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Climate Change – Predictions, Economic Consequences, and the Relevance of Environmental Kuznets Curves

by

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ABSTRACT

Summarises some of the predicted natural consequences of increasing concentrations of greenhouse gases in the atmosphere. Changes in temperature, climates, physical and chemical impacts on the biosphere as well as biodiversity loss are considered. Then some of the expected social and economic consequences of global warming are discussed. Subjects considered are the impacts of global warming on bio-industries and social conditions, the economic costs of greenhouse gas emissions and the effects of climate change. Attention subsequently turns to the environmental Kuznets curve and the inappropriate use of the relationship. For example, it is stressed that reducing the intensity of greenhouse gas emissions in relation to GDP does not necessarily reduce total greenhouse gas emissions. Furthermore, even if they are reduced, greenhouse gases can continue to accumulate in the atmosphere. Some suggestions are then made about how the global warming problem might be addressed.

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1. Introduction

Most natural scientists are predicting significant rises in the temperature of the Earth's atmosphere (and its oceans) in this century. This process of global warming is attributed to the accumulation in the atmosphere of greenhouse gases consisting mostly, but not entirely, of carbon dioxide. The build-up of carbon dioxide is mainly due to the combustion (by humans) of fossil fuels and the loss of living things that act as sinks for carbon dioxide, for instance, forests. Some of the predicted consequences of global warming include alterations in climate, a substantial loss in biodiversity and for the world as a whole a lower standard of living (worse economic conditions) than would otherwise prevail. This phenomenon is a threat to ecological sustainability and to economic sustainability.

In the first part of this paper, I'll summarise predicted changes in temperatures and climates, physical and chemical changes in the biosphere, and probable reductions in biodiversity expected to occur as a result of climate change. In the second part, I'll discuss some of the social consequences of global warming and its impacts on bio-industries, and its economic consequences as forecast in the Stern Report. Subsequently, some of the misperceptions associated with the environmental Kuznets curve will be exposed, for example, that as a result of continuing economic growth, the global rate of emissions of greenhouse gases will automatically decline.

2. Predicted Changes in Temperatures on Earth and in its Climates

It is impossible to predict **precisely** by how much atmospheric temperatures will rise in this century and the **exact** extent of sea level rises resulting from this but most natural scientists are agreed that the likely changes are a matter for concern. Natural scientists estimate:

> "that by the end of this century, global temperatures could rise by up to 6° C and sea levels by about 80cm although the average prediction is for a rise of 4-5° C in temperature and a rise of about 40 cm in the sea level, if business continues as usual. If effective measures are taken to curb global greenhouse emissions, there

is likely to be a significant delay before greenhouse gas concentrations in the atmosphere decline. This means the reversibility of greenhouse gas concentrations takes some time and during that time, growing adverse environmental consequences will continue to be experienced.

Predictions by scientists about the biophysical consequences of increasing concentrations of greenhouse gases in the atmosphere are based on complex simulation models and are estimated for several scenarios. Although considerable uncertainties exist, the weight of evidence indicates that significant global warming can be expected in this century together with sea level rises" (Tisdell, 2009, p.375).

Some of the changes in weather patterns predicted by the United Nations International Panel on Climate Change (IPCC) are listed in Table 1. The changes will not be geographically uniform. While most areas are likely to become more drought-prone, some will become wetter.

Table 1   Projected changes in weather events in this century as a result of global warming

Changes in weather patterns	Likelihood[a]
Higher maximum temperatures and more hot days over most land areas	Virtually certain
Higher minimum temperatures over most land areas	Virtually certain
More intense precipitation events	Very likely
Increased risk of drought	Likely
Increased intensity of tropical cyclones	Likely
Increased incidence of extreme high sea level	Likely

[a]*Virtually certain* implies >99% probable, *Very likely* implies > 90% probable, *Likely* implies >66% probable
Source: Based on IPCC (2007, Table 3.2, p.58)

Furthermore, the estimate of a 4-5°C rise in global atmospheric temperature in this century is a global average. Some regions will experience more warming and other areas less. For example, the polar regions are experiencing rapid warming. UNEP (2007, p.12) states:

"During the 20th century, Arctic air temperatures increased by approximately 5 degrees C. This increase is ten times faster than the observed global near surface temperature. An additional warming of about 4-7 degrees C in the Arctic is predicted in the next 100 years."

