Civil Society Report on Climate Change

CSCCC

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About the Civil Society Coalition on Climate Change

The Civil Society Coalition on Climate Change seeks to educate the public about the science and economics of climate change in an impartial manner. It was established as a response to the many biased and alarmist claims about human-induced climate change, which are being used to justify calls for intervention and regulation.

The Coalition comprises 41 independent civil society organisations who share a commitment to improving public understanding about a range of public policy issues. All are non-profit organizations that are independent of political parties and government.

www.csccc.info

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Summary

The science of climate change remains hotly contested, with substantial disagreements over what impact humanity might have on the earth's future climate (e.g. McKitrick, forthcoming; Green and Armstrong, 2007; Lindzen, 2005; Houghton, 2005). Nevertheless, there is considerable pressure on politicians to take action. Unfortunately, the organisation set up to advise governments on what action to take, the Intergovernmental Panel on Climate Change, has shown itself to be heavily biased (Henderson, 2007; Holland, 2007; Peiser, 2007; Tol, 2007; Kasper, This Volume). This report is an attempt to provide an independent assessment of the implications of climate change for humanity and the policy options that might be adopted.

The report has been prepared by a coalition of 41 civil society organisations from around the world. Background papers were prepared by some of the most noted experts in their respective fields. We then summarised the main findings of those experts and came up with our own policy recommendations.

Note: Funding for this project has come entirely from private individuals and foundations. No donor had any influence on what was produced, or even saw any of the material prior to publication.

Background: the climate debate in the 21st century

While global warming very likely is real and may well cause problems, the debate has become distorted by alarmists who claim that unless drastic and urgent action is taken, catastrophic climate change will decimate humanity. They say that global mean temperature must not rise by more than 2 degrees Celsius above the temperature in the mid-19th century. If it does, a vicious cycle of warming might result, leading to devastating droughts, disease, pestilence, famine, floods and other disasters.

These alarming claims have helped propel global warming from a scientific curiosity to the mother of all environmental scares in a little over 20 years. The threat has been made more visceral through clever marketing on the part of environmentalist groups, as well as journalists who know that bad news sells. Scientists seeking funding for their research – and perhaps also suffering from ideological bias – have been happy conspirators, writing papers and appearing in the media. Meanwhile, many businesses, from corn growers to hedge fund managers, have found it convenient to jump on the bandwagon.

And once the wagon got moving, politicians became generally wary of stepping in the way. This is why we ended up with a treaty that supposedly requires 'industrialised' countries to reduce their emissions of greenhouse gases (GHGs) to 5 per cent below 1990 levels by 2008–2012. This treaty, the Kyoto Protocol, agreed in 1997, was seen as the first step on the road to reducing global emissions of GHGs. In reality, it has barely made a dent in those emissions – in spite of costing many billions of dollars.[1]

It is worth bearing in mind at the outset that the claims of 'consensus' and objectivity so often made in respect of this issue smack of hubris for a very good reason. There is even a sense that the cart may have been put before the horse. After all, environmentalists have been arguing for decades that we should reduce our consumption of fossil fuels. During the early 1970s, at the birth of the modern (anti-capitalist) environmental movement and in the context of an apparently cooling atmosphere, the pretext for such reductions was the threat of global cooling – which was supposed to result from aerosols emitted as a by-product of human use of fossil fuels. The co-author of one of the key papers on global cooling, Stephen Schneider, subsequently became a prominent proponent of global warming (Rasool and Schneider, 1971; Schneider, 1989).

And now, as we approach the substantive implementation period for Kyoto (2008–2012), huge uncertainty exists over what will happen at the end of 2012, when Kyoto expires. The additional scaremongering that we have seen over the past 24 months has largely been generated in an attempt to convince us that a post-2012 agreement with binding targets and timetables for emission reductions is necessary. But is such an agreement really necessary? Or is this just a ruse by powerful vested interests who fear that the lack of a subsequent commitment period will undermine the existing restrictions, from which they are making billions of dollars at our expense?

This report seeks to put the threat of climate change into perspective. More importantly, it seeks to offer policies that would enable all people around the world to live better, happier, longer, more productive lives. These policies would also enable future generations to be less adversely affected by climate change.

The report begins with a measured assessment of the likely impact of climate change on human health, weather-related natural disasters, agriculture and forestry. We summarise a series of contributions made by some of the most eminent experts in their fields, which are included as subsequent chapters. These expert analyses were commissioned in order that we might better understand how humans have been affected by climates in the past and in the present; how we have adapted to those climates – or not; and thus what the real prognosis might be for the future.

The major difference between these expert analyses and the reports produced by the IPCC (and other biased analyses), is that we asked the authors to analyse how humans have responded and might respond realistically to the problems they face. We did this in recognition of the fact that humans are intelligent problem solvers. When faced with a threat, humans are not generally passive; we react, identify the source of the threat and seek to address it. The more entrepreneurial among us convert the threat into opportunities. So it has been with agriculture, forestry, health threats and natural disasters in the past – and, barring aggressive interventions by governments, so it will be in the future; as the following section demonstrates.

Human health

Alarmists claim that a rise in global temperatures will result in a dramatic increase in all sorts of diseases. The World Health Organization even claims that human-induced global warming is already killing at least 150,000 people per year, including 77,000 due to protein malnutrition, 47,000 due to diarrhoeal disease, and 27,000 due to malaria (explained in more detail by Indur Goklany in this report, page 51).

While it is true that many millions of people currently suffer from communicable diseases, there is little if any substance to the claim that people are dying from these diseases as a result of climate change. Paul Reiter observes:

> *Two factors are key to the transmission of infectious diseases of humans: human ecology and human behavior. When the cycle of transmission includes mosquitoes, ticks, rodents or other intermediaries, their ecology and behavior are also critical. When multiple species are involved, the levels of complexity are even greater. Lastly, the virulence of the pathogen, the susceptibility of its hosts and the immunity of the host populations can be critical at all levels.*
>
> *Climate and weather are often invoked as the dominant parameters in transmission, but their true significance can only be assessed in the perspective of this daunting complexity. (page 22)*

Enteric (intestinal) diseases are much more common among people in poor countries than people in affluent countries. Approximately one million people die each year from dehydration as a result of diarrhoea, practically all of them in poor countries. In wealthy countries, diarrhoeal diseases such as cholera and dysentery were eliminated primarily through the introduction of modern sanitation and sewerage systems in the late nineteenth and early twentieth centuries. However, as Reiter notes (page 25) there has been a resurgence of some food-borne pathogens in affluent countries as a result of modern agricultural and food preparation practices. Favourable conditions for the spread of enteric diseases often prevail in hospitals, day-care centres and homes for the elderly.

Though many poor countries have public sanitation laws on their books, in practice, such measures frequently are non-existent. In the densely populated peri-urban shanties that are ubiquitous in such countries, a lack of clean water and sewerage exacerbates the conditions which enable both enteric and vector-borne diseases to run rampant.

With regard to enteric diseases, Reiter concludes that

> *Human health is determined by a constellation of events and circumstances. In the developing world, the main defects are in the social matrix: a scarcity of basic needs: shelter, food, clothing, electricity, clean water, a safe living environment, education and access to healthcare. In wealthier countries, new and challenging problems have arisen as a direct result of economic success. In both cases, straightforward strategies are available to correct the problems, given suitable economic circumstances. (page 26)*

Vector-borne diseases such as malaria are essentially diseases of poverty. Many of today's affluent countries once experienced levels of vector-borne diseases similar to those now experienced by poor countries. In the fourteenth century, one-third of Europe's population died from the Black Death, which was spread by fleas that thrived on rats living in the sewers of medieval towns. Wealthy countries have largely eliminated such diseases through a combination of environmental interventions (such as the use of pesticides and mechanized agriculture), improved water and sewerage systems, improved human living conditions, and the development of vaccines and medicines.

However, such diseases remain a significant public health problem in Sub-Saharan Africa and in poorer parts of Asia and Latin America. Reiter notes:

> *Malaria is the most important of all mosquito-borne diseases. Each year, 350–500 million cases of malaria occur worldwide, and over a million people die, most of them young children in sub-Saharan Africa.*
>
> *This appalling toll is mainly restricted to the tropics, but less than forty years have passed since the final eradication of the disease from Europe. (page 28)*

Reiter outlines no fewer than nine behavioral and ecological factors, and three climatic factors, which affect the transmission of malaria to human beings. He concludes that the complex interaction of these factors makes it difficult to predict the likely impact of long-term climate change on the transmission of malaria.

Another area of concern is mosquito-borne zoonoses (animal diseases that are capable of transmission to humans) such as yellow fever, dengue, and Chikungunya. Reiter says that "infections in humans are incidental, acquired by an arthropod that has been infected by feeding on a bird or mammal" (page 36) and this makes their transmission even more complex than enteric diseases or malaria.

Finally, diseases such as tick-born encephalitis (TBE) are frequently invoked to be symptomatic of global warming but like the other types of diseases he considers, Reiter observes that the factors which govern the transmission of TBE are interconnected and complex. In fact, he says:

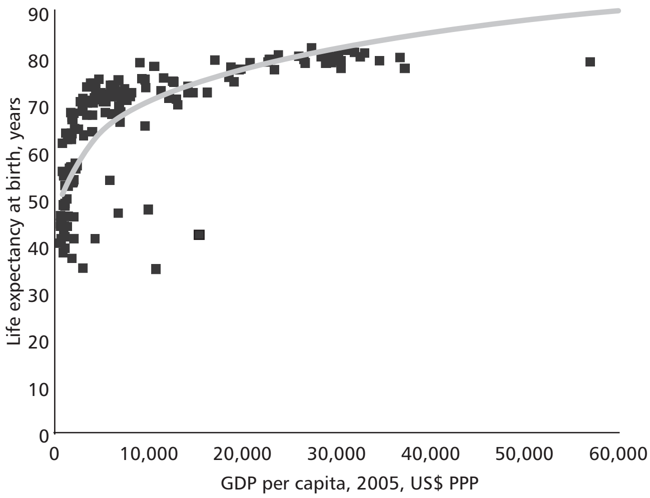
> *The factors that influence transmission are so complex that they present an outstanding example of how intuitive thinking from a starting point of changing climate can offer an explanation that is simple, persuasive, and wrong. (page 40)*

In conclusion, Reiter states:

> *The ecology and natural history of disease transmission, particularly transmission by arthropods, involves the interplay of a multitude of interacting factors that defy simplistic analysis. The rapid increase in the incidence of many diseases worldwide is a major cause for concern, but the principal determinants are politics, economics, human ecology and human behaviour. (page 41)*

Given the complexity of the transmission and distribution of these diseases, and especially given the important role of human action as a determining factor, it is clearly unrealistic to make predictions of future incidence of disease simply on the basis of changes in climate.

Figure 1 **GDP per capita and life expectancy at birth**



Source: World Development Indicators, World Bank (2007). Most recent available data were used.

There is an inconsistency in the forecasts of disease incidence produced by the IPCC. The scenarios in which the highest rates of increase of disease are experienced are the same scenarios in which the world is assumed to warm the most – as a result of rapid increases in emissions of carbon dioxide. These increases in emissions result from rapid increases in economic activity – especially in poorer countries.

Yet there is a very strong and robust relationship between average GDP per capita and life expectancy at birth (Pritchett and Summers, 1996). This is especially true of GDP per capita at lower levels (see Figure 1), where a small increase results in a comparatively large increase in life expectancy. The reason is that such increases in output coincide with people accessing clean water, sanitation and other services that reduce the incidence of communicable diseases. If economic growth did occur at the rates envisaged in the more extreme IPCC scenarios, it seems most unlikely that there will be a substantial increase in mortality from communicable diseases; it is far more likely that the opposite would happen.

Given the strong relationship between GDP per capita and the prevention of communicable diseases, the main policy implication is that societies – and especially poorer societies – should be structured in such a way as to increase rates of GDP per capita.

In addition, it is of utmost importance that existing restrictions on the ability of people to access clean water, sewerage, and sanitation services be removed. For example, in many poor countries, governments fail to supply clean water and sewerage to peri-urban and rural populations (Solo et al. 1993). Meanwhile, those same governments have made it illegal for private companies to supply water and sewerage, even though this is the only option for hundreds of millions of people (Okonski and Cudjoe, 2006). Removing restrictions on the private supply of water and sewerage is a matter of extreme urgency.

The success of the Rotary Club programme to vaccinate against polio, as well as other programmes run by various private and public organizations, suggests that there is also a role for vaccination programmes. Beyond the removal of any regulatory restrictions, tariffs and other government-imposed barriers that may unnecessarily increase the cost and difficulty of implementing such programmes, the policy implications are not clear. While governments do get involved in vaccine programmes, their success is mixed, and there is considerable evidence of waste and ineffectiveness in government-run healthcare programmes in poor countries (Lewis, 2007), so a general rule cannot be proposed.

Another area where intervention may be beneficial (either through private or public sector actors) is through vector control programmes, especially for the *Anopheles* mosquito which transmits malaria.

There is also clearly a role for increasing access to existing treatments for the diseases of poverty, as well as for the development of new treatments. Again, the main policy implication is that existing barriers to such access – including pervasive tariffs and regulations – should be removed (Irvine, 2004; Bate, Tren and Urbach, 2005).

Finally, it is worth re-emphasising that at present, hundreds of millions of people continue to suffer and millions of people die each year as a result of diseases that are readily prevented and/or cured. The fact that the incidence of such diseases remains so high is testament to the failure of measures taken by the international community to address this problem.

The reasons for this failure are manifold but fundamentally two factors are significant. First, the UN and its various agencies do not have the capacity, knowledge or competence to implement programmes that would reduce significantly the incidence of these diseases. Second, the governments of many poorer countries actively prevent entrepreneurial wealth generation and thereby perpetuate both poverty and disease. It is simply unacceptable that the UN as a whole and many of its member governments blame 'climate change' for problems that either they have failed to address or that they have actively caused.

Weather-related catastrophes

In mid-November 2007, a cyclone hit the southern coastline of Bangladesh. Estimates suggested that at least 5,000 people died as a result of the tidal surge and winds, which were equivalent in force to a hurricane. In addition to this tragic loss of life, thousands were displaced and lost their homes, hundreds of fishermen lost their boats, rice farmers' crops were destroyed, as were shrimp farms. In 1991, at least 143,000 died in a similar event. This year's tragedy might have been far worse but for the fact that over a million people were given sufficient forewarning to move out of harm's way.

Simultaneous to the cyclone, the IPCC released its Fourth Assessment Report. Environmental activists and television media, as well as one of the Bangladeshi representatives to the IPCC, were quick to allege that the cyclone was the result of global warming caused by industrialized nations.

Indeed, it has become commonplace for climate alarmists to use individual weather events – cyclones, hurricanes, floods, storms, droughts, and other phenomena – as definitive 'evidence' of present global warming. They warn that future planetary warming will cause such events to become more frequent, more fierce, and thus cause more devastation and loss of life.

In this report, Indur Goklany analyses available US and global data regarding mortality and mortality rates from extreme weather events, for a time period covering approximately the past century, up to 2007. His analysis indicates that:

> *Aggregate mortality and mortality rates due to extreme weather events are generally lower today than they used to be. Globally, mortality and mortality rates have declined by 95 percent or more since the 1920s. (page 47)*

In the context of global deaths from all causes, Goklany shows that while extreme weather-related events "garnish plenty of attention worldwide because of their episodic and telegenic nature", their contribution to the global mortality burden is only 0.03–0.06 percent. In summary, the data show that:

> *The average annual death toll for 2000–2006 due to all weather-related extreme events was 19,900. By contrast, the World Health Organization estimates that in 2002, a total of 57.0 million people died worldwide from all causes, including 5.2 million from other kinds of accidents. Out of these, road traffic was responsible for 1.2 million deaths, violence (other than war) for 0.6 million, and war for 0.2 million. (page 50)*

Thus, as a relative proportion of all deaths, the death toll from weather-related extreme events is small. Goklany says:

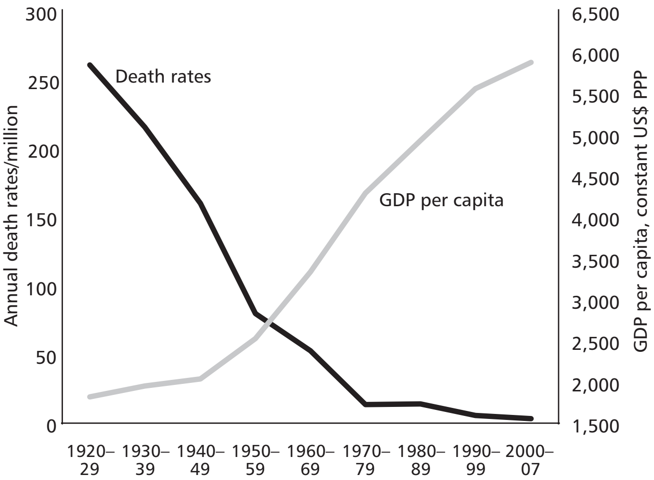
> *Based on current contributions [of extreme weather events] to the global mortality burden, other public health issues outrank climate change. (page 51)*

Moreover, as Figure 2 shows, death rates fall dramatically as wealth and technological sophistication increase. All indications suggest that deaths from natural disasters will continue to fall as societies become more technologically and economically sophisticated. However, as Goklany concludes,

> *Greater adaptive capacity is necessary but not sufficient to effectively cope with extreme events. Such capacity must be deployed more rapidly and used more fully. (page 56)*

While the climate of a region – especially associated floods, droughts, storms, heatwaves and cold spells – affects everyone, it disproportionately affects the poor. This is because poor people are less able to adapt than are wealthy people. Wealth has enabled the development of better building technologies, so that dwellings are better able to withstand the elements. It has made possible the development of better infrastructure such as the Thames Barrier, which protects London and its

Figure 2 **Death rates from extreme weather events and GDP per capita**



Note that while the number of deaths and death rates were apparently lower in the period 1900–1920 than in 1920–1950, this is largely an artefact of poor data during those early years. If better data were available, it would most likely indicate that death rates were similar or perhaps even higher than in subsequent decades.
Source: EM-DAT (2007) and WDI (2007). Most recent data available were used in each case.

surrounds from tidal surges. The wealthy also have wider access to the better warning systems afforded by mass media and communications technologies, which enables them to escape adverse events.

People who reside in wealthy countries can also limit indirect effects by – among other things – economic diversification and using modern agricultural technologies (which means that climate-sensitive activities such as agriculture constitute a smaller proportion of economic output), and by purchasing insurance. In combination, these factors contributed heavily to the decline in deaths and death rates due to weather-related disasters in the 20th century.

In general, insurance is highly beneficial, but inappropriate insurance schemes can encourage people to build in disaster-prone areas. Government-subsidised insurance programmes are particularly susceptible to this – since they are often created in response to disasters – and result in 'moral hazard,' encouraging people to engage in such risky behaviour.

The above discussion of extreme weather, and in particular the decline in weather-related mortality over the past century, indicates that policymakers should undertake specific measures to enhance the adaptive capacity of their people, and nations, to deal with extreme weather events.

Wealthy countries have developed insurance markets because they have created an underlying institutional order – namely, property rights, freedom of contract, and a transparent judicial system – which supports the transactions that occur in those markets. Because poor countries tend to lack these institutions, few if any entrepreneurs are willing to supply insurance.

At the same time, a lack of property rights means that the poor are not able to create more robust structures – such as brick homes, instead of mud and thatch huts – in which to dwell. Thus, when a cyclone hits Bangladesh, thousands of people lose their lives, and hundreds of thousands of people lose their homes in the deluge. When a hurricane hits Florida, there is certainly physical devastation – but few people die, and few homes are washed away or destroyed beyond repair. The important difference between the two places is that most people in Florida own their property, whereas in Bangladesh, the opposite is the case.

Thus, our first suggestion to policymakers is that poor countries urgently need to undertake economic and legal reforms to enable insurance markets to develop and function. Specifically, this means formalizing property rights, eliminating government-imposed barriers to entrepreneurship, and creating functioning, transparent legal systems. For similar reasons, governments must recognize currently disenfranchised citizens, and extend formal legal rights to them.

This brings us to a second potential reform. Those governments who seek policies that enable their citizens to cope with potential climate changes should remove barriers to private insurance. In addition, they should eliminate government subsidies to insurance, including bail outs and other policies that encourage moral hazard.

Third, there are real improvements which need to be made in the physical infrastructure of poor countries – for instance, bridges, dams, dykes, electricity, water and sewerage, and telecommunications. This is particularly applicable in those countries such as Bangladesh where millions of people live in low-lying deltas. But corruption is rife among government officials of many such countries, meaning that funds for infrastructure projects are often siphoned away and used for other purposes altogether. If governments cannot organize themselves to provide infrastructure, then they should enable private entrepreneurs to do so – and not inhibit them, as currently tends to be the case.

A related problem is that state-run monopolies – whether they provide electricity, water, or telecommunications services (e.g. telephone, Internet) – generally provide poor service at an extremely high cost and prevent the poor from availing themselves of lower prices from competition. For this and a variety of other reasons, our fourth recommendation is that such state-operated companies should, at the very least, be subjected to competition. Then entrepreneurs will have incentives to serve more customers with better products, in a less costly manner (Arunga and Kohara, 2007; Okonski and Cudjoe 2007). Such competition will enhance the adaptive capacity of individuals to be prepared for extreme weather events.

Bangladesh is often used as an example of an underdeveloped country whose 130 million inhabitants are greatly at risk of global-warming-induced flooding because they live in a low-lying river delta. Bangladeshi officials frequently invoke global warming in their appeals for the governments of wealthy countries to provide their country with foreign aid.

It is thus appropriate to compare Bangladesh with The Netherlands, a country of around 16 million inhabitants. Most of The Netherlands lies below sea-level but it has not experienced a flood since 1953. Purely on the basis of the threat of inundation from the sea, The Netherlands should be more 'at risk' than Bangladesh. So why is Bangladesh so much more at risk of losing human life and experiencing economic losses from flooding compared to The Netherlands?

The simple reason is that The Netherlands has been a liberal democracy for over three centuries and has benefited from more-or-less continuous economic growth during that period. That economic growth has enabled Holland to invest in infrastructure – in the form of dykes – which protect it from flooding. By contrast, prior to independence in 1971, Bangladesh was ruled by a series of more-or-less oppressive absentee landlords (the Moguls, the British, Pakistan). Since independence, it has been ruled by a series of more-or-less oppressive and incompetent elected officials. As a result, and in spite of (perhaps even in part because of) billions of dollars in aid, the majority of its inhabitants remain poor and disenfranchised, unable to control their immediate environment.

This comparison demonstrates why the policy measures recommended above are imperative, and especially for poor countries, which are almost certainly more vulnerable to the potential effects of extreme weather events – with or without climate change.

Agriculture and forestry

Alarmists have made much of a few models that predict a decline in the Indian monsoon, saying that this could have a devastating effect on agricultural output in that continent. But such models fail to take into account changes in technology which are already occurring and which are likely to continue into the future. An unstated presumption is that India will remain largely agricultural and that farmers will not have access to financial markets.

However, in reality India and other countries in the region have the potential to shift quite dramatically from agriculture into manufacturing and services, with the result that the proportion of people likely to be affected by any decline in output would be smaller. Meanwhile, financial markets could in principle soften further any blow by enabling farmers to insure their crops and hedge weather-related risks.

These observations serve to highlight the contrast between an entrepreneurial, opportunity-seeking view of the world and the misanthropic, passive recipient view promoted by the alarmists. In their analysis of the likely impact of climate change on agriculture and forestry, Professors Douglas Southgate and Brent Sohngen demonstrate the merits of thinking through the problem from an entrepreneurial perspective:

> *In a market setting, the choices made by individual economic agents reflect personal and local circumstances. These choices are also conditioned by prices, which are reliable indicators of the scarcity of goods such as food*

> *and timber which are bought and sold in markets. (page 62)*
>
> *If the exchange of goods, services, inputs, and resources is not subject to egregious regulation, then shifts in demand, supply, or both lead to quick adjustments by individual actors. This capacity of markets will serve agriculture well as it adapts to global warming. (page 65)*

However, Southgate and Sohngen are careful not to paint a Panglossian view of the current situation, especially as regards the political mismanagement of water resources, which are and will remain crucial for agriculture:

> *Already excessive, the waste and misallocation created when water is supplied too cheaply to farmers will grow worse as the planet warms. (page 66)*

When it comes to forestry, Southgate and Sohngen dismiss another myth often perpetuated by environmentalists – the myth of the wild, untainted forest:

> *Most of the world's forests have been heavily influenced by human management, having been harvested once or multiple times or having regenerated after prior agricultural use. Simply recognizing that climate change could have substantial consequences in the absence of management, as the ecologists have done, ignores human responses and the costs of these responses. (page 66)*
>
> *It is often claimed that less developed regions close to the equator will suffer disproportionately because of global warming. Commercial forestry is a major counter-example, however. As temperatures rise, wood products obtained from warm settings will increase, not decrease, and it is likely that the portion of global timber supplies coming from the low latitudes will increase as the portion harvested in temperate settings declines. (page 67)*

Southgate and Sohngen then go on to suggest the appropriate policy response to the threat of possible climate change – both generally:

> *As emphasized in this paper, successful adaptation to global warming is most likely to happen where goods, services, inputs, and resources are allocated in markets that are free and competitive. In part, this means unencumbered agricultural trade at the international level. By the same token, efficient pricing of water – as occurs if that resource is bought and sold freely as opposed to being distributed by governments at subsidized prices – is essential at the national level. (page 66)*

…and also specifically in the context of the forestry sector:

> *The best way to capture the benefits of higher temperatures in the forestry sector is to allow markets to work. For this to happen, governments need to refrain from regulating or otherwise meddling with prices and commerce. Instead, they must solidify the legal and institutional framework that markets require, by strengthening property rights for example. (page 68)*

So, if governments are concerned about the implications of climate change on agriculture and forestry, there are various policy implications. First, they should remove all subsidies, price-distorting taxes, and regulations from agriculture, forestry and related sectors. Such policies hinder the ability of individual actors to adjust to changing circumstances, and thus stifle the benefits that free competition yields in terms of managing scarce resources.

Second, they should enable private ownership, exchange and management of land and water, without bureaucratic intervention. Third, they should privatize government-owned land and water. This combination would enable effective and efficient pricing of water and other scarce resources, meaning that people and entrepreneurs have an incentive to use those resources more efficiently.

Fourth, governments should not unduly restrict the deployment of new technologies, for instance, genetically modified crops and trees. Such technologies offer real potential for humanity to use its resources more efficiently, enabling us to adapt more effectively.

A framework for adaptation and sustainable development

As potential problems resulting from climate change are multiple, no single solution can be proposed. However, underlying many of the problems is a lack of wealth and technological development, so actions that lead to wealth creation and technological advancement are likely to be beneficial. The question is: what can actually be done to improve the situation?

Today, two worlds exist. Children in poor countries still die of diseases that are utterly preventable and which have been eradicated in wealthy countries. Women and children in poor countries spend their days in pursuit of water, energy and food, while their counterparts in wealthy countries enjoy the political, social and economic freedoms afforded by relative prosperity. Poverty is the single most important factor in determining vulnerability to climate and other whims of nature. The best way simultaneously to achieve adaptation, human wellbeing and sustainable development is for poor countries to adopt a strategy which strikes at the fundamental causes of poverty.

Such a strategy would involve the adoption of institutions that provide stronger incentives for people to invest their time, effort and resources in the pursuit of better solutions. What do we mean by 'institutions'?

Institutions are the framework within which people act and interact – they are the rules, customs, norms, and laws that bind us to one another and serve as boundaries to our behaviour. The right institutions can reduce the number of decisions that we need to take; they can remove the responsibility to calculate the effect of each of our actions on the rest of humanity (an impossible task) and replace it with a responsibility to abide by simple rules.

The single most important institution for generating incentives compatible with sustainable development is the rule of law, which at its most basic level means that the same laws apply to everyone – the governed and the governing alike. An implication is that laws must be of general application. If societies were governed by the rule of law, political decision-makers would be less able to favour special interests, since they could not enact specific laws favouring any individual, group or company. Without the ability to impose specific regulations, such as restrictions on the use of SUVs and incandescent lightbulbs, politicians would have a stronger incentive to identify the best way to address any particular problem through the establishment of clear, abstract rules with general application.

Such rules would likely include: clearly defined, readily enforceable and easily transferable property rights, the ability to create and enforce contracts, open trade, and limited government. These 'institutions of the free society' enable adaptation by fostering resilience in the face of uncertainty. The absence of such institutions creates poverty and creates vulnerability to change in general. Following is a brief discussion of the importance of each institution:

- *Rule of law*: The rule of law is the best guarantee against corruption. When it is absent – that is, when the power of discretion is vested in politicians, bureaucrats and civil servants – bribery and corruption are inevitable.
- *Property rights*: Property rights offer an effective means to resolve competing claims over resources. To function effectively as an incentive both to use and conserve resources, property rights must be well-defined, enforceable and transferable. In this way, property rights are capital; they give people incentives to invest in their land and they give people an asset against which to borrow, so that they might become entrepreneurs. The innovation of new technologies occurs when people are allowed to benefit from the investments they make through ownership of property.

  However, most poor countries lack well-defined, readily enforceable, and transferable property rights. People in such countries are oppressed by tenure rules which make it difficult for them to rent, buy or sell property formally. Land transactions typically involve paying large bribes to local officials, who have a vested interest in maintaining the status quo.
- *Contracts*: Another fundamental institution for sustainable development is freedom of contract. This includes both the freedom *to* contract – the freedom to make whatever agreements one desires, subject to fair and simple procedural rules – and the freedom *from* contract – the freedom not to be bound by the decisions of others. Freedom of contract is a fundamental part of the freedom to associate with others. It includes the freedom to transact – to buy

and sell property – and as such it is an essential adjunct to the right to clearly defined and readily enforceable property rights. Contracts and property rights underpin the functioning of markets. Freedom from contract prevents others from attempting to interfere with one's right to engage in exchange. The freedom to contract also enables people to bind themselves to agreements and thereby creates greater legal certainty. This in turn encourages people to engage in trade and investment. Armed with enforceable property rights and contracts, the peasant becomes a merchant.

- *Open trade*: Open markets and free investment encourage competition. By removing barriers to trade, all people can engage in mutually beneficial exchanges. This enhances competition, creates incentives for innovation and leads to more rapid advances in human welfare and environmental protection. Removing market-distorting taxes and subsidies, especially to agriculture and other products where people in poorer countries have a comparative advantage, encourages economic development and benefits consumers.
- *Limited government*: While there is no magic formula for good governance, the imposition of limits on the power of the state at least reduces its capacity to cause harm. The most fundamental limits are those formal and informal rules governing what the legislature can and cannot do. Well-specified constitutional rules can create effective limits, especially when enforceable by citizens through the courts of law. In addition, rules requiring transparency and accountability of elected officials and bureaucrats may be helpful in restraining bad and self-serving behaviour.

When societies are governed by the institutions of the free society, entrepreneurs are able to compete with one another, driving innovation – as each seeks to identify new, better and cheaper ways of satisfying the wants of others. Over time, such innovation results in efficiency gains, as products and production methods are devised that consume fewer resources per unit of output. This in turn frees up more resources for other investments, leading to a virtuous circle of economic growth.

Economic growth benefits all members of society. Even the poorest benefit because they are able to purchase everyday goods at lower cost, freeing up their individual resources (including their own human capital) to be utilised in alternative ways. For instance, economic growth enables people more readily to acquire life-enhancing technologies, such as clean water and cleaner forms of energy.

Unfortunately, the institutions of the free society cannot be imposed from outside, since by their nature they rest upon cultural acceptance and attempts to impose them externally would likely result in cultural opposition. However, civil society organisations both within and outside countries that lack these institutions can have an impact on the culture. The civil society organisations that are the publishers of this report stand in solidarity with one another to support the rule of law and the institutions of the free society in every country in the world. By so doing, we challenge those who seek to undermine the rule of law through the imposition of arbitrary and discriminatory laws.

In the context of the debate over climate change, we specifically reject the introduction of laws that arbitrarily support – through subsidies or regulations – specific technologies (such as so-called 'renewables', nuclear power and insulation for housing) as well as laws that arbitrarily restrict – through taxes or regulations – specific technologies (such as incandescent light bulbs, petrol-powered motor vehicles, etc.). In so doing, we seek to make clear that we do not oppose or support any specific technology but rather believe that each should be forced to compete on an equal footing.

Thus, for the same reason we believe that specific regulations imposed on certain technologies in response to heightened public fears and pressure group lobbying, rather than because of any inherent problems with the technologies, should be removed. We refer in particular to nuclear power, agricultural biotechnology, and other technologies that might offer effective ways to address climate change. Likewise, subsidies to technologies such as coal mining, which contribute unnecessarily to the use of this high-carbon technology, should be removed.

If technologies are allowed to compete on a true level playing field, rather than on a playing field rigged by regulations, taxes and subsidies, then cost-effective solutions to societies' many problems will be identified and implemented more quickly. Thus, if governments are truly concerned about threats that might arise as a result of climate change, they should swiftly enact programmes that focus on the removal of such barriers.

