries, which would suffer losses of 9 per cent and 21 per cent respectively with and without the carbon fertilization effect, as compared with an 8 per cent gain and 6 per cent loss in industrial countries. Estimates by country and region suggest that South Asia and Africa would be the two regions most harmed by climate change. In Southeast Asia, in the absence of adaptation, the damages of climate change to agriculture would also be severe, ranking from 15.1 per cent for Viet Nam to 26.2 per cent for Thailand if the carbon fertilization effect did not materialize.[25]

The potential adverse impact of climate change on agriculture is of particular significance to the Asia-Pacific region where more than 60 per cent of the total population and their dependents (numbering 2.2 billion people) are dependent on agriculture. Water-related stress is expected to reduce irrigated agriculture and adversely affect rice cultivation. ADB and IFPRI (2009) estimated that rice production could drop by as much as 14-20 per cent over the next four decades. This is expected to push up prices across the region and increase the number of malnourished.

Fisheries and forestry

Sectors allied to agriculture are also likely to be affected adversely by warming. An area of activity that is likely to be significantly affected is marine and inland fishery. The ambient temperature influences the body temperatures of aquatic species. Hence an increase in surface temperatures, that would affect the temperatures of the oceans, seas, rivers and inland water bodies, would in all likelihood raise body temperatures of a range of aquatic species. This is expected to significantly affect metabolism and, hence, the reproductive seasonality, efficacy and therefore production of fish. There could also be changes in the resistance and susceptibility to diseases and toxins as well. Climate change-induced temperature changes

[25] Zhai and Zhuang 2009.

can also impact on the spatial distribution of fish resources and therefore on fishing and aquaculture activities.[26]

But besides air and water temperatures, a number of other climate variables are known to influence fisheries: precipitation, salinity, ocean circulation, river flow, sea and lake levels, ice cover and glacial melt, and storm frequency and intensity. The potential effects of these variables are diverse. To start with, they affect, as noted above, the abundance and distribution of exploited species and assemblages, and therefore the level of production. In addition, increases in the frequency and severity of extreme events adversely affect fishing operations and infrastructure. Further, given their location, fishing communities may be more sensitive to climate changes that affect people's livelihoods and food security, and to impacts on aspects unrelated to economic activities, such as diseases or damage due to disasters.

Besides the Americas, the largest fisheries in terms of total capture production and employment are in Asia. Among the world's major fishing nations are China, Japan, Indonesia, India and Thailand. Among Least Developed Countries, the only one that features among the top 33 fishing nations is Bangladesh, with significant inland and marine fishing activity. Thus, Asia is likely to be significantly affected, with possible adverse implications for the livelihoods of poor fishing communities.[27]

However, the evidence on the nature of the changes that would occur is still uncertain. Both negative and positive impacts are predicted, depending on region and nature of fishery activity (marine or inland fisheries or aquaculture). But expectations are that in the foreseeable future biological changes induced by climate shifts would lead to physiological stresses and adverse life cycle impacts. As a result, there could be increased vulnerability in terms of less stable livelihoods, besides safety risks arising from harsher weather conditions and the need to fish further away from landing sites.

Three issues are seen as influencing the vulnerability of the Asia-Pacific to changes in fisheries due to climate change. The first is the high fisheries dependence of the region. Besides being an important source of livelihood, fish accounts for a significant share of export revenues in Southeast and South Asia. The second is that it is an important source of dietary protein amounting to as much as 40 per cent of the animal protein consumed in the region.[28] A concomitant of such dependence is over exploitation. Whether it is lakes such as Chilika in India or Southeast Asian coral reefs, current appropriation levels are many multiples of the sustainable catch. Any reduction in the resource can have grave consequences. And climate change can in many ways affect the resource. Third, Asian fisheries depend, for example, on many rivers that originate in the mountains, including the Indus, the Brahmaputra, the Ganga and the Mekong originating in the Himalayas. While climate change impacts are uncertain, it could lead to earlier peaking of seasonal flows or even reductions in flows, because of reduced snowfall and the melting of glaciers. This could severely impact river-dependent fishing populations.

[26] FAO 2008.
[27] Allison et al. 2009.
[28] Allison et al. 2009.

Forests and climate change

The role of forests in the climate change process is complex, since their presence offers an important means to mitigation of CO_2 emissions, especially in tropical countries, whereas their removal releases CO_2 into the atmosphere. Trees absorb CO_2 to convert them into organic matter such as leaves and roots, releasing carbon when they die and decay or are burnt. Since, in the process, they absorb more carbon then they release, forests serve as natural carbon sinks. This is significant for two reasons: first, forests cover more than a fourth of the earth's land area, and account for more than three-quarters of the carbon stored in terrestrial plants and nearly two-fifths of that stored in the soil; and, second, deforestation accounts for a significant share of CO_2 emission. The amount of CO_2 sequestered in forests is estimated at nearly half of all the carbon in terrestrial plants. Tropical deforestation can also deplete the moderate levels of soil carbon. Thus, the cost is lowest and carbon benefit largest, when tropical deforestation is reduced and reversed.[29]

Anthropogenic deforestation results from a range of activities, such as: shifting (slash and burn) cultivation; small-scale and large-scale permanent cultivation in agriculture; clearing of forests for mining and industrial expansion; wood extraction, through logging and fuel wood harvesting and activities such as road building. Although commercial wood extraction is focused on a relatively few tree species in tropical forests, it most often results in substantial waste. While only around 10 per cent of the wood volume may be harvested, many non-target trees are killed or damaged.[30] Further, commercial logging involves laying roads for removing the timber, which in turn provides access for agricultural expansion and other developmental (forest-clearing) activities. Finally, government policies encouraging resettlement from urban centres into forested areas also have adverse effects. According to the IPCC, land use changes, primarily deforestation, were responsible for the release about 5.8 Gt CO_2 (gigatons or billion metric tons of CO_2) annually, or about 17 per cent of all annual anthropogenic GHG emissions in the 1990s.[31] Hence if forest cover can be sustained and deforestation reversed, the world can relatively cheaply mitigate the problem of GHG emissions.

On the surface, the record in Asia-Pacific is positive. Between 1990 and 2010, net forest cover in Asia increased by 0.7 million hectares. But this average conceals significant differences. There has been large-scale afforestation in countries like China, and significant programmes of afforestation in India and Viet Nam. On the other hand, over the same period Southeast Asia lost 3.32 million hectares of forested area.[32] In some countries (such as Thailand) there has been a decline in primary forest despite the existence of formal logging bans. Across the Asia-Pacific, rates of deforestation were the highest in Southeast Asia, where forest cover decreased by 0.41 per cent per annum between 2000 and 2010, compared to a 0.36 per cent annual decrease in Oceania and annual increases of 0.28 per cent in South Asia and 1.16 per cent in East Asia. On average, the loss of tropical forests is greater than deforestation in boreal and temperate forests. This makes the Southeast Asia case significant. Southeast Asia (especially the Indochinese Peninsula, Indonesia and the Philippines), accounts for approximately a third of the tropical forest area in the world. Indonesia alone

[29] Gorte and Sheikh 2010.
[30] Gorte and Sheikh 2010.
[31] Barker et al. 2007.
[32] FAO 2010.

accounts for around 9 per cent of the world's tropical forest area and for nearly 13 per cent of global tropical deforestation.[33]

Natural forests are also known to contain more biomass (250 tC/hectare) than plantations (50 tC/hectare) or agroforestry systems (90-120 tC/hectare).[34] The net result is that the Asia-Pacific region, with its high deforestation and spatially widely different afforestation rates has been found to be the major source of forest-related emissions, with levels higher than in Sub-Saharan Africa or Latin America. Conservation of natural forests is crucial for climate change mitigation strategies in this region.

Deforestation in Southeast Asia is largely driven by small-scale, shifting or permanent agricultural activity. In fact, except for Malaysia and Indonesia, commercial logging is less important as a cause of deforestation. But deforestation in Indonesia and Malaysia due to commercial logging is important overall, since they have extensive forests and are characterised by high deforestation rates. Even here, however, large-scale commercial agriculture is emerging as the predominant cause of deforestation, particularly as a result of oil palm cultivation as a major commercial crop, with extensive areas being cleared for oil palm plantations.[35] The other plantation crop responsible for deforestation is rubber, especially in Thailand and Malaysia.

Given these developments there is considerable agreement that, in recent decades, tropical deforestation has been responsible for the largest share of CO_2 released to the atmosphere as a result of land use changes. According to one estimate, at current rates of deforestation, the clearing of tropical forests could release an additional 87 to 130 GtC of CO_2 to the atmosphere by 2100.[36] Thus, the task of reducing emissions from deforestation and forest degradation (REDD) must be an important area of focus for mitigation efforts, especially in developing countries of the Asia-Pacific region.

Livelihoods of poor tribal populations are also likely to be affected by the impact of climate change on forests.[37] They are dependent on forest vegetation, which may not adapt to climate change. As much as 70 per cent of forest vegetation can be adversely affected. Since not all species are likely to be uniformly affected, there is likely to be a significant change in the composition of forest cover in different regions. There is also likely to be a spread of species from other regions as climate changes. The stress resulting from the transition is likely to result in loss of forest cover and biodiversity.