This is expected to bring about biophysical changes that will result in the extinction of several species that depend for their survival on Arctic habitats.

3. Some Physical and Chemical Impacts on the Biosphere of Global Warming

A clearly visible impact of global warming is the reduction on the Earth's ice cover. Many glaciers are retreating, snow and ice cover is shrinking on many mountains (e.g. on Mount Kilimanjaro in Africa) and the extent of floating ice-cover in oceans nearest the Poles is declining, especially in the Arctic Ocean.

The shrinking of floating sea ice in the Arctic Ocean is highlighted by the trend line in Figure 1. This line implies that there has been approximately a 25% decline in floating sea ice in the Arctic Ocean in a 30-year period (1979-2009).
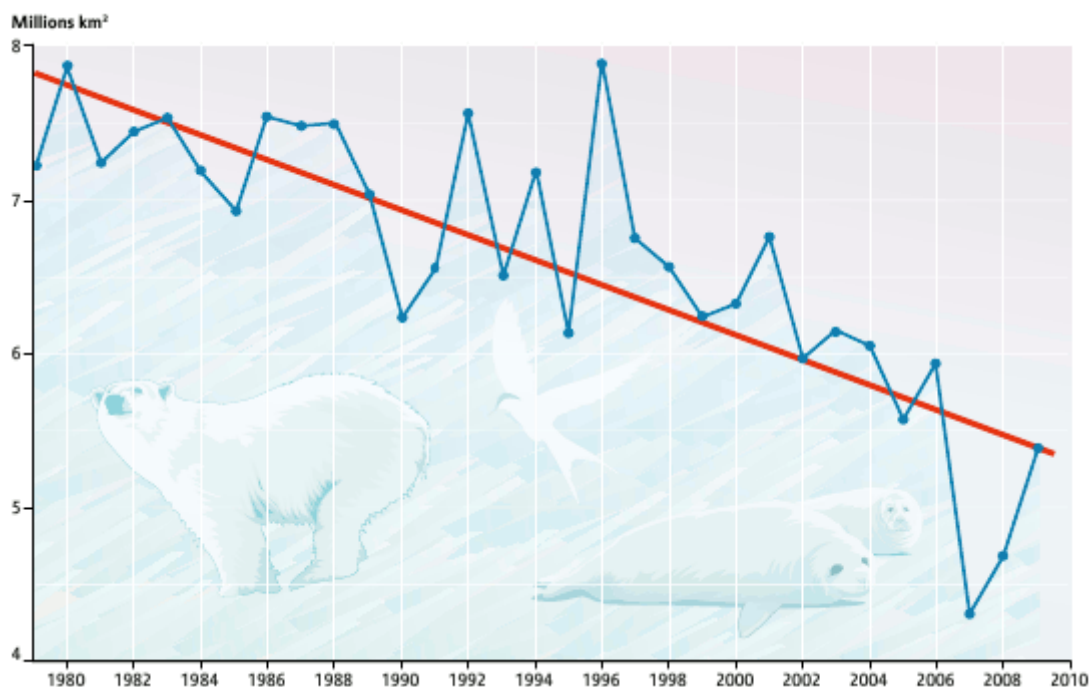

Fig 1   The annual minimum (in September) of floating sea ice in the Arctic Ocean as compiled by the Secretariat of the Convention on Biological Biodiversity (2010) and reported in Shah (2012, p.3)

According to the Secretariat of the Convention on Biological Diversity (2010, p.57), the loss of sea ice in the Arctic is likely to accelerate global warming and will adversely affect biodiversity beyond the Arctic. It states:

- "Bright white ice reflects sunlight.

- When it is replaced by darker water, the ocean and the air heat much faster, a feedback that accelerates ice melt and heating of surface air inland, with resultant loss of tundra.