In addition, we recommend that governments do more to ensure that individual property rights are well-defined, easily enforced, and openly tradable. The lack of such property rights remains a severe barrier to efficient and equitable use of resources, and results in overexploitation of resources as diverse as water, wood and whales.

Insuring against climate catastrophe

On the basis of the foregoing analysis, it seems reasonable to conclude that human society should be able to adapt to future changes in the climate, whether caused by man or by natural fluctuation. However, this assumes gradual change – which is what most scientists studying climate change say is likely to happen (the IPCC, for example, suggests that the earth will likely warm gradually by between 2ºC and 4.5ºC in the coming century)(IPCC, 2007).

It is nevertheless possible (though very much less likely) that the climate might change more abruptly, making adaptation at best more difficult and at worst impossible. While it still makes sense to implement the above-mentioned policies to enhance humanity's ability to adapt, it is worth also considering what sorts of policies might enable us effectively to address the problem of abrupt, possibly catastrophic change.

The threat of abrupt climate change is currently being used as a justification for taking urgent action to reduce human emissions of greenhouse gases. However, such a policy is unlikely to have the desired effect and will certainly have many undesired effects.

First of all it is important to stress that climate change is only one of many potential catastrophes awaiting humanity. Others include an asteroid impact and the eruption of a supervolcano (NASA, 2007; Sparks, Self et al. 2005). Such catastrophic events could end human life.

Potentially, all of humanity's available resources could be spent attempting to counter these threats. The problem is that in so doing, humanity would have nothing left to address more mundane problems, such as providing clean water, food and shelter. So the challenge is to identify policies that would provide some degree of insurance against catastrophe without consuming excessive resources.

An insurance policy is one that either pays out in the future in response to specific but unforeseen events materialising, substantially reduces the probability of specified harms occurring, or substantially reduces the extent of those harms should they occur. However, most climate related policies advocated under the header of 'insurance' do none of these things.

The Kyoto Protocol, for example, seeks to reduce emissions of greenhouse gases, but it does so only to a very limited extent. Lomborg (2001, p. 304) estimates that the Kyoto Protocol – if adhered to strictly by all signatories until 2100 – would delay the warming predicted by the IPCC by six years. Meanwhile, the cost of implementing Kyoto has been estimated at over $100 billion per year (Energy Information Administration, 1998; ICCF, 2005). That does not appear to be a very cost-effective insurance policy: actually, since the likelihood of catastrophe is barely reduced, it is not really an insurance policy at all.

The limits of the Kyoto Protocol were apparent when it was negotiated and are now the subject of much discussion, as nations prepare to enter into negotiations for a post-2012 agreement to address the threat of dangerous climate change (the objective of the UN Framework Convention on Climate Change). However, again the discussion is largely focused on reducing emissions of greenhouse gases.

In the years since Kyoto was agreed in 1997, emissions from most countries have risen dramatically, especially in rapidly developing countries such as China and India, but also in countries developing at a more moderate pace such as the US, and Australia. Emissions have also risen in most of the countries that have ratified the Kyoto Protocol, such as Canada, Japan and the EU. The costs to such countries of limiting emissions substantially would be enormous and could only be achieved through a combination of massive investments in energy efficiency improvements and a switch to lower carbon fuels.

While some of these investments would make economic sense anyway (many Chinese State Owned Enterprises are highly inefficient in their use of energy, for example), most would not. The resources diverted into reducing energy use and switching to lower carbon fuels would not be available for other investments. As a result, economic growth would be reduced. Given the importance of economic growth to reducing poverty and in many countries also to political stability, it is difficult to envisage most politicians signing up to, let alone ratifying such a commitment.

Given the implausibility of persuading China, India, Brazil and South Africa to agree to major emissions reductions, consider an alternative scenario: Rich countries agree to reduce emissions by, for instance, 5 per cent below 1990 levels – i.e. the Kyoto Protocol commitment but continued indefinitely. This might cost somewhere between $100 billion and $1 trillion a year by 2020.[2]

Yet, as noted earlier, the impact would be to delay warming by only a few years. Meanwhile, if the alarmists are correct, then at some point in the coming century, a dreaded 'tipping point' might still be passed, beyond which devastation becomes inevitable. Now, the investment in reduced emissions might delay the onset of the catastrophe by a few years, but on its own that would seem to have little real merit. In other words, we might end up blowing a trillion dollars and still find ourselves without a planet.

If the alarmists are correct and a relatively small rise in GHG concentrations would result in catastrophic climate change, then relying on limiting emissions seems an extremely hazardous approach. A recent paper by Weaver et al. (2007) concluded that "if a 2.0ºC warming is to be avoided, direct CO_2 capture from the air, together with subsequent sequestration, would eventually have to be introduced in addition to sustained 90% global carbon emissions reductions by 2050." That's a pretty extreme set of measures – and the cost would be similarly extreme![3]

Some proponents of Kyoto-style restrictions on emissions claim that they will not be costly or will even have economic benefits. If that were true, then such restrictions would clearly be acceptable, even desirable, regardless of the size of benefits they supply. But it is almost certainly not true. Indeed, it is difficult to imagine the circumstances under which such restrictions might be costless. As noted in this report by economist Wolfgang Kasper:

> *Mitigation costs in terms of lost long-term global economic growth are much more difficult to assess than the household costs inflicted by specific legislative proposals. Politicians and bureaucrats around the Western world are now imposing piecemeal regulations 'to save the planet', often without much analysis of their effectiveness and the costs. (page 81)*

> *Energy users are being burdened with costly regulations and compliance costs; taxes are being diverted into subsidies for some politically preferred solutions; and new 'climate regulations' block otherwise promising avenues for wealth creation. These costs of climate mitigation will without doubt on balance be massively negative. (page 81)*

Energy is an essential 'factor of production'; that is to say, it is an important ingredient in all economic activity. Society can either obtain its energy from low-cost sources, such as coal, oil, gas, and (to an extent) nuclear and hydro, or it can get its energy from high-cost sources, such as wind turbines, solar cells, and biomass fuels (wood, dung, corn-alcohol, etc.).

If society obtains its energy from low-cost sources, then more resources are available to be spent on other inputs to production (including wages), which means that economic growth occurs at a faster pace and people earn more money while doing more fulfilling jobs. If society obtains its energy from high-cost sources, then there will be correspondingly fewer resources available for wages and growth-enhancing activities.

So, by increasing the cost of all forms of energy, mitigation policies will reduce the total number of jobs, reduce the average level of skill of workers, and reduce the rate of economic growth. This is hardly a recipe for a more sustainable economy or society. While such policies would almost certainly reduce the differential in income and wealth between people in rich and poor countries, they would do so in the main by destroying wealth and reducing income of those in rich countries. The reason for this is twofold. First, energy is a basic factor of production, so increasing the cost of energy by mandating a shift to lower-carbon forms will reduce output. Second, hydrocarbons are used by consumers in all manner of applications, both directly, for example in cars and gas stoves, and indirectly, when they turn on their lights. So, reducing the availability of hydrocarbons will create energy poverty.

Some industrial production might shift from richer to poorer countries as a result of tighter restrictions on emissions in the former. However, for the most part people in the poorest countries would suffer because they have little industrial capacity but would see a fall in demand for their (mainly agricultural) products.

In defence of their 'economic benefits' claim, some climate alarmists assert that mitigation policies will lead to job creation and economic benefits. It is probably true that some jobs will be created as a result of such policies. However, it is also highly likely that the number of jobs lost will exceed the number that are created – so there will be a net loss of jobs. Moreover, the value of the jobs lost will probably be greater than the value of the jobs gained – so mitigation will be responsible for reducing average incomes.

Others see the opportunity to make money in mitigation policies, such as carbon trading programmes, and subsidies for low- or zero-carbon energy technologies. Again, it is true that some people will probably make money as a result. However, it is also true that the amount of money gained will be smaller than the amount of money lost. And the number of people who benefit will almost certainly be smaller than the number of people who lose.

Economists have coined a term to describe the activities of those who seek regulations, taxes, subsidies and other government programmes that result in personal benefits to them at a cost to society: 'rent seeking'. As Kasper notes:

> *Pervasive rent seeking is counterproductive in economic terms, as well as profoundly unjust. To the extent that arguments about global warming are detected as just a new excuse for rent seeking, they will be treated with disdain and contempt – regardless of their scientific merit. (page 87)*

> *To most natural scientists, concepts such as public choice and rent seeking are of course unfamiliar. They therefore fail to understand that social scientists and the public are cynical about the climate advocacy of recent years, which they view as a case of massive rent seeking. This is the main reason why economists are recalcitrant to uncritically accept the assertions of the climate activists. (page 87)*

Still others justify climate mitigation on the basis that we must avoid *all* risks associated with climate change. To such observers, who often suggest that the social sciences should not be involved with addressing the question of how best to deal with climate change, Kasper says:

> *[It is not] legitimate to suggest that any hypothetical risk of future damage to human wellbeing must be avoided at all cost. The appropriate approach is economic; namely, to weigh properly assessed and priced costs and benefits, taking account of fundamental social values, such as freedom, justice, security and peace. (page 78)*

He maintains:

> *The climate experts will fail if they disregard the fundamental insights of these social-science disciplines. Experts frequently fail in their pursuits not because they make a mistake in the narrow area of their expertise, but because they overlook some very fundamental insight in another discipline. (page 79)*

Finally, Kasper notes that mitigation policies seem to appeal to scientists and technocrats, in contrast to the apparently 'disorderly' workings of the market system:

> *Most observers with a scientific or engineering background are inclined to a system of coordination akin to a centrally designed and controlled train timetable, rather than the rules-based coordination of independent motor car [drivers]. Many do not seem to comprehend the working of the invisible hand. They prefer instead some high-minded, well-informed authority to sort out all necessary information prior to any action, and to control all subsequent actions. (page 90)*

Yet the fundamental problem is that mitigation relies on central government planning to achieve a particular outcome: a target. Kasper proposes that:

> *Humans have diverse wants – Mao suits for all may have been technically efficient, but made the Chinese unhappy. Diverse alternatives which are allowed to compete in the market are often the seed for solutions that prove useful only later. If a central planning committee in 1895 had picked steam engines to propel cars (at the time this technology looked promising), then we would not have today's car industry. (page 91)*

Technocratic plans for the climate (whether driven by global agencies or national governments) are predicated on the same fatal conceit that led to the failure of socialism: that government is better able to identify and act upon information that is ultimately only available to individual economic actors within society (Hayek, 1945). Kasper observes:

> *Entire nations – let alone the entire world economy, as in the case of global greenhouse gas management – are not organisations like firms. A nation is an association of free individuals, not employees of a government whose orders they must obey. The citizens are the principals, and the government is but their agent. (page 90)*

In most cases, as already noted, it is apparent that limiting GHG emissions will very likely make any problems resulting from climate change more intractable by slowing down rates of economic growth, reducing average incomes and limiting the adoption of existing technologies and the development of new technologies.

Moreover, an obsession with global target-setting will go far towards enabling rent-seekers to achieve private benefit at public expense, but it will serve to undermine the very social values that have enabled humanity to flourish.

An alternative insurance policy

If we really are on the verge of a climate catastrophe, then the policies promoted by most alarmists are not sufficient to address the problem (Weaver et al, 2007) – even through they would be enormously costly (Kasper, This Volume).

Ross McKitrick has suggested instead the introduction of a tax on carbon that is proportional to the temperature of the tropical troposphere. The logic is this: all climate models predict that the tropical troposphere (the part of the climate from about 1 to 15 km above the surface of the earth and between 20º North and 20º South of the Equator) should warm more rapidly than the lower atmosphere. Indeed, so strong is the predicted warming in the tropical troposphere that it would act like the proverbial 'canary in a coal mine'. By linking a carbon tax to that temperature, therefore, there is the potential to introduce a self-correcting mechanism. If the tropical troposphere begins to warm dramatically, the tax would rise substantially, incentivising the development and use of lower carbon technologies.

But even McKitrick's proposed tax might not be enough, in which case other technologies would have to be introduced that would limit the warming of the atmosphere. These might be technologies that suck carbon out of the atmosphere (Markels and Barber, 2001), or they may be technologies that reduce the temperature more directly – such as shooting sulphur into the upper atmosphere (Crutzen, 2006). In any case, alarmists in search of an insurance policy might consider investing in the development of a smorgasbord of such technologies. Some, such as James Lovelock and Chris Rapley (2007), have at least begun to look at alternatives.

While we do not advocate either McKitrick's carbon tax or substantial investments in geoengineering, we acknowledge that these are likely substantially superior to the other 'insurance' policies being advocated by alarmists.

Adaptation: a new role for 'foreign aid'?

A parallel strategy to mitigation advocated by many climate alarmists, including so-called 'development' NGOs and international agencies, is that of 'adaptation'. But this is not to be confused with the kinds of adaptation discussed above. These folks narrowly construe adaptation to mean 'aid' transfers from the governments of wealthy countries ostensibly for the purpose of combating the effects of climate change. This has, unsurprisingly, resulted in a dramatic widening of the supposed consequences of climate change.

Such foreign aid is partly motivated by feelings of guilt: wealthy countries are presumed to have caused the climate to change as a by-product of wealth-creation, so some of that wealth must be transferred to poor countries in order to help them deal with the impacts. In reality, foreign aid is mainly being offered as a carrot to encourage poor countries to assume obligations under a post-2012 agreement.

Yet transfers of financial resources from the governments of rich countries to the governments of poor countries have been largely unsuccessful in stimulating adaptation. Consider Figures 3 and 4, which show the relationships between cumulative per capita spending on aid and economic growth (3) and changes in life expectancy (4).

From 1975 to 2002, foreign aid made no net contribution to the economic development of recipient countries.[4] The governments of two countries, Gabon and Nicaragua both received over US $2,000 in aid per capita, yet GDP per capita in both fell by more than $2,000 – a remarkable feat!

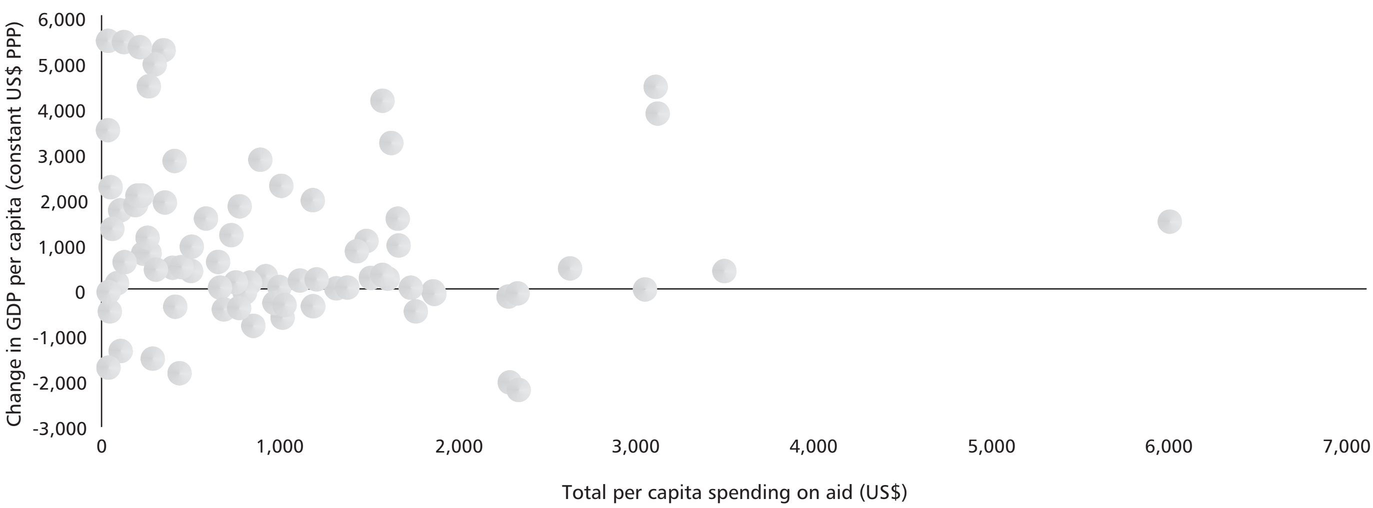
Figure 4 is perhaps the most striking. Since 1960, aid has – on average – had no perceptible impact on life expectancy.

Aid has been a failure because a lack of government funds is not the primary problem in poor countries. To illustrate, consider the case of Nigeria – a country which happens to contain one of the largest oil deposits on the planet. Oil wealth in Nigeria has been controlled by government officials – until recently it was in the hands of the murderous kleptocrat General Sanai Abache –who used it to line their pockets and to placate the political elite, rather than to promote development.

There is little point to pouring money into a country whose government has no intention to encourage economic development and the elimination of poverty. Indeed, as Mengistu showed in Ethiopia, Mobutu in Zaire, Pol Pot in Cambodia, and Idi Amin in Uganda, dictators will happily accept 'aid' if it helps to prop up their regimes. In such cases, government-to-government transfers are not merely counterproductive, they are murderous.

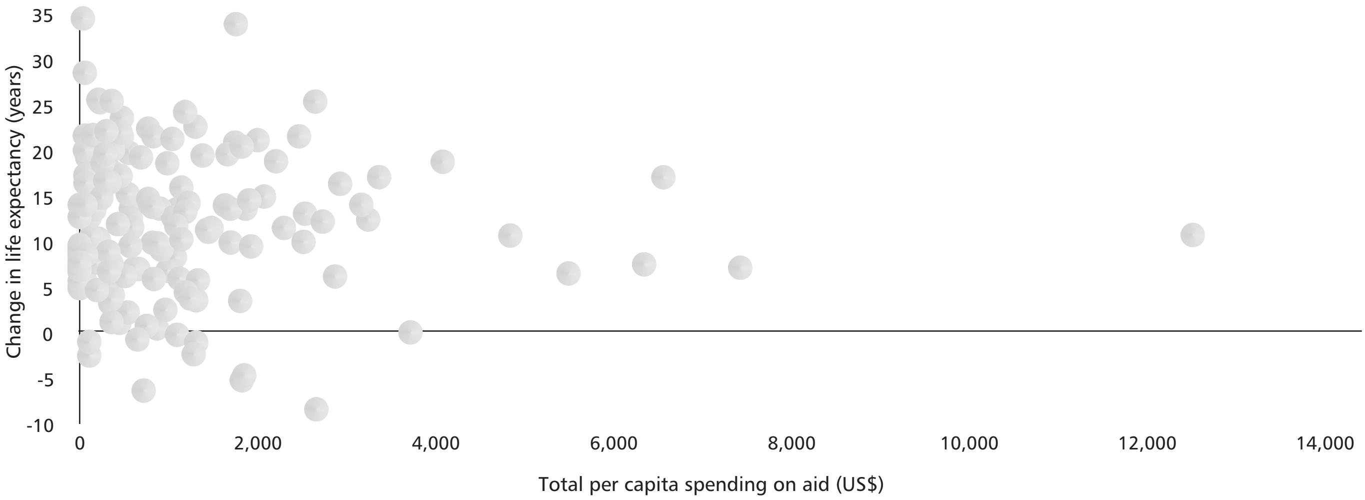
The more fundamental problem is that 'aid' is based on a largely false premise, namely that poverty itself is a barrier to development. In general this is simply not true. Economic development in Western Europe did not

Figure 3 **Impact of aid on economic development 1975–2002**



Source: World Development Indicators, World Bank, 2004

Figure 4 **Impact of aid on life expectancy 1960–2002**



Source: World Development Indicators, World Bank, 2004

require massive redistribution from the rich to the poor. Rather, it required a change in the structure of Europe's institutions; a move away from the feudal system of the early middle ages to a trading economy.

While some parts of sub-Saharan Africa now appear to be facing a genuine crisis, in the form of disease (HIV/AIDS) that is destroying part of the economically productive sector of society, it is probably unique in the world (if not world history) in requiring external assistance to escape from such a quagmire. And even then, such assistance is unlikely to lead to significant growth; rather, it might merely prevent total economic collapse.

What aid schemes have done is to short-change the poor. While aid is given in the name of the poor, bureaucracies have generally not used aid in ways that benefit poor people at large. If countries are to develop sustainably, institutional reforms that eliminate the fundamental causes of poverty are far more likely to deliver benefits to poor people.

Conclusion

To the extent that global warming occurs gradually, the best strategy is likely to be adaptation. The appropriate policy response in such circumstances is to reduce barriers to adaptation, such as regulatory restrictions and taxes that inhibit the free flow of information and prevent entrepreneurs from identifying and seeking to fill market niches.

Access to modern technologies allows people to use their resources more efficiently, to be healthier and to live a more benign existence. Such technologies are not an end in themselves: they allow people to work fewer hours and with less effort, to earn a living rather than subsist, to control their environment and to invest in the future of their children, their community and their country, as well as their environment.

Economic development and the associated increases in wealth, enhanced technologies and improved infrastructure have been the primary drivers of the improvement in the lives of people globally. Increased wealth means that children can go to school rather than working on the farm. Improved technologies enable the eradication of water-borne diseases. Improved infrastructure means children can obtain the variety of foods and medicines that will enable them to grow up and live healthy, long lives.

Given the strong relationship between prosperity, health and a clean environment, the best policy for reducing the vulnerability of people to potentially negative aspects of climate change is one that enables people to become rich and thereby avail themselves of all the adaptive measures that the wealthy can afford. As Wolfgang Kasper concludes in this report:

> *Global economic growth of the sort attained over recent decades seems an excellent method of 'future proofing' human civilisation, should the need really arise. (page 81)*

Climatic change may turn out to be benign or malignant – we do not know. But policies aimed at mitigation through control of atmospheric carbon would almost certainly be harmful. Meanwhile, aid transfers given under the pretext of 'adapting' to possible negative effects of future warming are unlikely to be cost-effective and might even be counterproductive.

The political commentator HL Mencken once said that 'for every problem there is a solution that is simple, direct and wrong'. In the case of climate change the simple, direct and wrong solution is to impose restrictions on emissions of greenhouse gases. A more constructive perspective suggests that poverty exacerbates all sorts of problems, whether or not they are caused by changes in the earth's climate. Under this view, only by eliminating poverty can we solve the myriad problems that prevent humans from achieving sustainable development.

Development is not just about fulfilling people's basic needs, but allowing them to choose how they develop and to choose which technologies they use. We have a moral responsibility towards fellow human beings who are alive today to ensure that this happens.

Summary of policy recommendations

General recommendations

- Property rights should be well-defined, easily enforced and openly tradable.
- Restrictions on formal ownership of property should be removed.
- Governments should recognize currently disenfranchised citizens, such as those who live in peri-urban areas of poor countries, and extend to them the same formal legal rights that are available to other citizens.
- Legal systems should be open and transparent; the judiciary should be independent of the legislature and the executive.
- Government-imposed barriers to entrepreneurship, such as licensing systems and other arbitrary or discriminatory regulations, tariffs and taxes should be removed.
- Subsidies, taxes and regulations that arbitrarily support or restrict specific technologies (such as 'renewable' energy, nuclear power, incandescent lightbulbs, and insulation for housing) should be eliminated.

Health-specific recommendations

- Existing restrictions which limit the ability of people to access clean water, sewerage, and sanitation services should be removed.
- Regulatory restrictions, tariffs, taxes and other government-imposed barriers that may unnecessarily increase the cost and difficulty of delivering vaccines, medicines and other medical treatments should be removed.
- Targeted vector-control programmes, such as indoor residual spraying with insecticides, should be undertaken to control the spread of malaria and perhaps other vector-borne diseases.

Weather-related recommendations

- Individuals should be free to purchase private insurance.
- Government-subsidised insurance programmes and other policies that incentivise people to expose themselves and their property to otherwise uninsurable risks should be scrapped.
- Where services such as water, electricity, and telecommunications are provided by statutory monopolies, those companies should be forced to compete with private suppliers.

- Other government-imposed barriers to the private provision of such services and to the supply of infrastructure – such as bridges, roads, dams, and dykes – should be removed.

Agriculture and forestry recommendations

- All subsidies, price-distorting taxes, and regulations should be removed from agriculture, forestry and related sectors.
- Private ownership, exchange and management of land and water, should be permitted without bureaucratic intervention
- Government-owned land and water should be privatized.
- Technologically specific regulations, taxes and subsidies that act as a barrier to the development and deployment of new technologies, such as genetically modified crops and trees, should be removed.

Notes

1 Although many studies of the possible costs of Kyoto were carried out in the late 1990s, few actual cost estimates exist. In 2005, the International Council on Capital Formation looked at actual policies being implemented by European countries in an effort to comply with Kyoto and estimated the total cost to Germany, Italy, Spain and the UK at over $100 billion (ICCF, 2005). Even if the ICCF is out by a factor of 10 (which seems unlikely), the cost to those four countries would still be at least $10 billion.

2 Based on ICCF's estimates for Europe and the Energy Information Administration's (1998) estimates for the US.

3 A 2005 study by Charles Dumas of Lombard Street Research estimated the total cost of preventing human induced global warming at an enormous $18 trillion (Heath, 2005).

4 The dates were chosen because of data availability at the time the graphs were produced (2004).

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Paul Reiter

Human Ecology and Human Behavior

Climate change and health in perspective

Executive summary

Human ecology and human behavior are the two key factors that determine the transmission of human infectious diseases. When the cycle of transmission includes mosquitoes, ticks, rodents or other intermediaries, their ecology and behavior are also critical. When multiple species are involved, the levels of complexity are even greater. Lastly, the virulence of the pathogen, the susceptibility of its vectors and hosts, the immunity of those hosts and the collective immunity of the host populations all contribute to the force of transmission. The significance of climate factors can only be assessed in the perspective of this daunting complexity.

- **Enteric infections**: In the developing world, scarcity of basic needs such as shelter, food, clothing, electricity, clean water, education, and healthcare is the dominant factor in disease transmission. In wealthier countries, new and challenging problems have arisen as a result of economic success. Straightforward strategies are available to prevent infections in all these scenarios, given suitable economic resources. In nearly all cases, climate is at most a minor, often irrelevant parameter.

- **Mosquito-borne diseases**: Mosquitoes are found throughout the world in all climates. Meteorological variables are of limited value as a guide to the population densities, behavior and geographic range of vector species. The same is true for the pathogens they transmit. Future changes in climate may result in minor changes in prevalence and incidence of mosquito-borne diseases, but the critical factors will remain human ecology and human behavior.

- **Tick-borne diseases**: As with mosquito-borne diseases, the prevalence and incidence of tick-borne infections is affected by an incredible range of parameters. In northern temperate regions, for example, Tick-borne Encephalitis is influenced by agricultural practices, land-cover, populations of small mammals and their predators, small mammal immunology, population and behavior of large mammals, hunting, wild-life conservation, industrial activity, income levels, leisure activities, depth of winter snow, the micro timing of springtime temperatures, and summer rainfall and humidity. Moreover, the interaction of these variables is distributed over a two to three-year period. In the context of this complexity, it is ludicrous to claim a direct cause and effect relation between climate and infection.

In conclusion, it cannot be over-stressed that the ecology and natural history of disease transmission, particularly transmission by arthropods, involves the interplay of a daunting multitude of interacting factors that defy simplistic analysis. The rapid increase in the incidence of many diseases worldwide is a major cause for concern, but the principal determinants are politics, economics, human ecology and human behavior. A creative and organized application of resources to reverse this increase is urgently required, irrespective of any changes of climate.

Introduction

There is a remarkable constancy in the majority of articles that have been published on climate change and infectious diseases. They name a disease, describe where it occurs and how it is transmitted, and then make a succession of statements on the action of temperature and rainfall on specific components of its transmission cycle. These statements lead to conclusions that are persuasive because they are intuitive: tropical diseases will claim ever more victims in the (poorer) tropical countries and will move into temperate regions, those of temperate regions will move towards the poles, all will move to higher altitudes, and so on. Many of these predictions are backed by credible "evidence" that the process has already begun. Most are focused on arthropod-borne diseases[1]: there is a tragic increase in the death toll from malaria in the tropics, the disease is moving to higher altitudes, cases are occurring in Europe, ticks and tick-borne diseases are increasingly common and are moving northwards, chikungunya fever has appeared in Italy and the mosquito that transmits it is native to Asia. Enteric diseases also feature high on the list: epidemic cholera has appeared on the western seaboard of Latin America and epidemics of meningococcal meningitis are becoming more frequent in the Sahel. Many such articles focus on the vulnerability of people in poorer countries, and place the blame squarely on the activities of the industrial nations.

Articles structured in the same way, and with a similar message, are also common in the professional scientific press (WHO 1996, Lindgren and Gustafson 2001, McCarthy et al. 2001, Epstein 2005, Haines et al. 2006, McMichael et al. 2006, Menne and Ebi 2006). Some are based on mathematical models that select a climate variable (usually temperature), propose a direct interaction with a transmission parameter (i.e. multiplication of pathogen, survival of vector), and inevitably arrive at the same conclusions. In many cases it is clear that such articles have been written by persons with little or no background in the relevant field. A deplorable trend is the inclusion of a political message, much as in the popular media.

Multiple depths of complexity

Two factors are key to the transmission of infectious diseases of humans: human ecology and human behavior. When the cycle of transmission includes mosquitoes, ticks, rodents or other intermediaries, their ecology and behavior are also critical. When multiple species are involved, the levels of complexity are even greater. Lastly, the virulence[2] of the pathogen, the susceptibility of its hosts[3] and the immunity of the host populations can be critical at all levels.

Climate and weather[4] are often invoked as the dominant parameters in transmission, but their true significance can only be assessed in the perspective of this daunting complexity. Moreover, the key parameters – temperature, rainfall and humidity – cannot be viewed independently. The effects of temperature are modified by humidity. The daily range of each may be more significant than the daily mean. Brief periods of atypical heat or cold can be more significant than long-term averages. Heavy storms can have a different impact than light prolonged rainfall. One year's events may have a significant impact on subsequent years.

There are several approaches to assess the significance of such parameters:

- The history of prevalence, incidence and geographic distribution in the context of the prevailing climate;
- Current prevalence, incidence and geographic distribution of disease under current climatic conditions;
- Targeted studies of incidence and prevalence, climate and weather;
- Empirical studies of climate parameters, pathogens and vectors in the laboratory
- Models that seek to describe transmission in mathematical terms.

History

Systematic records of climate, mainly from a small number of land-based stations in the Northern Hemisphere, are only available for the past century or so. Global data, obtained by weather balloons and weather satellites, are only available for the past few decades. Nevertheless, a large amount of proxy information is available (Grove 1988, Lamb 1995, Le Roy Ladurie 1971). Archival materials are a rich source of indirect information, particularly on the timing and occurrence of drought, flood, unusual heat, cold or other extreme weather events. A wide range of evidence is also available from archaeological, geological, fossil and other sources.

Literate, scholarly systems of medicine dating back more than 3,000 years are available for many parts of the world. Pathological signs in bones, fossil excreta and other items can be studied in archaeological material. Molecular techniques can yield additional information from such remains. In Europe, parish records, the diaries and publications of physicians and other archival material are a rich source of information. Thus, as with climatology, we can turn to a variety of sources for evidence of diseases in past climates.

Climate and current distributions of disease
The distribution of many diseases coincides with certain climate patterns, but in many cases the reverse does not hold true. For example, malaria disappeared "spontaneously" from large areas of Western Europe and North America after the mid-1800s, precisely the period when the current warming trend began (Reiter 2001).

Short-term climate variations (weather) and disease transmission
Favorable weather incidents may result in increased transmission, but here again, caution is needed when extrapolating to future incidence. For example, short periods of drought may reduce malaria transmission, whereas longer periods can initiate epidemics (Macdonald 1973).

Laboratory studies
Some parameters can be measured in the laboratory (Christophers 1960, Monath 1998). Thus, the duration of the extrinsic incubation period – the time required for a vector to become infective after it takes an infected blood meal – is inversely proportional to temperature. In most parts of the tropics, however, temperatures are more than adequate for rapid incubation, so higher temperatures are unlikely to result in a significant increase in transmission. Indeed, higher temperatures, particularly at low humidity, may reduce the life-span of the vector, which is by far the most significant parameter in the dynamics of transmission (see page 20).

Mathematical models
At the start of the 20th Century, Sir Ronald Ross stepped beyond intuition by building simple mathematical models to describe the cycle of malaria transmission. The advent of low-cost computers has propelled mathematical modeling into a major role in the description of complex systems, including ecology, epidemiology and public health (Murray 2002). Most models are constructed from variables, and the interactions between these variables are driven by sets of equations that are termed operators. The approach involves many new and rapidly evolving techniques but is often too abstract and esoteric to be understood by non-mathematicians.

Complex systems imply the need for a large number of variables and operators, but as this number increases, so does the variance – and the uncertainty – of the models.

In a sense, therefore, models are an extension of the intuitive approach because the ultimate selection of variables, the mathematical descriptors of the operators, and the constraints on both are made by the modeler. This is not to say that such models are inappropriate. On the contrary, they represent an important and exciting advance in epidemiology and related fields. Nevertheless, the selection of variables is a critical, but often unmentioned, constraint in forecasts of the impacts of future climate change on human health, not to mention on the forecasts of the climates on which they are based.

In conclusion, a holistic view of the role of human behavior and human ecology in the natural history and dynamics of an infectious disease is the only valid starting point for a study of the significance of climate parameters in its transmission. Having established what we understand and don't understand about the system as a whole, we can begin to speculate on future scenarios in the context of changing climates.