Emissions and growth

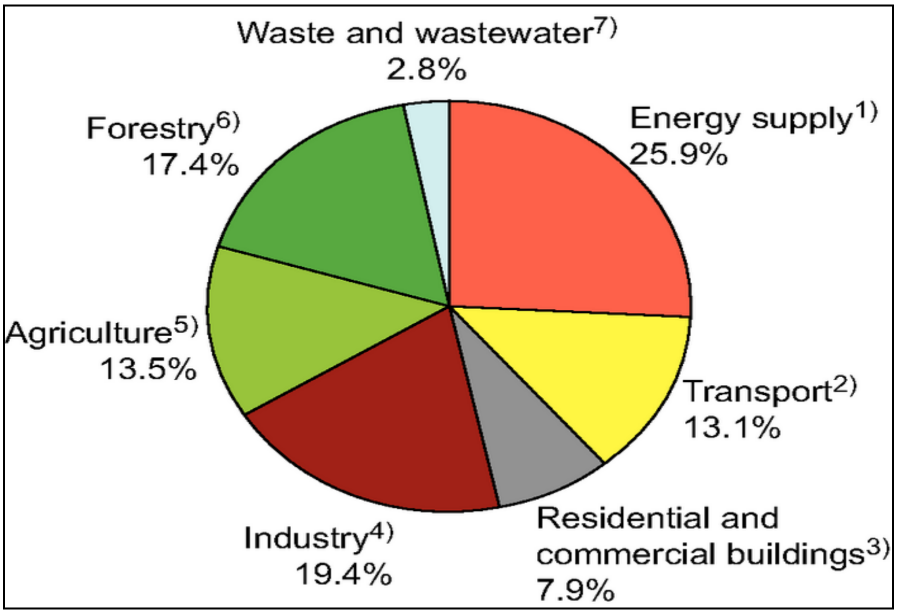
For these and other reasons, efforts to mitigate emissions and adapt to global warming and climate change are imperative. It is inevitable that developing countries too will need to move to low-carbon pathways of development. If technological change to accommodate that shift without affecting growth adversely would take time, then the difficulties of realising a range of requirements set by the challenge of eradicating poverty and advancing human

[33] Gorte and Sheikh 2010.
[34] FAO 2010.
[35] Gorte and Sheikh 2010.
[36] Houghton 2005.
[37] Nilsson 2008.

development will be all the greater when the climate change challenge is addressed adequately. This is because reducing emissions is expected to impact adversely on growth, with likely attendant effects on human development indicators.

It must be noted that, while contributions by developing countries to the GHG emission reduction initiative is imperative, any one Asian country's emissions reduction will have little impact on global warming (with the possible exception of China). Thus, the case for mitigation efforts by developing countries, including in Asia, is predicated on the presence of a global agreement and global action to reduce GHG emissions to realise stabilisation targets. The principal sources of GHG emissions are: (i) CO_2 emissions due to the burning of fossil fuels, that accounted for around 56.6 per cent of anthropogenic GHG emissions in 2004; (ii) CO_2 emissions due to deforestation and decay of biomass (17.3 per cent) and other factors (2.8 per cent); (iii) methane (CH_4) emissions due to the digestive process in ruminant animals such as cows, buffalo and sheep, agricultural activities such as paddy farming and land use changes (14.3 per cent); (iv) nitrous oxide (N_2O) from activities such as the use of chemical fertilizers in agriculture (7.9 per cent); and (v) F(luoro) gases released by refrigeration and fire suppression systems (1.1 per cent).[38]

Figure 2: Contribution of human activity to GHG emissions 2004

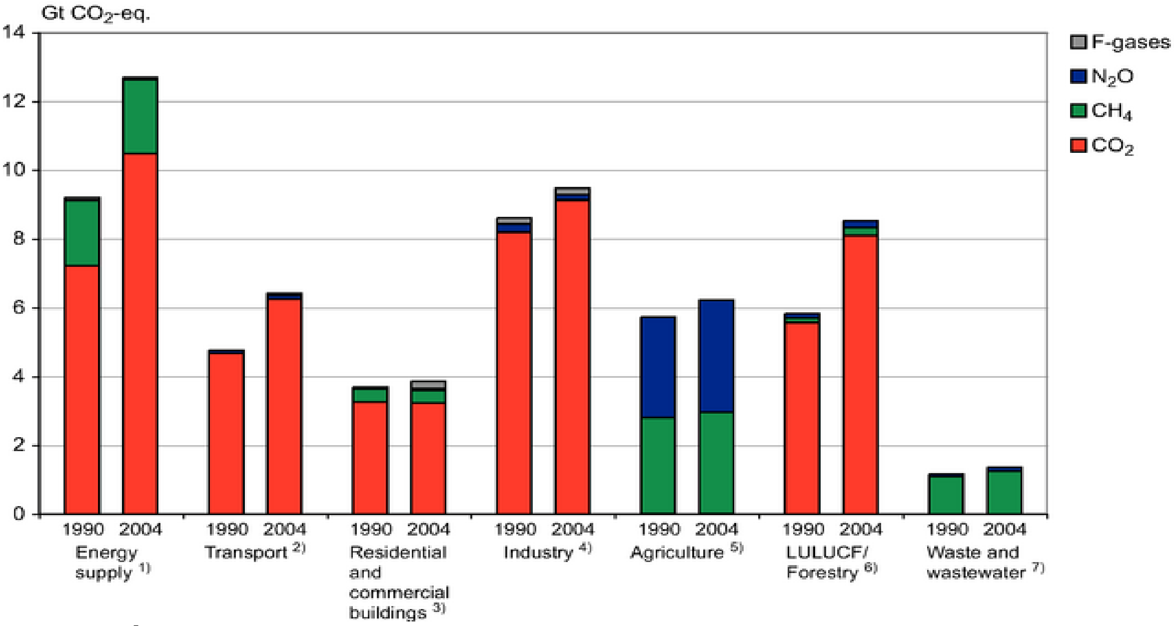


Source: Barker et al. 2007.

It should be clear from this that human activity directly and indirectly contributes substantially to GHG emissions. The contribution of various human activities to aggregate GHG emissions in 2004 and individual GHG gases in 1990 and 2004 are given in Figures 2 and 3. The similarity in emission on average between Asia and the rest of the world emerges from Figure 4, though there are significant inter-country variations within regions.

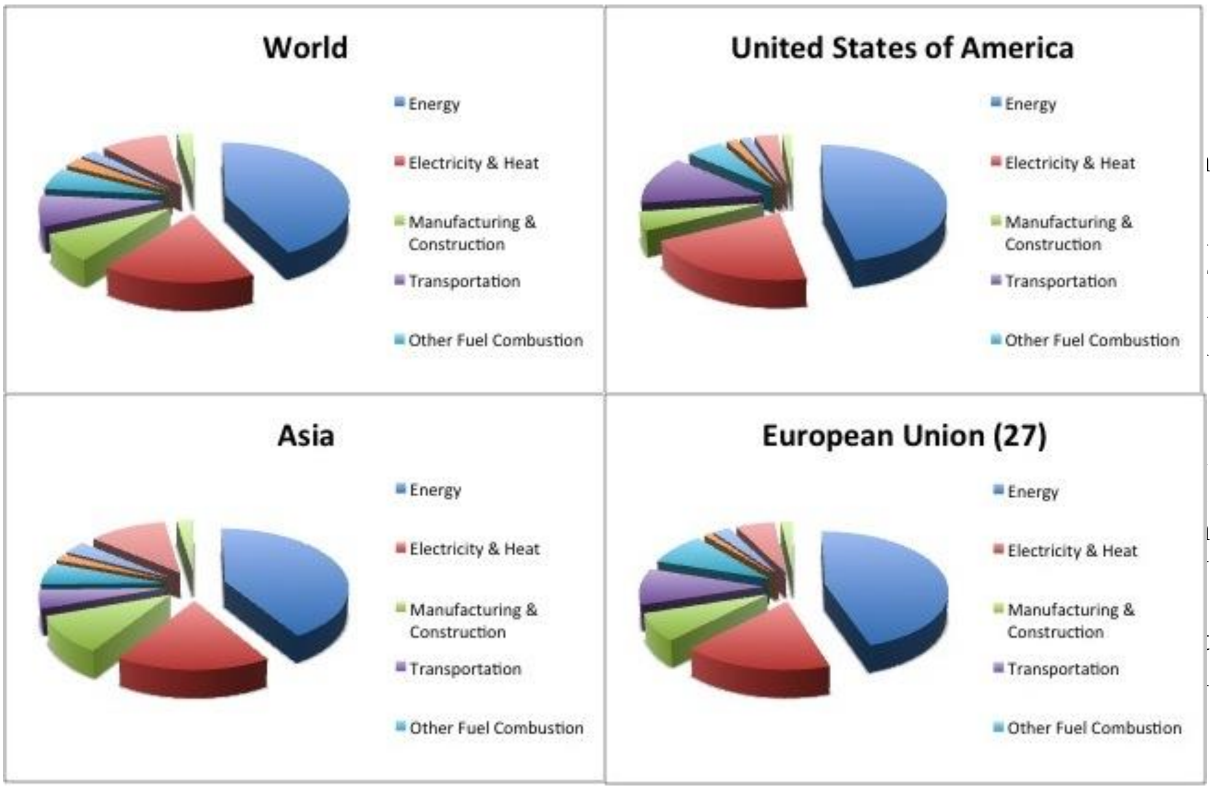
[38] Barker et al. 2007.

Figure 3: Contribution of selected economic activities to emissions of different gases 1990 and 2004



Source: Barker et al. 2007.

Figure 4: GHG emissions by sector in 2000 (excluding land use change) CO_2, CH_4, N_2O, PFCs, HFCs, SF_6



[39] IEA 2007.

In the case of transportation, though considerable fuel economies are expected as well as an increase in the use of hybrid and electric cars, these effects would be more than neutralised by the increase in demand for cars. According to one estimate, the number of cars worldwide will increase by 2.3 billion between 2005 and 2050, and the number of cars in emerging and developing countries will increase by 1.9 billion.[40] Investment in road infrastructure is expected to facilitate this trend.