- Less sea ice leads to changes in seawater temperature and salinity, leading to changes in primary productivity and species composition of plankton and fish as well as large-scale changes in ocean circulation, affecting biodiversity well beyond the Arctic."

Note that the melting of **floating** ice will have no effect directly on the sea level because the floating ice already displaces water.

Oceans are slowly warming and also dissolving some of the CO_2 in the atmosphere. As a result, weak acidification of the oceans is occurring. This is a threat to marine organisms that make shells and skeletons of calcium carbonate. The oceans have had higher acidity in the distant past but today their acidity is increasing rapidly giving little time for marine organisms to adapt. This is endangering some marine organisms which play a central role in the food chain and in ecosystem biodiversity.

Another problem associated with global warming is ocean stratification. The warmer water tends to stay on top of the ocean and mixing of water from lower depths (which is often nutrient-rich) is retarded. This has an adverse impact on populations of phytoplankton which provide food for many marine organisms.

There are also large portions of the oceans that are now 'dead zones' because they are oxygen deficient. These are mainly due to fertilizer and sewage run-off but ocean stratification may contribute to their occurrence. A large dead zone of some 22,000 square kilometres occurs every spring in the Gulf of Mexico due to run-off transported by Mississippi River. These dead zones have adverse consequences for the fisheries and can reduce marine biodiversity.

4. Climate Change and Biodiversity Loss

According to an item highlighted by the Nature Publishing Group (2004): "Many [wild] plants and animals are unlikely to survive climate change. New analyses suggest that 15-37% of 1,103 land plants and animals would eventually become extinct by climate changes expected by 2050. For some of these species, there will no longer be anywhere suitable to live. Others will be unable to reach places where the climate is suitable".

Species which are obligated to live in high cold mountain tops and those dependent on floating ice environments (such as polar bears) will have nowhere to go if these areas warm sufficiently.

As for the movement of species in response to climate change, the matter seems to be quite complicated. Due to human development of land areas, the scope for the migration or movement of many species in response to climate change is limited. They virtually exist only in isolated protected natural or near natural areas. While human beings could help translocate them, there may be no suitable habitat in a climate more suitable to their requirements. There are, however, fewer barriers to the migration of marine species than to the movement of terrestrial ones. Nevertheless, not all species able to migrate might find suitable habitats in areas which are more suited to their temperature requirements.

This may be especially true of species high in the food chain which rely on climax or near climax communities to meet their needs. To re-establish such communities at a new location takes a considerable amount of time and because of differences in the ability of wild species to migrate, and variations in local environmental conditions, communities may fail to replicate themselves in a changed location. Consequently, the habitats required by some species may disappear entirely resulting in their extinction. New ecosystems (with reduced biodiversity) are likely to evolve in most locations.

Furthermore, generalists that are able to disperse may find it easier to survive than specialists if they do not face too much interspecies competition in their new location. The successful dispersal of specialists is likely to depend on the near simultaneous successful dispersal of the specialised ecological resources on which they depend.

Urban *et al* (2012) show how differences in the dispersal ability of species as climate changes can cause extinctions. As they point out, alterations in interspecific competition also can hasten the extinction of some species. They state that "Current forecasts probably underestimate climate change impacts on biodiversity by neglecting competition and dispersal difference" (Urban*, et al.*, 2012, p. 2072).

As for biodiversity among domesticated plants and animals, heat-tolerant (and in some cases, drought-tolerant) varieties are likely to be increasingly preferred. Animals that are not heat tolerant will need to be housed in warmer regions in cooled environments. This is likely to add to the cost of animal production. As will be discussed in the next part of this lecture, the location of production by bio-industries can be expected to alter.