First level of complexity: enteric diseases

Enteric infections kill nearly 2 million people per year. According to the World Health Organization, they are the second highest cause of death from infectious disease (WHO 2003). Transmission is from person to person, either directly or through contaminated food and water. They are an outstanding illustration of the dominant role of human ecology and human behavior in the dynamics of transmission (Levine and Levine 1995). It is informative to examine the natural history of these diseases in detail and in the context of repeated claims that their incidence is likely to change as a result of climate change.

Background

In much of the developing world, particularly in the crowded conditions of rapidly urbanizing populations, pervasive faecal contamination of food and water presents ideal conditions for transmission of a host of bacterial, protozoal, parasitic and viral diseases. By contrast, in the industrialized regions of the world, distinct patterns of diarrhoeal disease are occurring with increasing frequency, despite piped water, flush toilets, wastewater treatment, microbiologically monitored drinking water, adequate housing and widespread awareness of the importance of faecal-oral hygiene.

Enteric disease and industrialization

The filth and festering poverty of 19th Century London described by Charles Dickens – crowded conditions, open sewers, offal and garbage in the streets, rag-pickers, "swill children" and other scavengers – were as typical of the great cities of Europe and North America as they are of urban populations in much of the developing world today. The only difference is one of degree; 19th Century cities were tiny compared to today's burgeoning mega cities.

Cholera (Sack et al. 2004) and typhoid (WHO 2007a) were the dreaded diseases of Dickens' era, killing tens of thousands in pandemics that swept around the world. These pandemics were a classic example of the role of transportation and human mobility in the dissemination of pathogens. In the modern world, this factor is ever more prevalent. The only major difference is in the mode, speed of transport, and sheer volume of traffic.

Ten global pandemics of cholera are recognized from the start of the 19th Century until recent times. The bacterial pathogen *Vibrio cholera* sailed from port to port in contaminated kegs of water and in the excrement of shipboard victims. Progression by land was somewhat slower, but remorseless. The first cases to reach Western Europe were in the 1820s. Sunderland, an industrial town in northeast England, was hit in the winter of 1831. Other British cities were rapidly affected, as well as many in Western Europe and North America. In one month, for example, 1,220 immigrants to Montreal, Canada, were dead on arrival, and the disease spread rapidly to Quebec and other cities, killing tens of thousands. In many cases, the wealthier classes were the least affected. Indeed, when the first epidemic hit Paris in 1832, the contrast was so obvious that some believed it was a plot by the aristocracy to weed out the poor.

A second pandemic reached England in 1854 and raged for more than two years. John Snow's classic epidemiological study, in which he pin-pointed a water pump as the source of local infections by mapping the distribution of cases (McLeod 2000), led to the creation of public health agencies, the introduction of sand filtration, chlorination of water, an extensive system of water-mains, sanitary disposal of sewage, and public education in basic concepts of hygiene. By the turn of the 20th Century, cholera and typhoid were relatively rare in London and in most of the economically advanced cities of Western Europe and North America.

Enteric diseases in developing countries

Urban ecology

In most economically advanced countries, public sanitation, enforced by strict legislation, is so much a part of urban infrastructure that many inhabitants are hardly aware of its existence. Such measures are non-existent, or at best inadequate, in much of the rest of the world. Rapid urbanization and high birth rates are dominant factors in the ever-increasing toll of viral, bacterial and protozoal diseases. In much of the world, it is not uncommon for children less than two years old to suffer severe diarrhoeal illness for four to six months in the first two years of life, with more than one-third of all deaths in this age group attributable to such infections (WHO 2007b).

Changing patterns of agriculture

Human and animal faeces are used as fertilizer to boost food production in many countries, with obvious dangers. In some countries, farmers who switch to a single cash crop (sugar, coffee, cocoa) may do so at the expense of staple food crops (Levine and Levine 1995). This may render children prey to malnutrition and infection if substitute diets are deficient in essential nutrients. In some countries, population pressures and other factors have forced rural people from relatively isolated hamlets and villages to larger agricultural communities, with attendant problems of sanitation and disease transmission (Kennedy et al. 1992).

War and civil strife
Throughout history, war has been a major, often dominant human behavioral factor in public health. Today, as never before, conflicts in dozens of countries are responsible for mass displacement of populations, with accompanying malnutrition and disease. The ecology of enormous refugee camps provides an optimum environment for enteric disease and many other types of infection. Death rates are frequently measured in days, rather than years. This scenario is not restricted to the developing world. For example, disruption of public health infrastructure resulted in a high incidence of diarrhoeal disease in Europe during the Balkan wars in the 1980s (Weiss and McMichael 2004).

Maternal behavior
In many developing countries, the incorporation of women into the workforce has led to a major decline in breast-feeding. Breast milk is bacteriologically sterile, and contains antibodies and non-immunological anti-bacterial systems that are highly effective against enteric infections (Reiter 1985). Infants deprived of this protective nutrition are particularly prone to intestinal infection (Qureshi et al. 2006).

Early weaning of infants is encouraged by availability of manufactured substitutes, often backed by persuasive advertising. Apart from the absence of anti-bacterial components, the dilution of such formulae with contaminated water is a dangerous route to severe infection (Horton et al. 1996).

Enteric disease in wealthy industrialized countries

Imports of food from developing countries
The advent of cheap transport by air and sea has provided poor countries with a valuable source of foreign currency through exports of agricultural products. In a number of instances, unexpected outbreaks of bacterial and protozoal disease have been traced to these exports. In 2000, for example, widespread infections by *Cyclospora cayetanensis*, an intestinal protozoan, occurred in the United States as a result of imports of faecally contaminated raspberries from Guatemala (Ho et al. 2002). In another instance an outbreak of cholera in Maryland, USA, was traced to contaminated frozen coconut milk imported from Thailand (Taylor et al. 1993).

Mass production and consumption of food
Economies of scale have led to a revolution in food production and food consumption, particularly in industrialized countries. Intensive farming of chickens and eggs in densely packed indoor colonies numbering hundreds of thousands of birds provides an ideal environment for enteric pathogens, particularly *Salmonella* and *Campylobacter*. Consumption of uncooked or partly cooked products of such "farms" has resulted in several major epidemics in northern Europe and North America.

Fast food chains are a major component in food consumption in wealthy countries, and, to an increasing extent, in those with emerging economies. These chains rely on a brand identity that requires strict standardization of the end product on a national and even international scale. Here again, economies of scale require centralized, mass-production and mass-preparation of the basic ingredients, followed by dissemination over long distances.

Unsanitary preparation and cooking practices can lead to huge and widely disseminated outbreaks of enteric infection (Tuttle et al. 1999). A classic example was the entero-haemorrhagic strain of *E. coli* that emerged in Europe and the United States in the 1980s, infecting tens of thousands of people, with a significant proportion of severe, sometimes fatal illness (Jay et al. 2004). These epidemics were traced to intensive cattle rearing and insufficient cooking of meat processed as hamburgers. Interestingly, this pathogen is uncommon in poorer countries, where intensive livestock rearing and fast-food chains are less common.

Day-care centres
Just as in poorer countries, the children of working women in industrialized countries are weaned early in order for their mothers to return to work. Problems of infected food are reduced by sterile prepared foods, availability of clean water, and attention to personal hygiene, but the crowded conditions of nursery schools, particularly in low income neighbourhoods, have led to a high prevalence of enteric pathogens such as *Giardia* and *Shigella* (O'Donnell et al. 2002).

Hospitals
Hospitals are close-packed communities of people under the care of staff who are in close contact with multiple patients, many of whom arrive with low defense against infection. For this and other reasons, diarrhoeal disease among hospital patients is an increasingly serious problem in many technically advanced countries (O'Brien et al. 2007). In the UK, for example, hospital deaths as a result of infection by the spore-forming bacillus *Clostridium difficile* account for nearly as many deaths as those from road accidents. Control of *C. difficile* is difficult because of rapidly increasing resistance to a wide range of antibiotics, and because normal alcohol scrubs and other sanitary measures are ineffective (McMaster-Baxter and Musher 2007).

Geriatric wards and homes for the elderly
A similar ecological niche exists in colonies of elderly persons. In many cases, low stomach acidity allows living pathogens to pass easily through the stomach (Morley 2007). Other factors include chronic disease and poor personal hygiene. Breakdowns in food-hygiene in such institutions can result in outbreaks of enteric disease with high fatality.

International travel
Traveler's diarrhoea is a familiar term for a condition that affects persons from affluent countries when they visit countries with relatively unhygienic conditions and a higher incidence of enteric disease. Cheap air travel exposes millions of people to such infections during holidays abroad. Outbreaks of similar infections on cruise ships are another example of recreational exposure.

Summary

The dominant theme of the examples above, and of those that follow, is that human health is determined by a constellation of events and circumstances. In the developing world, the main defects are in the social matrix: a scarcity of basic needs: shelter, food, clothing electricity, clean water, a safe living environment, education and access to healthcare. In wealthier countries, new and challenging problems have arisen as a direct result of economic success. In both cases, straightforward strategies are available to correct the problems, given suitable economic circumstances. New technologies, such as the development of genetically modified food-crops and novel methods for control of pathogens, will also become available. In nearly all cases, climate is at most a minor, often irrelevant parameter. A continued, obsessive emphasis on climate change is unwarranted, and will misdirect efforts to implement these strategies.

Second level of complexity: mosquito-borne diseases

Speculations on the potential impact of global warming on human health often focus on the mosquito-borne diseases. Predictions are common that malaria will move into Europe, that dengue is increasing its range in the tropics, that mild winters enabled West Nile virus to become enzootic in the United States, and so on. A search of the electronic catalogue of the National Library of Medicine (PubMED) listed more than 200 articles on climate change and health, the majority citing vector-borne diseases, particularly malaria. Many are simply speculative reviews with liberal quotation from other reviews, frequently written by the same authors (Haines et al. 1993, Martens et al. 1995a, Martens 1995, Martens et al. 1995b, Patz et al. 1996, Epstein 1997, Epstein et al. 1998, Haines 1998, Lindsay and Martens 1998, McMichael et al. 1998, Patz et al. 1998, Kovats et al. 1999, Patz and Lindsay 1999, Epstein 2000, Githeko et al. 2000, Haines et al. 2000, Kovats 2000, Patz et al.

2000, Haines 2001, Kovats et al. 2001, Patz and Reisen 2001, Patz et al. 2002, Patz and Kovats 2002, Bunyavanich et al. 2003, Hales and Woodward 2003, 2005, Casimiro et al. 2006, Patz and Olson 2006)[5].

These authors, their deluge of publications, and the enormous media attention that they generate, have had a major impact on public perceptions of climate and malaria. Moreover, eight of them have had important input in the health chapters of the reports of the Intergovernmental Panel on Climate Change (IPCC), and one (Paul Epstein) is one of "a small group" of twelve persons that former US Vice-President Al Gore cites as having "played a particular role in advising me" in his highly successful books and Oscar winning film (Gore 2006). In 2007, Gore and the IPCC were jointly awarded the Nobel Peace Prize for their efforts.

Background

Many people are unaware that there are more than 3,500 species of mosquitoes, that they are found throughout the world in all climates, and that colossal numbers breed in snowmelt pools that overlie the permafrost in the Arctic tundra.

In nearly all species, the female obtains the protein she needs to develop her eggs by feeding on vertebrate blood. Some species are highly selective, restricting themselves to one, or at most a few closely related host species. Others have a less clearly defined diet, and may alternate between birds, mammals and even reptiles.

If the blood meal contains a pathogen, the mosquito herself must become infected before she transmits to the next host. More specifically, the pathogen must infect her salivary glands, because transmission occurs by injection of salivary secretions during a subsequent blood meal. The period from ingestion to infection of the salivary glands is termed the extrinsic incubation period, and is shorter at higher temperatures (Gilles and Warrell 1993).

There is a widespread misconception that mosquito-borne diseases require tropical temperatures, or at least the temperatures of the warmer regions of temperate regions. A glance at a map of global isotherms reveals that summer temperatures in many temperate regions are at least as high as in the warmest seasons of many regions in the tropics. The crucial difference is that the tropics do not have cold winters. Moreover, if tropical mosquito-borne pathogens are introduced to temperate regions in the right season, they can be transmitted if suitable vectors are present (Reiter 2001).

There is also a misconception that mosquitoes die in winter, and that more die in colder winters, but it is obvious that mosquitoes native to temperate regions have evolved strategies to survive low temperatures. In the tropics, comparable adaptations are necessary for surviving unfavorable dry periods, which may last for several years. In both cases, such adaptations merely impose a seasonality on transmission. In southern Europe, for example, *Plasmodium falciparum* (the most dangerous species of malarial pathogen) was transmitted from July to September (Bruce-Chwatt and de Zulueta 1980). In Mali, where the disease is still endemic, it is limited to the same three months by the dry season (Craig et al. 1999).

The physical environment is an important modifier of local climate. *Anopheles arabiensis*, an important vector of malaria in Africa[6], can survive in the Sudan when outdoor temperatures are above 55°C by hiding in the thatch of buildings in the daytime, feeding after mid-night, and laying eggs at dawn or dusk (Omer and Cloudsley-Thompson 1970). In Lapland, *Anopheles maculipennis* can survive the winter in houses and stables, feeding occasionally, and even (in the past) transmitting malaria when outdoor temperatures were below – 40°C (Hulden et al. 2005).

Culex pipiens, a vector of West Nile virus in the northern hemisphere, is common as far north as Nova Scotia and Finland. It overwinters in the adult stage; I have collected live specimens in Tennessee that were sheltering at – 20°C. *Aedes aegypti*, the principal urban vector of dengue and yellow fever, is a tropical species for which temperatures below 0°C are fatal, but its range extends in 11 states from Texas to South Carolina, surviving the sub-zero winter temperatures in niches protected from the cold (Carpenter and LaCasse 1955). Thus, meteorological variables alone are of limited value as a guide to the development times, behavior and geographic range of vector species, and the same is true for the pathogens they transmit.

Malaria in temperate climates

> *"Everything about malaria is so moulded and altered by local conditions that it becomes a thousand different diseases and epidemiological puzzles. Like chess, it is played with a few pieces, but is capable of an infinite variety of situations"*
>
> *Malaria in Europe, An Ecological Study* (Hackett 1937)

Malaria is the most important of all mosquito-borne diseases. Each year, 350–500 million cases of malaria occur worldwide, and over a million people die, most of them young children in sub-Saharan Africa (WHO 2003). This appalling toll is mainly restricted to the tropics, but less than forty years have passed since the final eradication of the disease from Europe. It is instructive to review the history of the disease in Europe in the context of the continuous natural variation of climate, both in temperate and tropical climates.

More than sixty species of *Anopheles* mosquitoes are capable of transmitting human malaria. Those that exist in Europe probably began colonizing the region as the icecaps retreated, at the end of the Pleistocene (approximately 11,550 years before present). Human populations, also moving northward, almost certainly brought malaria parasites along with them. The introduction of agriculture around 7,000 BC led to larger populations of relatively settled people, and increasingly favorable conditions for malaria transmission. Extensive deforestation may have also contributed to prevalence, by creating additional habitat for anopheline mosquitoes. Similar ecological changes in modern times have caused major increases in the prevalence of the disease in the tropics.

Malaria was common in ancient Greece and imperial Rome. Hippocrates (460–377 BC) gave detailed descriptions of the course of infections and their association with wetlands. He even noted that splenomegaly (enlarged spleen, often a symptom of chronic malaria infection) was particularly prevalent in people living in marshy areas. The Pontine Marshes, close to Rome, were notorious as a source of infection, and it is clear from descriptions of the symptoms and treatment of 'intermittent fevers' that three species of parasite – *P. falciparum, P. ovale* and *P. vivax* – were common (Bruce-Chwatt and de Zulueta 1980).

After the fall of the Roman Empire, the armies of Visigoths, Vandals, Ostrogoths and other 'barbarians' that swept the continent had to contend with malaria, often as a major setback to their campaigns. Several popes and churchmen, including St Augustine, the first Archbishop of Canterbury, died of malaria during their journeys to Rome.

During the "Medieval Warm Period", which reached its peak around the year 1200 AD, 'agues', 'intermittent fevers' 'tertians', 'quartans' were described from caliphate Spain to Christian Russia. In the first decades of the 15th Century, a rapid cooling trend caused many years of famine and a large-scale abandonment of farms, but malaria persisted, even in northern regions.

The first half of the 16th Century was warm again, but the period from the 1550s to the early 18th Century – dubbed the Little Ice Age – was probably the coldest of any time since the end of the last major ice age. Despite this spectacular cooling, malaria persisted throughout Europe (Reiter 2000). Data from burial records around the Thames estuary reveal mortality in "marsh parishes" comparable to that in areas of transmission in sub-Saharan Africa today (Dobson 1989, 1997).

Temperatures were probably at their lowest from 1670 to 1700, yet during that period Robert Talbor (*c.*1642–1681) became an exceedingly wealthy man by selling an effective prescription for curing malaria to the European aristocracy. His concoction was based on cinchona bark, and he had developed it by experimenting on malarious patients in the marshlands of Essex.

In the 18th and 19th Centuries, malaria was common in most of England and in many parts of Scotland. It was endemic throughout Denmark, coastal areas of southern Norway, and much of southern Sweden and Finland. In Russia it was common in the Baltic provinces and eastward at similar latitudes throughout Siberia. The northern limit of transmission was roughly defined by the present 15°C July isotherm (not the 15°C *winter* isotherm cited by the Intergovernmental Panel on Climate Change)(IPCC 1996).

Spontaneous decline

In the second half of the 19th Century, malaria began to decline in much of northern Europe. Denmark suffered devastating epidemics until the 1860s, particularly in the countryside around Copenhagen, but thereafter transmission diminished and essentially had disappeared around the turn of the 20th Century. The picture was similar in Sweden, although isolated cases were still being reported until 1939 (Renkonen 1944). In England, there was a gradual decrease in transmission until the 1880s, after which it dropped precipitously and became relatively rare except in a short period following World War I. In Germany, transmission also diminished rapidly; after World War I it was mainly confined to a few marshy localities (Bruce-Chwatt and de Zulueta 1980).

The decline of malaria in all these countries cannot be attributed to climate change, for it occurred during a warming phase, when temperatures were already much higher than in the Little Ice Age. Nor can it be attributed to deliberate mosquito control, for it came before recognition of the role played by the vector. A number of other factors, however, can be identified, all attributable to the ecology and behavior of both the vectors and its hosts:

Ecology of the landscape
Improved drainage, reclamation of swampy land for cultivation and the adoption of new farming methods (there is an old Italian saying: "malaria flees before the plough") all served to eliminate mosquito habitat.

New farm crops
New root crops, such as turnips and mangel-wurzels were adopted as winter fodder. These enabled farmers to maintain larger numbers of animals throughout the year, thus diverting mosquitoes from feeding on humans.

New rearing practices
Selective breeding of cattle, and new introductions (e.g. the Chinese domestic pig), in combination with the new fodder crops, enabled farmers to keep large populations of stock in farm buildings rather than in open fields and woodland. These buildings provided attractive sites for adult mosquitoes to rest and feed, diverting them from human habitation.

Mechanization
Rural populations declined as manual labor was replaced by machinery. This further reduced the availability of humans versus animals as hosts for the mosquitoes, and of humans as hosts for the parasite.

Human living conditions
New building materials and improvements in construction methods made houses more mosquito-proof, especially in winter, another factor that reduced contact with the vector.

Medical care
Greater access to medical care, and wider use of quinine (in part due to a major reduction in price) reduced the survival rate of the malaria parasite in its human host.

Control campaigns
In countries where profound changes in crop production and stock rearing were absent, malaria did not decline "spontaneously" (Bruce-Chwatt and de Zulueta 1980). In Russia, for example, from the Black Sea to Siberia, major epidemics occurred throughout the 19th Century, and the disease remained one of the principal public health problems for the entire first half of the 20th Century.

In the 1920s, in the wake of massive social and economic disruption, a pandemic swept through the entire Soviet Union. Official figures for 1923–25 listed 16.5 million cases, of which no less than 600,000 were fatal (Bruce-Chwatt and de Zulueta 1980). Tens of thousands of infections, many caused by *P. falciparum*, occurred as far north as the Arctic seaport of Archangel (61° 30′N). A huge, multi-faceted anti-malaria campaign was initiated in 1951. It involved widespread use of DDT and other residual insecticides, antimalarial therapy, land reclamation, water management, public health education and other approaches. This mammoth effort finally brought about a dramatic reduction of transmission; by the mid-1950s the national annual incidence was below one per 10,000.

The contrast between the devastation caused by malaria in the Soviet Union until the 1950s, and its quiet withdrawal from other European countries in the previous century, is a vivid illustration of the importance of non-climatic factors in transmission. Until the collectivization of farmland that began in the winter of 1929–30, the Soviet Union had been largely unaffected by the agricultural revolution. By 1936, all farming was essentially in government hands, but in protest, many peasants slaughtered their horses and livestock, and destroyed their equipment. These events ran counter to many of the changes that had reduced transmission in much of Europe (Reiter 2001).

Malaria remained highly prevalent in much of Mediterranean Europe, the Balkans, and the countries bordering the Black Sea until after World War II. Much of the region had been relatively unaffected by the environmental changes associated with modern agriculture. Part of this lack of change can be attributed to the disease itself, for poverty and lack of progress characterized many of the highly malarious regions. In northern Italy, for example, much of Piedmont and Lombardy was free of transmission. By contrast, large portions of the rest of the country, particularly in Sardinia, Calabria and Sicily, remained virtually uncultivated until the 1950s, at least in part because of the ravages of the disease. The same was true for major regions in Spain, Greece, Romania and Bulgaria.

The advent of DDT revolutionized malaria control. Cheap, safe, effective applications of the chemical could be targeted at the site where most infections occur – in the home. Initial efforts in Italy, Cyprus and Greece were so successful that a decision was made to eradicate the disease from all of Europe. The entire continent was finally declared free of endemic malaria in 1975. One of the last countries affected was Holland.

The history of the decline of malaria in North America is similar to that of Europe. In the 1880s, the disease was widespread in nearly all states east of the Rocky Mountains, from the semitropical Gulf Coast states to the northern border and into Canada (Fisk 1931, Faust 1941). It was also present west of the Rocky Mountains, particularly in areas where rainfall is abundant. As living conditions improved, and antimalarial drugs became more widely available, the incidence of the disease declined (Moulton 1941). In 1946 the United States Congress established a new agency, the Communicable Disease Center. This was the forerunner of the U.S. Centers for Disease Control and Prevention (CDC), and its principal mission was to eradicate malaria from the entire country. Its headquarters were in Atlanta, Georgia, because the southern states were the main region still affected by the disease. The disease was finally eradicated in the late 1950's. Today, as in Europe, there are many parts of the country where anopheline vectors are abundant, but the transmission cycles have been disrupted and the pathogens are absent.

Malaria in the tropics

Increases in the incidence of malaria in the tropics are frequently attributed to climate change but this claim ignores fundamental concepts in the dynamics of transmission. Among these, the concept of *stability* is critical.

In much of equatorial Africa, parts of northern India, Indonesia, South America and elsewhere, transmission is termed *stable* because it is fairly constant from year to year. The disease is endemic, but epidemics are uncommon. In other regions, including much of India, Southeast Asia, Central and South America, the disease is also endemic but is termed *unstable* because transmission can vary greatly from year to year, and the potential for epidemics is high.

These terms are, of course, a simplification; there is a wide range of degrees of stability, depending on complex factors in local circumstances. The examples below refer to sub-Saharan Africa, because it is the focus of much of the scientific and public debate, but the principles involved apply to many other parts of the world.

Stable endemic malaria

In regions where the anophelines are anthropophilic (prefer to feed on humans) and have a high survival rate (see page 35), transmission is usually stable. The disease is hard to control because transmission is efficient and transmission rates are so high that most people experience many infective bites per year. Severe illness and mortality occurs mainly among "new arrivals," i.e. children and non-immune immigrants. Older inhabitants have survived multiple infections and

Figure 5
Current suitability of local climatic conditions for stable transmission of malaria in sub-Saharan Africa, i.e. regions where significant transmission occurs every year

Epidemic transmission is limited to narrow bands to the north and south of the shaded area.

Adapted from a map based on available long-term climate data published by the MARA/ARMA[7] project, http://www.mara.org.za/mapsinfo.htm/

maintain a degree of immunity by repeated re-infection. They can have bouts of illness that may be life-threatening, but are usually relatively mild.

Unstable endemic malaria
This generally occurs in regions where the anophelines are zoophilic (bite animals as well as humans), or their survival rates are low, or where both apply. Transmission can vary greatly from year to year, with epidemics separated by many years of relatively low activity.

Behavioral and ecological factors that affect transmission

As in temperate regions, the behavior and ecology of vector and host are the dominant factors in transmission, and as with enteric diseases, many can be attributed to explosive population growth and poverty.

Birth rate
The world's population has grown from 2.5 billion in 1950 to 6.2 billion in 2007. In sub-Saharan Africa, there are now nearly five times as many people (ca. 750 million) as there were in 1955. In some countries, more than half the population is under 15 years of age. A high

birth rate invokes a high incidence among "new arrivals", and thus of new infections. Clinical studies in some parts of Africa quote 998 infections per 1000 infants (Snow et al. 1999).

Forest clearance
Many malaria vectors breed in open sunlit pools. Forest clearance provides abundant new habitat for these species, a classic cause of the emergence of malaria problems (Walsh et al. 1993).

Agriculture
Irrigation creates an ideal habitat for mass-production of mosquitoes, as can construction of dams for hydroelectric power. Rice cultivation provides an environment for many of the most efficient malaria vectors. Conversely, the cultivation of ground depressions can suppress such vectors and thereby reduce transmission (Mouchet et al.).

Movement of people
Infected people in pursuit of work can introduce malaria to areas where it is rare. Non-immune people are at high risk if they move to areas of transmission. Extensive road building and modern transportation have greatly exacerbated this factor.

Urbanization
Water storage and inadequate water disposal can provide habitat for mosquitoes, particularly in rapidly expanding urban areas. The absence of cattle can promote stable transmission by forcing zoophilic species to feed on people. Moreover, many tropical cities are surrounded by densely populated satellite settlements that are essentially rural in nature.

Insecticide resistance
Physiological resistance to insecticides is common in many regions. *Behavioral resistance* can also be a major problem: species that prefer to feed and rest indoors (*endophilic*) can switch to outdoor (*exophilic*) activity in response to treatment of indoor surfaces with insecticides.

Drug resistance
In many parts of the world, the malaria parasite has evolved resistance to commonly used anti-malarial drugs. Substitutes are available, but are much more expensive.

Degradation of the health infrastructure
Lack of funding, institutional difficulties, rapid urbanization and other problems associated with rapid development have eroded the public health sector of many countries. In addition, the AIDS pandemic has overwhelmed the ability of authorities to deal with other diseases.

War and civil strife
In times of conflict, mass movements of people, e.g. soldiers and refugees, often promote malaria transmission. The breakdown of public health services, damage to water distribution and drainage systems, and the destruction of homes often exacerbate the situation. High concentrations of people in camps for displaced persons can also be disastrous.

Climatic factors that affect transmission

The distribution of climates suitable for endemic malaria transmission in sub-Saharan Africa is shown in Figure 5. It is clear that the vast majority of people in Africa live in regions of stable endemic transmission. In other words, throughout their lives, people living in the grey areas of the map are regularly exposed to multiple bites from infective mosquitoes; studies in some regions have shown that people experience up to 300 infective bites per year. Under such circumstances, just as it is impossible to pour more water into a glass that is already full, it is illogical to suggest that increased temperatures will result in an increased incidence of infections.

In regions of unstable, epidemic transmission, incidence may be affected by variations in climatic factors, but the relationships are often complex and counterintuitive, and in many cases the factors that precipitate transmission are unclear.

Temperature
High temperatures should increase the likelihood of transmission because they reduce the extrinsic incubation period, but the frequency of biting, egg

laying and other behaviors are also likely to accelerate. These are high-risk activities, so survival – and thus transmission rate – may also be affected (see page 35).

Humidity

Survival may be reduced when hot weather is accompanied by low humidity, but in areas where such conditions are normal, local species are adapted to cope with them. For example, in the severe drought and extreme heat of the dry season in semi-arid parts of the Sudan, female *Anopheles arabiensis* survive for up to eleven months of the year by resting in dwelling huts, wells and other sheltered places (Omer and Cloudsley-Thompson 1970). Blood feeding continues, so transmission is not interrupted, but eggs do not develop until the rains return. This *gonotrophic dissociation* is remarkably similar to the winter survival of *An. atroparvus* in Holland and other parts of Europe in the past (Bruce-Chwatt and de Zulueta 1980). In both cases, inactivity leads to a high survival rate and continued transmission of malaria, even under adverse climatic conditions.

Rainfall

Rainfall can promote transmission by creating ground pools and other breeding sites, but heavy rains can have a flushing effect, cleansing such sites of their mosquitoes. Drought may eliminate standing water, but cause flowing water to stagnate. Thus, in arid areas, prolonged drought may cause malaria to decline, whereas in areas where rainfall is normally abundant, vast numbers of mosquitoes can be produced and "drought malaria" may follow. The same applies to artificial streams in irrigated regions and storm drains and sewers in urban areas. Drought may also stimulate people to store water in cisterns, drums and other man-made containers that serve as breeding sites.

The complexity of the influence of climate on malaria transmission in the tropics is well illustrated by the history of epidemics in Sri Lanka (Macdonald 1973). In the 1930s, the disease was common. In a "normal" year, 1.5 million cases – about a quarter of the total population – were treated in hospitals and dispensaries. However, in the years 1934–35 there was a catastrophic epidemic that is estimated to have killed 100,000 people. The country's southwestern quadrant, a region with an average annual rainfall of more than 250 cm, was worst hit.

The dominant vector in that part of the country is *An. culicifacies*, a species that breeds along the banks of rivers. In normal years, it was not abundant. Malaria was endemic, but the stability index was low; in most years the disease was relatively unimportant.

The monsoons in the preceding five years had been exceptionally favorable, with abundant heavy rainfall leading to excellent rice crops. Under such conditions, river-flow was high, *An. culicifacies* was rare, and the population was exceptionally healthy. However, when two successive monsoons failed, the rice crops were lost and there was widespread hunger. Colossal numbers of *An. culicifacies* were produced in the drying rivers and irrigation ditches.

The epidemic that followed was exacerbated by the weakened condition of the people. In addition, the immunity of the population was especially low because the previous five years had been wet and therefore relatively free of malaria. By contrast, in the drier parts of the island, where *An. culicifacies* was dominant but the stability index was higher, immunity protected the population from the worst ravages of the epidemic.

Malaria was almost eradicated from all of Sri Lanka in the 1960s, but in recent years, lack of effective control has allowed the disease to return as a public health problem.

Highland malaria

A topic that is repeatedly cited in the climate change debate, both in the scientific and the popular press, is that warmer temperatures will drive malaria transmission to higher altitudes in the Highlands of Africa, particularly East Africa. Indeed, environmental alarmists often state that this is already happening (Epstein 2000, Gore 2006).

It is certainly true that, just as in lowland regions, the incidence of malaria has increased in highland areas, and it is perfectly acceptable to cite temperature as a limiting factor at high altitude. Vectors such as *An. gambiae* are commonly found as high as 3,000 m above sea level, but endemic malaria disappears above

1,800–2,000 m. What is rarely mentioned is that less than two percent of the African continent (including North Africa) is above 2,000 m, and that much of this is so arid that it offers little opportunity for cultivation. Moreover, the history of malaria in highland areas is a compelling example of the dominant role of human behavior and human ecology, not climate, as the driving factors in the dynamics of transmission.

Kenya Highlands

The city of Nairobi, capital of Kenya, was founded in 1899 during the construction of a railway from Mombassa, on the coast, to Lake Victoria. The site was chosen because it was on the last stretch of level ground before the steep descent into the Rift Valley. It was a swampy area, and had always been known as an unhealthy locality "swarming with mosquitoes" (Miller 1971).

Indeed, in 1904, when the town had already grown substantially, a committee of doctors petitioned the Colonial government that the entire municipality be relocated because it was a spawning ground for disease. At 1,680 m, it marked the upper limits of malaria transmission at that time, but the disease began to appear at higher altitudes after the clearance of forests for the development of tea estates and the importation of infected laborers (Garnham 1948). The first sizeable epidemic, shortly after World War I, was attributed to the return of local soldiers from Tanzania. A major epidemic in 1926 led to recognition that economic development was a key factor in the proliferation of mosquito breeding sites, and hence the source of the increasingly serious problem:

> *That there have been no notable general alterations in the domestic environment of the natives of these reserves during recent years is true, but on the other hand it is to be remembered that in every direction roads, and to a lesser extent, railways, have been carried into and through these areas, and always where there are roads, artificial and undrained excavations are to be found* (Gilks 1926) quoted by (Snow et al. 1999)

The following year, the Municipal Corporation of Nairobi agreed to match a grant of £20,000 (the equivalent of nearly £400,000 in 2007)[8] from the Colonial government for eradication of anopheline breeding sites in the Nairobi area. Nevertheless, there were six major epidemics in the city between the two World Wars, with serious rates of transmission extending to the Londiani district (2,250–2,490 m) and even at a farm near Mount Timboroa, at 2,490–2,550 m (Garnham 1945).