To these effects we need to add the increase in emissions on account of energy transmission and distribution systems and air transportation.[41] Finally, all this occurs also in the most populous countries of the world with at least one of them (China) characterised by improved well-being even among the lower income deciles of the population.[42]

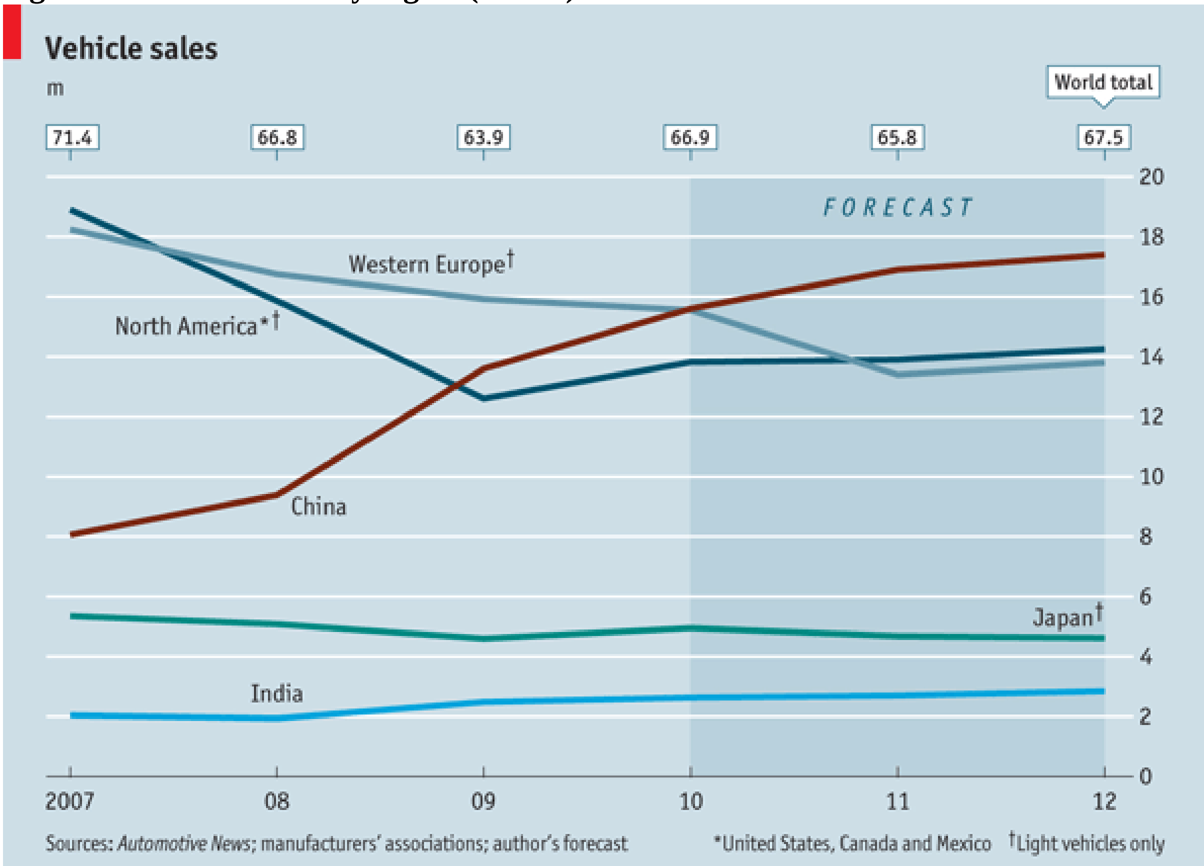
The critical issue is the shortfall in access to energy and transport in many countries in the Asia-Pacific region. In 2004 60 per cent of the 1.6 billion people worldwide with inadequate access to energy lived in this region.[43] This makes expansion of energy supply an inevitable aspect of the development trajectory here. For a host of reasons varying from costs to the availability of and access to technological options countries in the region that seek to deal with the supply-demand imbalance are increasingly relying on fossil fuels, with an important role for coal. This is particularly true of countries like China, India and Indonesia with large coal reserves.[44]

The share of the Asia-Pacific region in the world's coal consumption, which amounted to about 40 per cent in 1999, rose by 81 per cent by 2006. China and India alone accounted for 45 per cent of the world's consumption by the latter date.[45] This is only expected to increase further.[46]

As for transport, in 2006 Asia accounted for 19 per cent of the total worldwide transport-related emissions. This is projected to rise to 31 per cent by 2030.[47] An important reason for past and projected increases in transport-related emissions is the rapid pace of urbanization in the region. The urban population in the region is expected to increase by 44 million every year over the next 20 years, to add another 1.1 billion people. While Asia already has 10 of the world's 25 largest cities, they are expected to expand even further.[48] One consequence of that urbanization is that emerging Asian countries are estimated to have added 35 million vehicles (excluding 2- and 3-wheeled vehicles) to their fleets between 2006 and 2009, with China alone accounting for around 80 per cent of that increase (Figure 5). Vehicle sales in China are expected to continue to increase to reach aggregate North American levels in the not too distant future.

[40] Chamon et al. 2009.
[41] Helm 2008.
[42] According to the Human Development Reports for 2004 and 2009 (UNDP 2004; UNDP 2009), GDP per capita in current US dollars increased from $989 to $3205.5 in China between 2002 and 2007. On the other hand the share of the poorest 10 per cent in income or consumption rose from 1.8 per cent to 2.4 per cent. As opposed to this the corresponding figures for India were $487 to $1176.9 and 3.9 per cent and 3.6 per cent,
[43] UNDP 2007, based on IEA 2006.
[44] ADB 2009a.
[45] ADB 2009a.
[46] Garnaut et al. 2008.
[47] ADB n.d.
[48] ADB 2010.

Figure 5: Vehicles sales by region (million)



Source: *The Economist* 2010.

Under the "business as usual" scenario, developing Asia, including China and India, is expected to account for around 45 per cent of the total world increase in oil use through to 2025—the vast majority for transport.[49] This in turn will have significant implications for pollution and energy security across the region. As of 2007, combustion of fuels in the transport sector accounted for 13 per cent of gross worldwide emissions and 23 per cent of global carbon dioxide emissions. According to the ADB (2010), of the 6 billion tons of transport-sector related CO_2 emissions, 1 billion tons are estimated to be from Asia. Emissions in the region are expected to double by 2030, if changes in transportation patterns occur, and China and India are expected to account for 56 per cent of this increase." Chinese transport-related CO_2 emissions are expected to increase fourfold from 19 per cent of total emissions in 2005 to 27 per cent in 2030, and GHG emissions from India from 8 per cent to 13 per cent of the total. This makes the task of addressing transport emissions in Asia crucial to the global CO_2 mitigation effort.[50]

The obvious policy "take away" from this skewed scenario is that since many Asia-Pacific developing countries are at levels of income that imply that increases in income would be associated with significant increases in energy intensity and transportation demand, climate change mitigation policy must look to promote production patterns and technologies that are less energy intensive, seek to reduce the carbon intensity of energy supply (by encouraging the use of gas-based rather than coal-based technologies, besides solar and wind power

[49] ADB 2010.
[50] ADB 2010.

wherever feasible)[51], and reduce the carbon footprint of populations by investing in and encouraging the use of public transport as well as communications and other technologies that can reduce the need for long distance travel. However, given the legacy of carbon accumulation in the environment, current income levels in many developing countries, and the available technological options, it is unlikely that mitigation would be able to reduce carbon emissions to levels where it could stall warming and climate changes adequately. Thus, adaptation efforts and policies would have an extremely important role to play.

The emissions-growth relationship

Given the sources of emissions discussed above, analysts have focused on two aspects of the relationship between growth and emissions. One is the nature of the relationship between aggregate and per capita GDP growth, the rate of GHG emission and the concentration of GHG gases. The other is the role of specific technological options and choices in individual sectors in increasing the extent of GHG emission.

There are three issues involved in examining the relation between growth and emissions. The first is the relationship between levels of per capita income and the level of per capita emission. The second is the relationship between the increment in per capita GDP and the increment in per capita emissions at different levels of per capita income. And the third is the distribution of population across countries with different levels of per capita income that determines the current volume and the rate of change of aggregate global GHG emission.

The evidence does seem to suggest that as average per capita incomes increase, carbon emissions tend to rise monotonically. Studies attempting to examine the relation of GDP to carbon emissions normally use purchasing power parity estimates of GDP rather than GDP valued at market exchange rates. Based on such data, one set of econometric studies[52] have found that while there is a monotonic relationship between GDP per capita and per capita emissions measured in terms of CO_2 equivalence, the marginal propensity to emit (or the ratio between the increment in emissions and the increment in GDP) tends to fall as income rises within the sample set of countries studied. Overall, the evidence seems to be that global carbon dioxide intensity has been falling over the last three decades or so,[53] though there are some who argue that this trend has been stalled or reversed in recent years.[54] The point, in any case, is that the reduction in intensities has not meant a fall in CO_2 emissions, but merely reflects the fact that emissions growth has not kept pace with GDP growth.

This comes through from Table 1, which shows that as we go up the income scale in terms of country groupings, the rise in per capita income is accompanied by a rather sharp increase in per capita emissions.

[51] Nuclear power, which was under a cloud after the Three Mile Island and Chernobyl incidents, had seen a revival in recent years on account of technological developments and climate change implications. However, the effects of the 2011 earthquake and tsunami in Japan have forced some rethinking with regard to nuclear energy the world over.
[52] For example, Heil and Selden 2001.
[53] King 2008.
[54] Raupach et al. 2007.

Table 1: Per capita CO_2 emissions by income category of countries			
Income Category	GDP per capita (current US$)	GDP per capita, PPP (constant 2005 international $)	CO_2 emissions (metric tons per capita)
High income	37708.05	33890.66	12.49
Upper middle income	7159.52	10893.97	5.26
Middle income	2958.67	5324.65	3.31
Lower middle income	1848.27	3849.60	2.79
Low income	432.47	980.53	0.28
World	8433.89	9535.27	4.63

Source: World Bank 2011.

What is striking about these figures is the huge discrepancy in per capita incomes and emissions between the High-income countries and the Middle-income countries and the significant difference between the Upper-middle and Lower-middle income countries both in terms of per capita income (however measured) and in terms of per capita emissions. These differences obviously impinge on the relative contributions of different countries to CO_2 emission and the stock of CO_2 in the atmosphere.

Sticking with groups of countries based on the income range we find that the relationship between emission intensities and GDP per capita is non-linear (Table 2). Emissions intensity rises sharply as we move up the ladder from low to lower middle income country groups, but then falls significantly in the upper middle and high income groups.

Table 2: **Relative contribution to CO_2 emission by income category of countries**					
Country Category	GDP per capita, PPP (constant 2005 international $)	CO_2 emissions (kg per 2005 PPP $ of GDP)	Share in CO_2 emissions	Share GDP, PPP (constant 2005 international $)	Share in Population
High income	33890.66	0.37	44.9	59.2	16.6
Upper middle income	10893.97	0.49	16.9	17.0	14.9
Middle income	5324.65	0.62	50.8	39.7	71.1
Lower middle income	3849.60	0.73	33.9	22.7	56.3
Low income	980.53	0.19	0.7	1.3	12.2

Source: World Bank 2011.