5. Resumé of the First Part of this Paper

Scientists predict that significant levels of global warming will occur in this century due to the accumulation of greenhouse gases (particularly CO_2) in the atmosphere. This has a 'hot house' impact on the Earth. In turn, this is expected to lead to major changes in climates and to significant rises in sea levels. A reduction in the coverage of floating sea-ice (particularly in the Arctic Ocean), the retreat of glaciers and reduced ice and snow cover on some mountains is already occurring as a result of an increase in the atmosphere's temperature. Furthermore, substantial changes are occurring in the oceans. These include their warming, acidification, and stratification. All of these developments (together with the growing size of oxygen-deficient zones) in the oceans are likely to reduce marine productivity and result in the demise of many marine species. While global warming has occurred before, the current episode of it is very rapid and is occurring at a rate which makes it difficult for ecosystems and wild species to adjust to it. This difficulty is compounded by the fact that many species live in insular (isolated) environments due to human development of their surroundings. Furthermore, in some cases, climate change will result in some species becoming extinct because the habitat they require will no longer exist on Earth. In other cases, the required habitat needed to support species in new locations will take too long to evolve to save them from extinction or may not evolve at all. Some loss of biodiversity in domesticated existing animals and plants can also be expected as a result of climate changes.

6. Introduction to the Predicted Social and Economic Consequences of Global Warming

In this part of this paper, I'll outline some of the likely consequences of global warming for bio-industries and consider how it will affect several features of society, such as the location of human settlements and the exposure of humans to various diseases. Then estimates of the economic cost of global warming will be outlined and discussed. Subsequently, the view will be critically examined that falling intensities of greenhouse gas emissions result in a reduction in the total emissions of these gases. With economic growth the intensity of greenhouse gas emissions by China has declined and India will also reduce the intensity of its emissions but their total emissions continue to rise. This type of relationship is predicted by the environmental Kuznets curve, which will also be explained in this lecture. The relationship indicated by it has led some individuals to conclude that with sufficient economic growth globally, the global warming problem will eventually disappear. The solution to the problem is even greater economic growth! It is pointed out that this is a dangerous conclusion. Before concluding, some policies that may be adopted to reduce greenhouse gas emissions are outlined briefly.

7. Impacts of Global Warming on Bio-Industries and Social Conditions

Climate change will result in several industries (especially bio-industries such as cropping, agriculture generally and aquaculture) no longer being economic in areas where they are now located due to rising temperatures, increasing water shortages, and in some cases, desertification. If cropping is still possible, the type of crop grown can be expected to alter in many areas. However, by appropriate adaptation some existing crops may continue to be grown in their existing areas. For example, Ortiz-Bobea and Just (2012) argue that by adjusting the planting times of corn in most states of the United States, reduction in yields which might be expected as a result of climate change can be significantly reduced.

Nevertheless, not all areas will become drier; some will become wetter. Miller (2012, p.41) reports that average specific humidity at sea level is increasing as oceans warm. He also reports (2012, p.41) "Scientists expect the weather patterns to change substantially. Basic circulation patterns will move towards the Poles, just as some plants and animals are doing as they flee (or take advantage of the expanding heat). The tropical rain belt is already widening, climatologists report. The subtropical dry zones are being pushed poleward, into regions such

as the American Southwest, southern Australia, and southern Europe, making these regions increasingly susceptible to prolonged and intense drought". This may mean that southern China will become wetter and northern China drier than now.

If this is so, some communities in northern China may eventually be no longer economically viable and therefore, out-migration can be expected. Rising sea levels will also result in population movements and loss of infrastructure. This appears to be a particular problem for low-lying coral atoll countries such as Kiribati, Tuvalu and the Maldives. The inhabitants of these islands could become international environmental refugees. However, low-lying parts of the east coast of China will also be affected. Furthermore, countries such as Bangladesh have much low-lying alluvial land, much of which will be lost as a result of sea level rises. Communities which rely on this land for their livelihood will be dislocated.

Warmer days and nights will add to greater heat stress in humans. The distribution of some diseases will increase. Mosquito species that are capable of carrying malaria will expand their range as will mosquitos which carry dengue fever.

It is possible (in principle) to calculate the economic costs of such developments and, of defensive actions to reduce their impacts. This is one possible approach to estimating the cost of global warming. Other approaches include estimating the social costs of carbon dioxide emissions and considering along with other factors, the amount by which global per capita consumption is likely to be reduced as a result of global warming.