The fundamental cause of the upward advance of malaria was widespread deforestation and development, as the areas were opened up for large farming ventures. As already discussed, the construction of roads and railways generated innumerable flooded "borrow pits" (depressions left by excavation for materials) and also contributed to the dispersal of the mosquito. The introduction of the ox wagon caused a proliferation of rough cart roads; water in the wheel ruts provided a prolific breeding site for vectors. Milldams on rivers interfered with natural drainage (Garnham 1945).

These and many other factors were components of a drastic ecological change, and it was this change that brought transmission to the Highlands. The disease continued to be a serious public health problem until the 1950s, when the colonial government organized an extensive control program, mainly based on DDT, after which the area was essentially malaria free until the 1970s.

The tea-growing estates (1,780–2,225 m) in the Kericho district have an extensive medical service for employees and their dependents that was initiated in 1925. Health care at the central hospital of Brookebond Kenya Ltd. is extended to some 100,000 inhabitants of the region. However, there is no attempt at mosquito control, and malaria has re-emerged as a serious problem. Epidemics occurred almost every year from 1990 to 1997, with a mean annual attack rate of around 50 percent (Malakooti et al. 1998). Peak transmission was from May to July, after the principal rainy season and before mean monthly temperatures drop below 18 °C. A questionnaire survey (June 1997) indicated that only 8 percent of patients had traveled to areas with known malaria transmission in the previous 30 days.

The main factor in this recrudescence may be increased resistance to antimalarial drugs, as well as the unsupervised use of ineffective medications, but the picture is not entirely clear (Shanks et al. 2000). Whatever the cause, the history of multiple epidemics in the earlier part of the century, including many at higher altitudes, makes it un-necessary to infer climate change as a contributory factor. Moreover, a set of well-maintained meteorological records shows no significant change in temperature over recent decades (Hay et al. 2002). Indeed, in a detailed report to the World Health Organization, a group of malaria specialists based in Nairobi dismissed those who claim a global warming link as "scientific Nostradamus's" (Snow et al. 1999).

New Guinea Highlands

In the early 1930s, a human population estimated at one million people and previously unknown to outsiders was contacted in the mountains of New Guinea. It appeared that these so-called "Stone Age people" were malaria-free, and this was attributed to their unique state of isolation. By contrast, the lowland coastal regions were highly malarious.

At first, the highlanders became a new source of labor for the coastal plantations, but after World War II, there was a rapid increase in the number of small landholders growing *Arabica* coffee and other crops in the mountains. In the late 1940s, government scientists warned that the increasing contact between the regions could bring disaster, for epidemic malaria had already appeared in several highland areas at around 1,500 m (Christian 1947–49). By the mid-1950s several alarming outbreaks lead to the enforcement of a law that required employers of highlanders working on the coast to supply them with antimalarials, and to ensure that the medications were actually taken. On repatriation, highlanders were held by the government in compulsory quarantine for two weeks and given curative malaria therapy (Spencer et al. 1956, Peters et al. 1958).

These regulations failed to stop the emergence of the disease and its spread to many isolated valleys. The increase in prevalence was clearly attributable to a rapid increase of anopheline populations after forest clearance, and to the construction of roads, airstrips, plantations, mines, water impoundments, and other human artifacts. Several vectors were involved, including *An. farauti* and *An. punctulatus* (Peters and Christian 1960). These species breed in open sunlit pools and are in many ways analogous to *An. gambiae* and *An. funestus* in sub-Saharan Africa.

Subsequent studies suggest that the parasite may have arrived in the highlands as early as the 1940s but did not become evident until forest clearance and development were more widespread. Whatever the chronology, the recent history of the disease is clearly attributable to the introduction of the parasite to non-immune populations and the proliferation of its vectors as a result of large-scale ecological change.

Transmission models based on vectorial capacity

Much of the speculation about the impacts of climate change on mosquito-borne disease utilizes models based on *vectorial capacity*, a rudimentary expression of transmission risk:

$$c = \frac{ma^2p^n}{-\log_e p}$$

m is the mosquito density per human, *a* is the average number of bites per day for each mosquito, *p* is the probability of a mosquito surviving through any one day, and *n* is the *extrinsic incubation period*, the time taken for the pathogen to develop in the mosquito until the insect becomes infective. The only factor directly affected by a climate variable is *n*, which is inversely related to temperature. Since *p* is less than unity, p^n will increase at higher temperatures, although *p* itself may increase or decrease as a result of other factors. The denominator is an exponential function, so *p*, survival rate, is by far the dominant parameter.

Caged mosquitoes can live for three to four months, but their median age in the field is a matter of weeks at most. Few die of senescence; most are killed by predators, disease, and other hazards. Feeding and the search for oviposition sites are probably the most hazardous activities. Exceptions are mosquitoes in the dormant phases mentioned above.

Vectorial capacity and similar elementary concepts were developed to describe the fundamental features of transmission, mainly in the context of control operations. With the exception of *n*, calculation of *C* is dependent on quantitative values that can only be obtained in the field. It is difficult to make realistic estimates of these values, however, because their measurement is heavily dependent on a thorny range of assumptions. Moreover, *C* is limited to entomological parameters and the duration of extrinsic incubation period; it does not incorporate the parasite-rate in humans or mosquitoes, nor any ecological or behavioral factors. Thus, while helpful in our understanding of the interaction between selected variables, such models have little value for assessing the likely impact of long-term climate change.

Summary

Simplistic reasoning on the future prevalence of malaria is close to irrelevant. Malaria is not limited by climate in most temperate regions[9], nor in the tropics. In nearly all cases, "new" malaria at high altitudes is well below the maximum altitudinal limits for transmission, and in sub-Saharan Africa the altitudes above the present limits are so small as to be insignificant. Moreover, there is no evidence that climate has played any role in the burgeoning tragedy of this disease at any altitude; as with enteric diseases, most of the other significant variables are attributable to defects in the social matrix. Future changes in climate may result in minor changes in prevalence and incidence, but obsessive emphasis on climate change as the dominant parameter is unwarranted. There is a desperate need for cheap, effective control campaigns, as were implemented during the DDT era. The development of new strategies, such as the release of transgenic mosquitoes carrying lethal genes, should be a priority.

Third level of complexity: mosquito-borne zoonoses

Nearly six hundred viruses (arboviruses) transmitted by arthropods – principally mosquitoes, sandflies, biting midges and ticks – have been described by scientists. Of these, about a hundred are known to produce clinical infection in humans, though infection is often asymptomatic. All are zoonoses; they circulate in nature without involving humans. In most cases, infections in humans are incidental, acquired by an arthropod that has been infected by feeding on a bird or mammal. Thus, unlike malaria, infection of humans involves a third level of complexity.

Yellow Fever, Dengue and Chikungunya

In their original habitat, these three viruses are transmitted between primates by forest-dwelling mosquitoes. They are among the few zoonoses that are regularly transmitted between humans. The majority are termed "dead end" because the level of virus in the blood during infection (viraemia) is insufficient to infect an arthropod and thus does not contribute to the chain of infection.

Humans are infected when they enter the forest to hunt, gather food (fruit, honey etc.), harvest timber, make charcoal, and other activities. In addition, in recent years, a number of unvaccinated tourists from developed countries have died of yellow fever after visiting the South American rainforest.

Unlike parasitic diseases such as malaria, viraemia for all three viruses – and indeed for most viral diseases – is short-lived, a matter of days. A viraemic person entering a village or town, however, can relay the virus to the community via mosquitoes living in the peridomestic environment. Chief among these is the Yellow Fever mosquito, *Aedes aegypti,* a highly effective vector of all three viruses because it feeds almost exclusively on humans.

A second species, the Asian Tiger mosquito, *Aedes albopictus*, has generally been regarded as less effective because it does not discriminate between hosts; blood meals taken from animals and birds that are not susceptible to the viruses do not contribute to the transmission cycle. Nevertheless, in recent years, the species has proved highly effective in urban transmission of chikungunya (Reiter et al. 2006), possibly because levels of this virus in the blood are very high, and because it has a high rate of infection and replication in the mosquito; all would contribute to a high vectorial capacity. Both species live in close contact with humans because they have adopted man-made containers such as water storage vessels, abandoned tyres, buckets and blocked gutters as a substitute for tree-holes and other natural containers in their original habitat.

Aedes aegypti, Ae. albopictus, and the three viruses share an important feature: all have been disseminated worldwide by human activities. *Aedes aegypti*, Yellow Fever and Dengue were introduced to the New World from Africa, transported in slave ships. Yellow Fever (and possibly dengue) is now enzootic in the forests of Latin America, and occasionally gives rise to urban transmission. In the past 30 years, *Ae. albopictus* has become widely established from Chicago to Buenos Aires in the Americas, in 12 countries in Europe, and at least three countries in Africa. Nearly all infestations are attributable to an international trade in used tyres (Reiter and Sprenger 1987, Reiter 1998). Dengue and Chikungunya viruses circulate freely around the world in aircraft, transported by infected passengers (Gubler 1997). The rate of this globalization of vectors and pathogens will continue to increase so long as the global economy continues to flourish.

Yellow Fever

In the 18th and 19th Centuries, devastating epidemics of Yellow Fever ("Yellow Jack", "Vomito Negro" etc.) occurred in many countries, as far north as Dublin and Cardiff in Europe and New York and Boston in the United States. One of the greatest epidemics on record globally began in 1878 in Memphis, Tennessee and quickly spread as far north as Illinois and Michigan. An estimated 19,500 people were infected in Memphis, and more than 100,000 in the country at large. The vector, *Ae. aegypti,* persists in eleven states from Texas to South Carolina, but, for reasons unknown, disappeared from Europe about 50 years ago (Reiter 2001).

A safe, cheap and effective vaccine is available against Yellow Fever, but, apart from Brazil, very few countries routinely vaccinate populations at risk. The global pandemics of dengue that affect nearly all the cities in the tropics are a clear warning that an introduction of Yellow Fever virus into an urban population could have catastrophic consequences. In such an event, world stocks of vaccine would be totally inadequate to halt transmission.

Dengue

There are four serotypes of dengue; infection with any serotype results in lifetime immunity, but not to the other serotypes, so, theoretically, a person can be infected four times. Like Yellow Fever, chikungunya and indeed many other viruses[1°], illness begins with a sudden onset of high fever and 'flu-like' symptoms. The disease is usually self-limiting – fever rarely lasts more than a week – but a small percent of cases require hospitalization, up to five percent of which can die of haemorrhage and other complications.

The first epidemic on record was in Philadelphia in 1780, and, as with yellow fever, numerous outbreaks followed in many temperate regions in Europe and the Americas. One of the largest epidemics on record occurred in 1927–28 in refugee camps in Greece, with an estimated 1,000,000 cases and 1,000 deaths. The global prevalence of the disease has grown dramatically in recent decades and it is now endemic in more than 100 countries throughout the tropics, with some 2.5 billion people – two-fifths of the world's population – at risk (Gubler 1997). The only effective approach to control is to eliminate the breeding sites of the mosquito. This has been applied effectively in the past, but in the teeming cities of today's tropics the task is next to impossible (Reiter and Gubler 1997).

Chikungunya

Symptoms of chikungunya are similar to those of dengue, but also involve arthritic complications that may last for many months. Pandemics of chikungunya have been known in Africa and Asia for many decades, but only garnered the world's attention in 2005 when the disease appeared on the island of La Reunion, a *departement* of France[11] in the Indian Ocean. Epidemic transmission was first reported on the East African coast, and introduction to other regions was by infected air passengers. The vector was *Ae. albopictus*, and more than 260,000 cases, a third of the population, was affected. The epidemic was highly publicized in Europe because the island is legally a part of France, and because neighboring Mauritius, a major tourist destination, was also affected. It ended in 2007, but remains rampant (as of November 2007) in India (an estimated 2,000,000 cases) and in South East Asia, though with relatively little publicity.

As already mentioned, modern transportation has enabled *Ae. albopictus* to extend its range worldwide. It is already established in Belgium and Holland, and there is no reason to suppose it will not move northwards in Europe, perhaps into Scandinavia. Nor is there reason to believe that outbreaks of chikungunya could not occur at these latitudes, for the conditions suitable for transmission are the same as those for malaria.

Indeed, a small outbreak occurred in the autumn of 2007 in northern Italy, in the delta region of the river Po. The area was once notoriously malarious, but the disease disappeared when the marshes were drained at the beginning of the 20th Century. The outbreak, which began in two small villages, was traced to a traveler from India. The *Ae. albopictus* infestation had been traced to used tyres imported from Atlanta, Georgia, and the infestation in the United States traced to shipments of used tyres from Japan.

Thus, human activities had altered the local ecology and eliminated malaria. They also provided a new environment (human settlement) suitable for the establishment of an exotic species of mosquito that had been carried across the Pacific Ocean and subsequently the Atlantic Ocean by modern transportation. This was followed by an exotic virus that arrived in a passenger who was infected on yet another continent and was transported by a new and effective vector, the jet aircraft.

The significance of this series of events was lost in a declaration by the World Health Organization that "although it is not possible to say whether the outbreak was caused by climate change…conditions in Italy are now suitable for the Tiger mosquito" and in a short article by one of the most prolific climate change activists (Epstein 2007).

West Nile encephalitis

West Nile virus is transmitted between birds by ornithophilic mosquitoes, many of which rarely bite mammals. It is an Old World virus with a huge range from southern Europe, to South Africa, the Indian subcontinent, Southeast Asia and even Australia. For the most part, the virus goes un-noticed though it is clear that incidence is high in many parts of the world. In temperate regions there is evidence that the virus survives winter in hibernating mosquitoes, but there is also repeated introduction from other continents by migrating birds. Humans are incidental to transmission – dead end hosts. Infections are usually asymptomatic or mildly febrile, but a small portion involve inflammation of the brain and can be fatal, particularly in older people. In Europe, transmission is usually signaled by clusters of cases of encephalitis in horses.

Human clinical cases are rare and sporadic; the number of human cases confirmed in the whole of Europe rarely exceeds five in any year. Two exceptions stand out: a major epidemic involving at least a thousand cases in Bucharest, Romania, in 1996, and a similar outbreak in Volgograd (formerly Stalingrad), Russia, in 1999. In both cases, leaking water, heating and sewage pipes in the basements of Soviet-style "functionalist" apartment buildings created perfect breeding site for *Cx. pipiens*, an effective vector that breeds in organically polluted water. Inadequate refuse disposal encouraged high populations of House Sparrows to complete the zoonotic cycle. The problem is widespread in ex-Soviet bloc countries, and will undoubtedly get worse in coming years (Marina Sokolowa, personal communication).

In 1999, the virus was identified in a sudden outbreak of encephalitis in the Queens district of New York. It was probably imported in infected live birds; protection from local mosquitoes is not required by quarantine regulations. Once established, the speed of transcontinental spread was spectacular and totally unexpected. By 2003 it had reached the Pacific seaboard, and had been detected in every state except Washington and Oregon.

The virus is now enzootic from Canada to Venezuela, including Mexico, Central America and the Caribbean Islands. Dispersal clearly takes place through birds, both migrant and resident. Some 25,000 human cases – about 1% of the total number of infections – and just over 1,000 deaths have been reported in the United States. Viraemia in New World birds is very high, and lethal to at least 250 species. For this reason, the introduction of the virus has had a catastrophic impact on wildlife, a phenomenon typical of the introduction of an exotic virus into a new environment.

Environmental alarmists have ascribed the conquest of the Americas by West Nile virus to unusually warm winters and other climatic phenomena, and have predicted future changes in range in many parts of the world (Epstein 2000, Parkinson and Butler 2005, Paz 2006). As with so many similar claims, there is no scientific basis for this. Temperatures can drop below –30°C in the provinces of Canada where transmission is now an annual event, and in Bucharest and Volgograd (formerly Stalingrad), where the major urban outbreaks occurred.

Another claim is that the epidemiology of West Nile virus in Europe will follow that of the New World in a future, warmer climate. There is zero evidence to support this either. Summer temperatures in many parts of Europe are far warmer than required for epizootic transmission and suitable species of mosquitoes are abundant, yet the virus is rare, or at least transmission is rarely evident.

Japanese encephalitis

This important human pathogen is taxonomically related to Yellow Fever, Dengue, and West Nile viruses. It was once the leading cause of viral encephalitis in a large part of Asia, from Japan to the Indian sub-continent to Borneo, Indonesia, the Philippines and New Guinea. A safe, effective vaccine is available, but there are still an estimated 50–100,000 cases per year, particularly in the poorer countries, 60% of which are fatal (Diagana et al. 2007, Schioler et al. 2007).

Like West Nile virus, the pathogen mainly infects birds and is transmitted by ornithophilic mosquitoes; humans and horses are dead end hosts. Domestic pigs, however, contribute a fourth level of complexity (the virus is included in this section because it is mosquito-borne). Infection is asymptomatic, but viraemia is high and sustained. Pigs are thus an important amplifying host because they live in close proximity to humans in many communities. Several species of mosquito are involved in transmission.

Factors that affect the herd immunity

The key component of zoonotic human infections is contact with the natural cycle of transmission. This can only occur through activities in their natural habitat. The urban vectors, *Ae. aegypti*, *Ae. albopictus* and *Cx. pipiens* have adopted the peridomestic environment because humans provide a suitable alternative to that habitat. In the case of the two *Aedes* species, humans are the perfect host: they offer safe shelter indoors, a freely available source of blood, and breeding sites in abundance, even in relatively affluent neighborhoods. *Cx. pipiens* is abundant in urban areas for the same reasons: it breeds prolifically in organically polluted water and human activities provide this in abundance, from faecally polluted ground water to sewage treatment plants.

Immunity is a critical feature of virus transmission, both in nature and in the urban environment. Immunity to malaria and other parasitic diseases is only partial. Parasites can circulate in the blood of infected persons, and can be re-introduced by infective bites. In contrast, immunity to viruses is generally life-long. Therefore, whereas a population can support chronic infection with malaria, the circulation of viruses is regulated by the "herd immunity", the common immunity of the inhabitants. As a result, transmission occurs in peaks, with intervening periods of little or no activity. In a sense, viral epidemics are like forest fires; they burn furiously until available fuel has been consumed, after which there is a recovery period in which fuel accumulates once more.

Sylvatic transmission of primate viruses follows this pattern; epizootic waves followed by periods of relatively low transmission. The inhabitants of the South American rain forest have learned that when the forest goes silent (i.e. when there is high mortality of the Howler monkeys), Yellow Fever is circulating. The same is true for people in North America; a high mortality in wild birds and animals indicates circulation of West Nile virus in the vicinity. In both cases, importation of an exotic virus has had a disastrous impact on indigenous species.

The "forest fire" phenomenon is particularly evident in isolated communities. For example, dengue is repeatedly introduced to islands in the Pacific Ocean and the Caribbean, and explosive epidemics generally occur when a particular serotype has been absent for some time. This activity may last two or sometimes three years, after which the virus circulates at low levels or becomes extinct. Yet again, the key factors for transmission are human behaviour and human ecology:

the size of the human population, the introduction of a new serotype, the herd immunity to the relevant serotype, the abundance of artificial containers that are the principal mosquito breeding sites, and contact with the vector (Reiter and Gubler 1997, Reiter et al. 2003).

In most of the tropics, the climate is suitable for transmission for at least part of the year, so transmission will occur if the virus is introduced. Yet there is definitely a marked seasonality of transmission of dengue in many parts of the world. The causes of this peak are not always evident, but immunity remains the dominant parameter, so even if the climate were to become more favorable for transmission, the effect would be to shorten the duration of epidemics without increasing the overall incidence of cases. In temperate regions, as already mentioned, epidemic transmission has occurred in the past, even in an era when temperatures were considerably lower. Warmer conditions might increase the duration of the transmission season, but the critical factors will remain human ecology and human behavior.

Fourth level of complexity: tick-borne encephalitis

Ticks are second only to mosquitoes in the human diseases that they transmit. Tick-borne encephalitis (sometimes called Central European encephalitis, Russian Spring-Summer encephalitis, Far Eastern Tick-borne encephalitis) is chosen as an example, because there has been a rapid increase in incidence in Europe in the past two decades, and climate change is frequently invoked as the causative factor. In truth, the factors that influence transmission are so complex that they present an outstanding example of how intuitive thinking from a starting point of changing climate can offer an explanation that is simple, persuasive, and wrong.

The life cycle of ticks is very different from that of mosquitoes. In mosquitoes, the pre-adult stages are aquatic, so only the adult feeds on blood and is thus a potential vector (although in some cases, the virus can be transmitted to the next generation via the egg stage). The vector of Tick-borne encephalitis – classed as a “Hard Tick” – goes through three stages after the egg hatches: larva, nymph and adult. Each stage takes a single blood meal. In temperate regions, the entire cycle can take three years.

Tick-borne encephalitis is a typical zoonosis. The virus is closely related to all the viruses mentioned above except Chikungunya, and is exclusively a disease of rodents; here again, humans and other animals are dead end hosts. More than 10,000 human cases are reported in Europe and Russia each year, mostly at higher latitudes. About one percent of cases are fatal, although mortality rates as high as 40 percent have been reported in outbreaks of a sub-type of the virus in Siberia and the Far East.

Adult female ticks lay as many as 100,000 eggs in their lifetime, an indication of the enormous mortality in the immature stages. Only the larvae and nymphs feed on rodents; the adults feed on other animals, including humans. As with most other viruses, viraemia in the rodent host only lasts a few days, so there is a limited window of opportunity for direct infection of the larvae. However, the virus can also pass from infected nymphs to larvae if both are feeding in close proximity on the same host. This feedback mechanism (called co-feeding) enables relatively few infected nymphs to infect the much more abundant larvae even on a non-viraemic host, an amplification system that is critical for continued transmission.

Larval ticks moult to nymphs up to a year after feeding. Survival between the three developmental stages depends on a habitat that provides suitable moisture conditions for the tick and suitable habitat for the host over the years of their development. Adult ticks “quest” for hosts by stationing themselves at elevated points on grasses or other ground vegetation and waiting for a passing animal. In woodland, their principal hosts are deer, though they will attach to other species, including humans. Questing behaviour and survival are also determined by moisture, as well, of course, as the chances of contact with a suitable host.

Ticks survive winter at soil level, where snow cover insulates them from extreme cold. Springtime activity begins when temperatures rise above a critical threshold, which is lower for nymphs (a mean daily temperature of about 7°C) than for larvae (about 10°C). These differences are critical, because earlier activation of nymphs can prevent synchrony with larvae. Rainfall is critical for adult survival; activity is suppressed during rainy periods, but mortality is high when humidity is low (Sumilo et al. 2006).

The incidence of tick-borne diseases has increased dramatically in Europe in the past two to three decades. The increase has been particularly high in the ex-Soviet Bloc countries, and has been widely attributed to a warming trend in the climate (Lindgren and Gustafson 2001, Danileová et al. 2003).

Careful study, however, has revealed that although climate may have contributed to the change in incidence, other factors are clearly involved (Sumilo et al. 2006). Activities of humans in tick habitat are particularly important.

In Latvia and Lithuania, for example, the collapse of agriculture and industry after the economic transition led to increased activity in woodland for a large portion of the population, particularly among female, older, poorer and rural people.

By contrast, in Estonia, where economic conditions improved rapidly after the change, visits to woodland were less frequent, and were associated with recreational walking and gathering berries and mushrooms. In this cohort, tick-bites were most frequent when rain-free summer weekends followed a week of heavy rainfall. There is evidence that the incidence of tick-borne infections is correlated to these variations in behavior (Randolph and Sumilo 2007).

Abundance of deer is another important factor. The rapid increase in the incidence of tick-borne infections has coincided with an enormous increase of deer populations in large areas of Europe and North America. Much of this is due to re-forestation in regions where agriculture has been abandoned, or where conservation efforts have reduced hunting activities. Reforestation has also provided ideal habitat for rodents, particularly mice of the genus *Apodemus*, which are the principal host of the virus. Populations of these small rodents undergo regular asynchronous cycles with those of their predators, although the amplitude of recurrent peaks is affected by masting (seed production) of trees such as oak and beech.

In summary, the list of putative parameters affecting transmission of tick-borne encephalitis to humans includes agricultural practices, land-cover, small mammals and their predators, small mammal immunology, large mammals, hunting, wild-life conservation, industrial activities, income levels, leisure activities, and of course, climate variables. These include the depth of winter snow, the micro timing of the onset of springtime temperatures, and summer rainfall and humidity. And, of course, the interaction of these variables is distributed over a three-year period.

Final comment

The ecology and natural history of disease transmission, particularly transmission by arthropods, involves the interplay of a multitude of interacting factors that defy simplistic analysis. The rapid increase in the incidence of many diseases worldwide is a major cause for concern, but the principal determinants are politics, economics, human ecology and human behaviour. A creative and organized application of resources to reverse this increase is urgently required, irrespective of any changes of climate.

Notes

1. Insects, ticks, spiders, crustaceans etc.
2. Strains of many pathogens show distinct differences in their infectivity towards a particular host. In this chapter, this degree of infectivity is defined as virulence.
3. In this context, host refers to any organism that is infected by the pathogen. In the case of arthropod-borne pathogens, the arthropod is generally referred to as the vector, and the organism that it infects as its host.
4. Climate is always varying, so climatologists define it as the mean of a set of climate variables over a specific period, usually not less than 30 years. Weather is the short-term variation of climate.
5. These articles all refer to malaria, and all propose that incidence and prevalence will increase as a direct result of climate change

6. In all parts of the world, malaria is transmitted by a group (genus) of mosquito species called *Anopheles*.
7. Funded at various stages by the International Development Research Centre of Canada (IDRC); South African Medical Research Council (SAMRC); Wellcome Trust, UK; Swiss Tropical Institute; UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR); Multilateral Initiative on Malaria (MIM) of the UNDP/World Bank/WHO Special Programme for Research & Training in Tropical Diseases (TDR).
8. Based on retail price index, http://www.measuringworth.com/ppoweruk/
9. Effective vector species are still present, sometimes common, in many of the regions that were previously malarious, and transmission can occur if the parasite is introduced by the arrival of infected people. Such local cases, however, are easily eliminated by treatment with antimalarial drugs. Unfortunately, these incidents are exploited by environmental alarmists as evidence of the impact of climate change.
10. Many non-viral diseases also start with these symptoms. The author has had typhus, malaria and dengue. In the first days of illness, he diagnosed his typhus infection as malaria, his malaria as dengue, and his dengue as malaria. Apart from other considerations, it is not a good idea to consult a medical entomologist to diagnose a fever.
11. Equivalent to a county in the USA and the UK.

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Indur M. Goklany

Death and Death Rates Due to Extreme Weather Events

Global and U.S. Trends, 1900–2006

Executive summary

Despite the recent spate of deadly extreme weather events – such as the 2003 European heat wave and the 2004 and 2005 hurricane seasons in the USA – aggregate mortality and mortality rates due to extreme weather events are generally lower today than they used to be.

Globally, mortality and mortality rates have declined by 95 percent or more since the 1920s. The largest improvements came from declines in mortality due to droughts and floods, which apparently were responsible for 93 percent of all deaths caused by extreme events during the 20th Century. For windstorms, which, at 6 percent, contributed most of the remaining fatalities, mortality rates are also lower today but there are no clear trends for mortality. Cumulatively, the declines more than compensated for increases due to the 2003 heat wave.

With regard to the U.S., current mortality and mortality rates due to extreme temperatures, tornados, lightning, floods and hurricanes are also below their peak levels of a few decades ago. The declines in annual mortality for the last four categories range from 62 to 81 percent, while mortality rates declined 75 to 95 percent.

If extreme weather has indeed become more extreme for whatever reason, global and U.S. declines in mortality and mortality rates are perhaps due to increases in societies' collective adaptive capacities. This enhanced adaptive capacity is associated with a variety of interrelated factors – greater wealth, increases in technological options, and greater access to and availability of human and social capital – although luck may have played a role. Because of these developments, nowadays extreme weather events contribute less than 0.06 percent to the global and U.S. mortality burdens in an average year, and seem to be declining in general. Equally important, mortality due to extreme weather events has declined despite an increase in all-cause mortality, suggesting that humanity is adapting better to extreme events than to other causes of mortality. In summary, there is no signal in the mortality data to indicate increases in the overall frequencies or severities of extreme weather events, despite large increases in the population at risk.

Introduction

Even prior to Hurricanes Katrina and Rita striking the U.S. coast, there was speculation in medical and scientific journals, the popular press and elsewhere that climate change would exacerbate extreme weather events through, among other things, intensification of the hydrological cycle, hurricanes and other storms, and, thereby, raise deaths and death rates globally as well as in the United States (see, e.g., IPCC 2001: Table SPM-1; Patz 2004; MacMichael and Woodruff 2004; Schiermeier 2003, 2005; Trenberth and Taylor, no date).[1]

This speculation has been fueled by recent, somewhat controversial, studies suggesting that hurricane intensities might be stronger because of climate change (e.g., Webster et al. 2005; Emmanuel 2005a, 2005b; Pielke, Jr., 2005; Landsea 2005). Moreover, the occurrence of recent weather related disasters – ranging from the Central European floods of 2002, the 2003 European heat wave, and the back-to-back disastrous Atlantic hurricane seasons of 2004 and 2005 – has only intensified suspicions. All of this was epitomized by a recent *Time* magazine cover story warning all to worry more about global warming (Kluger 2006; see also, for example, Anderson and Bausch 2006).

Some have claimed that, all else being equal, climate change will increase the frequency or severity of weather-related extreme events (see, e.g., IPCC 2001; Patz 2004; MacMichael and Woodruff 2004). This study examines whether losses due to such events (as measured by aggregate deaths and death rates[2]) have increased globally and for the United States in recent decades. It will also attempt to put these deaths and death rates into perspective by comparing them with the overall mortality burden, and briefly discuss what trends in these measures imply about human adaptive capacity.

Trends in deaths and death rates, while of intrinsic interest for public policy purposes, may also have a bearing on trends in economic losses. Goklany (2000) speculates that while a wealthier society may invest more in limiting loss of human lives, it may be less concerned about property losses, even though a wealthier society is also likely to have more property at risk. This suggestion finds some support in data which show that the ratio of death-to-property-loss for tornadoes in the U.S. has declined in recent decades (Doswell et al. 1999, Brooks and Doswell 2001).

Trends in mortality and mortality rates

Global trends, 1900–2006

In general, climate change could change the frequencies, intensities and/or durations of extreme weather events such as floods, droughts, windstorms and extreme temperatures – increasing them at some locations and for some periods, while decreasing them at other locations and other periods. Some of the effects of these changes will tend to offset each other and/or be redistributed over space and time.

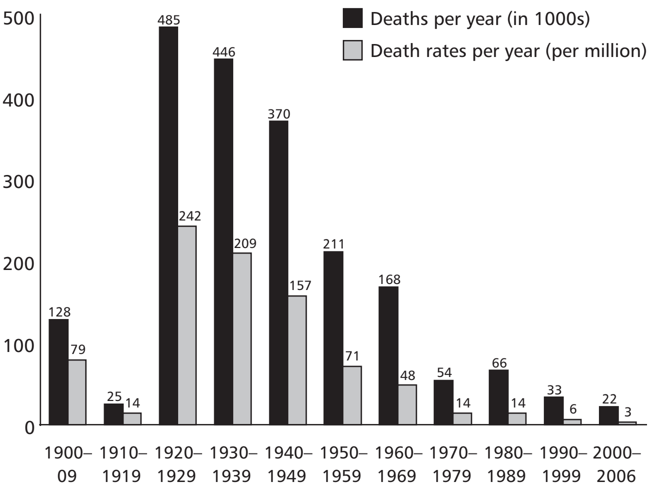
For instance, an increase in deaths due to heat waves at one location might be compensated for by a decline in deaths due to fewer or less intense cold waves at the same or another location. Alternatively, climate change might redistribute the temporal and spatial pattern of rainfall, droughts and other such events.

Accordingly, to estimate the net impact of climate change on mortality (if any), it is probably best to examine cumulative deaths at the global level aggregated over all types of extreme events. Because of the episodic nature of extreme events, such an examination should ideally be based on several decades', if not centuries', worth of data. Any such examination should, of course, be cognizant that adaptive capacity and exposure of human populations to risk also change over time.

In particular, one should examine mortality rates so as to filter out the effect of population growth on the population at risk. However, it may be argued that the use of mortality rates is inadequate to eliminate the effect of increases in populations at risk since, as the population becomes larger, people will migrate to riskier and more vulnerable locations as the less vulnerable locations are occupied. In addition, some state policies may inappropriately create a "moral hazard" situation in which individuals have incentives to bear less than their full burden of risk, effectively transferring portion of their risk to other segments of society; this may place even wealthier populations at greater physical risk (in addition to increasing financial risk; Goklany 2000).