This does point to the advantages that could accrue if policy is used to accelerate the decline in the marginal propensity to emit, relative to the available historical trend. In 2004, the average CO_2 intensity of the more carbon efficient industrialised countries with a diverse combination of electricity production technologies (Germany, Italy, Japan, Switzerland and UK) stood at 321.7 tCO_2/Million International Dollars. Global GDP for that year was estimated by the World Bank at Int. $52,673 billion. If all countries had achieved the intensity of these countries, 2004 CO_2 emissions would have amounted to 16,946 $MtCO_2$ or 57 per cent of the actual 29,734 million tonnes of CO_2.[55]

The problem of course is that emissions do not depend only on technology, but also on the composition of consumption and production at different levels of income. While at the margin GDP increases may be associated with diversification away from high emission

[55] King 2008.

intensity sectors, those sectors are still absolutely large even in the developed countries. That is why per capita emissions and share in aggregate emissions of the developed countries are large even though their emissions intensities are lower at the margin. There are two implications emerging from here. The first is that technology acquisition and transfer can help current day developing countries accelerate the rate of decline of emission intensities relative to GDP. But, inasmuch as their levels of development would influence the pattern of consumption and production as income increases, their per capita and aggregate emissions are bound to increase significantly. While some advantages can be garnered from transferring technology developed in the richer countries to the poorer countries through international cooperation, this is as of now unlikely to neutralise the basic tendency towards emission increases due to anthropogenic factors.

Decomposition of emission by source

If we examine the relative contributions at the margin of OECD (developed) and non-OECD (developing and transition) countries, it emerges that the non-OECD countries, which were responsible for roughly one-third of global emissions, energy, and output in the early 1970s, had increased their shares to just over half of global energy use and emissions, and 45 per cent of global output by 2005. There were signs of acceleration of this trend as well. Between 2000 and 2005, non-OECD emissions had risen almost six times as fast as OECD emissions, accounting for 85 per cent of the growth in emissions.[56] The factors underlying these differences come through when we try and analyse the source of emissions in rich and poor countries. Ignoring differences in population and focusing on the role of energy consumption and supply in releasing CO_2, through what has been termed the "Kaya identity"[57], it is possible to decompose the contribution to emissions growth into those due to changes in GDP, energy intensity (of GDP), and carbon intensity (of energy). The identity is as follows:

$\Delta CO_2 = \Delta GDP * \Delta(Energy/GDP) * \Delta(CO_2/Energy)$.

Using such a relationship to measure the contributions of these elements to CO_2 emissions we find that the influence of all three on emissions had increased significantly in the non-OECD countries as a group. On the other hand, the OECD countries have shown a slowdown in growth, and a marginal reduction in energy intensity and carbon intensity during 2000–05 when compared with the previous decade.[58]

What is significant from the point of view of the mitigation effort is the evidence of a significant reduction among developing countries as a group in the rate of decline of the energy intensity of economic activity and the carbon intensity of energy use. During the 1990s, energy intensity in the non-OECD countries registered a rapid decline, with energy consumption growing at a quarter of the rate of growth of GDP, and emissions growing slightly slower than energy production. This changed after 2000, with a turn to more energy-intensive and carbon-intensive growth in the developing and transition world. As a result, energy use has grown at three-quarters the rate of GDP, and carbon emissions about a fifth faster than energy use.[59]

[56] Garnaut et al. 2008.
[57] Kaya and Yokobori 1997.
[58] Garnaut et al. 2008.
[59] Garnaut et al. 2008.

Overall, while energy intensity (the energy/GDP ratio) has fallen in both developed and developing countries, in the former the decline has been smooth and continuous, while in the latter it fell slowly over the 1970s and 1980s, plunged in the 1990s, and then stabilised at around 70 per cent of its 1971 level. The elasticity of energy use with respect to GDP in non-OECD countries, which was nearly one in the 1970s and 1980s, stood at only 0.25 in the 1990s, but had risen to 0.74 during 2000–5.[60] These variations could be because of the geographical distribution of growth. If rapid growth is occurring in those non-OECD countries where income levels are such that increases in income lead to a significant increase in energy intensity, then average energy intensity is likely to rise. On the other hand, if growth occurs mainly in countries whose income is beyond the threshold point after which increases in income are accompanied by a decline in energy intensity, average intensity is likely to be stable or fall.

In this connection, what is remarkable is the influence of one country, China, on the trend in energy intensity in non-OECD countries. Energy intensities are remarkably constant for developing countries once China is excluded. China started out with an extremely high energy intensity, which declined through the 1980s and 1990s, when it chose to move away from subsidizing energy consumption by keeping prices low, and then stabilized at the turn of the century.[61] More recently China's energy intensity has been rising rapidly. This is undoubtedly related to the pattern of China's recent development, especially over the last two decades. An aspect of this development is the dominance of manufactured production in the increment to GDP over this period. The industrial sector including power generation and heat production and supply and construction accounts for 84 per cent of China's CO_2 emission.[62] India, which recorded lower but significant growth in the 1990s and GDP growth rates significantly closer to that of China during the 2000s,[63] has relied far more on services to deliver additions to GDP, with attendant benefits in terms of a much lower energy intensity.

One reason for the unusual trajectory of energy intensity in China is the nature of its recent growth trajectory. As is well known, one aspect of China's trajectory of growth is the significant role of production of manufactures for export, resulting from the logic of a process of globalisation in which capital and technology are far more mobile than labour. This encourages a shift in global production to sites with cheaper reserves of labour of various kinds. In recent years China has emerged as one such favoured site. As a result, China accounts for emissions that are not just induced by its own consumption levels and patterns, but also by part of the increase in the consumption of manufactures elsewhere in the world. That is, China's emissions would have been far less and that of the rest of the world more, if at the same rate of global growth, all countries had produced domestically a substantial and equal share of the manufactured goods they consumed. This is a matter that we discuss further later in this paper.

Trends in carbon intensity

The trend in carbon intensity (emissions/energy) is more consistent across time in both sets (OECD and non-OECD) of countries. In the developed world, it declined till the mid-1990s

[60] Garnaut et al. 2008.
[61] Sheehan and Sun 2007, cited in Garnaut et al. 2008.
[62] UNDP China 2010.
[63] World Bank 2011.

and then stabilised at around 85 per cent of its 1971 level. In the developing world, it was stable through most of the period and has more recently been rising.[64]

Carbon intensity has on average remained stable despite rising oil prices in recent years because of the increasing reliance on coal, which is more carbon-intensive than oil and gas. In the 1980s and 1990s, a reduction in the share of oil in total energy demand was made up for by a corresponding increase in gas. But since 2000, the share of gas has remained constant, and the share of coal has increased. The same trends with regard to coal are visible in both developed and developing regions, though in much more dramatic terms in the latter. Between 2000 and 2005, coal use increased in developing countries on average by 9.5 per cent per year, and by 11.7 per cent in China.[65] In 2005, 61 per cent of the world's coal was consumed in developing countries, up from 51 per cent just 5 years earlier.[66] In 2005, coal provided 63 per cent of China's energy, 39 per cent of India's energy, and only 17 per cent of the rest of the world's energy.[67]

Thus, the acceleration of emissions this decade appear to have been caused by three factors: the rapid acceleration of growth in parts of the developing world; the end of a period of rapid decline in energy intensity in China; and an end to the decarbonization of energy supply in both the developed and (especially) the developing world.

To this we must add the much-noted fact that two of the fast growing countries, China and India, have huge populations. Thus even moderate increases in per capita emissions in these countries would result in significant increases in aggregate emissions. It is true that it is not population size alone but the pattern of consumption and of populations in individual countries that determines differentials in emission rates and intensities.[68] But the exclusion of population variations and focus on GDP, emission intensities and carbon intensities in the decomposition discussed above does conceal some features of recent trends.

In fact, looking at the world as a whole, population is by no means a driver when it comes to emissions. High income countries in 2007 accounted for 45 per cent of total emissions even though they were home to less than 17 per cent of the world's population (Table 2). What mattered far more is that they accounted for 59 per cent of the world's income. Lower-middle income countries on the other hand had 56 per cent of the world's population, but accounted for only 33.9 per cent of CO_2 emissions, even though they were less emission efficient, because they contributed only 23 per cent of global incomes.

[64] Garnaut et al. 2008.
[65] Garnaut et al. 2008.
[66] Garnaut et al. 2008.
[67] IEA 2007.
[68] Satterthwaite 2009.

Table 3: Emissions indicators for top 10 CO_2 emitting countries							
Countries	CO_2 emissions (kg per 2005 PPP $ of GDP)	Share in CO_2 emissions (kt)	CO_2 emissions (metric tons per capita)	Share in GDP (current US$)	Share in GDP, PPP (constant 2005 international $)	Share in Population, total	CO_2 emissions (kt)
China	0.95	21.32	4.96	6.26	10.94	19.91	6,533,018.26
United States	0.44	19.03	19.34	25.18	20.86	4.56	5,832,193.98
India	0.53	5.26	1.43	2.21	4.80	16.99	1,611,042.48
Russian Federation	0.78	5.01	10.81	2.33	3.15	2.15	1,536,099.02
Japan	0.31	4.09	9.81	7.84	6.41	1.93	1,253,516.69
Germany	0.29	2.57	9.57	5.96	4.35	1.24	787,291.01
Canada	0.47	1.82	16.89	2.55	1.88	0.50	556,884.03
United Kingdom	0.26	1.76	8.84	5.01	3.29	0.92	539,175.92
Korea, Rep.	0.41	1.64	10.38	1.88	1.92	0.73	502,909.65
Iran, Islamic Rep.	0.67	1.62	6.98	0.51	1.16	1.07	495,581.65

Source: World Bank 2011.

The complex threshold effects that influence the role of population and other factors comes through when we examine the country-wise evidence pertaining to the top 10 countries in terms of total emission (Table 3). In this restricted league table too, the top two countries account for more than 40 per cent of the CO_2 emissions in the world, whereas the remaining eight are responsible for just 24 per cent. The two are China and the United States. But the difference between the two is obvious. While China's high contribution was because it accounted for a fifth of the world's population, the United States with less than a twentieth of the world's population emerged a leader in emissions because of its high share in GDP and its high per capita income and emission rate.