8. Putting Figures on the Cost of Greenhouse Gas Emissions and the Effects of Climate Change

Two other approaches to estimating the economic costs of greenhouse gas emissions have been tried. One is to try to estimate the social marginal costs associated with each extra unit of such emissions, for example, each extra tonne of CO_2 emitted. The other is to consider by how much per capita consumption or income is likely to be reduced by global warming and consequent climate change. Let us consider each of these approaches in turn.

The IPCC (International Panel on Climate Change) reviewed estimates of the social marginal cost associated with the emission of an extra tonne of CO_2 equivalent and found that they ranged from US\$3 per tonne to US\$95 per tonne with the average being US\$12 per tonne

(see Anon, 2008). The problem is that these estimates are quite sensitive to assumptions made about the biophysical consequences of global warming as well as decisions about how to discount future possible effects of global warming. The larger the rate of discount of future economic impacts of global warming, the smaller will be the calculated economic cost of an extra tonne of CO_2 equivalent. There is considerable controversy about the rate of which future costs and benefits should be discounted. Some writers claim that there should be no discounting of future net benefits.

In any case, given the global warming hypothesis, it is clear that individuals and other economic actors do not bear the full social cost of emitting greenhouse gases. If they were to do so, this would make them more careful in adopting actions which add to such emissions. Therefore, there have been proposals (which have been implemented in some countries) that these emissions be taxed or mechanisms be adopted (such as emission trading schemes) which result in the pricing of their emissions.

A review (Stern, 2007) undertaken for the British Government examined the possible global macroeconomic effects of climate change. It combined economic modelling with the climate predictions of the IPCC (2001). Stern estimated that per capita global consumption will be reduced by at least 11% (compared to what would have been in the absence of global warming) over the next two centuries. This takes account of both market-related reductions in global per capita consumption (5%) as well as the non-market-related reductions. If global warming is towards the upper limit of predictions the economic losses will be greater. It is also believed that the poor in many developing countries will suffer a higher proportionate reduction in income than those in higher income countries. Therefore, global warming will have adverse effects on the distribution of income.

9. The Environmental Kuznets Curve and Some Wishful Thinking about Global Warming

Selden and Song (1994) found evidence suggesting that levels of air pollution emissions in relation to the GDP of nations tend to rise at first with their economic growth and then decline as their GDP becomes larger. They suggested that this relationship is typically of a reversed U-shape and they called it the environmental Kuznets curve (EKC). Kuznets (1955) found a similar relationship between income inequality and economic growth.

The curve ABC in Figure.2 illustrates a typical environmental Kuznets curve. It shows the amount of a pollutant emitted in relation to the GDP of a country. If the focus is on CO_2 emissions, it shows tonnes of CO_2 emitted as a proportion of GDP. If y represents the level of GDP and x represents units of CO_2 emitted, then EKC specifies the relationship between x/y and y. In Figure 2, pollution intensity reaches a maximum when the nation's GDP reaches y_1 and then declines with further increases in GDP.
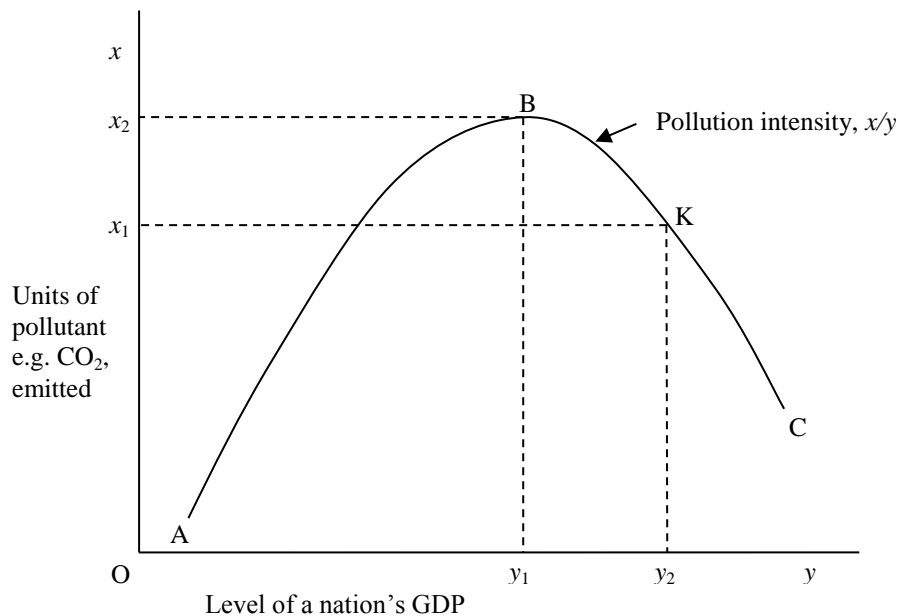
Fig. 2   A 'typical' environmental Kuznets curve