Figure 6 displays data on aggregate global mortality and mortality rates between 1900 and 2006 for the following weather-related extreme events: droughts, extreme temperatures (both extreme heat and extreme cold),

Figure 6 **Global death and death rates due to extreme events, 1900–2006**



Note that in figures 6 through 9, data for the last period are averaged over seven years worth of data.
Sources; EM-DAT (2007); McEvedy and Jones (1978); WRI (2005, 2007)

Table 1 **Global deaths and death rates for various types of events, 1900–1989 and 1990–2006**

	Deaths per year		*Death Rates per year (per million people)*	
	1900–1989	*1990–2006*	*1900–1989*	*1990–2006*
Droughts	130,042	185	57.99	0.03
Floods	75,212	7,637	31.95	1.29
Windstorms	10,856	13,650	3.96	2.45
Slides	469	868	0.16	0.15
Waves/Surges	128	207	0.06	0.03
Extreme Temperatures	110	5,671	0.03	0.91
Wild Fires	21	47	0.01	0.01
TOTAL	216,839	28,266	94.16	4.87

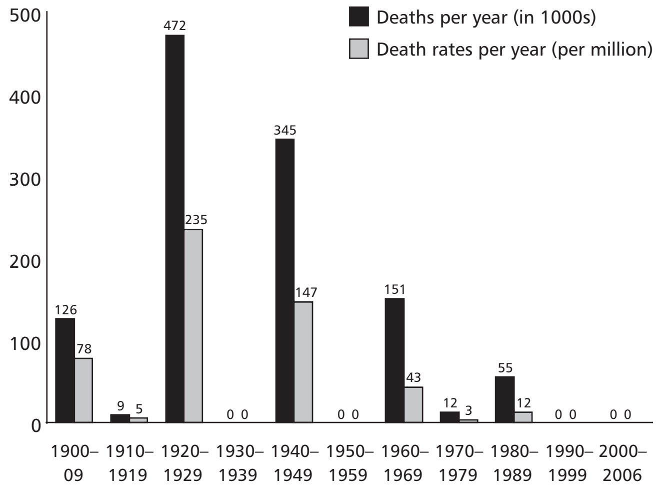
Sources: EM-DAT (2007); McEvedy and Jones (1978); WRI (2007)

floods, slides, waves and surges, wild fires and windstorms of different types (e.g., hurricanes, cyclones, tornados, typhoons, etc.).[3,4] It indicates that both death and death rates have declined at least since the 1920s. Specifically, comparing the 1920s to the 2000–2006 period, the annual number of deaths declined from 485,200 to 22,100 (a 95 percent decline), while the death rate per million dropped from 241.8 to 3.5 (a decline of 99 percent).

Table 1 provides a breakdown of the average annual global deaths and death rates for the various categories of extreme events for 1900–1989 and 1990–2006. The columns are arranged in order of declining mortality ascribed to the various events (highest to lowest) for the former period. This shows that:

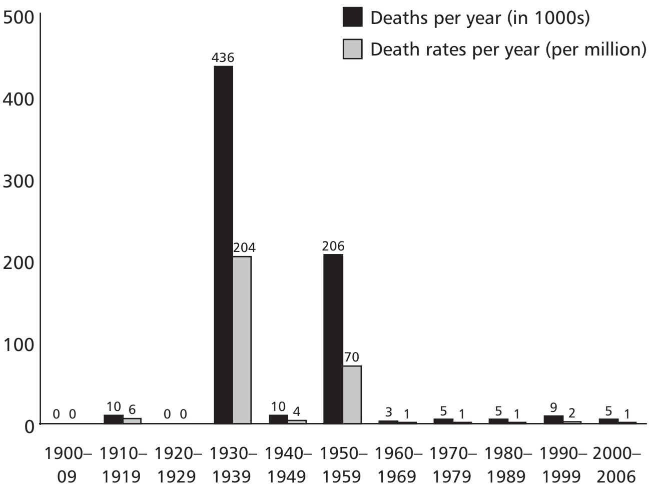
- During much of the 20th Century, the deadliest extreme events were droughts, followed by floods and windstorms. Over the 107-year record, droughts and floods were responsible for 59 and 35 percent of all fatalities worldwide due to all extreme weather events, while windstorms contributed an additional 6 percent. Thus, these three categories together accounted for over 99 percent of the fatalities due to extreme events.
- Aggregate annual mortality for the seven categories of extreme events declined by 87 percent between the 1900–1989 and 1990–2006 periods, while the annual mortality rate dropped by 95 percent.
- Declines in mortality between the two periods were mainly due to declines in annual fatalities owing to droughts and floods (see also Figures 7 and 8). The remarkable 99.9 percent drop in annual drought fatalities indicates that, for whatever reason,

Figure 7 **Droughts: global deaths & death rates, 1900–2006**



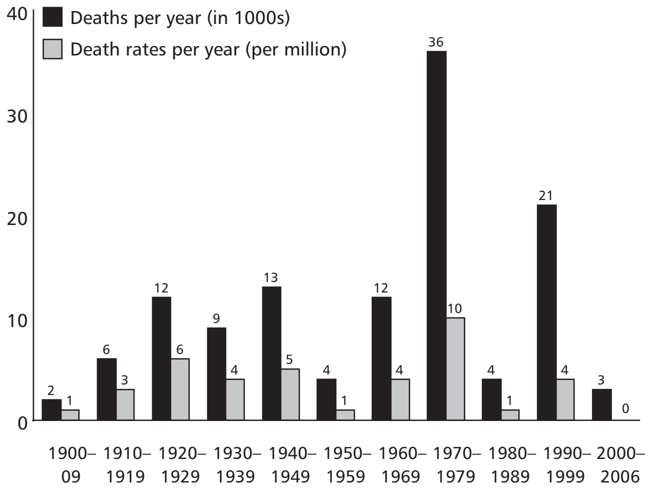
Sources: EM-DAT (2007); McEvedy and Jones (1978); WRI (2005, 2007)

Figure 8 **Floods: global deaths and death rates, 1900–2006**



Sources: EM-DAT (2007); McEvedy and Jones (1978); WRI (2005, 2007)

Figure 9 **Windstorms: global deaths and death rates, 1900–2006**



Sources: EM-DAT (2007); McEvedy and Jones (1978); WRI (2005, 2007)

available food supplies per capita have increased in marginal areas. This is possibly due to greater food production at the global level, and an enhanced ability to move food from food surplus areas to deficit areas through institutions such as international trade, and governmental and nongovernmental aid agencies and philanthropies (e.g., through the World Food Program or the International Red Cross). All of this is facilitated by better transportation and communication networks, and irrigation facilities (Goklany 1998).
The 89.8 percent decline in annual flood fatalities between the two periods possibly reflects better control, prevention and management of floods through construction of dams and other infrastructure, supplemented by better emergency response measures facilitated by improvements in transportation systems, flood forecasting, and management of water facilities, among other things.

- While average annual fatalities due to windstorms increased from around 11,000 to 14,000 per year between the two periods, the annual mortality rates declined by 38 percent (see also Figure 9).
- Annual mortality rates dropped for virtually every category except extreme temperatures and slides.

The spike in deaths and death rates owing to extreme temperatures during the 1990–2006 period occurred because of the 2003 European heat wave. However, these fatalities were more than compensated for by declines in flood and drought fatalities.[5]

The global mortality burden from extreme events

To place the current death toll due to all extreme weather events in a wider context, consider that the average annual death toll for 2000–2006 due to all weather-related extreme events according to EM-DAT (2007) was 19,900. By contrast, the World Health Organization (2004) estimates that in 2002, a total of 57.0 million people died worldwide from all causes, including 5.2 million from other kinds of accidents. Out of these, road traffic was responsible for 1.2 million deaths, violence (other than war) for 0.6 million, and war for 0.2 million (see Table 2). Thus, while extreme weather-related events garnish plenty of attention worldwide because of their episodic and telegenic nature, their contribution to the global mortality burden is relatively minor: 0.03 percent of global deaths. Their contribution to the global burden of disease should be similarly small.

Table 2 **Global deaths per year due to various causes, early 2000s. Note: All data are for 2002, except for deaths due to extreme weather events, which are based on the annual average from 2000–2006**

Cause of death	*No. of deaths*	*Percent of total deaths*
I. Communicable Diseases	**18,324,000**	**32.13%**
Tuberculosis	1,566,000	2.75%
HIV/AIDS	2,777,000	4.87%
Diarrhoeal diseases	1,798,000	3.15%
Malaria	1,272,000	2.23%
Other tropical diseases	129,000	0.23%
Other infectious & parasitic diseases	3,362000	5.90%
Subtotal – Infectious and parasitic diseases	10,904,000	19.12%
Respiratory infections	3,963,000	6.95%
Nutritional deficiencies	485,000	0.85%
Maternal and perinatal conditions	2,972,000	5.21%
II. Non-communicable Conditions	**33,537,000**	**58.81%**
Malignant neoplasms	7,121,000	12.49%
Cardiovascular diseases	16,733,000	29.34%
Respiratory diseases	3,702,000	6.49%
Other non-communicable conditions	5,981,000	10.49%
III. Injuries	**5,168,000**	**9.06%**
Road traffic accidents	1,192,000	2.09%
Violence	559,000	0.98%
War	172,000	0.30%
Extreme weather events	***19,868***	***0.03%***
All other injuries	3,225,600	5.66%

Sources: WHO (2004), EM-DAT (2007)

Notably, the contribution of extreme events to the mortality burden for accidental causes of death is also small (at 0.4 percent). Also, over the last fifty years at least, the general decline in annual mortality due to extreme weather events (see Figure 6) has occurred despite an increase in all-cause mortality (WRI 2005).

A review paper in *Nature* (Patz et al. 2005) estimates that climate change may have been responsible for over 150,000 deaths worldwide in 2000. This estimate is largely based on an analysis put out under the auspices of the World Health Organization (McMichael et al. 2004). The latter study arrived at its estimate by ascribing to climate change (a) 77,000 out of about 250,000 deaths due to protein malnutrition, (b) 47,000 out of about 2 million deaths due to diarrhoeal disease, and (c) 27,000 out of over 1 million deaths due to malaria (see WHO 2002). It also ascribed 2,000 deaths to floods in 2000, based on the EM-DAT database.

Although the review paper's estimates for non-flood-related deaths are problematic,[6] if one accepts them as valid, that means that climate change currently accounts for less than 0.3 percent of all global deaths. Accordingly, based on current contributions to the global mortality burden, other public health issues outrank climate change.

U.S. trends in mortality and mortality rates, 1900–2006

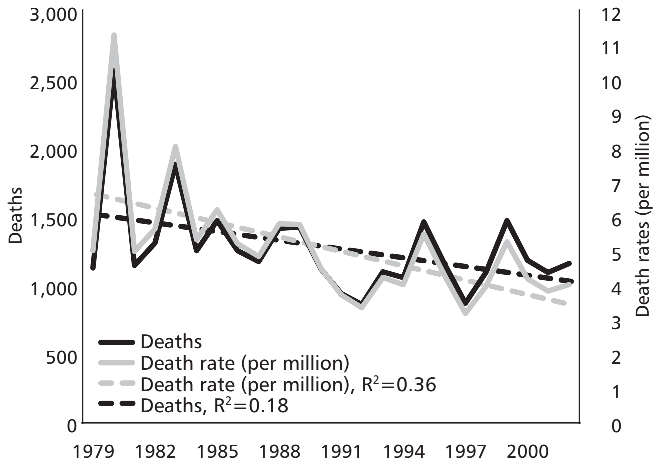
Among the problems in developing a long time series for U.S. deaths due to all (or most) extreme weather phenomena is that the length of the U.S. (data) record varies according to the type of event.

The *Annual Summaries* (e.g., NCDC 2004, 2007) published by National Oceanic and Atmospheric Administration's National Climatic Data Center (NCDC) provides time series data on fatalities due to hurricanes, floods, tornadoes and lightning, respectively, from 1900, 1903, 1916 and 1959 onward. Each year's summary also gives that year's death toll due to a variety of other weather-related phenomena such as extreme cold, extreme heat, drought, mudslides, winter storms, avalanches, etc., but it does not provide any time series data for these other categories of natural disasters.

Another problem is that the data for several phenomena from these summaries are at variance with other data sources. Specifically, there are discrepancies between mortality data from these *Annual Summaries* and (a) the Hydrologic Information Center's (HIC 2007) estimates for floods, (b) the National Hurricane Center's data for hurricanes (Blake et al. 2007), and (c) CDC's WONDER database for extreme cold and extreme heat.

Based on previous conversations with personnel from the various agencies (Goklany 2000), it was decided to use HIC data for floods (as adjusted per Goklany 2000), and Blake et al. (2007) for hurricanes through 2006. The Center for Disease Control's WONDER database was used for extreme heat and cold, because it is based on actual death certificate records, which, in turn, are based on medical opinion as opposed to the National Weather Service's expert opinion.[7]

Figure 10 **Cumulative U.S. deaths and death rates, 1979–2002, for hurricanes, floods, lightning, tornados, extreme heat and extreme cold**



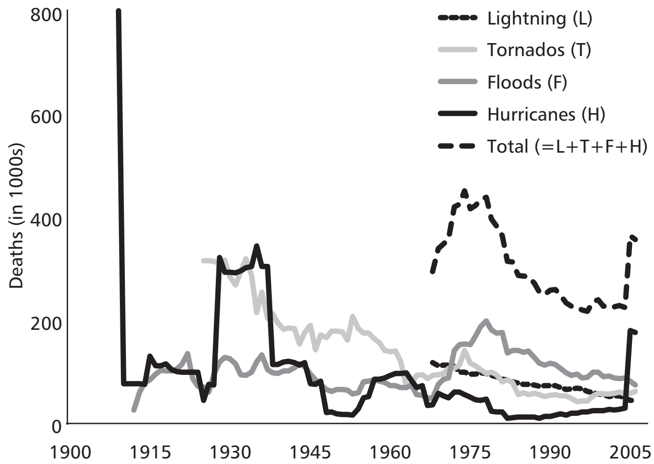
Linear trend lines were generated using EXCEL.
Sources: for hurricanes, Blake et al. (2007); for lightning and tornados, NCDC (2004, 2007) and Hinson (2005); for floods, HIC (2007); for extreme heat and cold, CDC (2005)

Figure 10 shows the trend in cumulative deaths and death rates for a subset of extreme weather events – specifically, hurricanes, floods, tornados, lightning, and extreme heat and cold – from 1979–2002.[8] It shows that despite any warming that may have occurred, both

Table 3 **US deaths due to weather-related events, 1979–2002. Sources: for extreme events, see text; for total all-cause mortality, USCB (2004).**

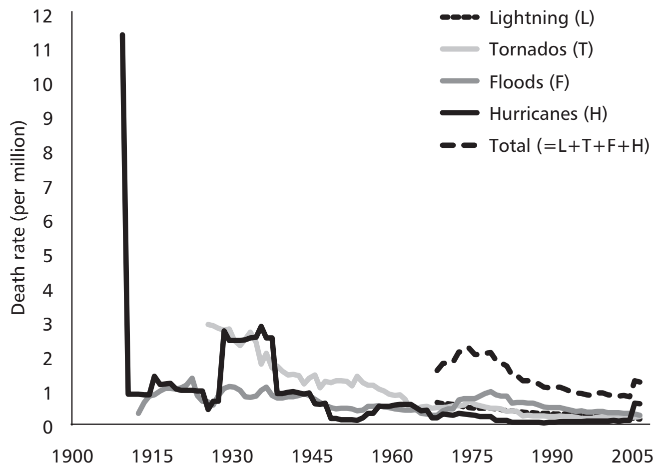
	Cumulative deaths	*Deaths per year*	*Percent of annual all-cause deaths*
Extreme cold (XC)	16,313	680	0.031%
Extreme heat (XH)	8,589	358	0.016%
Flood (F)	2,395	100	0.005%
Lightning (L)	1,512	63	0.003%
Tornado (T)	1,321	55	0.003%
Hurricane (Hu)	460	19	0.001%
Sum	**30,590**	**1,275**	**0.058%**
Total deaths, all causes, 1979–2002 average		2,189,000	100.000%

Figure 11 **U.S. Deaths due to hurricanes (1900–2006), floods (1903–2006), tornados (1916–2006), lightning, (1959–2006) and total (1959-2006)**
10-year moving averages



Sources: for hurricanes, Blake et al. (2007); for lightning and tornados, NCDC (2007) and NWS (2007); for floods, HIC (2007) and Goklany (2000)

Figure 12 **U.S. deaths rates due to hurricanes (1900–2006), floods (1903–2006), tornados (1916–2006), lightning, (1959–2006) and total (1959–2006)**
10-year moving averages



Sources: for hurricanes, Blake et al. (2007), for lightning and tornados, NCDC (2007) and NWS (2007); for floods, HIC (2007) and Goklany (2000); and for population, USCB (2007)

deaths and death rates have not increased over this period. If anything, they might have declined over this period, during which all-cause mortality increased by 28 percent (USCB 2004).

Notably, the bulk of the weather-related deaths (53 percent) during this period were caused by extreme cold. In rank of importance, these were followed by extreme heat, floods, lightning, tornados, and hurricanes, which contributed 28, 8, 5, 4 and 2 percent, respectively (see Table 3.)

Figures 11 and 12 show the 10-year moving averages for deaths (and death rates) due to hurricanes from 1900–2006, floods from 1903–2006, tornados from 1916–2006, and lightning from 1959–2006, as well as for cumulative deaths (and death rates) from these four individual categories of events (from 1959 to 2006). Death rates in Figure 7 are calculated using national population estimates from the US Census Bureau (USCB).[9]

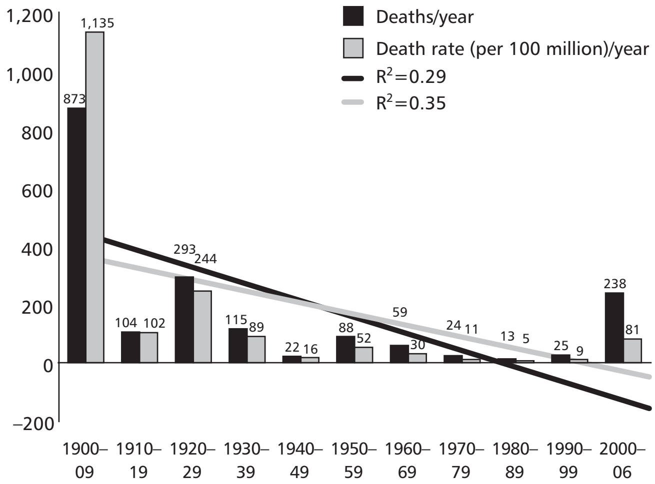
Figure 11 shows that for the most recent 10-year period for which data are available, average annual deaths declined below their earlier peaks in the 10-year moving averages by 62 percent for floods, 63 percent for lightning, 81 percent for tornados and – despite Hurricane Katrina – 80 percent for hurricanes. Such declines are consistent with results of earlier analyses (Goklany 2000).

Similarly, Figure 12 indicates that the corresponding declines for death rates (comparing their peaks with the most recent 10-year period) were 80 percent for floods, 75 percent for lightning, 95 percent for hurricanes and 92 percent for tornados.

Both figures show:

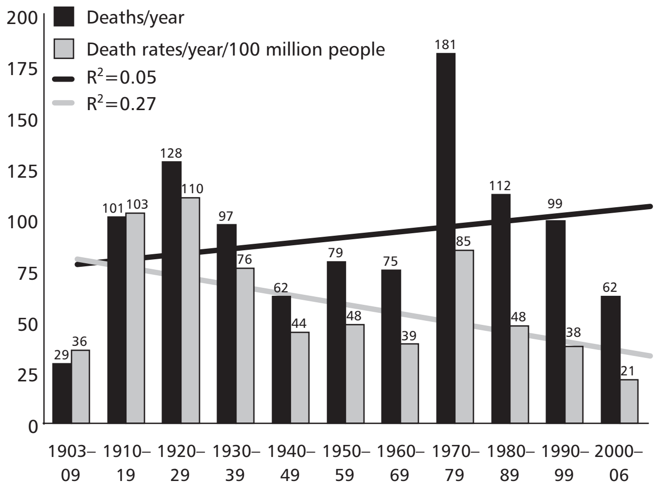
- A large spike for hurricanes at the very beginning of the record due to the Galveston Hurricane of 1900, and a smaller spike due to Hurricane Katrina at the very end. This is punctuated by a relatively high plateau in the late 1920s which extended into the late 1930s, and troughs extending from the late 1940s to the early 1950s and, again, in the 1980s and 1990s.[10] This is also illustrated in Figure 13.[11]
- Mortality and mortality rates dropped more or less steadily for lightning and tornados over the period for which records are available. These results are consistent with earlier analyses for both sets of

Figure 13 **Annual U.S. deaths and death rates due to hurricanes, 1900–2006**



Linear trend lines were generated using EXCEL.
Sources: Blake et al. (2007); USCB (2007)

Figure 14 **Annual U.S. deaths and death rates due to floods, 1903–2006**

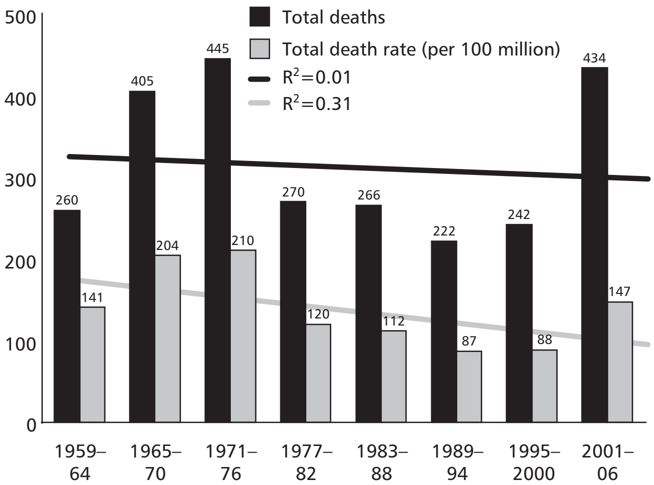


Linear trend lines were generated using EXCEL. The data for 1900–1909 are based on the seven-year average from 1903 through 1909 because the HIC's series starts in 1903.
Sources: HIC (2007); Goklany (2000); USCB (2007)

events by Goklany (2000), and Doswell et al. (1999) for tornados.

- Mortality from floods exhibits no particular trend from 1903 to 2006, although mortality rates might have declined somewhat (see also Figure 14). Once final figures are compiled, mortality due to floods in 2005 may be higher than in other recent years because of floods related to hurricanes that year.[12]
- Cumulative annual mortality and mortality rates for the above four categories of extreme weather events also indicate no specific trend from 1959–64 to 2001–06, although death rates may have declined (Figure 15; see also Figures 11 and 12).

Figure 15 **Cumulative annual U.S. deaths and death rates from hurricanes, floods, lightning, and tornados, 1959–2006**



Linear trend lines were generated using EXCEL.
Sources: For hurricanes, Blake et al. (2007); for lightning and tornados, NCDC (2004, 2007) and NWS (2007); for floods, HIC (2007); for population USCB (2007)

The previous figures (11 through 15) show that current deaths and death rates are, in general, lower than in the past. Predictably, death rates have declined more rapidly than deaths per year, confirming results from previous studies (Goklany 2000).

Discussion and conclusions

The information presented above indicates that globally as well as for the United States, the aggregate contribution of extreme weather events to the mortality burden is relatively minor at present, ranging from 0.03 to 0.06 percent.

Moreover, if the frequency, intensity and duration of extreme weather events has increased in recent decades

– all empirical issues best left to climatologists – there is no signal of that in the data on either mortality rates or (more importantly) mortality, despite an increase in populations at risk.

The data at the global level, while incomplete, indicate:

- Aggregate annual mortality and mortality rates owing to extreme weather events have declined between 95 and 99 percent, respectively, since the 1920s regardless of whether the frequencies, intensities and/or durations of extreme weather events have increased (or not) due to human-induced or natural climate change.
- Much of the above improvement is due to a substantial decline in mortality due to droughts and floods, which apparently caused 93 percent of the fatalities due to extreme events between 1900 and 2006.
- Death rates for the different categories of extreme events were generally lower in the 1990s and early- to mid-2000s than in previous decades – with the notable exception of death rates for extreme temperatures, which were higher because of the 2003 European heat wave.
- Regarding windstorms, both mortality and mortality rates peaked in the 1970s. The average annual mortality due to windstorms from 1990–2006 exceeded the average over 1900–1989 by 26 percent, but the mortality rate was 38 percent lower.

With respect to the United States:

- In an average year, more lives are lost to extreme temperatures – both extreme heat and extreme cold – than to more heavily publicized events such as tornados, hurricanes and floods. According to data from the Centers for Disease Control, on average extreme cold claims more lives than tornados, floods, lightning, hurricanes and extreme heat, combined.
- In general, mortality and mortality rates from the various categories of extreme events examined here (tornados, hurricanes, floods, lightning and extreme temperatures) are lower today than they have been in the past. Based on 10-year moving averages, comparing the most recent 10-year period against the peak periods, mortality declined by 60–80 percent for floods, lightning, tornados and hurricanes, while mortality rates declined by 75–95 percent. However, there are no consistent trends for mortality due to floods, and both mortality and mortality rates for hurricanes spiked in 2005. Nevertheless, these spikes are lower than levels than were reached in previous periods.

Thus, it appears that mortality rates and – more significantly – mortality for the most deadly and destructive forms of extreme weather events have declined substantially over the past several decades. This suggests two possibilities if indeed climate change has exacerbated extreme events. One possibility is that humanity has been extremely lucky in terms of where and when these events have struck. The other possibility, a more likely explanation, is that society's ability to cope with extreme events has not only improved, it has also put its increased adaptive capacity to good effect.

Several interrelated factors have contributed to this increase in adaptive capacity. First, today's societies have a wider range of technological options at their disposal, enabling them to finesse the consequences of extreme events before they strike and to cope with their aftermath after they have struck. Such options range from early warning systems, building codes, and better meteorological forecasts, to better construction, communications and transportation systems, all of which have increased the ability to transport people and materiel (including food, medical and other essential supplies) in and out of disaster zones.

Second, many of these options were learnt through experience and were enabled through the ability of wealthier societies to research and develop new technologies and practices. Greater wealth also allowed them to obtain and implement more effective technologies. Once those technologies and practices have been developed in wealthier, more technologically sophisticated nations, it is possible for poorer societies to learn from and adapt them to their own circumstances.

Third, societies have greater access to human and social capital to protect themselves from, and cope with, adversity in general and extreme weather events in particular (IPCC 1991; Goklany 1995, 2000, 2006; Goklany and Straja 2000).

However, as indicated by the European experience with the 2003 heat wave and the U.S. experience with Hurricane Katrina, the importance of human and social capital cannot be overemphasized. They are just as important as wealth and increased access to technology. Moreover, greater adaptive capacity is necessary but not sufficient to effectively cope with extreme events. Such capacity must be deployed more rapidly and used more fully.

Nevertheless, the decline in deaths and death rates from extreme events indicates that if the frequencies, intensities and durations of extreme events have increased, then adaptive capacity has evolved even faster. Thus far wealth, technology, and human and social capital have for the most part (despite notable exceptions) apparently trumped natural climatic variability and human-induced climatic change.

Finally, it has been suggested that declining trends for deaths (and death rates) due to extreme events might be accompanied by – or might contribute to – increasing trends in economic losses. This idea is based on the general notion that individuals might accept greater financial risks provided personal safety is more assured (Goklany 2000). In addition, a wealthier society is likely to have more property at risk.

For the U.S., results of this paper, combined with previous studies of economic losses due to various categories of extreme events, suggest (but do not prove) that declining mortality is indeed accompanied by higher economic losses if losses are measured in terms of real (constant) dollars for floods, hurricanes, and tornados. However, this does not seem to be the case if losses are measured in terms of a fraction of wealth (measured as fixed tangible reproducible assets, which excludes land values) (Pielke and Landsea 1998, Doswell et al. 1999, Goklany 2000, Pielke, Jr, and Downton 2000, Downton et al. 2005).

Globally, the analysis in this paper and the estimates of economic losses in constant dollars provided by the IPCC's Third Assessment Report suggest that declining mortality is also accompanied by increasing property losses (see also, Faust et al. 2006). However, it is impossible to say at this time whether the upward trend for economic losses would hold were global economic losses to be measured in terms of global wealth, because appropriate data are lacking.

Notes

1 This paper uses "extreme weather events" synonymously with "extreme events."

2 The risk of death due to any cause, e.g., floods, is estimated by the number of deaths caused by floods divided by the magnitude of the population potentially exposed to floods. Thus the death rate for floods (measured as the number of flood deaths either per 1,000 people or per million people) is a measure of the risk due to floods. If the risk of floods increases, then if all else stays the same, the flood death rate should increase. But, in fact, all else rarely stays the same. Increases in the frequencies and magnitudes of floods may be offset by better protection from floods or disaster preparedness, for instance. Thus trends in death rates from floods tell us whether overall risk to populations from floods are increasing, decreasing or staying constant.

3 Figure 6 is constructed using data the following sources: (1) For deaths, EM-DAT (2007). EM-DAT is the International Disaster Database maintained by the Office of Foreign Disaster Aid and Center for Research on the Epidemiology of Disasters at the Université Catholique de Louvain, Brussels, Belgium. (2) For population from 1900–1925, McEvedy & Jones (1978). (3) For population from 1950–2006, World Resources Institute (2007). (4) For population from 1926–1949, estimates were based on interpolation for each year using the 1925 estimate from McEvedy and Jones and the 1950 estimate from WRI (2005), assuming exponential population growth. For 2004, I excluded the deaths due to the Boxing Day Tsunami disaster (which, according to EM-DAT killed 226,435 people). Death estimates, in particular, are approximate and, possibly, more prone to error as we go further into the past. As is evident from the following footnote, EM-DAT is not quite complete. While events in the

earlier years might have been missed, EM-DAT should have captured the major natural disasters, particularly in recent years. This suggests that mortality and mortality rates might have been higher in the early decades of the 20th century than is indicated in Figure 6, and subsequent figures and tables.

4 EM-DAT contains data on the occurrence and effects of over 7,700 hydro-meteorological disasters in the world from 1900 to present. Specifically, these disasters are due to drought, extreme temperatures, floods, slides, waves and surges, wildfires, and wind storms. The data are compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. For a disaster to be entered into the database one or more of the following criteria must be met: (a) at least 10 people must have been reported killed, (b) at least 100 people must have been reported as affected, (c) a state of emergency must have been declared, or (d) there should have been a call for international assistance.

5 EM-DAT (2005) ascribed over 45,700 deaths to the 2003 European heat wave, while EM-DAT (2007) assigns over 72,200 deaths to that event.

6 The authors themselves note that among the challenges in developing estimates of the health impacts of climate change is that "climate change occurs against a background of substantial natural climate variability, and its health effects are confounded by simultaneous changes in many other influences on population health….Empirical observation of the health consequences of long-term climate change, followed by formulation, testing and then modification of hypotheses would therefore require long time series (probably several decades) of careful monitoring. While this process may accord with the canons of empirical science, it would not provide the timely information needed to inform current policy decisions on GHG emission abatement, so as to offset possible health consequences in the future. Nor would it allow early implementation of policies for adaptation to climate changes." Hence the estimates were based on modeling studies, with quantification based on anecdotal information. The temperature-disease relationship used to develop the estimate for diarrhea, for example, was based on 6 years worth of data from Lima, Peru, and 20 years of data from Fiji. In addition, the amount of climate change estimated for 2000 was based on the results of a general circulation model at resolution of 3.750 longitude and 2.50 latitude. The results of such models, which are inexact at best at the global level, tend to greater uncertainty as the resolution gets finer.

7 To further complicate matters, the NWS website provides a "67-Year List of Severe Weather Fatalities" (from 1940–2006. Unfortunately, the data in this list for lightning is inconsistent with the data from its *Annual Summaries*. Enquiries to NOAA, so far, have not resolved these discrepancies satisfactorily.

8 In the WONDER database, mortality data for 1979–1998 are coded using the International Classification of Disease, version 9 (i.e., ICD-9) for 1979–1998, and ICD-10 for 1999 onward. To identify deaths due to extreme heat, I used codes E900.0 and E900.9 for ICD-9 (per Goklany and Straja 2000), and X30 for ICD-10. The corresponding codes used for extreme cold were E901.0 and E901.9, and X31, respectively.

9 For hurricanes it might have been more appropriate to use annual estimates of the coastal population to estimate death rates, but that would have complicated calculations of cumulative death rates.

10 These figures are based on an estimate of 1,525 deaths in 2005 per Blake et al. (2007). The figures also assume a death toll of 8,000 for the 1900 Galveston Hurricane (Blake et al. 2007).

11 Note that in Figure 13 the data for the last period is based on a seven-year average, while that for other periods are based on ten-year averages.

12 There is a probably an unavoidable degree of subjectivity involved in assigning deaths from hurricane-initiated events to either the hurricane or flood categories.

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Douglas Southgate and Brent Sohngen

Weathering Global Warming in Agriculture and Forestry

It can be done with free markets

Executive summary

During the 20th Century, atmospheric concentrations of CO_2 and other greenhouse gasses (GHGs) rose appreciably. There is some evidence that this caused limited warming of the planet, with worldwide temperatures about 0.6°C higher in 2000 than in 1900. Since GHG concentrations will increase this century, some additional warming of the planet seems likely.

Specific climatic impacts that will result as atmospheric concentrations of GHGs continue to change are difficult to predict. But given specific assumptions about the future course of global warming,[1] economic consequences can be examined. Two sectors in which these consequences have been scrutinized are agriculture and commercial forestry.