However, when we compare China with India (which too accounts for as much as 17 per cent of the world's population), the assessment changes substantially (Table 3). China's high per capita income and manufactures-dependent growth results in a much higher emission intensity (0.95 kg per 2005 PPP $) that is almost double that of India's (0.53 kg). This makes its CO_2 emission almost 5 metric tonnes per person as compared with India's low 1.43. So even though India has a population close to China's, its share in emissions is just 5.26 per cent as compared with China's 21.32 per cent. This occurs despite the fact that India is the world's third largest emitter. The implication is that if India does catch up in terms of per capita GDP with China by pursuing a similar development trajectory, the implications for global atmospheric CO_2 levels can indeed be grave. Since the 1990s, GDP increments in India are based more on services than on manufacturing, unlike in China where manufacturing growth has been extremely important. This does rein in emissions to some degree. But given the already high share of services in India's GDP, it is to be expected that if India sustains its current high rates of GDP, the role of the commodity producing sectors in general and manufacturing in particular would increase substantially.

Emission trajectories in Asia-Pacific

To summarise the point being made, underlying global levels and incremental rates of emission are vastly diverse country contributions due to a combination in each case of accumulated historical emissions, current emissions and potential future emissions. Such divergences characterise countries in the Asia-Pacific region as well, given their varied characteristics, development trajectories and levels and rates of growth. To start with, in terms of CO_2 emission per $ of 2005 PPP GDP, Mongolia and China, with 1.33 and 0.95 kg respectively, are clearly outliers in a group of 34 Asia-Pacific countries, developed and developing, for which the relevant data are available from the World Bank's World Development Indicators database. These two countries are followed by a set of seven countries (Maldives, Malaysia, Thailand, India, Viet Nam, Australia and Indonesia), which recorded emissions per unit of PPP GDP of between 0.5 and 0.6 kg. Tonga, Brunei Darussalam, Republic of Korea, Pakistan and Fiji are close together in the 0.4 to 0.42 kg range, Japan and New Zealand are at 0.3 and 0.31, and the rest consisting of developed countries and regions like Singapore and Hong Kong (SAR), China, and Less Developed Countries like Bangladesh and Bhutan fall below the 0.3 kg range.

Table 4: Carbon emission intensity among Asia-Pacific countries

Country Name	CO_2 emissions (kg per 2005 PPP $ of GDP)	CO_2 emissions (kg per 2000 US$ of GDP)
Mongolia	1.33	5.93
Marshall Islands	..	0.75
Palau	..	1.58
China	0.95	2.66
Maldives	0.60	0.84
Malaysia	0.57	1.46
Thailand	0.56	1.60
India	0.53	2.08
Viet Nam	0.53	2.12
Australia	0.52	0.72
Indonesia	0.50	1.70
Tonga	0.42	0.86
Brunei Darussalam	0.41	1.09
Korea, Rep.	0.41	0.68
Pakistan	0.41	1.48
Fiji	0.40	0.76
Japan	0.31	0.24
New Zealand	0.30	0.50
Papua New Guinea	0.27	0.80
Philippines	0.25	0.66
Timor-Leste	0.25	0.57
Singapore	0.24	0.38
Bangladesh	0.24	0.63
Samoa	0.22	0.52
Bhutan	0.20	0.73
Micronesia, Fed. Sts.	0.19	0.27
Cambodia	0.18	0.64
Solomon Islands	0.17	0.36

Kiribati	0.16	0.43
Sri Lanka	0.15	0.54
Hong Kong (SAR), China	0.14	0.17
Lao PDR	0.14	0.56
Vanuatu	0.12	0.30
Nepal	0.12	0.49
Macao (SAR), China	0.06	0.10
Afghanistan	0.02	..

Source: World Bank 2011. *Notes*: .. indicates "not available'. Countries are listed in descending order of emissions intensity.

Table 5: Selected emission indicators for countries in Asia-Pacific

	CO_2 emissions (kg per 2005 PPP $ of GDP)	Share in CO_2 emissions (kt)	Share in GDP (current US$)	Share in GDP, PPP (constant 2005 international $)	Share in Population, total
China	0.95	55.42	27.03	35.50	36.08
India	0.53	13.67	9.54	15.59	30.79
Japan	0.31	10.63	33.87	20.80	3.50
Korea, Rep.	0.41	4.27	8.12	6.23	1.33
Indonesia	0.5	3.37	3.34	4.07	6.15
Australia	0.52	3.17	6.63	3.67	0.58
Thailand	0.56	2.35	1.91	2.53	1.83
Malaysia	0.57	1.65	1.44	1.75	0.73
Pakistan	0.41	1.33	1.11	1.96	4.45
Viet Nam	0.53	0.94	0.53	1.07	2.33
Philippines	0.25	0.60	1.11	1.45	2.43
Korea, Dem. Rep.	..	0.60			0.65
Singapore	0.24	0.46	1.37	1.17	0.13
Bangladesh	0.24	0.37	0.53	0.96	4.32
Hong Kong (SAR), China	0.14	0.34	1.60	1.42	0.19
New Zealand	0.3	0.28	1.07	0.56	0.12
Myanmar	..	0.11			1.35
Sri Lanka	0.15	0.10	0.25	0.41	0.55
Mongolia	1.33	0.09	0.03	0.04	0.07
Brunei Darussalam	0.41	0.06		0.09	0.01
Cambodia	0.18	0.04	0.06	0.13	0.39
Nepal	0.12	0.03	0.08	0.14	0.77
Papua New Guinea	0.27	0.03	0.05	0.06	0.18
New Caledonia	..	0.02			0.01
Macao (SAR), China	0.06	0.01	0.14	0.13	0.01
Lao PDR	0.14	0.01	0.03	0.06	0.17
Fiji	0.4	0.01	0.03	0.02	0.02
Maldives	0.6	0.01	0.01	0.01	0.01
French Polynesia	..	0.01			0.01
Afghanistan	0.02	0.01	0.08	0.13	0.77
Bhutan	0.2	0.00	0.01	0.01	0.02
Palau	..	0.00	0.00		0.00

Solomon Islands	0.17	0.00	0.00	0.01	0.01
Timor-Leste	0.25	0.00	0.00	0.00	0.03
Tonga	0.42	0.00	0.00	0.00	0.00
Samoa	0.22	0.00	0.00	0.00	0.00
Vanuatu	0.12	0.00	0.00	0.00	0.01
Marshall Islands	..	0.00	0.00		0.00
Micronesia, Fed. Sts.	0.19	0.00	0.00	0.00	0.00
Kiribati	0.16	0.00	0.00	0.00	0.00

Source: World Bank 2011.

It must be noted, however, when the emissions intensity is measured relative to constant price 2000 GDP computed in dollars at market exchange rates, the differences shrink rapidly, excepting for Mongolia. Thus, as indicated in Table 4, China with 2.66 kg per dollar of GDP is closer to India and Viet Nam at 2.08 and 2.12 respectively.

Thus, there is no clear linear and monotonic relationship between level of development or per capita income and emissions intensity relative to GDP, so that differences in per capita income are associated with very wide variations in per capita CO_2 emissions across countries. Countries like Brunei Darussalam, Australia, Singapore and the Republic of Korea have emissions in the range of 10 to 20 metric tonnes per capita. Japan, New Zealand, Malaysia and Hong Kong (SAR), China, are in the 5 to 10 metric tonnes range. China, Thailand and Mongolia are in the 4-5 metric tonnes range and India and Viet Nam fall as low as in the 1-1.5 metric tonnes per capita category.

However, once we allow for the huge differentials in population, China and India jump to the top of the aggregate emissions league table, only to be followed by Japan, Republic of Korea, Indonesia and Australia. But here too there are important differences. As indicated in Table 5, China with 36 per cent of the population in 39 Asia-Pacific countries, accounts for 55.4 per cent of CO_2 emissions, whereas India with 31 per cent of the population contributes only 13.7 per cent. On the other hand, Japan with 3.5 per cent of the regional population contributes 10.6 per cent of annual CO_2 emissions.

As noted earlier, there is one major difficulty in apportioning responsibility for emissions based on these estimates. The estimates relate only to emissions resulting from *production* activities within a country's territory, and not to the emissions implicit in the level and pattern of consumption of the population of a country. With many developing countries becoming the production hubs for servicing the consumption needs of developed country populations, this could convey a wrong impression of the responsibility of the populations of individual countries for global emissions at the margin.

As Dieter Helm (2008) argues: "A country (for example, the UK) could have a relatively low production of greenhouse gases, but at the same time have a high consumption level. It could produce low carbon- intensive goods (such as services, rather than manufacturing), but import and consume high carbon-intensive goods (steel, aluminium, glass, and chemicals). In the UK's case, the shift of high carbon-intensive production to China, India, and other developing countries has had this effect. Furthermore, it could achieve a given Kyoto target by moving energy-intensive industries offshore—without making any noticeable difference to climate change.

Some numbers indicate the scale of these effects. On the UN FCCC basis, the UK's record is impressive, having already surpassed the Kyoto target of a 12.5 per cent reduction by 2008–12. Just adding back in aviation and overseas activities of UK residents puts a dent in this performance—emissions have fallen only 11.9 per cent. Even this adjustment puts the UK's meeting of the Kyoto target in jeopardy. But taking all greenhouse gases embedded in imports and subtracting greenhouse gases embedded in exports, Helm et al. (2007) provide a crude estimate that emissions between 1990 and 2003 have increased by 19 per cent."

This should make clear that taking account of emissions associated with a population's consumption rather than production is critical, especially because human development advance requires enhancing a range of consumptions of populations in developing countries.

Development and the carbon space

The close relationship between growth and development, on the one hand, and emissions, on the other has two implications. First, it implies that countries that are currently developed are responsible for the historical accumulation of GHG gases in the atmosphere. Second, it implies that even if mitigation efforts start early, current-day developing countries are likely to be major contributors to GHG emissions in the foreseeable future. This creates a major problem because the total carbon space available is limited, inasmuch as the stock of carbon dioxide in the atmosphere cannot be allowed to exceed an identified level without risking extremely grave climate consequences. Since the existing stock of atmospheric carbon dioxide cannot be easily reduced, the question of equitably sharing carbon space between developed and developing countries becomes exceedingly difficult. The over-occupation of carbon space by the developed countries implies that sharp and immediate cuts in emissions by them are a prerequisite for advance in dealing with climate change.[69]

Taking account of estimates[70] that a carbon space budget of 393Gt of carbon (1440 Gt of carbon dioxide) over 2000-2050 results in a 29 per cent to 70 per cent probability of a 2 degree C rise in surface temperature, and recognising that we cannot be excessively optimistic about emissions reduction, Kanitkar et al. (2010) set the allowable budget at that level. Then taking account of the 93Gt of carbon that has already been released between 2000 and 2009, they examine the implications of restricting emissions to the balance amount over the rest of the fist half of this century, assuming that nations with less than a fair share of the budget are allowed extra emissions and those with a less than fair share will have to ensure cuts. They find that "the extent of over-occupation of carbon space by the developed nations is such that they will have only negative entitlements to carbon space in absolute and relative terms until 2050 and beyond".