Differences of opinion exist about the applicability of this curve. For example, it may not apply to all pollutants. It has some applicability, however, to air pollution resulting from the combustion of fossil fuels. Reasons for this include the following:

1. Economic growth is associated with new investments and new technologies. These can be expected to economize on the use of fossil fuels. For example, new coal-fired power stations are more efficient than those of older vintage.

2. The economic structure of growing economies tends to alter as they grow. Tertiary industries (service industries) which are less energy-intensive tend to gain in relative importance.

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3. With increased per capita incomes, political pressures tend to grow to have a cleaner environment.

There is evidence that both China and India, as a result of their recent phases of economic growth, are now experiencing a decline in their intensities of CO_2 emissions. They are beyond point B on the EKC in Figure 2 at a point like, K. Does this mean that their total emissions of CO_2 are declining? The answer is no. This is also likely to be the case for many other countries experiencing a decline in pollution intensities.

This is illustrated in Figure 3. In order to determine if total emissions of CO_2 are declining, one must take into account the rate of change, dx/dy, of emissions, **not** the average rate of emissions, x/y, which are shown by the environmental Kuznets curve. It is known that when an average value is rising, the corresponding marginal value, dx/dy, exceeds the average value, and that this marginal value is below the average value when the average is falling. Thus, in Figure 3, the marginal curve of emissions corresponding to the environmental Kuznets curve, ABC, is like that represented by curve DBEFG. Although pollution intensity declines once GDP exceeds y_1, the total level of CO_2 emissions continue to increase until $y = y_3$. At this point $dx/dy = 0$, that is the marginal level of emission of CO_2 is zero, and the total amount of CO_2 emitted reaches its peak. After that point, total emissions of CO_2 decline but may still be high (for example at y_4) and may continue to accumulate in the atmosphere.
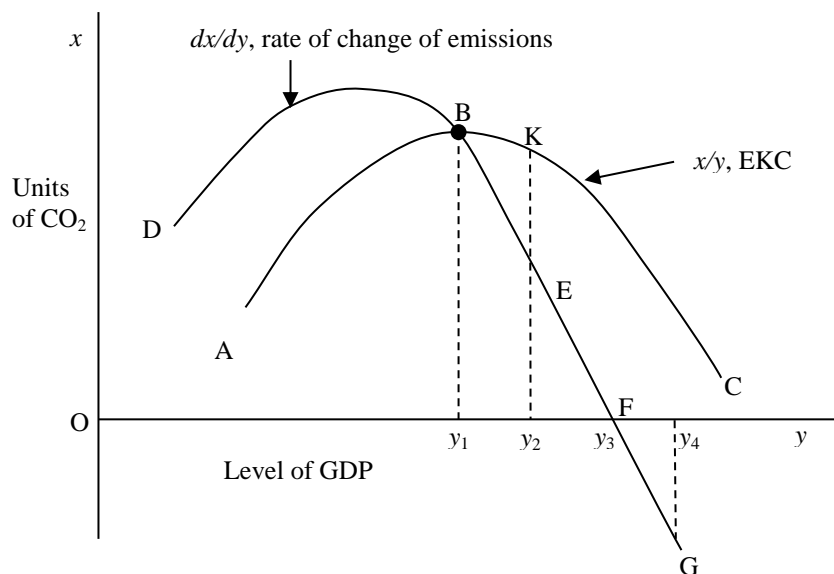
Fig. 3　**Illustration that the total level of emissions of CO_2 does not peak when its environmental Kuznets curve peaks. The total level of emissions continue to rise after this peak until dx/dy, the rate of change of emissions, equals zero.**