In general, the costs of environmental change hinge on how people choose to adapt. In the agricultural and forestry sectors, successful accommodation of global warming will not require central planning by governments. To the contrary, adaptation is best accomplished by relying on the sort of decision-making that happens routinely in competitive and unregulated markets – decision-making that is decentralized and individualistic, yet coordinated because everyone faces the same prices for scarce resources.

Thanks largely to the adaptations that producers and consumers will make in the marketplace, global prices of farm products will not be greatly affected if average temperatures rise by 1.0°C to 4.0°C during the 21st Century, as the Intergovernmental Panel on Climate Change (IPCC) is currently forecasting. With prices staying about the same, the main economic consequence of global warming in the farm economy will be to raise or lower the values of agricultural land. Since the 1990s, economists have investigated this consequence in the United States. Some of this research suggests that the aggregate impact of global warming on land values will be negative. However, the expected magnitude is not all that great.

In the face of higher temperatures as well as less precipitation in some settings because of global warming, efficient adjustment is impeded when governments meddle with market forces. This is true of agricultural protectionism. It is also true of distortions in the pricing of water. In particular, farmers in dry regions have little reason to adopt conservation measures if governments subsidize their use of water.

On the whole, higher temperatures will promote tree growth, certainly in places which continue to receive adequate precipitation. Risks of fire will increase as well, although probably not enough to affect timber supplies. Moreover, expected trends in the forestry sector contradict a widely-held belief about the impacts of global warming, which is that developing regions close to the equator will suffer more than affluent settings in temperate latitudes. To be specific, higher temperatures are apt to accelerate a geographic shift that is already underway. As ever larger portions of the global timber supply are obtained from sub-tropical plantations, where trees are grown and harvested in cycles lasting just 10 to 20 years, the share of timber harvested from temperate and boreal forests will decrease.

In the forestry sector no less than in agriculture, efficient adaptation to global warming requires that protectionism be avoided. With or without global warming, the sector's development depends on strong property rights, in developing countries as well as in affluent nations.

Introduction

Available evidence suggests that average global temperatures have risen only slightly since the Industrial Revolution began. After no noticeable change during the 1800s, a slight rise occurred during the first half of the 20th Century. Next came modest cooling for about three decades, possibly in part because of increased emissions of particulates which reflect solar radiation out into space. Since 1970, warming has coincided with reduced particulate pollution. All told, average global temperatures are about 0.6°C higher today than they were 100 years ago (NCDC, 2007).

Meanwhile, atmospheric concentrations of CO_2, which is an important greenhouse gas, have risen from approximately 280 parts per million (ppm) before the Industrial Revolution to 380 ppm today (Marland et al., 2007). The current rate of increase is roughly 1.5 ppm per annum (Houghton, 2005) and the concentration at the end of the 21st Century might be as high as 970 ppm (IPCC, 2001).[2] In the absence of profound technological change, curtailing growth in CO_2 emissions would require severe economic contraction, entailing the decommissioning of most of the world's existing industrial capacity and abandoning the internal combustion engine.

No one is counting either on a technological revolution or on an economic collapse, so the debate among those who agree that variations in CO_2 have a noticeable effect on the global climate revolves around how fast, not whether, the molecule will accumulate in the atmosphere. To give one example, Demirbas (2004) argues that the rate of CO_2 emissions should be slowed by 60 percent, to prevent the mean global temperature from rising by more than a couple of degrees Celsius. In comparison, the policy measures adopted at Kyoto, Bonn, and other intergovernmental meetings are un-ambitious, which suggests that nearly everyone is resigned to at least some anthropogenic global warming.

Both authors of this paper are economists, so we lack the credentials needed to sort out how climatic conditions are affected as water vapor, CO_2, and other atmospheric components vary. Our expertise relates to evaluating the costs and benefits of global warming and its control (or mitigation). Observations that follow for two sectors, agriculture and commercial forestry, draw on a fundamental insight from economics, which is that the costs of environmental change depend largely on how people choose to adapt. For example, these costs consist mainly of diminished production of goods and services if adaptation is not economically practical. But if environmental change is easily accommodated, costs consist largely of adaptation expenses, which sometimes are fairly low.

This report takes as given the current projection from the Intergovernmental Panel on Climate Change (IPCC), which is that global temperatures will rise by 1.0°C to 4.0°C during the next 100 years (Solomon, Qin, and Manning, 2007). In addition, careful attention is paid to the guidance and incentives that markets will provide to producers and consumers as they adapt to warming of this magnitude. In a market setting, the choices made by individual economic agents reflect personal and local circumstances. These choices are also conditioned by prices, which are reliable indicators of the scarcity of goods such as food and timber which are bought and sold in markets.

By and large, our findings relate mainly to the world as a whole. We acknowledge the problems arising at a more limited geographic scale because of global warming, though we do not examine them in the pages that follow. Neither does this paper address catastrophic outcomes that are very unlikely, though not completely out of the realm of possibilities. Furthermore, entire categories of impacts – mass biodiversity loss, for example – are outside the scope of this paper.

Clearly, higher sea levels resulting from the thermal expansion of ocean surfaces would be devastating for places like Bangladesh and the Maldive Islands, not to mention Venice and New Orleans. Likewise, Norway, Scotland, and neighboring lands would suffer a great deal if the Gulf Stream weakened, say because accelerated melting of ice in Greenland and around the North Pole reduces the salinity of the northern Atlantic Ocean. All that said, our contribution to the debate over global warming is to assess whether or not humanity as a whole may run out of food or wood products as temperatures rise, particularly if these commodities are exchanged in free, competitive markets.

Agricultural adaptation

Due regard for arithmetic can be very important in economics. For example, macroeconomic trends in a country that is open to trade and investment tend not to be interpreted correctly if one forgets that a deficit in the current account is normally offset by a surplus of the same absolute magnitude in the capital account, and vice versa.

However, economics is not just about arithmetic. As emphasized right at the beginning of any introductory economics class, the discipline's main focus is on how people deal with scarcity, which cannot be captured by a subtraction or two here and a multiplication there. Sadly to say, some assessments of global warming amount to arithmetic masquerading as economics.

To illustrate the shortcomings involved, consider economic damages within the agricultural sector created by global warming if one assumes, unreasonably, that farmers do not adapt at all to higher temperatures. If they continue to plant the same crops in the same places, with no variation in the use of labor, chemicals, and other inputs, then the only things that change are yields, which may increase in some settings but will decline elsewhere. Suppose there is a net loss in total output, which can be called Δ and which is best expressed in cereal-equivalent tons. If this net loss is small relative to overall production, then prices are unaffected. In this case, economic damages are found by multiplying the prevailing price, called P, by Δ.

Estimating the cost of global warming is more complicated if Δ is not a minor portion of total agricultural production. In this case, the market-clearing price rises, to P' let us say, which causes consumption to decline (in line with the change in output). As explained in Annex 1, the value of lost production is represented by the area under the demand curve between (lower) consumption at P' and (higher) consumption at P, not a simple product of Δ multiplied by an unchanging price. Areas under demand curves were estimated in early economic assessments of the impacts of higher temperatures on agriculture. One such assessment was carried out by Rosenzweig and Parry (1994).

Adaptation with free trade

Subsequent economic research has not been based on the notion that farmers are completely passive in the face of climate change, but instead adapt in various ways – as do their customers. To describe various shifts in demand, supply, and price, Mendelsohn (2006) offers a stylized illustration, one involving two commodities (maize and wheat) and two nations (Russia and the United States). Wheat grows better in cooler weather, so a rise in temperatures would reduce the number of hectares planted in the United States, but increase the area in Russia, where most farmland is closer to the North Pole. Meanwhile, plantings of maize would increase in the former country and decline in the latter.

International trade would dampen the price adjustments resulting from these changes in agricultural land use. For example, a larger wheat harvest, which on its own would drive down domestic prices of that commodity, would be accompanied in Russia by increased wheat exports, which would push the domestic market value of that commodity back up. Russia would also import more maize, which would restrain any increases in that product's price. Actions taken on the demand side of the market would also prevent relative prices from changing much. If for example maize became much more expensive while the market value of wheat remained the same, then livestock producers would change the rations fed to cattle and other domestic animals. As they did this, demand for maize would decline, hence bringing down its price, and demand for wheat would increase, thereby putting upward pressure on its market value.

Note that, even in the absence of a large swing in relative prices, farmers face a strong incentive to adapt efficiently to climate change. Consider an individual who has been growing wheat in Iowa. With per-hectare production falling and the ratio of maize prices to wheat prices not changing much, switching to the other crop is attractive. Meanwhile, additional land is being sown to wheat at higher latitudes, in Russia. In each case, market forces are promoting exactly the right response to a warmer environment.

Ricardian analysis

The best economic studies of the agricultural impacts of global warming are based on two premises. One is that farmers and other participants in commodity markets adapt in various ways to climate change. The other is that price adjustments are limited, both because of these adjustments and because of free trade. In one study based on these premises, the investigators used an approach they called Ricardian, in the sense that the agricultural impacts of higher temperatures would consist entirely of changes in land values (Mendelsohn, Nordhaus, and Shaw, 1994). The general underpinnings of this approach, which also can be described as hedonic,[3] are explained in Annex 2.

The study's geographic scope only encompassed the United States, as opposed to being global. Accordingly, it did not consider some of the agricultural adaptations to be expected if farm products are traded freely. Also, Mendelsohn, Nordhaus, and Shaw (1994) supposed that a temperature rise of 1°C or 2°C would leave commodity prices little affected, which as already indicated is most plausible if governments do not interfere with exports and imports. In a regression analysis, the investigators related land values reported in the 1982 U.S. agricultural census to climate, soil parameters, and other factors. Using regression coefficients, they projected the effects of higher temperatures on land values. In some regions, the estimated effects were found to be negative. Elsewhere, global warming would cause land values to increase. For the country as a whole, economic impacts were anticipated to be modest, either slightly positive or slightly negative.

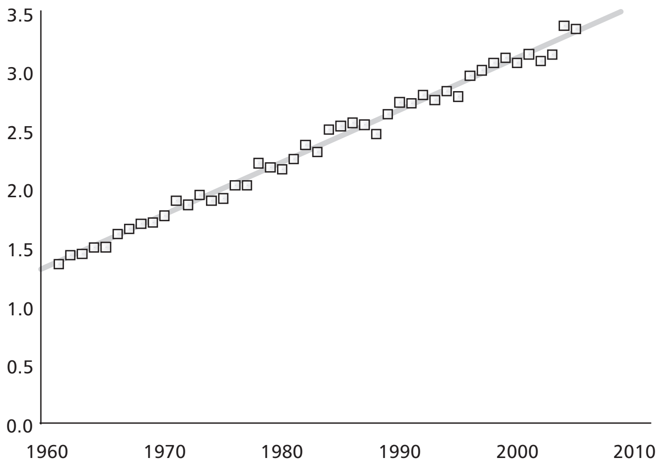
Improvements have been made subsequently in this sort of research. Deschenes and Greenstone (2007) applied statistical changes to estimate weather coefficients better. In addition, they used a panel of census data collected from 1978 through 2002. The two researchers found that modest warming on the scale investigated by Mendelsohn, Nordhaus, and Shaw (1994) would cause the value of agricultural real estate in the United States to decline by 3 to 6 percent. However, they could not reject the null hypothesis that there would be no statistically significant impact.

Another econometric study was carried out by Schlenker, Hanemann, and Fisher (2006). Among other things, their model featured different descriptions of linkages between climate and crop yields as well as an adjustment for spatial correlation of regression errors, which if left uncorrected can distort the testing of hypotheses. They only used data for that part of the United States east of the 100th meridian (which bisects North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas), where non-irrigated agriculture is the norm. In 75 percent of the sampled counties in this region, higher temperatures were found to have a statistically significant impact on land values. Schlenker, Hanemann, and Fisher (2006), who assumed no major change in commodity prices, concluded that the aggregate impact would be adverse.

Relative to what has been done in the United States, the Ricardian approach has not been used extensively to estimate how global warming would affect European agriculture. However, studies that focus on how climate change affects values of agricultural land have been undertaken in various parts of the developing world. Seo and Mendelsohn (2007), for example, surveyed 2,500 farms across Latin America and estimated how temperature and precipitation might influence net revenues and land values. Three climate scenarios were considered in this study and consequences for large and small operators were examined separately. For both categories of farms, the estimated impacts of two of the three climate scenarios were negative, with these impacts expected to worsen as temperatures reach high levels late in the 21st Century. However, the effects of the other scenario were found to be mildly positive, at least during the next two decades. Seo and Mendelsohn (2007) also found that irrigated farms would be affected less by climate change than rain-fed operations.

Using exactly the same climate model to project future environmental conditions, Kurukulasuriya and Mendelsohn (2007) investigated the effects of higher temperatures for a sample of more than 9,000 African farms. Estimated impacts varied substantially, more than what was found in Latin America. This is mainly because, under one of the climate scenarios, precipitation would increase more in Africa than on the other side of the Atlantic Ocean. Since dry conditions have prevailed in large swathes of the continent, any

Figure 16 **Average global cereal yield**
Mt/ha, 1961–2005



Source: Southgate, Graham, and Tweeten (2007), p. 58

change that would bring about more rainfall would be beneficial.

As a rule, research carried out in the United States and other settings does not place great emphasis on technological change, even though it is to be expected that higher temperatures will stimulate a search for new ways to use natural resources and other inputs to produce farm goods. This is a research gap of considerable importance since technological advances in the past have had a huge impact on agricultural yields. For example, maize yields in the United States, which held steady at 1.5 to 1.6 metric tons per hectare between the late 1860s and middle 1930s, subsequently increased five- or six-fold, due to hybridization, the use of inorganic fertilizer and other chemical inputs, and other improvements (Southgate, Graham, and Tweeten, 2007, p. 50). Likewise, technological improvements during and since the Green Revolution have caused average global cereal yields to climb from less than 1.5 metric tons per hectare in the early 1960s to more than 3.0 metric tons per hectare today (Figure 16). The adverse effects of global warming on crop yields would have to be enormous to counter the likely beneficial impacts of future technological developments on U.S. and global agriculture.

Will farmers be able to keep up with climate change?

Something to keep in mind about the research carried out by Mendelsohn, Nordhaus, and Shaw (1994) and other investigators is that it provides two snapshots of the agricultural economy. In each snapshot, input and output markets are assumed to have reached equilibrium, in the face of higher temperatures or the absence of same.

To be sure, this methodological approach neglects the costs of moving from one equilibrium to another, which would be substantial if climate change is so rapid that farmers' expertise is rendered irrelevant and machines tailored to old production technologies have to be junked before their functional lives have come to an end. However, neglect of the adjustment issue is not really worrying, at least for many of the world's farmers. Mendelsohn (2006) observes that most crops are sown and harvested annually and that agricultural machinery depreciates fully in just a few years. Under these conditions, farming systems can be revamped every decade or two, which is more than enough to keep pace with climate change. Essentially the same conclusion has been reached by Kaiser et al. (1993), who contend that farmers will be able to adapt to global warming as it occurs.

In other studies, an attempt is made to account for adjustments over time. These studies also focus on price changes. Parry et al. (2004) and Darwin (2004) both have utilized simulation approaches to analyze implications for the global food economy. In each case, crop yields were found to decline, thereby putting upward pressure on commodity prices. Depending on climate scenarios, price increases of as little as 1 percent in the near term to 25 percent by the middle of the 21st Century were projected. If this actually occurred, reductions in agricultural land values, which have been projected in some Ricardian studies that assume constant prices, would be ameliorated.

Once again, the advantages of free markets must be kept in mind. If the exchange of goods, services, inputs, and resources is not subject to egregious regulation, then shifts in demand, supply, or both lead to quick adjustments by individual actors. This capacity of markets will serve agriculture well as it adapts to global warming.

The importance of efficient pricing of water

As already indicated, Schlenker, Hanemann, and Fisher (2006) have concluded that global warming could do serious damage to rain-fed agriculture in the central and eastern United States. This result makes most sense if climate change causes precipitation to decline, in which case drier conditions might easily cause more harm than higher temperatures.

Just as they can adapt to warming, farmers are able to deal with diminished water availability in various ways. For example, Howitt (2005) found that a 25 percent cut in irrigation, which could easily happen due not only to drier conditions but also to increases in non-farm demand, would only cause agricultural earnings in California to fall by 6 percent. This is mainly because more land and water would be used to produce higher-valued crops. Mendelsohn and Dinar (2003) obtained similar findings in a study encompassing the entire United States.

Of course, this sort of adaptation occurs if prices for water are efficient. In contrast, proper adjustment to the drier conditions that higher temperatures will create in many settings is less likely if prices are distorted, by irrigation subsidies for example. More than in any other sector, payments by irrigators amount to a tiny fraction of the cost of delivering water to them (Okonski, 2006). As a result, adoption of conservation measures is discouraged, as is switching from one crop to another in response to mounting water shortages. By the same token, farmers enjoying irrigation subsidies are apt to resist the transfer of water to other sectors, which is what should happen as non-agricultural demands grow and resources become scarcer. Already excessive, the waste and misallocation created when water is supplied too cheaply to farmers will grow worse as the planet warms.

As emphasized in this paper, successful adaptation to global warming is most likely to happen where goods, services, inputs, and resources are allocated in markets that are free and competitive. In part, this means unencumbered agricultural trade at the international level. By the same token, efficient pricing of water – as occurs if that resource is bought and sold freely as opposed to being distributed by governments at subsidized prices – is essential at the national level.

Adaptation in the forestry sector

Climate change of the magnitude now being forecast by the IPCC will have pronounced influences on tree-covered ecosystems. Some forest types will shift location, farther from the equator or up mountain slopes. Others will burn more often, more severely, or both. Pests and diseases may affect new areas. Some locations will become unsuitable for trees, while tree growth will increase in other settings. While there is little agreement on the pattern and timing of impacts in specific locations, the ecologists consulted by the IPCC agree unanimously that climate change will affect forest structure and function profoundly (Parry et al., 2007).

By and large, this conclusion is based on research undertaken in unmanaged ecosystems, of the sort that remain in Alaska, Canada, and Russia as well as the Amazon and Congo Basins. However, most of the world's forests have been heavily influenced by human management, having been harvested once or multiple times or having regenerated after prior agricultural use. Simply recognizing that climate change could have substantial consequences in the absence of management, as the ecologists have done, ignores human responses and the costs of these responses.

Significantly, the impacts of global warming on timber production are unlikely to be catastrophic, even in the absence of human adaptation. At present, estimated impacts range from small and negative to large and positive. One reason why a collapse is unlikely is that warmer conditions should promote tree growth, particularly in regions where there is enough precipitation to offset the drying caused by higher temperatures. Also, higher levels of CO_2 in the atmosphere can fertilize trees, provided that other nutrients and water are available.[4] It is hardly surprising, then, that a recent survey of available studies points to a recent acceleration of tree growth globally, in spite of forest decline in some regions (Boisvenue and Running, 2006).

If global warming causes trees to grow faster, even without management, then supplies of timber will increase. Consumers will benefit, as prices for wood products fall. Costs will mainly be localized – confined to regions that experience diminished tree growth but where producers will actually suffer more because of price declines. These conclusions have been arrived at by a number of investigators (Joyce et al., 1995; Perez-Garcia, 1997; Sohngen and Mendelsohn, 1998; Sohngen et al., 2001; Joyce et al., 2001; and Alig, Adams, and McCarl, 2001).

Increased fire incidence?

There is a potential caveat, which is that forest fires may occur more frequently, affect larger areas, become more commonplace in settings where these events currently are rare, or otherwise do more damage (Bachelet et al., 2003, 2004; Scholze et al., 2006). Statistics indicate that fire activity has increased in the United States, for example, in recent decades (http://www.nifc.gov/stats/fires_acres.html). On average, a little less than 1.8 million hectares have burned each year since 1960, although the average from 1997 through 2006 was nearly 2.4 million hectares per annum. Some authors suggest that the recent increase in forest fire activity in the western part of the country can be attributed to climate change (Westerling et al., 2006).

Even if a linkage exists between global warming and forest fires, the effects on markets for wood products, while negative, are not expected to be substantial. Inventories of standing timber around the world are huge. Also, extraction rates in temperate latitudes, which are the main source of supply, are lower than growth rates, which means that timber stocks are accumulating. As an example, standing timber in the United States, which currently amounts to 26 billion m^3, is accumulating at an annual rate of 672 million m^3, or 2.6 percent. Since the 1950s, per-hectare volumes have increased by 0.6 percent per annum, from 56 m^3 to around 79 m^3, both because growth has exceeded extraction and because mortality has remained fairly low. Currently, annual harvests and mortality are 448 million m^3 and 168 million m^3, respectively, which added together are less than yearly accumulation, 672 million m^3 (statistics on US forests from Smith et al., 2002). It is hard to argue that timber harvesting in the United States is unsustainable. Indeed, the area burned every year might well have increased because there is now more to burn – for example, because of substantial growth in standing timber per hectare during recent decades.

Notwithstanding these criticisms, the possibility that climate change will increase burn rates remains worth addressing, largely because of hydrological impacts and lost opportunities for forest-based recreation. Even so, it is doubtful that timber markets will be negatively affected. One reason is that, when forest fires occur, they rarely damage forests in a way that prevents salvage harvesting. Sohngen and Mendelsohn (1998) and Sohngen et al. (2001) examined a set of scenarios that considered large increases in forest fire activity due to climate change. Their results suggest a range of adaptive behaviors among foresters, including harvesting some forests in anticipation of fires, salvage logging, regenerating more suitable species, and shifting harvests from one region to another to maintain adequate supplies. Only under scenarios where the adaptive ability of landowners is seriously constrained would consumers and landowners experience overall losses in welfare.

Temperate versus subtropical settings

It is often claimed that less developed regions close to the equator will suffer disproportionately because of global warming. Commercial forestry is a major counter-example, however. As temperatures rise, wood products obtained from warm settings will increase, not decrease, and it is likely that the portion of global timber supplies coming from the low latitudes will increase as the portion harvested in temperate settings declines.

One of the main reasons for this geographic shift is that temperate and boreal species tend to take longer to mature than do species in the tropics and subtropics. Among the latter are Eucaplyptus and certain varieties of pine, which can be grown in rotations of 10 to 20 years where temperatures are consistently moderate to high and where there is adequate precipitation. In contrast, rotations of Douglas Fir, which predominates in the forests of western Oregon, Washington, and British Columbia, last at least 40 years.

Due to the advantages of short rotations, plantations in warm settings where Eucalyptus, pine, and other fast-growing species are raised have been expanding. Globally, there are approximately 70 million hectares of fast-growing plantations used for commercial timber harvesting. These plantations currently account for 13 percent of the world's timber harvest. Over the coming several decades, the supply of timber from these plantations is expected to reach 40 percent of the market, largely because of fast-growing tree species (Daigneault, Sohngen, and Sedjo, 2007).

One of the main reasons for plantation development in the subtropics is that trees grow more quickly in this setting. In particular, species such as eucalyptus and pine thrive when introduced to regions that have, for instance, a longer growing season or more precipitation. For this reason, annual growth for non-indigenous trees in subtropical plantations varies between 10 and 15 m^3/ha, which is well above the average annual growth of 1–5 m^3/ha registered in temperate and boreal forests. Furthermore, traditional breeding programs may add 10 to 20 percent to timber yields across successive generations of trees (Sedjo, 2004). For rotations lasting just 7 to 20 years, these gains imply improvements of 0.5 to 2.0 percent per annum in the productivity of planted stands of trees. Application of modern genetics, which has barely begun in working forests, could further raise timber yields.

The expansion of subtropical plantations is likely to be accelerated by global warming, with direct consequences for the locations where timber is harvested around the world. This is not to deny that there are some regions close to the equator where tree growth will slow due to diminished precipitation. But in other places, where rainfall remains adequate, plantations will spread due to an obvious advantage of short rotations, which is that adjustments to new environmental conditions can be made in just 10 or 20 years. With much longer rotations, temperate and boreal forests do not share this advantage, which will become even more significant as the Earth grows warmer.

Taking into account the faster adaptation that occurs in the low latitudes, Sohngen et al. (2001) find that the effects of global warming on global timber supplies will differ greatly from agricultural impacts. Whereas agriculture in northerly settings such as Canada and Russia are likely to benefit the most from higher temperatures, forestry in these same settings will probably be placed at a disadvantage. Among other things, Sohngen et al. (2001) predict that the share of global timber production from South America, which has experienced considerable plantation development, will increase by as much as 13 percent over the next 50 years. Meanwhile, timber production in North America, where a great deal of harvesting still takes place in natural forests rather than plantations, is anticipated to fall by around 11 percent.

In light of these findings about geographic realignment, one cannot draw inferences about global forestry from trends in the United States alone. Sohngen and Mendelsohn (1998) estimate that a rise in the average national temperature of 1.5ºC to 5ºC would cause net welfare[5] in the U.S. forestry sector to increase by 13 to 15 percent. Results from Irland et al. (2001) suggest smaller overall economic impacts: annual welfare gains of 0.05 to 0.18 percent over the coming century. But for the world as a whole, Sohngen et al. (2001) suggest welfare increases of 2 to 8 percent per annum, with the largest increases occurring in poorer, subtropical regions. These changes imply benefits of $6 billion to $12 billion per annum during the next 100 years.

The role of property rights

Solely in terms of its impacts on global timber production, a warmer global climate is beneficial. Moreover, the best way to capture the benefits of higher temperatures in the forestry sector is to allow markets to work. For this to happen, governments need to refrain from regulating or otherwise meddling with prices and commerce. Instead, they must solidify the legal and institutional framework that markets require, by strengthening property rights for example.

The importance of property rights is underscored by the fact that industrial timber plantations, which offer an excellent setting for adapting to climate change, are largely concentrated in places with secure land tenure: the Iberian Peninsula, New Zealand, and the southern United States as well as Argentina, Brazil, and South

Africa. Plantation development also has occurred in other parts of Africa and in Southeast Asia, often to provide firewood and other products for local markets. However, commercial success in these regions has been impeded. While investors often build wood-processing facilities near sources of raw material (or they locate new plantations by existing mills) to minimize transportation costs, they are unwilling to stake the large sums required if land rights are in any way clouded.

Even in the United States, property rights are not entirely conducive to global warming adaptation. Approximately 43 percent of the country's forests are owned and managed by federal, state, or local governments. Particularly in the United States, public agencies are much less flexible than private landowners, and therefore are not as able to deal with climate change. Consider the U.S. Forest Service, which is responsible for about 40 million hectares. Recent evidence indicates that conducting salvage operations after fires is severely impeded by complex bureaucratic procedures (Prestemon et al., 2006). This problem reflects the more general challenge of altering procedures and guidelines for harvesting and regeneration. In the face of global warming, guidelines and procedures will have to change with regard to converting forests from one species to another, rehabilitation of timberland, as well as salvage harvesting. Considering the rigidities inherent in bureaucratic administration of natural resources and the magnitude of changes needed, long-term contracts and leases with private companies (possibly including those environmental organizations which have the resources needed for large-scale operations) have considerable appeal. This holds particularly true if contract – and lease-holders are given wide latitude to adjust the use and management of forests.

Forest tenure issues are different in Europe, where public-sector ownership is less prevalent. Instead, regulatory burdens are often heavy on private owners of timberland. Also, local customs circumscribe the type and quantity of harvesting as well as modes of regeneration in many places. As a result, adapting to climate change is more difficult in Europe than in the United States. For example, some zoning ordinances require landowners to maintain forest cover or regenerate specific species. This tends to complicate tasks such as removing vegetation that burns easily, phasing out slow-growing species, and planting other sorts of trees that are better suited to new conditions. At the very least, countries and regions with tight controls on land use will have to update regulatory structures quickly in response to global warming.

Canadian institutions are an interesting alternative, especially in terms of direct government control and administration. Most of the country's forests are public "Crown Lands." However, extensive tracts are leased for longer time periods (usually 20 to 40 years) to timber companies and other entities, which are then required to harvest according to an estimate of the annual allowable cut. This cut is determined primarily by ecological criteria, although lease-holders are allowed some flexibility with respect to the specific timing and location of extraction. Also, land must be regenerated either through accepted natural practices[6] or manual planting. By stipulating these conditions, the public sector can, at least to some extent, regulate the flow of income to the state while simultaneously influencing environmental outcomes.

While climate change can be accommodated within the framework of long-term leases, additional modifications might well be in order if temperatures continue to rise. For example, leased areas may have to be adjusted if existing lands become unsuitable for production forestry. Also, large fires outside the boundaries of existing lease-holds may oblige the government to permit salvage harvesting. This latter adjustment might prove problematic in regions where access is poor. Building roads is costly in such regions and salvage operations typically have low margins, which are bound to decline as lumber prices fall. Federal and provincial authorities may need to develop innovative contracts with landowners, to give the latter additional flexibility on harvest levels in accessible regions in order to entice them to build roads and extract salvage timber in inaccessible regions. Clearly, climate change will provide new challenges to governments that are responsible for large tracts of land.

The importance of free trade

Bureaucratic administration of resources and regulation of private lands are major examples of government impediments to adaptation that arise at a local level. The most important challenge to successful adaptation, however, has to do with trade policy. Since the forestry sectors in some countries will be disadvantaged by global warming, governments in those same countries will come under pressure to apply tariffs, institute quotas, and interfere in other ways with timber imports. Protectionism, which long has been the norm in the forestry sector, may work for a time. However, the costs of trade restrictions will grow as the climate changes. Resources will be increasingly misallocated, with over-investment taking place where the timber industry is growing less competitive and under-investment occurring in settings where comparative advantage is strengthening.

In contrast, free trade and the unencumbered flow of capital will produce two benefits. First, international markets will grow for timber producers in developing countries who stand to benefit from climate change. Second, prices will stay low for consumers of wood products, particularly in nations where global warming weakens the comparative advantage of the domestic forestry sector.

Conclusions

Compared to disagreements over how much temperatures will rise as levels of CO_2 and atmospheric components vary, there is strong consensus that profound changes in the global economy will be required if greenhouse-gas emissions are to be curbed. Some observers contend that the technological changes unleashed as people and firms search for ways to mitigate global warming will be beneficial, maybe even in the near term. But most concede that the adjustment will be costly, perhaps extremely so. For example, Weyant et al. (2006) have examined the economic sacrifice required to reduce temperature increases by 25 percent, relative to the business-as-usual trend. Using approximately 15 well-known energy models, they estimated that global GDP would be 0.4 percent smaller in 2025 and 4.8 percent smaller in 2100.

If mitigation is burdensome, then it makes sense to keep greenhouse gases in check only if the alternative, which is to adapt to global warming, is equally or more costly. Our findings for two key sectors of the economy suggest this is not the case. We will not all go hungry or run out of wood products if temperatures rise. To the contrary, the agricultural and forestry impacts could be modest, at least on a global scale.

This is not to suggest that global warming will not affect agriculture and forestry in some parts of the world. Temperate and boreal forests comprise one case in point; low-lying agricultural regions are another. Consider Bangladesh, where millions of rural households could be placed in jeopardy if higher temperatures lead to a rise in sea levels and an increase in the incidence of flooding.

A case can certainly be made for international support to help the Bangladeshi littoral deal with global warming. This assistance might consist of investment in dikes and other infrastructure for flood-control. Something important to keep in mind, however, is that much of the rural population that would be at risk will also be impoverished and vulnerable without global warming. For these people, the best assistance, regardless of what nature has in store, is to create new economic opportunities, outside of subsistence farming and other traditional lines of work. In turn, the best way to do this is to open up markets and invest in human capital.

The most important thing governments can do to limit the potential impacts of global warming is to avoid undercutting markets. Irrigation subsidies, weak property rights in forests, and protectionism in agriculture and forestry are harmful even when environmental conditions are consistently ideal. The damage will be multiplied if the Earth grows warmer. Indeed, the waste and misallocation created by these policies will almost certainly exceed the costs which could occur in commodity markets because of climate change.

Annex 1
Valuing consumption: a welfare perspective

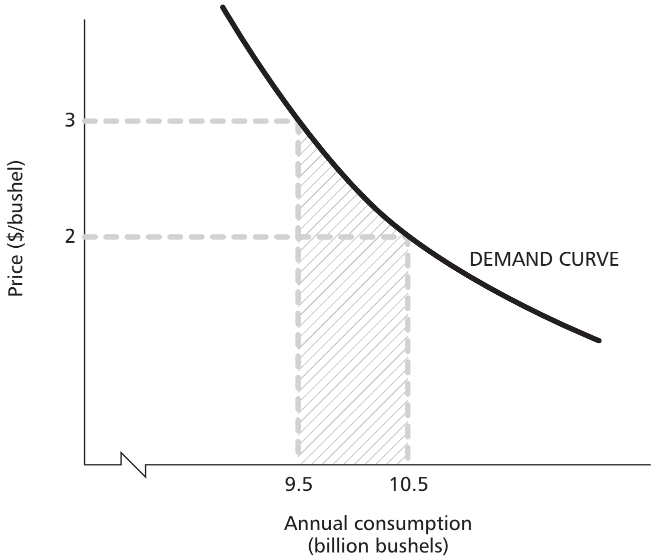
Many people are familiar with demand curves, each of which expresses the inverse relationship between consumption of a good and that good's price for a pre-determined combination of household incomes, prices of other goods, people's tastes, and so forth.