The fall-out of climate specific externalities

However, to focus exclusively on these differences across countries, when deciding on climate change action, would be to ignore the specificities of climate-related "externalities" that were highlighted by the Stern Review (2007), among other reports. In keeping with the basic notion of externalities, those who contribute to climate change do not solely or

[69] Kanitkar et al. 2010.
[70] Meinshausen et al. 2009.

proportionately suffer its consequences, and are not necessarily called upon to undertake and bear the costs of mitigation or forced to finance the costs of adaptation incurred by non-emitters who are adversely affected. With no economic incentives provided by markets to undertake such mitigation, it is unlikely that it would be implemented in adequate measure, if at all, unless governments intervene. What is more, those who contribute to deleterious climate change cannot be excluded from enjoying the benefits that the current climate affords.

The problem is that the climate change consequences of global warming are global, affecting countries, even when treated as homogenous entities, that contribute marginally to GHG emissions and have limited responsibility for the atmospheric concentration of GHGs resulting from human activity. In fact, examples of the likely effects of global warming on small island economies, for example, suggest that vulnerability and impact often tend to be higher in the case of countries that are not important GHG emitters. On the other hand, as and when countries that are far behind in the global per capita income league table experience significant acceleration in the growth of their per capita income in the near future, the available bundle of technologies would imply that their contribution to emissions would rise dramatically. The fact that countries like the Republic of Korea, in the not too distant past, and countries like China and India, currently, have experienced or are experiencing such acceleration, explains the growing concern about the possibility of unsustainable changes in climatic conditions.

A second important problem associated with global warming resulting from anthropogenic GHG emissions is that the current level of GHG accretion is partly a historical legacy, since once they are in the atmosphere, green house gases remain in place for several, and in some cases hundreds of, years. This implies that even in countries that are responsible for occupying a large part of the available carbon space, current generations may not accept responsibility for a part of the problem and may even absolve past generations of the responsibility of having made climate-deleterious consumption or investment choices, since they did not have prior knowledge of the consequences. While differentials in average per capita incomes and standards of living do provide a strong case for substantially differential distribution of mitigation burdens, the task of persuading current generations to do so is likely to be made difficult for these reasons.

Finally, the third problem is that a combination of historically more extreme inequality in the distribution of income and the fallout of the international demonstration effect has meant that a small elite in less developed companies can afford to and does imitate the lifestyle of the global rich, resulting in high, even if not similar, levels of GHG emissions. This weakens any argument that treats the rich, middle and the working classes in the developing countries as a homogenous group when allocating the burden of mitigation and adaptation.

Inequality and emissions

There is a strand in the literature that extrapolates from the fact that the marginal propensity to emit is seen to decline as we move from countries with lower to higher per capita income, to argue that the marginal propensity to emit would tend to be higher in the case of poorer sections of the population when compared to richer sections. In fact, Ravallion et al. (2000) state the conclusion rather strongly as follows: “In keeping with past work, we find a nonlinear (concave) relationship across countries between carbon emissions and average incomes. Consistently with the cross-country relationship, we have argued that inequality within countries should also matter to emission levels, and this is confirmed by our tests.

Our results suggest that a static trade off exists between reducing carbon emissions and promoting lower inequality both between and within countries. We also confirm past results suggesting that a trade off also exists between carbon emissions and economic growth. In the short term, poverty reduction through either redistribution or growth will tend to increase the carbon emissions that promote global warming."[71] In sum, according to this view, efforts to reduce poverty and advance human development are at least in the foreseeable future going to be adverse in their impact from the climate change perspective.

The inadequacies with regard to cross-country evidence on inequality need not detain us here. What we need to assess the robustness of this econometrically estimated relationship is an examination of the factors that might account for the observed relationship between income per capita across countries and the marginal emission rate. Technology provides the reason why the marginal propensity to emit declines with higher income. Richer countries have not only developed better technologies (such as fuel-efficient engines), but also have larger shares of population that have the incomes to purchase products that are more carbon efficient even if more expensive.

However, once we come to the relationship between intra-country income differences and their effects on the marginal propensity to emit, the non-availability of the technology does not offer an explanation for the differences between rich and poor. It can only be the ability of different sections to consume the appropriate technologies if they were to choose to. If through appropriate policies (such as investment in mass, fuel-efficient public transportation, for example) the government can make these technologies available to the poor as well, there is no reason why a redistribution that reduces poverty and advances human development should necessarily lead to increased emissions per unit increment in GDP. In fact, inasmuch as the presence of a large mass of poor and, therefore, cheaply available workers encourages consumption of a range of labour services by the rich that might otherwise be undertaken assisted by energy intensive equipment, a reduction in inequality due to a rise in the wages of the poor, may increase the marginal propensity to emit of the well to do. That is, it could be the presence of the poor that is rendering the rich carbon-efficient at the margin.

In fact, James Boyce (1994) offers powerful arguments as to why the presence of environmental inequality could lead to intensified environmental degradation. To quote: "First, the extent of an environmentally degrading activity depends on the balance of power between the winners, who derive net benefits from the activity, and the losers, who bear net costs. When the winners are powerful relative to the losers, more environmental degradation occurs than in the reverse situation. This reflects the operation of what I term a power-weighted social decision rule. Second, greater inequalities of power and wealth lead to more environmental degradation for three reasons: (a) The excess environmental degradation driven by powerful winners is not offset by the environmental degradation prevented by powerful losers; (b) inequality raises the valuation of benefits reaped by rich and powerful

[71] To moderate the impact of this heavy-handed conclusion econometrically arrived at, they go on to say: "However, we also find evidence of flattening out in the relationship between emissions and average incomes at middle-to-high income levels, and some signs of a reversal in the curvature at high average incomes. Thus it can be argued that the trade off between reducing inequality between countries and controlling carbon emissions will improve with growth, and eventually vanish, roughly when all countries reach the level of present-day middle income countries." Ravallion et al. (2000).

winners relative to costs imposed on poor and less powerful losers; and (c) inequality raises the rate of time preference applied to environmental resources by both the poor and the rich by increasing their poverty and political insecurity, respectively."

The fact that internal inequality is important also affects the positions taken by governments with respect to climate change action at the national and international level. Governments in rich countries, for example, wanting to appease their poor who contribute much less to climate change than their rich, seek to engage in international negotiations arguing that it is the rapidly growing developing countries that are now contributing and not just adding marginally to the problem. On the other hand, based on the distribution of carbon space and the level of per capita emissions, governments in poorer countries can quite reasonably argue that the responsibility for stalling GHG concentration levels needed to protect their own poor lies largely with the developed countries.

The significance of these issues needs to assessed taking into account the reality that the fall-out of climate change is global, and that governments in countries with affected populations cannot be the ones, or at least solely the ones, that devise and impose policies that result in mitigation. One corollary of this is the obvious conclusion that climate change mitigation policy requires global collaboration among governments and peoples, in countries both developed and developing. The other is that countries that are likely to be severely affected cannot wait for the mitigation tangle to be resolved, but have to think of ways that they can adapt to climate change to protect and advance the human development of their populations.

There are a number of conclusions that can be derived from all this evidence. Since there appears to be no choice with respect to reducing GHG emissions, all countries must look to what they can contribute to the effort, allowing for the legacy in terms of carbon space occupation. Given that legacy and the current level of per capita emissions, there is no question that the developed countries have a major responsibility here. They would need to halt the increase as well as significantly reduce the level of per capita emissions they contribute. To look to aggregate emissions and try and apportion responsibility in a climate change blame game to highly populated countries and income (per capita) poor countries like India and China would not help. The latter have to be allowed to raise their per capita income levels. But these countries need to look at their emissions relative to their GDPs and their marginal emission intensities to ensure that they do not contribute as much to GHG concentrations as their "predecessors" did, when they try and raise their per capita income levels. And since the climate change problem is unlikely to be altogether resolved even if mitigation efforts advance, all countries must work together to strengthen the adaptive capabilities of poorer populations in the poorer countries.

All that having been said, it is important to recognise the complexity of the task at hand. As Helm (2008) puts it: "Climate change is so intractable because the basic conditions for agreement—and for compliance and enforcement—are largely absent. To name but a few of the problems: the allocation of responsibility for the existing stock of carbon in the atmosphere (which developing countries point out was put there by the industrialized countries) is complex; carbon emissions per head are low in those countries most rapidly increasing their emissions; some countries (and, particularly, some countries' political elites) may actually benefit from climate change, and generally the effects vary greatly between countries; there are powerful—multidimensional—free-rider incentives; the measurement of emissions (including, to list just a few, rain-forest depletion, soil erosion, methane from permafrost melting, aviation and shipping, agriculture, and ocean and other sink depletion) is at best weak; and there are, at present, no serious enforcement mechanisms. It is hard to think of an international problem which lends itself less to a coherent, credible, and sufficiently robust and comprehensive general agreement."

Mitigation and adaptation

As noted above, given the level of certainty associated with the science of climate change and its associated effects, immediate efforts, within a ten-to-twenty year time frame, at mitigation aimed at substantially reducing emissions are a must. Much of this must be focused on the developed countries that need to cut emissions and go beyond commitments under the Kyoto protocol. But developing countries, especially middle-income countries and those registering high rates of growth have a responsibility too. Furthermore, there are significant "external" benefits in the human development areas associated with mitigation efforts. For example, reducing the use of coal can directly deliver significant health benefits. Needless to say, integrating these measures with policies aimed at furthering economic development in general and human development in particular would yield better results.