Another problem with the environmental Kuznets curve, and discussions based solely on it, is that it takes no account of the ability of the environment to assimilate the pollutants released. Their build up may be cumulative or cumulative once they exceed a minimum critical level. Thus one should not conclude from the EKC that continuing economic growth with business as usual will result in environmental problems ending. In fact, it may result in irreversible damage being done and result in declining incomes (Tisdell, 2001).

10 What Might be Done to Address the Global Warming Problem

The Stern report states that huge reductions in the level of greenhouse gas emissions are needed to stabilize the level of greenhouse gas concentration at about 450 ppm of CO_2 equivalent. Up to about an 80% reduction globally would be eventually needed in the level of emissions which prevailed in 2006. These huge reductions are unlikely to be politically acceptable. Furthermore, all countries cannot be expected to reduce their emissions by the same percentage. In particular, developing countries (which have a low per capita level of CO_2 equivalent emissions) would find this unacceptable.

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There are several ways in which CO_2 emissions can be reduced or capped. For example, they may be taxed or systems of tradable permits may be introduced (see, for example, Tisdell 2009, pp. 386-390). A further strategy is to encourage the production of energy from non-fossil fuels. The government may, for example, subsidise the development of alternative technologies for energy production such as solar energy and wind power. Government revenue obtained from taxing and pricing CO_2 emissions could be used for this purpose. China plans to expand its non-fossil fuel industry. A key target for the 12th Five Year Plan (2011-2015) is for China to supply 11.4 per cent of its primary energy consumption from non-fossil fuel (Anon, 2011).

In addition, in accordance with its 12th Five-Year Plan, China intends to reduce its CO_2 emission per unit of GDP by 17 per cent. However, as the discussion above of the environmental Kuznets curve indicates, this does not mean that its total CO_2 emissions will decline.

Another way to help reduce the accumulation of CO_2 in the atmosphere is to ensure that sinks for CO_2 become larger, for example, forested areas. According to the 12th Five-Year Plan, China plans to increase its forest coverage by 21.66 per cent and to expand its forest stock by 600 million cubic metres. This will increase Chinas' sequestration of carbon dioxide.

As a result of these measures, China will add less to the accumulation of CO_2 in the atmosphere than otherwise. However, no nation alone can completely solve the problem. International cooperative action is needed if the problem is to be addressed effectively.

11 Concluding Comments

Although there continues to be some climate change sceptics, most natural scientists are of the opinion that on average, the temperature of the atmosphere will rise by 4-5º C in this century. This will be accompanied by climate changes and rising sea levels but the changes will not be geographically uniform. Physical changes will occur in the biosphere and some chemical changes are expected such as some acidification of the oceans. Significant losses in wild biodiversity (and some loss in heritage biodiversity) as a result of global warming and associated changes in the biosphere are expected. Most industries will be affected by these

developments, some bio-industries that now exist in particular regions or locations are likely to be no longer viable, and relocation of many human settlements is likely to be required.

Global warming will also have economic costs. Future standards of living will be lower than in its absence. Levels of per capita income may be unsustainable. It is, however, very difficult to predict the exact economic effect. The Stern report suggested that for the world as a whole, consumption levels will be eventually 11 per cent lower than in the absence of global warming.

It seems unlikely that the upward trend in global warming will be halted in the foreseeable future but it may be moderated. Some policies that can help to do this were mentioned. It was also pointed out that it is important not to draw faulty conclusions from environmental Kuznets curves. In particular, the climate warming problem is unlikely to be solved by continuing economic growth, **based on business** as usual. This is a far too optimistic prediction.

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