However, demand curves have another interpretation – one used in welfare analysis, which provides a framework for evaluating an economy's performance (or efficiency). In a conventional market setting, such a curve indicates the marginal value of consumption – in other words, the maximum amount that someone would offer for a small (e.g., unitary) increase in product availability. Consistent with this interpretation, the value of a non-marginal change comprises the marginal value of the first additional (or lost) unit plus the marginal value of the second such unit, etc. This sum, which is often referred to as consumers' willingness-to-pay (WTP) for the change, consists of the integral of the demand curve (i.e., the area under the curve) between the two consumption levels, the original one and the one after the change.

An illustration is provided in Figure 17, which depicts the U.S. market for maize in stylized fashion. To begin with, 10.5 billion bushels are purchased annually at a price of \$2/bushel. If the price goes up to \$3/bushel, yearly purchases fall to 9.5 billion. WTP for this change is the shaded area in Figure 17 between the two consumption levels.

This value comprises two parts. One is the market value of the billion bushels evaluated at the original price: in other words, \$2 billion, which equals \$2/bushel x (10.5 – 9.5) billion bushels. The other component, called consumers' surplus, is not captured by maize suppliers, in the form of sales revenues. This surplus –represented in Figure 17 by the area bounded by the vertical line intersecting the horizontal axis at 9.5 billion, the horizontal line extending out from \$2 – arises because the marginal value (to some buyer) of the 9,500,000,001st bushel is nearly \$3 while the same bushel's price is just \$2, the marginal value of the 9,500,000,002nd bushel is slightly lower while its price is (again) \$2, and so forth.

Figure 17 **Demand of and consumers' WTP for U.S. maize**



WTP and its constituent parts are easy to calculate if the demand curve happens to be a straight line. To be specific, the integral under the demand curve is a simple trapezoid equal to ½ x (P + P') x |Q – Q'|, where P and Q represent the original combination of price and quantity and P' and Q' are the combination after the change. For example, the value that consumers would attach to 1 billion bushels of lost maize production if the demand curve in Figure 17 were a straight line would be ½ x (\$2 + \$3) x |10.5 billion – 9.5 billion| = \$2.5 billion. Of this amount, the market value comprises \$2 billion (see above). The balance, which is consumers' surplus, is represented by the triangular area: ½ x (10.5 billion – 9.5 billion) x (\$3 – \$2) = \$0.5 billion.

Finally, welfare analysis takes into account the opportunity cost of factors of production as well as WTP. In the preceding example, the value of any inputs no longer used to produce maize as output falls from 10.5 billion to 9.5 billion bushels would be deducted from WTP (\$2.5 billion for the straight-line case) to determine net impacts on welfare.

Annex 2
Resource rents: a Ricardian perspective

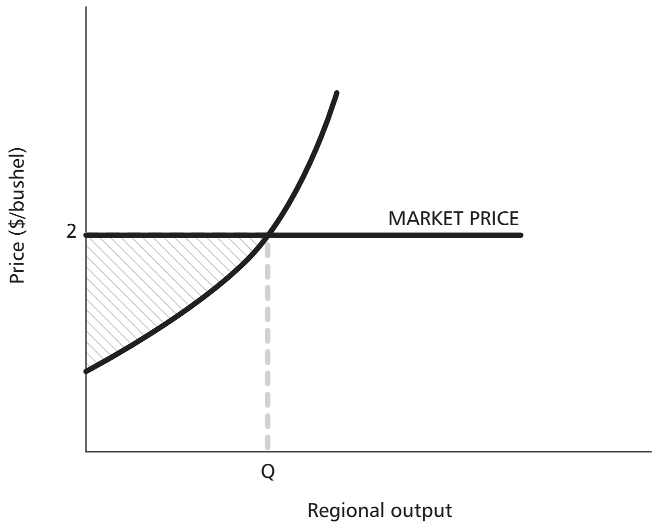
Just as practitioners of welfare analysis refer to demand curves to evaluate consumption, resource values can be described with reference to the supply curve. Classical economist David Ricardo developed this approach as he built a case against agricultural protectionism early in the 19th Century.

Let us think again of the maize market, in which equilibrium has been reached at a price of $2/bushel. Instead of examining the U.S. market in its entirety, consider what is happening in just one part of the country. Variations in that region's output have no impact on the market price, as indicated by the horizontal line extending out from $2 on Figure 18's vertical axis. The supply curve slopes upward, which reflects the tendency for production to rise as price goes up, given cumulative investment in productive capacity, the existing state of technology, input prices, and other exogenous factors. As explained in any introductory textbook, the curve indicates the marginal cost of output, exactly as the demand curve can be interpreted as a marginal-value curve. Just as marginal value declines as consumption goes up, marginal cost is positively tied to the output level

Reflected in the positive slope of the supply curve is heterogeneity among producers. Some of them possess resources that are unusually productive, others are located close to market hubs, still others enjoy both advantages. Regardless of the reason, these producers could supply maize at a price well under $2/bushel and still cover the costs of labor, chemicals, and other non-land inputs. Their output is represented by the lower part of the supply curve, close to the vertical axis. But there are also farmers whose land is both inferior and remote, who can barely cover non-land expenses even at the prevailing price. Production by these growers corresponds to the portion of the supply curve nearer its intersection with the price-line.

Significantly, everyone receives exactly $2 for every bushel delivered to market. What can be said of the residual balance between sales revenues and non-land expenses captured by farmers enjoying an environmental or locational advantage? Ricardo called this balance rents. These rents, which are represented by the shaded area in Figure 18, comprises the difference between market value of output – that is, sales revenues, which is found by multiplying output (Q in Figure 18) by price ($2) – and non-land costs, which are represented by the area under the supply curve between the origin and Q.

Figure 18 **Regional supply and producers' surplus in the maize market**



Ricardo contended that rents are expressed in real estate prices, which makes perfect sense. In land markets, bids for productive holdings that are centrally located are high, depending on prices for farm products as well as costs of inputs other than land. In contrast, prices offered for marginal land, where sales revenues barely cover non-land expenses, are modest.

Finally, rents and prices of real estate vary as market conditions change. For example, high commodity prices cause the area in Figure 18 bounded by the vertical axis, the supply (or marginal cost) curve, and the horizontal line representing price to increase. Rents can also increase even with no change in price, in particular because supply grows (i.e., shifts outward) due to low production costs. In contrast, higher production costs, which might result if global warming causes regional precipitation to decline, diminishes rents and, in turn, resource prices.

Notes

1 Throughout this paper, where we discuss "global warming," we mean human-induced, or anthropogenic, warming – unless we explicitly say otherwise.

2 The 970 ppm figure derives from the IPCC's Special Report on Emissions Scenarios, which has not been updated for the 2007 Fourth Assessment Report. The assumptions underlying this very high upper estimate have been called into question by many analysts.

3 Hedonic pricing is frequently used to evaluate environmental services that are not bought and sold in markets. Supposing that environmental quality is among the variables that influence property values, the analyst begins by running a regression in which these values are dependent. This yields regression coefficients that are then used to predict how real estate prices change in response to variation in right-hand side parameters, particularly including measures of environmental quality.

4 Although scientists have debated the potential role of carbon fertilization (Gitay et al., 2001), recent evidence points to strong positive effects on forests (Norby et al., 2005).

5 As explained in Annex 1, net welfare is found by subtracting input costs from WTP for consumed goods.

6 An example of natural regeneration would be to leave seed-trees in place after harvests.

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Wolfgang Kasper

The Political Economy of Global Warming, Rent Seeking and Freedom

'The urge to save humanity is always a false front for the urge to rule it.'
H .L. Mencken

The global warming debate is getting shriller. For the layman, it is also becoming more confusing. On the one hand, vehement voices assure us of a 'scientific consensus' that the world's climate is getting warmer and that the main cause is human activity. We are told that the debate is over, indeed that we may already be facing apocalypse now. On the other hand, respectable scientific observers express plausible doubts about whether there is any long-term warming, whether CO_2 levels are at all systematically correlated with global temperatures and, indeed, whether it is due to human economic activity.

The more intently one listens, the more the debate sounds like a dialogue of the shouting deaf, and the more it reminds one of the passionate divisions in the run-up to Europe's wars of religion.

The climate debate is about science and political economy

Being bombarded by impassioned argument and counter-argument, the bemused layman cannot possibly comprehend the masses of contradictory scientific data and the complexities of climate modelling. Nevertheless, he will have registered that temperatures have been rising somewhat during the second half of the 20th century, an era of unprecedented growth in material welfare powered by increasing energy use in the West, and now increasingly the third world. Does this foreshadow long-range global warming, as the UN's Intergovernmental Panel on Climate Change (IPCC) and many other government reports affirm?

Others attribute changes in global temperatures predominantly to solar activity or yet ill-understood other natural factors (Singer 1999; Baliunas 2002; Carter et al. 2006; 2007; Svensmark and Calder, 2007). After all, the earth has gone through considerable variations in average global temperatures during its long history.[1] Plausible objections to the modelling approach of the IPCC have certainly been raised, for example that the IPCC's predictions rely excessively on computer modelling and are at variance with actual observations and that observed fluctuations in CO_2 levels do not precede rises in global temperatures (Soon 2005; Carter et al. 2007).

In any event, if there is warming, it will in all likelihood be gradual and moderate. Would that be a bad thing? Siberians and surfers will welcome somewhat warmer conditions. Let us not overlook that humankind took great steps forward when global temperatures rose during the Holocene, or when humans could enjoy relatively warm centuries during what European historians call the 'Medieval climate optimum'. As the world becomes more affluent people are better able to cope with the whims of nature. Potential disasters can in all likelihood be averted by technical interventions, for example geo-engineering. The past record is also encouraging when it comes to the human cost of natural disasters. Although the number of recorded disasters has gone up dramatically, the number of lives lost has plummeted (van der Virk 2007; see also Goklany, this volume).

If temperatures rise, does it make more sense to simply adapt or to mitigate warming by cutting greenhouse gas emissions? The answer to this question depends on the assessment of costs and benefits, an exercise in economic analysis and political decision-making (Robertson 2006). What is good or bad for specific people most certainly cannot be determined by pure science. Mitigating feared temperature increases by mandatory cuts in carbon emissions will certainly inflict losses in terms of economic growth and make it more difficult to eradicate poverty, since – at least for the next generation or two – economic growth will depend mainly on the cost and availability of carbon fuels.

This is not to say that consumers and producers should not take CO_2 emissions into account when deciding what is feasible and sensible. But often it will be cheaper to adapt, for instance by insulating homes better or raising the dams in Bangladesh by a foot or two, than to deny the next generation, including poor Bangladeshis, access to the same cheap fossil fuels that the affluent have been using for generations (Goklany 2005). Besides, there may be little that humanity can in practice do to prevent rising global temperatures.

Many natural scientists connected with the IPCC and most climate activists pretend that the natural-science aspects of the climate debate are not intimately intertwined with economic and political issues. When two economists pointed out that the IPCC's warming scenarios were based on inappropriate income statistics (Castles and Henderson 2003; also [UK] House of Lords 2005), the chair of the IPCC brashly asserted that global warming and policies to address it were a purely scientific matter, so social scientists should stay out of the debate.

This sounds at best arrogant, but is in reality ignorant. The policies that flow from the proposals of this political UN committee have pervasive economic and social consequences, so much so that climate scientists are well advised to accept some of the insights from a broad spectrum of social sciences. There can be no denying that the IPCC policies and international conventions to mandate greenhouse gas emissions are highly political.

Nor is it legitimate to suggest that any hypothetical risk of future damage to human wellbeing must be avoided *at all cost*. The appropriate approach is economic; namely, to weigh properly assessed and priced costs and benefits, taking account of fundamental social values, such as freedom, justice, security and peace.

The fundamental economic issues entailed in the climate debate became clear when two, albeit separate, groups of eminent experts examined the Blair government's Stern Report (Stern 2007; Carter et al. 2006; Byatt et al. 2006). This report concluded that immediate action to mitigate climate change would be cheap and worthwhile, but postponement would reduce global production by between 1 to 5 per cent – far higher than what other climate economists had previously assumed ([UK] House of Lords 2005).

The two groups of reviewers – one consisting of natural scientists (Carter et al. 2006), the other of economists (Byatt et al. 2006) – came to the conclusion that the Stern Report contained fundamental economic and scientific errors, and that the scientific evidence is far from settled to merit major and costly policy action.[2] The top-down *dirigiste* approach advocated by Stern and the British government is predicated upon a model built around implausible economic assumptions. A previous study of the economics of climate change, conducted under the auspices of the British House of Lords (2005), came to much less alarmist conclusions than the Stern Report – but it was the Stern Report that captured the plaudits of the 'climate fraternity' and Europe's political establishment.

Astute observers of the process by which the findings of the IPCC have been promulgated and conveyed to policymakers have also found a certain 'disconnect' between the science in the IPCC's full Fourth Assessment Report and the summary of the findings, which is of course always the politically influential output of the IPCC. Matters of inordinate complexity and uncertainty, which thousands of government-appointed experts may have raised and which cannot be attributed to a single factor other than by relying on abstract computer models, are condensed in a text negotiated by political operators and bureaucrats, who frequently have no scientific expertise (McKitrick et al. 2007; Henderson 2007).

This adds to the above point that the IPCC goes beyond the objective analysis of natural phenomena and intends to convey implicit political messages that promote more top-down government interventions.

As long as it is denied or ignored that climate management is essentially an issue of political economy, we will observe a continued and fruitless 'dialogue of the deaf', political decisions will produce costly blunders, and arrogant advocacy will dominate the debate at the expense of sensible entrepreneurial solutions.

Some concerned natural scientists have accepted this point (Pielke et al. 2005; Kunkel et al. 1999; Reiter et al. 2004; Reiter 2007), but most aspiring 'climate managers' in politics and advocacy groups are reluctant to draw the appropriate conclusions. They already have chosen their preferred solutions and wish to close out the wider economic, ethical and political debate. This allows them to stay on the safe grounds of their specialist scientific knowledge and to avoid the fields of political economy and public policy, which are *terra incognita* to them. However, the climate experts will fail if they disregard the fundamental insights of these social-science disciplines. Experts frequently fail in their pursuits not because they make a mistake in the narrow area of their expertise, but because they overlook some very fundamental insight in another discipline.

One salient example is the IPCC's Fourth Assessment Report, which makes predictions many years ahead. Two eminent experts in the art of forecasting, supported by numerous colleagues, looked at the methodology of the report, and asked: "… is [the IPCC report] a good basis for developing public policy?" They concluded: "Our answer is 'no'", because the most fundamental principles of forecasting were violated (Armstrong and Green 2007: 1).

Politics and economics also come to the fore when decisions are made about who should shoulder the burden of mitigation. Should it be only those nations which are currently affluent, or everyone? As soon as redistributional issues enter a public-policy issue, the problems become immediately more intractable. And burden-sharing certainly is not a mute question at a time when two coal-fired power stations are opened in a rapidly growing China *every* week on average (US Energy Information Administration, 2007a). In the era of high mobility of international financial and human capital, it is relevant to know whether energy-intensive industries such as aluminium smelting would move from Kyoto-handicapped, though relatively 'clean' and energy-efficient Canadian or Australian producers, to exempted and poorly policed locations, for example in India or South Africa.[3] Long-term targets, which are fixed by central political horse trading at a global level, pose particular headaches for rapidly growing economies and those with high population growth and a comparative advantage in energy-intensive exports, such as the United States and Australia.

The method of negotiating internationally to fix mandatory targets raises another complex of problems about which economists have much to say: Should climate management rely on top-down central planning with mandated targets, or spontaneous, competitive innovation as new circumstances evolve and incentives change? The UN's global Kyoto Protocol clearly represents the central-planning approach. The fundamental and overwhelming problems with this method of coordinating human endeavours, which has been analysed exhaustively in the economic literature and which has produced uncontroversial conclusions (Kasper-Streit, 1998: 142–152), has hardly been given any attention in connection with the Kyoto exercise of centralised planning and target-setting.

The central-planning route may be plausible to natural scientists and engineers, but it meets with profound professional distrust by economists, historians and the friends of liberty. Central planning, even at the national level and even when enforced with draconian penalties, has hardly ever worked. To the contrary, it has all too often led to unforeseen, deleterious consequences.

More importantly, such top-down social engineering has hindered the attainment of fundamental human values, such as freedom, prosperity, justice, social harmony and security (Dorn 2007). Historians and economists have learnt the lesson that economic freedom and the resulting prosperity are essential for human enterprise to cope with new challenges, such as possible climate changes. If globe-spanning planning and regulations were to take us down a restrictive track, it would constitute the single biggest threat to freedom since the demise of the Soviet Union. It would also destroy much entrepreneurial competition, the time-tested social mechanism which has empowered humanity to cope with emerging problems and to prosper.

The upshot of all of this is that climate-change management is about social interaction and the economic feasibility of human responses to natural phenomena. Policymakers, who deal with undesirable natural developments, must take account of the lessons that historians and economists have drawn from the experience of sustained economic growth over the past two to three centuries, and must do so in an integrated way, not as a separate side issue. Climate scientists cannot go on ignoring the fundamental lessons about how emerging bottlenecks and scarcities are typically overcome.

The remainder of this essay outlines some of the straightforward insights from economic history and political economy, which natural scientists and policymakers typically overlook. To begin, we shall ask what has driven the amazing material progress of humankind over the past six generations and why that material progress rests on tenuous foundations. We will then ask why the experience of economic progress has not changed the minds of the doomsayers, although they have in the past been proven consistently wrong. We shall then elaborate on why most economists consider central planning and Kyoto-style target-setting to be a bad idea, and why many of them conclude that this method can endanger the very driving forces behind the human capacity to cope creatively with emerging problems such as possible global warming.

The costs of mitigation

Given attempts to keep troubling economic questions out of the climate debate, it is probably not surprising that properly assessed costs of temperature mitigation schemes of the Kyoto kind are few and far between. Nonetheless, estimates of the costs of various Kyoto-style schemes to cut carbon emissions now before the US Congress have now been reported:

- An MIT analysis of the consequences of the rather drastic Sanders-Boxer and similar bills currently before the US Congress arrived at an annual cost of US-$4,500 per American family by 2015, as well as an estimated 4.5 million job losses, mainly due to steeply rising energy costs (Paltsev et al. 2007).
- The US Energy Information Administration estimated that the cost of implementing Kyoto (cutting CO_2 by 5% below 1990 levels) for every American household would be equivalent to an additional tax of $7,000, inflicting 2.5 million job losses. (US Energy Information Administration 2007 b; Driessen 2007).
- WEFA Inc., an economic forecasting firm tied to the prestigious Wharton Business School, estimated the additional burden of the proposed emission controls on every American household at $ 3,700 (WEFA 1998).

These new cost burdens amount to between 8 and 15% of average American household incomes in 2005. Such orders of magnitude point to heavy new taxation of average citizens in the affluent countries. This also applies to European households, where the orders of magnitude can be assumed to be similar, although this author is not aware of authoritative cost estimates about the burden for European consumers. It should also be noted in this context that most European countries have so far failed to meet their Kyoto targets[4].

The public in wealthy, developed countries seems oddly ambivalent about bearing the costs of policies that are intended to mitigate global warming. Public opinion surveys indicate that climate change has become a general concern in affluent societies, but also that most people do not wish to sacrifice their own comfort and income. A recent survey in Germany, for example, showed that only 21% of respondents would give up flying to vacation destinations if that were to ‘save the earth’. In reality, global air traffic will continue to expand, and governments are busy preparing for that expansion. Likewise, traffic authorities work with projections that the number of cars in the world will increase fivefold by 2050. These sections of governments are working with projections which are hugely at variance with what the climate officials are planning. Meanwhile, huge numbers of people in emerging economies are moving into energy-intensive high-rise apartments and adopt patterns of consumption and production that require more energy. Is this hypocrisy or wilful inconsistency for reasons of political convenience?

Huge, politically mandated burdens certainly should require elected parliamentarians to take great care that the science on which the need for such imposts is based is absolutely solid, and that the alternative of adaptation has been carefully assessed. Alas, citizens cannot feel assured about this when they read “that we cannot even be certain whether the global human signal is one of warming or cooling. The gentle global warming that probably occurred in the late 20th century falls within previous natural rates and magnitudes of warming and cooling, and is *prima facie* quite unalarming" (Carter et al. 2007: 21).

Mitigation costs in terms of lost long-term global economic growth are much more difficult to assess than the household costs inflicted by specific legislative proposals. Politicians and bureaucrats around the Western world are now imposing piecemeal regulations 'to save the planet', often without much analysis of their effectiveness and the costs. Energy users are being burdened with costly regulations and compliance costs; taxes are being diverted into subsidies for some politically preferred solutions; and new 'climate regulations' block otherwise promising avenues for wealth creation. These costs of climate mitigation will without doubt on balance be massively negative.[5]

Since material wealth and technical prowess based on affluence will be essential to coping successfully with temperature changes, it would be foolhardy to subject current economic growth to major new political risks. Global economic growth of the sort attained over recent decades seems an excellent method of 'future proofing' human civilisation, should the need really arise. To understand these assertions, it is necessary to comprehend what has enabled growing numbers of human beings to realise such increases in material wellbeing.

The twin pillars of modernity, and the end of dire scarcity

The emergence of the modern world and the advent of the sustained rise in living standards are based on two inter-related achievements: rational science and economic freedom (Taverne 2005). Only when humans began to analyse natural phenomena rationally and explicated them in systematic ways – when lightning and thunder were seen as electric phenomena, rather than signs of the gods' anger – was the systematic improvement in production technology possible. *Scientific discoveries* by themselves, however, do nothing to improve mankind's material condition. Nor is this achieved by mere *inventions* and laboratory models. It takes entrepreneurs, who assume the risk of testing and utilising scientific discoveries, to bring about product and process *innovations*. Entrepreneurs evaluate risks and benefits and incur assessed risks in the hope that this will yield them a profit (Schumpeter 1961; Blandy et al. 1985; Nelson, 1988).

As we have known since David Hume (1711–1776), such practical discovery procedures can only come about when entrepreneurs are assured of secure private property rights, free markets and rule-bound government, in short: economic freedom (Kasper-Streit 1998: 220–253). In this context, it should be noted that entrepreneurship is not confined to producers. Societies with a pervasive entrepreneurial culture tend to be characterised also by well-informed, risk-taking buyers who rival with each other with what they know and own. They are an essential aspect of a genuinely innovative economy (Nelson-Winter 1977; Blandy et al. 1985).

Rational science, including its engineering applications, and economic freedom are therefore the twin pillars upon which modern civilisation is built. Where these two elements came together, an industrial revolution occurred and sustained economic growth took off.

This was an epochal event, whose profound psychological and societal consequences have not yet been completely absorbed. For tens of thousands of previous generations of human existence, dire scarcity kept human numbers in check. Starvation, illness, short life spans and material insecurity were the norm. Whenever additional resources were discovered and productive capacity increased a little, human numbers increased and this again whittled down average living standards to a basic survival minimum.

The dour clergyman-turned-economist Robert Malthus (1766–1834) made a name for himself by 'discovering' this dismal 'fact'. Alas, he wrote in the late 1780s, precisely when conditions began to change fundamentally with the industrial revolution. In the eight or so generations since, productivity and living standards have been raised persistently, first in north-western Europe and the overseas Anglo-Saxon 'offshoots' in America and Downunder, later also in Japan.

It is only over the past one or two generations that scarcity, in the strict traditional sense of the word, has also been overcome in a growing number of other communities. We now live in most unusual times in human history: 'the end of dire scarcity' for a growing number of fellow humans. Many economists now hold optimistic views of the future, namely that high living standards can spread to all and can continue to improve for everyone.

The theory of economic growth – a complex, evolutionary process – has preoccupied economists for many generations. Up to the middle of the 20th Century, many focussed on the accumulation of physical capital (as Karl Marx had done earlier). After this, others looked to the mobilisation of labour, skills, natural resources and the advances in technical knowledge. This was the era of neoclassical growth economics and model building, when OECD governments, the socialist camp and less developed nations alike were searching for a 'magic bullet' to raise the national growth rate (measured by real per-capita income).

Yet, an older tradition of economics looked to less mechanistic explications of the growth process. These economists focussed on the need for structural flexibility, since rigidified organisms do not grow. They saw entrepreneurship and innovation as the essential catalysts necessary to mobilise the proximate causes of growth, such as capital, natural resources or technology. And they asked why entrepreneurs were able to mobilise resources for growth in some societies, but not in others. The answer was that ultimately, a society's institutions (i.e. the rules of coordination, which range from ethical norms and customs to legislation and regulations) create an environment in which the resources are mobilised for growth, or are not if such institutions are absent.

What became known as the 'new growth theory' turned out to have been elaborated by the classical thinkers of the Scottish Enlightenment in the late 18th and early 19th Centuries. The core to explaining economic growth, then and now, is secure private property rights, free markets in which owners voluntarily use these rights, and the rule of law (in short: the institutions of economic freedom). Economists of that description consider the economy as a complex system in open-ended evolution. They make little use of abstract models. Neither does this brand of economics – now known as the 'neo-Austrian' or 'institutional/evolutionary economics' – shy away from making normative judgements about what is good or bad. Although this school of thought appears less 'scientific' than the neoclassical closed-system models, it has inspired economic reforms around the world since the 1980s and has been politically influential in advancing the present-day record of global economic progress.[6]

It now seems uncontroversial that the blessings of modern science and technology have become more accessible wherever economic freedom has been improved (Gwartney-Lawson, *passim*; Kasper-Streit 1998, chapters 13 and 14). Even the world's largest communist country, China, has meanwhile *de facto* privatised most agriculture and industry. It has also ensured a moderate protection of private property rights, which allows the people to revive old habits of competing.

On the other hand, the benefits of greater economic freedom have eluded all those whom private thugs and corrupt officials still deny private property rights under the rule of law (Soto 2001). Lenin's and Mao's resolute attempts became costly failures when they tried to mobilise modern science and technology in order to lift the masses out of poverty through state ownership and central planning, but without private property and competing entrepreneurs. A rich literature about long-term economic history and intercultural comparison is now available to document the interaction between basic economic freedom and objective, rational scientific inquiry as the *only* means of generating durable, wide-spread affluence and indeed modern civilisation (for a good survey of the findings of long-term economic history, see Stokes 2001). Exhaustive factor analysis has demonstrated that some 85% of the inter-temporal and international differences in real per-capita incomes are associated with, and explicated by, differences in economic and political freedom (Roll and Talbot 2001). It is indeed the institutions that matter.

The growth of the world economy over the past generation has accelerated to an average of 3.6% p.a., a historically unprecedented record. The mature economies are growing somewhat less fast, while others are growing much faster – such as China and other

Asian countries who are in a process of catching up with the affluent, old West. In the West, the old spectre of acute scarcity has been vanquished. People no longer live in a Malthusian world, but take rising living standards for granted.

However, there are still vast income gaps in the world. For example, the average Chinese produces and consumes still only about one-seventh of what the average North American does. The emerging economies such as China and India are therefore driven by a resolute will to 'catch up'. Globalisation will enable them to grow at a historically unprecedented pace and to lay claim to growing amounts of natural resources. The impact on natural resource exploitation will be attenuated by the gradual slowdown of world population growth and a massive shift to less material-intensive services in the global product mix. Nevertheless, CO_2 emissions in the emerging economies can be expected to grow rapidly. India's $C0_2$ emissions are predicted to more than double between 2003 and 2030, and China's to rise by 2.5 times. The combined carbon dioxide output of these two and other non-OECD countries in Asia will be triple that of Europe in 2030 (US Energy Information Administration 2007a: 93).

It is inconceivable that the spread of modern economic growth could somehow be stopped any time soon. It is completely unlikely that a global political compact could be reached even to slow the pace of global economic growth to stabilise greenhouse gas emissions. For the foreseeable future, much energy will be needed to power humanity's economic progress and most is bound to come from fossil fuels. Nor do we need to worry about global energy shortages (Huber-Mills 2005). Compulsory restrictions on the use of fossil fuels would not worry the post-modern children of affluence, but the world's poor and their governments, such as those of Brazil, South Africa, China and India, will certainly not allow their aspirations to be hampered.

The track record of the doomsayers – and economic progress

The extraordinary experience of material progress has not stopped doomsayers from regularly predicting an imminent end to it all. This appeals to many, in whose hearts and minds the very long-term human experience of dire scarcity lives on, as well as to scientists, who know that every closed system will succumb to eventual entropy. As discussed, Robert Malthus had us believe that human numbers would always be limited by the cold, cruel hand of scarcity. He was wrong. Likewise, Karl Marx – a great admirer of the creative energies of early bourgeois, capitalist society – prognosticated that the capitalist system would collapse due to capital saturation. Marx maintained (Figure 19) that successive additions to the capital stock (ΔK) would produce decreasing marginal additions to the national product (ΔO^* being smaller than ΔO in Figure 19). This would turn initial profitability eventually into terminal, system-destroying losses.[7]

Marx, too, turned out to be completely wrong: The market economy did not move along a given production function with ever-decreasing returns toward a 'crisis of capitalism'. Instead, free enterprise harnessed the growing software of scientific, technical and organisational knowledge to expand economic opportunities. New skills and new demands arose and some old 'hardware' was written off (what is often referred to as 'creative destruction'). Periodic crises occurred, but were always overcome by entrepreneurs who improved technology and industrial organisation and offered new, unimagined products (Kasper 2005; 2007).

Thus, rail and shipping networks of the steam era, when they reached their saturation points, were complemented and partly replaced by lorries, and later air transport. Today, we transport ideas nearly effortlessly and instantaneously around the globe thanks to the synthesis of computer and communications technologies. In the evolutionary process of competition, the capitalist system marches on.

Entropy is continually being postponed in the market system because there is spontaneous, competitive innovation when the right institutions enable entrepreneurs to test and utilise new knowledge and change production structures. Marx's static model misled generations of policymakers, when in reality production functions have become a movable feast. (As illustrated in Figure 20, we have not moved from point A to point B when adding hardware ΔK – capital,

Figure 19 **Capital accumulation and entropy**

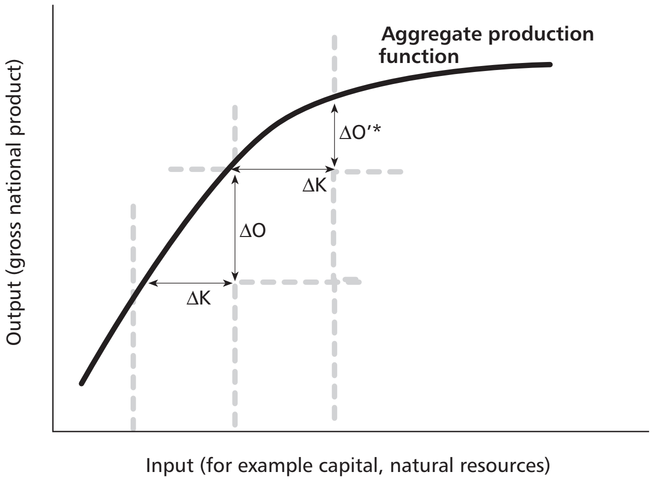
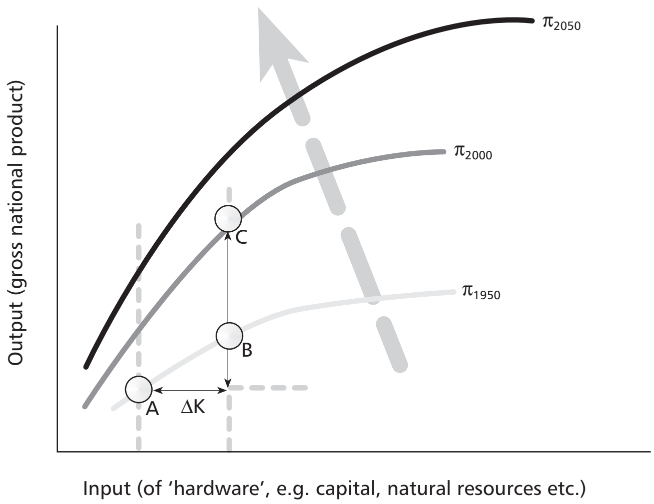


Figure 20 **Science, technology and enterprise have turned the production function into a movable feast**



The growth of the 'software of economic development' (knowledge, structural flexibility, entrepreneurship and institutions) is ceaselessly shifting aggregate production functions upward.

natural resources etc. – over the past fifty years, but instead have moved to a much higher production point C, thanks to improvements in the 'software of development': knowledge, entrepreneurship, institutions).

Karl Marx's simple error is often repeated, explicitly or implicitly, when natural scientists and other critics look at economic growth and stipulate eventual entropy. However, for a long time to come, we can rest assured that the economic system is open and that new 'software' will save us from terminal doom.

The ideas of Malthus and Marx have underpinned more recent messages of doom – from Oswald Spengler's *Decline of the West* in the 1930s, the 'Club of Rome's' prediction that the world was about to run out of raw materials in the 1970s, and more recently, the heavily promoted book *Collapse* by Jared Diamond of the WWF.