That having been said, while both rich and poor are at risk from global warming, it is the poor, primarily in the developing nations, who are the least able to withstand the shocks resulting from changing climatic conditions. In fact, in their case, the effects are not even transient but involve most often the long-term loss of wellbeing.[72] And from a human development perspective it is this inability of the poor to withstand shocks and suffer long-term or permanent damage that is of greater relevance and needs to be addressed by policy. This makes policy to adapt to the effects of climate change quite crucial.

On the mitigation front, from a cost effective point of view, measures such as stalling deforestation and expanding forest cover would be a prime objective. But in the final analysis, focusing on reducing the carbon intensity of energy production and consumption and substituting fuel efficient, especially public for private, transport is inevitable if there is to be any real impact. However, given technological capabilities and investment capacities, developing countries would need assistance from the developed for progress with regard to mitigation. While incentivising developed country assistance through market-mediated measures like the clean development mechanism and carbon credits may help, the level of assistance would have to be far higher than what the market would deliver.

Table 6 provides the IPCC's summary view on the kind of measures to be taken in developing countries with respect to mitigation.

[72] UNDP 2007.

Table 6: Integrating climate change considerations into development policies – Selected examples in the area of mitigation		
Selected sectors	*Non-climate change policy instruments*	*Potential affects*
Macro-economy	Implement non-climate taxes/subsidies and or other fiscal and regulatory policies that promote sustainable development	Total global GHG emissions
Forestry	Adoption of forest conservation and sustainable management practices	GHG emissions from deforestation
Electricity	Adoption of cost-effective renewables, demand-side management programmes, and transmission and distribution loss reduction	Electricity sector CO2 emissions
Petroleum imports	Diversifying imported and domestic fuel mix and reducing economy's energy intensity to improve energy security	Emissions from crude oil and product imports
Insurance for building, transport sectors	Differentiated premiums, liability insurance exclusions, improved terms for green products	Transport and building sector GHG emissions
International finance	Country and sector strategies and project lending that reduces emissions	Emissions from developing countries

Source: Based on Sathaye et al. 2007.

However, even if some success is achieved on the mitigation front, the achievement is unlikely to be adequate to prevent at least some significant changes in climate variables. Thus adaptation is also an important requirement. As has been noted[73], vulnerability to climate change depends upon three factors: exposure of individual sectors of a country to the physical effects of climate change; the degree of intrinsic sensitivity of the natural resource system or the dependence of the national economy upon social and economic returns from that sector; and the degree to which to which adaptive capacity enables these potential impacts to be offset. Building adaptive capacity in critical sectors subject to high exposure and sensitivity, would define the coping capacities of countries and their populations.

It needs to be noted that protection from the effects of climate change shocks alone would not exhaust adaptation requirements. They must help preserve long-term capabilities as well. Thus, left to themselves, weather adaptation by the rural poor, may result in low-risk, low-productivity choices in agriculture.[74] Hence, adaptation measures must seek to enhance the ability of the poor to improve their productivity while helping them deal with the increased climate risks.

Adaptation is particularly important in developing countries because, as Jayaraman (2011) puts it, "the temporal scale in which global warming effects will significantly manifest themselves is rapidly closing in on the temporal scale required for action to eradicate or at least sharply reduce these development deficits. For instance, the time-scale over which the

[73] See, for example, Allison et al. 2009.
[74] Jayaraman 2011.

Millennium Development Goals (MDG) were to be achieved are comparable to the time-scales over which discernible effects from at least a 1ºC rise in global temperature will manifest themselves. Given the delays in the achievement of the MDG it is clear that the problem is being exacerbated and that the two time-scales are approaching each other more closely."[75]

It is clear that, reducing the vulnerability of the world's poor to the potential fall-out of climate change, requires huge investments in infrastructure. Unfortunately, here too the burden falls more heavily on the less developed countries, since assessments indicate that retrofitting existing infrastructure to make them climate-proof is not too heavy a burden for the developed world. This, not only increases their responsibility in contributing more to the mitigation effort, but also makes it imperative for them to share the burden of adaptation.

Information is also crucial to the adaptation effort, since it must necessarily be based on assessments of the probable climate impact in various regions. Generating the detailed meteorological data for this purpose would require heaving investment in meteorological systems with advanced scientific capabilities.

A wide range of social protection mechanisms together with poverty reduction programs would also be crucial for the vulnerable to deal with climate shocks. In many developing countries such social insurance mechanisms are still in a primitive state.

Finally, disaster risk management institutions are a crucial ingredient of successful climate change adaptation.

Policy directions for the Asia-Pacific: Mitigation

From our discussion above it should be clear that there are many opportunities for cost-effective emission reduction in the Asia-Pacific. The contribution of the region as a whole must (as elsewhere) concentrate on three areas: carbon emissions from fossil fuel use, emissions related to transportation and emissions resulting from deforestation and forest degradation. In addition, given the fact that the region has substantial areas under cropland, managing that land could help sequester carbon in soils. Also being a major rice and livestock producer, the region could contribute to a reduction of methane emissions.

Central to the mitigation strategy would be an effort to improve the efficiency of energy use and reduce energy intensities, as well as a process of shifting away from coal and oil (particularly the former) as fuels, by enhancing the share of cleaner energy sources such as natural gas and renewables such as solar energy. Earlier nuclear energy was a preferred option, but given the review of safety considerations and the rethink on nuclear energy in the wake of the 2011 earthquake in Japan and the resulting accident at the Fukushima nuclear power facility, the task of mitigation in this area has been only rendered more difficult.

These changes would have to be engineered from both the supply and demand sides. Supply options include efficiency improvements in power generation, fuel switching from coal to natural gas, and the use of renewable energy including biomass, solar, wind, hydro and

[75] Jayaraman 2011.

geothermal resources. On the demand side, since the principal sources of GHG emissions are industry, the transport sector, and residential and commercial building activity, initiatives are bound to be varied and manifold.

The Asian Development Bank (2009b: 134) lists the following:

"*Residential and commercial building sector*: Use of more efficient lighting and electrical appliances, energy efficiency standards and rating programs, improved insulation, and behavioural change.

Industry sector: Use of more efficient boilers, motors, and furnaces, improved management practices such as energy auditing and benchmarking, heat and power recovery, fuel switching, and material recycling and substitution, particularly in energy-intensive sectors, such as iron and steel, cement, paper and pulp, and chemicals.

Transport sector: Switching to cleaner fuels, use of fuel-efficient vehicles, use of hybrid/electric options in road transport, better traffic management, modal shifts from road transport to rail and public transport systems, promotion of non-motorized transport, and land use and transport planning."

In addition to changes in the primary energy consumption pattern and fuel switching in electricity generation, mitigation options could also include CO_2 reduction through Carbon Capture and Sequestration (CCS) technologies. Geological storage of CO_2 in oil wells and coal beds and injection of CO_2 into deep saline aquifers are possible technological options in the future.

Forestry is another area where the Asia-Pacific can make a significant contribution to mitigation, given the large share of forested land area in the region. For example, forests cover about 47 per cent of Southeast Asia's total land area.[76] There are multiple options to reduce GHG emissions or to increase carbon storage in this sector. As noted in Nabuurs et al. (2007), forestry mitigation options include: maintaining or increasing the forest area through reduced deforestation and degradation (REDD) and through afforestation and reforestation; maintaining or increasing carbon density (tons of carbon per hectare) through forest management, forest conservation, longer forest rotations, and fire management; and increasing off-site carbon stocks in wood products and enhancing fuel substitution using forest-derived biomass. Most countries have now recognised that through these means emissions can be reduced significantly at relatively low cost and a greater amount of carbon could be stored in the forests, with other environmental benefits.

Finally, agriculture, given its importance, is an obvious target for mitigation policies given its large (even If declining) share in GDP. Options for mitigation of GHG emissions in the agriculture sector include: (i) reducing fertilizer-related emissions; (ii) reducing CH_4 emissions from rice paddies; (iii) reducing emissions from land use change; (iv) sequestering carbon in agro-ecosystems; and (v) producing fossil fuel substitutes. According to estimates made by the United States Environmental Protection Agency (2006), the economic potential for reducing net emissions of nitrous oxide (N_2O) and soil carbon from cropland in South and Southeast Asia at zero cost would be 2.1 $MtCO_2$-eq in 2010 and 2.3 $MtCO_2$-eq in 2020.

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[76] ADB 2009b.

In the Asia-Pacific, South, Southeast and East Asian countries are important producers of rice. As a result they can contribute to a reduction of CH_4 emissions while ensuring food security. Proper management of continuously flooded rice fields, involving a combination of water management and management of organic and mineral fertilizer inputs, is estimated to reduce emissions of CH_4 by between 7 and 63 per cent (with organic amendment) and by 9–80 per cent (with no organic amendment).[77]

Put together, measures such as these, which focus on the specific, even though diverse features, of the Asia-Pacific region, can ensure that the region can contribute substantially to the effort to mitigate the problem GHG emissions lading to global warming and climate change.

Adaptation: A regional perspective

Irrespective of the distance countries travel in the mitigation effort delineated above, it is inevitable that carbon emissions would remain high enough to ensure some degree of warming with likely significant effects on climate in the foreseeable future. Thus, some of the transitions that we are speaking of, which seem to have begun, could extend far enough to affect populations in developing countries adversely. These effects could be significant also because they pose challenges that are unlikely to have been historically experienced. Thus strengthening coping capabilities and helping populations adapt to climate change is crucial. Adaptation, as has been noted, is essentially about reducing vulnerability and increasing resilience.

It needs to be noted, however, that the tendency to avoid risk because of their pre-existing vulnerability conditions the poor to livelihood patterns that offer low returns, thus making them less capable of coping and adaptation. Vulnerability to climate variability can lead a section of the poorest into poverty traps, including sale of assets such as livestock and land, loss of human development opportunities, and so on. While a range of adaptation decisions would be required and likely to be made by private individuals and households or rural or urban communities, they are unlikely to go far enough and may even increase vulnerability. Public policy and intervention is crucial.

Given the dependence of populations of the region on agriculture for livelihoods and food security, it is to be expected that adaptation efforts in this sector would be crucial. Given its dependence on moisture, managing the effects of extreme weather events like droughts and excessive rainfall leading to flooding would be the focus. Central to that effort would be better irrigation, improved water management practices such as harvesting of groundwater and rainwater and protection of water catchments as well as superior drainage and flood control facilities, along with more R&D focused on adaptive cultivation practices. An essential requirement would be investment in infrastructure, including investment by governments, because adequate private investment is unlikely in these areas given the absence of or insufficiency of short-term returns.

Agricultural practices would also need to change as an adaptive process would include adjustments of the crop cycle to allow for early or delayed planting and harvesting depending

[77] ADB 2009b.

on crop and region. Farmers may also have to move out of certain crops or diversify to accommodate new ones to match changed climate patterns. Efforts are need to conserve water resources and ensure water availability. Changed weather could also introduce new pests requiring appropriate responses. All of this requires not just access to information, but more investment in relevant agricultural research as well as extension services that can wean farmers into adopting new farming methods.

With sea levels rising and the likelihood of extreme weather events increasing, populations living in coastal areas and sections dependent on the sea such as fishing communities need to be given special attention. A priority is of course the strengthening of coastal defences and protecting coral reefs and coastal vegetations so as to sustain biodiversity. These too require substantial investments in coastal infrastructure as well as infrastructure suited to disaster management, including systems geared to relocating affected populations in time. In addition since there are likely to be stress factors that could change the natural resources available in the coastal areas and in the sea, information on practices that could help preserve biodiversity as well as adapt to changes in the availability of resources such as fish species and vegetation is crucial.

Finally, there would be collateral changes in areas like health that would affect all areas including urban habitations and large cities. This would call for investments and information sharing in areas that may not, in the first instance, appear to be related to climate change. In the area of health, for example, the likelihood of new infections and diseases as well as likely increase in medical emergencies due to extreme events, would necessitate improved disease monitoring systems, early warning regarding the likelihood of unfamiliar infections, and infrastructure that permits quick responses to pandemics and other emergencies.

Thus, central to the adaptation effort is substantially increased investment in physical and social infrastructure, the creation of systems for information collection, collation, analysis and dissemination, and an emphasis on strengthening and diversifying a range of extension services offered by the state.

Integrating mitigation and adaptation into the development effort

Despite the large investments and expenditures necessitated by the challenge posed by climate change, it is by no means an additional "burden" on developing countries. Rather much of the technological improvements made and the infrastructure created could serve a host of development objectives. Investments in irrigation and flood control would help raise productivity, strengthened coastal infrastructure would favour development in those regions, better systems to communicate information and knowledge can be leveraged to serve a range of objectives and improved health facilities would advance human development and strengthen human capital. Moreover, to extract maximum returns from systems aimed at facilitating flexibility and quick adaptation, governments would be required to enhance capabilities through investments in education, for example. Thus, what is needed is to mainstream mitigation and adaptation efforts into national development strategies to facilitate their realisation as well as the realisation of a range of related developmental benefits.

But this transformation of national development strategies to respond to the challenge posed by global warming would fall short unless accompanied by a substantial degree of international cooperation. One reason for this is the fact that even though warming could result from national errors of omission and commission, the fall out is global, and in all probability would be experienced more by those less responsible for the outcome. Many of the countries that would be extremely adversely affected by climate change such as the Least Developed Countries and Small Island Economies of the Asia-Pacific, are least responsible for GHG emissions and are inadequately endowed with the resources needed to adapt to climate change. International support for adaptation efforts in such countries is needed not merely on humanitarian considerations but on grounds of justice.

On 20 May 2001, the Third United Nations Conference on the Least Developed Countries held in Brussels adopted the Programme of Action for the LDCs for the Decade 2001-2010, which was subsequently endorsed by the General Assembly in its resolution 55/279 of 12 July 2001. The thrust of the Programme was to accelerate realization of the Millennium Development Goals in these countries, with an overarching objective of ensuring "substantial progress toward halving the proportion of people living in extreme poverty and suffering from hunger by 2015 and promot(ing) the sustainable development of the LDCs".[78]

For these countries, which need substantial investments in infrastructure to cope and adapt, while domesic efforts are important, aid from abroad can be crucial. "The BPoA emphasised the importance of Overseas Development Assistance (ODA) and set the following three goals in this regard:

1. Donor countries providing more than 0.20 percent of their GNP as ODA to LDCs were to continue to do so and to increase their efforts (MDG 8, T-13);
2. Other donor countries which have met the 0.15 percent target were required to reach 0.20 percent expeditiously; and
3. All other donor countries which had committed themselves to the 0.15 percent target were expected to reaffirm their commitment and undertake either to achieve the target within the next five years or to make their best efforts to accelerate their endeavours to reach the target.

There has been some progress on these fronts as far as the 22 member countries of the OECD's Development Assistance Committee are concerned".[79] Even in 1996-97 four members (Denmark, Netherlands, Norway and Sweden) were providing aid to LDCs that exceeded 0.2 per cent of their Gross National Income (GNI). By 2007, neither the number of countries in, nor the composition of, the group providing aid in excess of 0.2 per cent of GNI had changed. However, the first of the aid targets had been realised, since all of them continued to provide more than 0.2 per cent of their GNI, with three of them in fact increasing the ratio of aid to LDCs relative to GNI. Since it was the same set of countries that constituted the group that was earlier providing 0.15 per cent or more of GNI as aid to LDCs, the second of the targets (attaining 0.2 per cent) was also realised, though there was no additional material progress on this count. It was the third of the targets that has remained unrealised, since as compared to 4 out of 22 countries that were providing at least 0.15 per cent of GNI as aid to LDCs in 1996-97, that number stood at a poor 5 out of 22 in 2009.[80]

From a climate change point of view, aid is important because of the importance in building infrastructure in these countries to reduce their vulnerability to the shocks and the long-term

[78] UN Regional Commissions 2010.
[79] UNESCAP 2009.
[80] OECD 2009.

impacts of whatever climate change occurs. For the eight countries for which data are available, other than for Myanmar which does not receive significant aid and Maldives which is characterised by a higher level of GDP, the ratio of aid to central government expenditures tends to be high (Table 7).

Table 7: Net ODA received (% of central government expense)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Afghanistan	na	na	na	na	na	na	206.04	168.32	196.13
Bangladesh	na	25.46	21.36	29.66	28.86	24.37	20.92	21.90	23.86
Bhutan	63.01	62.90	74.10	67.05	65.32	55.66	58.61	40.85	30.48
Cambodia	na	na	120.59	119.58	111.15	112.12	84.74	na	na
Lao PDR	na	na	na	na	na	na	na	89.66	na
Maldives	12.02	15.38	16.66	12.68	12.96	20.90	8.56	7.29	8.74
Myanmar	na	na	na	0.32	0.21	0.24	na	na	na
Nepal	na	na	na	na	39.97	34.09	na	na	na

Source: World Bank (2011). *Note*: na: not availaible

This does imply that the pattern of government expenditure could be influenced by donor priorities, reducing "aid effectiveness". To recall, the Paris Declaration on Aid Effectiveness (2005) emphasised five principles: ownership of development policies; alignment of donor support to countries' national development strategies; harmonization of donors' actions; managing resources and decision-making to ensure results; and making donors and partners mutually accountable for results. These principles could be undermined when donor role is large and overwhelming relative to a country's own resource mobilisation capabilities. As the OECD's report (2009: 71) notes: "Many of the problems in aid were perceived as being due in large part to donors – and not developing countries – deciding where and how aid should be used. The reasons why donors have often insisted on such a dominant role are not hard to understand: some of the least-developed countries have lacked the political or administrative institutions to support aid projects, or have suffered from such high levels of corruption that donor countries have not felt confident about channelling funding through official channels. At home, donor governments may only have been able to sustain support for their aid programmes with voters and supporters by pointing to concrete achievements in developing countries, such as a new school or hospital. More diffuse achievements – such as building a development "partnership" – have been a harder "sell"."

The result has been that aid tends to be diverted to areas where the results are more immediate and more tangible in terms of their impact on objectives like poverty alleviation. The casualty here has been the allocation of aid for economic infrastructure projects, which could be extremely important from a climate change point of view, as we shall see below. If we take total ODA provided by the OECD's DAC members, even during 1986-87 this sector accounted only for a fifth of total aid disbursed.[81] Twenty years later, by 2006-07, that figure had fallen to just 12 per cent.[82] This obviously reduces the contribution of aid to strengthening long term development prospects. Further, it means inadequate implementation of the following goals and targets incorporated in the Brussels Programme of Action (BPoA) that are crucial to adaptation. These include:

- Increasing road networks or connections in LDCs to the current level of other developing countries and substantially strengthening urban road capacities, including sewerage and other related facilities, by 2010. In most countries, the length of the road network has increased extremely slowly, if at all, and the share of paved roads in the total in Asia-Pacific LDCs has been low relative to the developing country average.
- Modernizing and expanding ports and airports and their ancillary facilities to enhance their capacities by 2010.
- Modernizing and expanding railway connections and facilities and increasing their capacities to the level of those in other developing countries by the end of the decade.
- Increasing average telephone density to 5 main lines per 100 inhabitants and Internet connections to 10 users per 100 inhabitants by the year 2010 (MDG 8, T-18). This goal is nowhere near attainment, though this is partly because mobile phone connections are increasingly substituting for fixed line connections. The figure for all telephone connections points to greater success in attaining this and a related target, despite the low performance with respect to fixed telephone lines.
- Increasing LDCs' communication networks, including telecommunication and postal services, and improving access of the poor to such services in urban and rural areas to reach the current levels in other developing countries. Even though telecommunication facilities, as measured by the number of fixed and mobile phone subscribers per 100 people for example, has increased significantly from a low base in 2000, these countries are nowhere near approaching the developing country average by 2010.

Thus, the case for providing substantial assistance targeted especially at adaptation efforts in poor countries is extremely strong. And that case is for "additionality". The redistribution of existing ODA can hardly serve the purpose. In fact, developing countries are owed the climate assistance as a matter of treaty obligations under UNFCCC and not as assistance under ODA.

Besides these factors, there is one overarching reason why cooperation is central to the mitigation and adaptation effort. Since climate change is partly the result of a legacy of emissions and there are binding limits on the carbon space available for exploitation before permissible levels of GHG concentration are exceeded, cooperation is need to ensure that that space is not quickly and unequally exhausted, leading to an inability to ensure the safety of future generations across the globe.

[81] OECD 2009.
[82] UNESCAP 2009.

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