Yet these too are misinformed on the same point. Human creativity and innovating entrepreneurs overcome feared crises, and with hindsight we do not even understand those fears. Who, for example, can still understand why the 'Club of Rome' garnered so much airtime with its prognostication that India was going to face mass starvation in the 1980s? Look at India now! And look at the fact that nutrition levels around the world have increased enormously and that virtually all raw materials are now cheaper than ever before. The human condition has never been better (Simon 1995; Moore and Simon 2000).

The growth of the 'software of economic development' (knowledge, structural flexibility, entrepreneurship and institutions) is ceaselessly shifting aggregate production functions upward.

History certainly has proven the doomsayers invariably wrong. The presumption in the present climate panic therefore must be scepticism in the face of any predicted disaster. Maybe cheap, zero-emissions energy will soon be available, maybe from nuclear fusion, maybe from fuel cells fed by tide- or wind-generated hydrogen (Huber-Mills 2005). We can never know what lies ahead. It is not implausible that we will later look back on the climate scare at the beginning of the second millennium with the same bewilderment that we now experience when we read of the forebodings in the 1880s that the world was about to run out of whale-oil, so essential to modern lighting, and that horse manure would become an intractable threat to the traffic and public health of Londoners and Parisians! Of course, optimistic expectations that entrepreneurs will always sooner or later overcome bottlenecks to continuing economic growth can never be 'proven' before they become reality.

Threats to science and freedom

Optimism about the future of humanity inspired by modern economic theory and long-term economic history needs to be tempered by the fact that we can never take material progress for granted. Objective scientific inquiry and entrepreneurial innovation can easily be stifled. In affluent, post-modern societies, objective, critical science and economic freedom already count for less than in earlier ages and 'techno-fixes' and global cooperation are frequently attacked.

The *zeitgeist* now appears to favour collectivism. At least most politicians do, which is not surprising as they are in the business of providing collective solutions, and benefit from interfering with individual pursuits. Political activism in Western democracies now habitually weakens property rights, the freedom of markets and the rule of law. Most accept this with indifference. In addition, the competitive capitalist system with its relentless challenges is uncomfortable; little wonder it has many enemies. Soviet-style socialism may be dead, but the collectivist assault on the productive system rolls on under different guises.

In the affluent, post-modern West, both pillars of modern civilisation are therefore now under threat, primarily because of the very success of the new affluence. Since the traditional condition of dire scarcity has ceased to pose an ever-present threat to people's wellbeing, we have observed a rise in relativism and spreading indifference to the conditions of progress. The affluent beneficiaries of sustained economic growth are frequently given to neo-romantic dreams and show no interest in understanding the foundations of our affluence (as outlined above). Institutions with sanctions for violators – such as secure property rights – are out of favour; self-seeking opportunism and fantasy are in. Such long-term consequences of the new affluence were foreseen by the great Austrian-American economist Joseph Schumpeter who – in the darker mood of his old age – feared the downfall of capitalism, because a new class of affluent pleasure-seekers would jettison the very institutions that underpin the capitalist success (Schumpeter 1947; Taverne 2005). They have a point.

In the West, secure private property rights are – it is true – no longer threatened by wholesale, Soviet-style expropriation, but we witness almost daily attacks on individual property rights by stealth. For example, elected parliaments prevent landowners from deciding freely what to do with their assets by proliferating land-use and environmental regulations, and industrial-relations legislation habitually prevents people from using their labour and skills as they see fit. Thus, property rights are nowadays being socialised piecemeal, one step at a time. Property is, after all, not the physical possession of an asset, but rather the source of an open-ended bundle of rights to make the best possible uses of what one owns, often by combining one's own rights with the property rights of others, for example a land developer or an employer (Kasper 2004). Even worse, parliaments and administrations confiscate individual property rights without just compensation.

Present-day governments have a tendency to assume that individual property uses cause others some harm. This is taken as a justification for placing the burden of proof on property owners that no harm is caused by specific uses of their property. However, it is a fundamental characteristic of individual freedom that the individual does not have to *prove* his right to exercise it. In a free society, it is the affected claimant who must prove, with reference to the body of existing laws, that he has been unduly harmed (Jasay 2002; and forthcoming). When people must apply to some authority before they exercise a property right and prove that such an exercise is permitted, they are unfree serfs. Nonetheless, the proliferation of licensing, permits and regulations seems unstoppable in Western democracies.

The second pillar of our affluence – rational, objective science and modern technology – is also under attack. Post-modern generations seem receptive to romantic, irrational notions about nature. They often reject scientific insight in favour of unproven myths (Taverne 2005). Thus, the tested knowledge of conventional medicine is now often rejected in favour of naturopathy and new-fangled psycho healing, which is neither tested objectively nor critically reviewed by peers. Astrology and creationism are on the rise despite the total absence of scientific evidence supporting these belief systems. People are readily impressed by unproven scares, from fear of magnetic waves to hysteria about gene-modified organisms. Dubious assertions of crusading ecologists pass muster in special environment courts, where normal juridical scrutiny is suspended and the rules of due process are not applied. Peer-reviewed scientific evidence is often rejected in favour of shoddy, undocumented assertions by activist amateurs. Environmentalism often also conflicts with our time-tested constitutions, which have served the advanced countries well (Ratnapala 2007).

In the global climate debate, too, it is easy to find overdrawn assertions which have not been tested by the usual scientific methods of critical peer review, publication and repeated, documented experiment. Nor are many policy-relevant scientific assertions these days explicated by relating them to a body of accepted scientific principles.

The problem is further heightened by a new breed of committed activists who reject the whole notion of progress and capitalist cooperation. Their objective is to undermine economic freedom and our growing affluence. Paradoxically, that affluence has allowed people to adopt new and diverse priorities, such as environmentalism, to give meaning to their lives. The fear of global warming can then serve as the ultimate justification for rejecting our existing society and a crusade to create a new breed of man.

As the late American sociologist Aaron Wildavsky pointed out: "Global warming is the grandmother of all environmental scares..… [It] is capable of realising the environmentalists' dream of an egalitarian society based on the rejection of economic growth in favour of a smaller population eating lower on the food chain… and sharing a much lower level of resources much more equally" (Wildavsky 1992).

Other affluent Westerners are unhappy with the diversity and cynicism of modern, pluralist society and wish for a new, unifying purpose, a collective task with which self-appointed elites can inspire the masses. It is revealing that US climate campaigner Al Gore sees the global-warming challenge as "a compelling *moral purpose*; a shared and unifying cause; the thrill of being forced by circumstances to put aside the pettiness and conflict that so often stifle the restless human need for transcendence… Those who are now suffering from a loss of meaning in their lives will find hope" (Gore 2006: 11, italics original). Similar motives to provide collective salvation induced Napoleon and Hitler to embark on wars, Roosevelt on the New Deal and Johnson on launching the 'Great Society'. All these collective ventures ended in tears.

The fact that all past doomsday scenarios have turned out to be wrong has never deterred 'the Annointed', as American economist Tom Sowell called them. They quickly drop one cause if that turns out to be mistaken and hasten to adopt another, always advocating collectivist, top-down solutions (Sowell 1995). They never seem to learn that competition among free individuals is most likely to overcome bottlenecks and offer feasible solutions.

Rent seeking for beginners

The present climate activism does not need to be explained by speculations about mass psychology, the *zeitgeist* of our prosperous times or the search of some for the ethereal meaning of life. Those versed in the economic discipline of public choice can readily identify another powerful motive: 'rent seeking'.

Once upon a time, it was generally assumed that all agents of government acted in a disinterested manner to advance the public good. Likewise, it was assumed that producers tried to maximise their incomes by simply competing within accepted parameters of market conditions, laws, regulations and technologies. We now know that this is not so, because rent seeking is pervasive.

Rent seeking is defined as recourse to political means to obtain material advantages and incomes, which could not be obtained by purely economic competition in free markets. Rents are sought by well-organised groups who demand interventions by legislators or regulators in the market or changes in the rules. They hope that this will ease the pressures of competitive rivalry and distort prices in their favour. The demand from rent-seekers is often met eagerly by suppliers of such interventions, who expect political support, party donations and maybe even corrupt payments in return; they may even have an ideological predeliction that coincides with the interests of the rent seekers.

Markets are typified by a few suppliers and many buyers. The few suppliers therefore have a concentrated interest in attaining artificially higher prices. Because they are small in numbers, they organise themselves to lobby; in contrast, the many buyers each face relatively small material losses from such interventions, and have little incentive to organise themselves against supplier lobbies.

For example, a government that imposes a car tariff will allot massive additional profits to the few car producers and marginally disadvantage the many buyers, who may buy a car only every five or seven years. If such privileges proliferate, the long-term consequence is that producers compete less avidly with innovative ideas (product and process innovation). Then economic growth slows down. Not only are the many buyers unfairly disadvantaged by higher prices, but all suffer losses in growth opportunities (Robertson 2006).

The observation that producers compete not only with technical and economic performance but also with political lobbying is one of the most important contributions to economic and political science over the past half century. (For a good introduction to public choice theory and rent seeking, see Buchanan 1978; and Gwartney, Stroup, et al. 2006; for more references see Kasper 2007: 46–50).

An important aspect of rent seeking is that politicians and their clients nearly always disguise their true motives by invoking the 'common good'. Thus, the tariff is 'sold' to the electorate as a scheme to grow industrial capacity and create or protect jobs, or to provide national security. Never mind that none of these objectives have ever been met by protectionism over the long run. Deception is part of the game.

Seen from a slightly different angle, public choice and rent seeking are part of the eternal fight between individual autonomy and spontaneous coordination, and collectivism, political power and self-appointed elites that play coercive political games. The collective push is rarely held in abeyance. There are of course legitimate causes where competitive individual efforts tend to fail, for example in national defence. But the proponents of collective action regularly expand into the terrain where collective action is counterproductive in purely economic terms.

Political agents find fertile ground for expanding their power in the area of environmentalism, where individual actions can have external effects that justify some collective intervention. They frequently brush aside methods of least possible damage to economic freedom to attain agreed public purposes in favour of coercive, interventionist policies. This is why sound policies are so often distorted by rent seeking that destroys the dynamic efficacy of the market system.

To most natural scientists, concepts such as public choice and rent seeking are of course unfamiliar. They therefore fail to understand that social scientists and the public are cynical about the climate advocacy of recent years, which they view as a case of massive rent seeking. This is the main reason why economists are recalcitrant to uncritically accept the assertions of the climate activists.

Widespread rent seeking also explains the public's cynicism about democratic government. An increasingly better-informed public knows instinctively that interventionism boils down to a gross violation of their fundamental freedoms, in particular their property rights and the freedom to use their assets as they see fit, as long as others are not harmed. Pervasive rent seeking is counterproductive in economic terms, as well as profoundly unjust. To the extent that arguments about global warming are detected as just a new excuse for rent seeking, they will be treated with disdain and contempt – regardless of their scientific merit.

For a long time, it was assumed that scientists are above such political selfishness, interested only in finding and testing the truth about natural phenomena. They have developed a strong professional ethic and relied on accepted scientific methods – an image, which the scientific community has of course cultivated.

Now, we observe that not only politicians but also the practitioners of science are not above the opportunistic pursuit of advantage by political manipulation. In science, for example, political ends seem to justify shortcuts with accepted scientific methods, thereby skewing the published findings. The competition for research funding, much of which comes nowadays from politically manipulated budget resources, all too frequently acts as an inducement to rent seeking by means of not-quite-objective research. Scientific establishments are nowadays typically led by savvy political operators, who are more interested in promoting their organisations than the scientific truth. Alas, scientists are, after all, as opportunistic as everyone else, if they can get away with it.

Such aspersions are of course greeted by scientists with dismay. When this was bluntly stated on the recent television programme *The Great Global Warming Swindle* (Durkin, 2007), it lead to widespread moral outrage among some climate scientists, but produced no substantive refutation. Meanwhile, the scientists interviewed in the programme treated the debate as purely scientific. Unfortunately, they too missed the public-choice point, namely that political demand for global warming theories is expressed by copious research funding and produces a ready supply of such theories by eager scientists.

Rent seeking, climate concerns and socialism

A critical look at the current climate debate easily reveals particular self-interest and robust rent seeking. Scientists, who must rival with many other pressure groups for scarce tax dollars, often realise that nothing is a better attention-grabber than the announcement of a potential danger which their research can fix, if only it is funded generously. Some of the brightest scientific minds have cooperated to convince the public and politicians that more climate research is the way to save the world.

The vehemence and impatience with which the global-warming protagonists now try to railroad the public and politicians into accepting the need for massive and costly action seems in itself an indication of rent seeking. As so often is the case, subsidy seekers find willing rent- and subsidy-creators in politicians and bureaucrats, who see career opportunities and greater power in adopting the new cause. Political action mobilises financial resources for those scientists who help to convince the public that political subsidies and interventions are indeed needed to avert a threat to humanity – the rent seeking machine thus feeds upon itself!

This is all the easier because the issues are complex, and span disparate fields of specialist science and political economy, so that citizens can hardly judge the veracity of the arguments. As usual the media and political attention seekers, from Gorbachev to Gore, jump on the bandwagon, all the while making us believe that they act for the public good and not their own gain. Thus, we now see ourselves confronted by rock and film stars who organise huge public events, telling us that "life on earth is endangered". They profit greatly from the campaign. Is this anything but pure, opportunistic rent seeking?

Frequently, assertions by scientists reveal blatant attempts at rent seeking. Thus, the 'hockey-stick' controversy was one give-away that the IPCC is not primarily interested in just analysing the scientific data, but in spinning a political message. The 'hockey stick', which appeared in the IPCC's Third Assessment Report, was derived by complicated statistical transformations of the raw data and was used to indicate accelerated warming over the past century. However, inquisitive scientists fed random data in the model that had yielded the famous 'hockey stick' – and still obtained a hockey stick (McKitrick 2003). What conclusion other than political intent can be drawn from this?

More recently, climate activists have come up with the 'tipping point theory'. Whereas a time-tested tradition in climate science was to consider the global climate as a system with self-stabilising characteristics, the 'tipping point' school considers the global climate as an inherently unstable system. According to this opinion, moderate temperature increases create cumulative greenhouse gas releases that drive up temperatures further, so that human life as we know it would soon be endangered.

US climate scientist Roger Pielke recently pointed out in a lively on-line discussion of the tipping-point theory among climate experts that "while the climate system does have 'tipping points', the reality is, since our knowledge of the real world climate system variability and change remains limited, that we do not know if human activity moves us closer or further from them."

(Pielke, 2006; also Rial et al. 2004) It seems certainly a gross exaggeration to claim that only small human populations will be able to survive in what is now Antarctica (Lean 2004). Such untested assertions again point to transparent political spin-doctoring.

The climate scare has also been embraced by political leaders of all stripes as well as international organisations in search of more influence. The European Union – whose draft constitution rejected 'free and undistorted competition' and who has made 'neo-liberal' a term of political abuse – is deftly using climate concerns to expand its political influence. And the huge, unelected United Nations bureaucracy, confronted with regular failures in its primary roles of ensuring human rights and international peace, appears to have discovered its salvation in managing global emission standards. It now advocates planning methods and mandatory top-down controls that conflict with the protection of basic human rights, of which economic freedom is an integral part.

In Europe and other mature industrial locations, tax and regulatory cost burdens – most notably the welfare state – have seriously handicapped industrial competitiveness. Western Europe's remaining industrial core now specialises predominantly in turning cheap imports of raw materials and labour-intensive components into sophisticated manufactures. For example, imported aluminium is turned into automobile components. When firms in high-cost locations are under cost pressure, it makes political sense to try to inflict additional costs for energy use on sophisticated competitors in America or China. It also makes sense to grant exemptions under the Kyoto Protocol to unsophisticated raw material processors who supply European industry with raw materials, but cannot compete with it in markets for the sophisticated end products.

This kind of opportunistic policy – a lesson in how to handicap competitors with global regulations – is also being pursued by the EU through bans on gene-modified agricultural products and its chemicals policy (Kasper 2007: 59–63). In all these cases, protection is never mentioned and the political opportunism is disguised by reference to scares that have no foundation in proper scientific analysis.

Scientific and industrial observers, who probably do not feel confident to side with one radical view or the other on global warming, accept that there is *a risk* of growing costs to humanity through global warming. They argue that it is wise to avert the risk by restraining man-made greenhouse gas emissions. At first sight, this sounds reasonable and plausible. But a mere, remote possibility is not a probability, which rational policy should tackle. Further analysis shows that this violates the basic economic principle that we must always weigh probable risks and costs against predicted gains. Looking at the potential costs alone yields a distorted picture. Entrepreneurs engage in cost-benefit analysis and assess expected profits before incurring risks. By contrast, politicians, who have recourse to compulsory taxation and regulation, do not. And bureaucrats tend to shirk risks, because they can rarely appropriate the gains from risky decisions.

Thus, a heavily politicised community foregoes the benefits of proper economic assessment and economic freedom, which are many – from a longer, healthier life and lower child mortality, to easier work, greater comfort, better education and greater civil and political liberty (Gwartney-Lawson, *passim*). These benefits of course carry greater weight in emerging economies, like China and India, and in poverty-stricken regions of the world, so that we cannot assume that they will sign up to costly measures to address the mere possibility of global warming.

The argument of risk-avoidance irrespective of cost makes sense to people who are not exposed to the full costs and benefits of their decisions (the normal course of affairs in competitive markets). Many an industrial and mining spokesman (or woman) will be inclined to highlight the climate risks of coal use, for instance, once governments make subsidies available for 'clean coal'. They will also know that restrictions on mining coal confer certain monopoly powers to existing miners, which will translate into higher profits. They will be guided by new subsidies to implement schemes – such as windmill farms and parks of solar panels – which make no economic sense. The fact that many big energy companies have joined the 'global warming fraternity' cannot be seen as proof that they have accepted the IPCC position.

Climate activists will of course reject such public choice considerations, but the lessons of public choice economics cannot be dismissed lightly.

The political opportunism and rent seeking bias in the IPCC has been attacked by individual scientists, who have been put off by the politicisation of their research. The IPCC, whose reports are produced at immense cost and involve a busy schedule of conferences and meetings in pleasant places, draws on the work of thousands of climate experts, many from government agencies. But it is controlled by a small group of UN-appointed officials.

The IPCC has also been found guilty of "spin-doctoring" by a team of observers led by Ross McKitrick, who took the trouble of comparing the available evidence in Working Group I of the IPCC's Fourth Assessment Report with the conclusions of its official 'Summary for Policymakers' (McKitrick et al. 2007). The Summary – the most influential IPCC output in steering public and political opinion – is the product of bargaining among member governments. It reads as if the conclusions were decided before the whole evidence had been reviewed (Henderson 2007). This would not be the first such occurrence of misuse of scientific advice by policymakers. If the facts do not fit the intent, too bad for the facts!

The McKitrick team, whose work was critically reviewed by more than fifty international scientists, found no compelling evidence of dangerous or unprecedented climate changes and concluded that public perceptions of more extreme weather conditions were due to more media coverage of such events. One conclusion was: "Attributing an observed climate change to a specific cause like Greenhouse gas emissions is not formally possible".

When independent and sceptical experts come to such conclusions, the IPCC's political intent seems transparently obvious. Its conclusion that recent global warming is mainly caused by economic activity, prosperity and CO_2 generation has been taken up eagerly by self-aggrandizing politicians, bureaucrats, rock stars and the media.

Nations are not organisations whose actions should be planned

It has often been observed that rational, centralised planning appeals to scientists and engineers, who view the spontaneous coordination of actions in the market as disorderly chaos. In reality, markets also establish order, but in different ways. Market coordination is spontaneous because all participants obey shared rules – like flying starlings or swarming fish that proceed a dynamic order without a controller or commander. Order results when participants communicate ceaselessly and avoid conflicts.

Most observers with a scientific or engineering background are inclined to a system of coordination akin to a centrally designed and controlled train timetable, rather than the rules-based coordination of independent motor cars. Many do not seem to comprehend the working of the invisible hand. They prefer instead some high-minded, well-informed authority to sort out all necessary information prior to any action, and to control all subsequent actions. Of course, we as individuals normally plan the actions in our daily lives by first reviewing the necessary information, and weighing available alternatives in the light of our preferences. Firms do the same before launching a new product or process and periodically when they revise their business strategy. It would be irrational and costly to proceed otherwise.

But entire nations – let alone the entire world economy, as in the case of global greenhouse gas management – are not organisations like firms. A nation is an association of free individuals, not employees of a government whose orders they must obey. The citizens are the principals, and the government is but their agent. Equally importantly, the information requirements for making nation-wide plans are infinitely greater than when individuals or firms make a plan. We deal here not only with technical knowledge, but also with changing and spatially diverse bits of information, often of an implicit nature, that no one single mind or committee could ever hope to master and utilise (Hayek 1945; Hayek, 1973–1979).

Economic systems are not static or closed, but evolve with complex feedbacks and unintended consequences.

The conditions for certain decisions and actions mutate and influence variables, which in turn feed back into the original decisions and actions (Kasper-Streit 1998: 44–59 and 134–161). As discussed, the neoclassical brand of economics has a tendency to abstract from open evolution in order to simplify the subject matter, and econometricians make assumptions that typically close the economic system so that they can obtain mathematical solutions. This orthodox tradition of economic analysis misses a key point about national economies over the long run: economic life evolves in unpredictable ways, and no past trend or regularity foreshadows the surprises of real-life evolution. Natural scientists and aspiring climate managers should take note.

A separate issue with planning is motivation and agent opportunism. When people are self-responsible and entrepreneurs pursue their own profit, they weigh costs against expected gains and ensure that the two are commensurate. By contrast, a plan bureaucrat faces lopsided incentives. If he risks an innovation which succeeds, he may get a medal, but cannot appropriate the material gains. But when a risky innovation fails, he faces demotion and reprimand. In other words, planning agents behave rationally when they are risk-averse. As a result, innovation and hence economic growth is narrower and slower under central planning and command.

Yet another problem endemic in central planning, as compared with the free market order, is that information is sifted *ex ante,* and just one solution is selected. This goes at the expense of diversity. However, humans have diverse wants – Mao suits for all may have been technically efficient, but made the Chinese unhappy. Diverse alternatives which are allowed to compete in the market are often the seed for solutions that prove useful only later. If a central planning committee in 1895 had picked steam engines to propel cars (at the time this technology looked promising), then we would not have today's car industry. And a planning committee in charge of airplane development would never have been able to implement the myriad ongoing innovations that changed the contraption of the Wright brothers into the Dreamliner in the short span of just 100 years.

It is therefore no coincidence that Soviet-style central planning was such an abysmal failure. Plan bureaucrats lacked the necessary information (which market prices signal promptly in the capitalist system) and often neglected to act even on available information. The planned economies ended in stagnation and chaos, as technology and the division of labour became more diverse and more complex. In contrast, self-interested market participants cope with these conditions effectively because they coordinate their actions spontaneously in response to frequently changing price signals.

These conclusions are in principle clear and generally accepted. Nonetheless, climate technocrats and self-seeking climate managers are now often falling back on the methods of central planning. They confound everyone's experience of micro planning with the macro task of planning global industry and transport to attain certain emission targets. Educators, too, simplify the global-warming problem, as if anyone could know the number of gigatons of CO_2 which need to be eliminated, by which industries and in which regions.[8]

Everything that should have been learnt from the Soviet experience and its Austrian-economics critique is glibly ignored. Most rich-country governments have subscribed to the Kyoto Protocol, which has all the hallmarks of central planning. The multi-objective pursuit of happiness is being denigrated as consumerism and the rich diversity of human aspirations is replaced by stifling carbon targets. Target setting has become a measuring rod by which Greens are judging the quality of a government's global-warming policies. We are in danger of, again, repeating the Soviet experience of applauding good-looking targets because we confuse mere target setting with genuine achievement.

The cause of emission reductions would be better served by pragmatic, market-directed initiatives, such as the Asia-Pacific Partnership on Clean Development and Climate, than on grandiose international accords for a treaty among more than one hundred governments, which no one can enforce.

Another problem endemic in planning is that the planners rarely know at what level of prescriptive detail to stop. If a first plan goes wrong, they tend to conclude that, next time around, planning must be more perfect and more comprehensive. Because planners need a closed system where the key parameters are known to them, they will try to smother open-ended evolution. They impose politically preferred solutions. Thus, nuclear and hydropower are rejected, whereas wind, geothermal and solar are heavily promoted, and this without any rational analysis of the relative long-term costs and benefits.[9]

When planners develop a habit of becoming prescriptive about specific details, they risk massive errors and inflict costly distortions on economic life. Thus, we now hear that air transport is a growing contributor to greenhouse gas emissions and that specific air-transport controls (in the form of 'green' passenger taxes, bans on air-freighting specific products, a reduction in new airports to be built, etc.) must be adopted. The governments of many affluent countries have also begun to provide costly subsidies for alternative energy generation such as windmills or photovoltaic panels. These are far from being economically viable, and induce consumers to buy technical apparatus which leaves a huge 'carbon footprint' even before the first quantum of 'clean energy' is collected. The subsidies are creating eager 'green companies' and other rent-seekers that lobby for more such distortive market interventions.

Industry- and technology-specific planning – with bureaucrats and lobbyists 'picking winners' – makes no economic sense. In competitive markets, investors compare the marginal costs of *all* methods in *all* industries to find the most cost-effective way of avoiding CO_2 emissions.

Central planning under political auspices is unavoidably liable to political rent seeking and corruption. This has already become clear under the Kyoto Protocol, too. European governments, its main promoters, 'awarded' Russia huge carbon credits on the grounds that Siberia had large taiga forests. In reality, this was of course done to bribe Russia to sign the Protocol.

When they introduced cap-and-trade systems for carbon control, European governments readily yielded to the temptation of handing large quantities of 'carbon emission rights' to certain favoured industries (Open Europe 2007). When these are traded, they become valuable financial assets. Economists, however, know that trading of such rights only serves its purpose if independent, incorruptible experts fix total quotas, for example as was done to limit the Icelandic fish catch. The recent European experience of national governments competing with each other in handing out emission licenses was a far cry from such an independent and objective standard.

The issues of knowledge and moral hazard multiply when planning is done not just for one nation, but the entire world economy. The knowledge problem is then overwhelming. Enforcement against national resistance is illusory. The EU cannot even enforce the budget targets in its Stability Pact against the opportunistic leaders of the major European countries. The UN is so demonstrably toothless vis-à-vis any agreement-breaking nation, let alone the big powers, that it is inconceivable that a UN 'world government' could monitor emission target compliance, let alone enforce sanctions for violations.

Conclusion

So, what can an economically literate observer conclude from all of this? First, the scientific evidence on global warming is not yet settled sufficiently to provide a basis for potentially very costly and major policy initiatives. All we know is that global climate change may occur and that there are many ways to adapt to higher temperatures if these bother people or if they create hardship. In the meantime, we should of course monitor all available evidence on global temperatures and not squander energy unnecessarily.

A second conclusion is this: At a time when the creative powers of free-market capitalism are widely taken for granted or even denigrated, and when rent-seekers are on the lookout for new excuses to institute interventions that further their incomes, status and careers, we risk destroying the very foundations of our modern prosperity by implementing policies that destroy the free-market order.

The cost-boosting interventions which most Western governments are now implementing to manage emissions will be detrimental for economic growth and job creation. The West will lose competitiveness at a time when many new industrial countries are improving their institutions and raising their technical capacities. Many in the West now see China and India as an economic threat, because affluent, spoilt Westerners are understandably reluctant to join the competition with these emergent economies. The scene is set for a global tug of war between diverse national interests.

If the outcome were to be a concerted management of world industry and transport by UN climate planners, this would affect future prosperity throughout the world and our capability to cope with troublesome global warming. A UN-led global compact of the Kyoto kind will imperil individual freedom, individual property rights and openness.

This would be tragic for our children, grandchildren and the poor in the third world, for it would eliminate the single most effective means known to man to cope with emerging scarcities and challenges: economic freedom, openness and spontaneous competition. We must therefore resist those political and lobbying interests, who promote and exploit climate concerns for their own opportunistic ends. If we fail, climate control will soon become the most serious threat to individual freedom since the demise of Soviet socialism.

If the history of human enterprise (as well as the Austrian-economics research into competition and innovation) is anything to go by, a complex issue such as climate change is best addressed by spontaneous, independent reactions to credible market signals. Such signals will become evident as and when sufficient numbers of people are affected directly and adversely by global warming. Constructive responses will then be spontaneous, because numerous free, independent and property-owning agents will respond. There will be no need for 'climate change managers' – just as the starlings in the sky or fish in the sea have no need for a commanding general with a strategic plan!

Notes

1 Temperatures since the emergence of modern man some 200,000 years ago have been up to 7°C lower during ice ages than the 'global average in the Northern hemisphere' from 1870 to now, which covers the period since the spread of modern industry. A global average temperature is a difficult to establish concept, since regional temperatures vary so much. During the 'climate optimum' of the European Middle Ages, global temperatures were also 0.5°C higher than that average. During the 1990s, global temperatures were 0.4°C above the average since 1870 (source: Alfred-Wegener-Institute, Bremerhaven/Germany; see also: Singer-Avery 2007). Since 1998, the rise in global temperatures has apparently stopped.

2 The Stern model makes the mistake, which Karl Marx and neoclassical model builders made before, to assume that little technical change would occur in the future, in this case to mitigate carbon emissions. Instead, Stern relies on extreme assumptions and operates with worst-case scenarios. Another untenable aspect of Stern's prognostications is that he values the costs to future generations almost with the same weight as those of the present, despite the fact that future generations will be much more affluent and more capable to deal with warming problems than we are now. Veteran Yale University economist William Nordhaus criticised Stern's choice of such a low discount rate. He concluded that more conventional discount rates, as commonly used by individuals, governments and businesses, would wipe out Stern's alarmist conclusions. Stern's recent defence of his choice of discount rates seems to weaken his case somewhat, but does not convince (Stern 2007; Hamid, Stern and Taylor 2007; Carter et al. 2007).

3 Exporters of energy-intensive products, such as aluminium, are helping importing countries to avoid much of their greenhouse gas output. If global carbon-trading regimes are set up, should importers hand carbon credits to the world's specialists in energy-intensive products? At a time when everyone from the owners of the Siberian taiga to schools with green backyards is given carbon credits by eager politicians, this is a question worth discussing.

4 Instead, most EU countries rely on buying 'carbon credits' from third countries, which already indicates how hard it will be politically to get ordinary citizens in affluent societies to comply with even more stringent emissions targets.

5 The Stern Report's attempt to provide cost estimates for mitigation lacks credibility, because it was a transparent attempt to come up with very low costs for cutting emissions by making implausible model assumptions and ignoring observed facts (Carter et al., 2006, Part II).

6 The neoclassical orthodoxy, which often assumes 'perfect knowledge', lends itself to easy teaching and closed-system econometric modelling. It still dominates many economics departments and fills numerous textbooks and professional journals. The institutional-evolutionary brand of economics has, by contrast, found much acceptance in law schools, business schools and engineering courses, for the simple reason that it sees an explicit and valuable role for those who cultivate legal rules, take risks in business enterprise and are concerned with innovations.

7 This analysis is in the neoclassical orthodox tradition. It contains the assumption of decreasing returns to scale, which underlies much of the analysis, which took its inspiration from agricultural production at a time of little progress of knowledge. Some Marxian economists have imbued this assumption of eventual entropy – stagnation and the crisis of capitalism – even with a normative content, calling the end state "the Golden Age". Odd!

8 A good example is a simplistic, smart-alecky video presentation by the activist Swedish *Vattenfall* group on the internet <www.vattenfall.com/climatemap/>, which has become a popular teaching tool in schools.

9 If one were to undertake proper 'carbon accounting', one has to include in the equation the emissions necessary for production of the glass, metals and plastics, which windmills, photovoltaic cells, coal power stations etc. require.

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Biographies

Paul Reiter

Paul Reiter is a British scientist whose entire career has been devoted to the biology, ecology and behaviour of mosquitoes, the transmission dynamics and epidemiology of the diseases they transmit, and methods for their control. He worked for 22 years as a researcher in the Division of Vector-borne Infectious Diseases of the US Centers for Disease Control and Prevention (CDC). In 2003 he was appointed Professor at the Institut Pasteur, Paris, where he established a new unit of Insects and Infectious Disease.

He has led the entomological component of numerous field investigations of outbreaks of vector-borne disease on behalf of the US Government, the World Health Organization (WHO), and the Pan American Health Organization. He is a member of the WHO Expert Advisory Committee on Vector Biology and Control, and has served as a consultant to governments worldwide.

He has been actively involved in the international debate on climate change for more than a decade. He served as a lead author for the US National Assessment of Potential Consequences of Climate Variability and Change, and an Expert Reviewer for the Intergovernmental Panel on Climate Change Fourth Assessment Report. He is a frequent commentator in the news media on this and other issues that concern vector-borne disease.

Dr. Indur M. Goklany

Dr. Indur M. Goklany has worked on environmental and energy policy issues for over three decades in federal and state governments, and the private sector. He has written over one hundred monographs, book chapters and papers on topics ranging from climate change, human well-being, economic development, technological change, and biotechnology to sustainable development.

He has worked for the U.S. Department of the Interior, which manages 20 percent of the U.S. land area, and associated mineral, energy and water resources, the U.S. Environmental Protection Agency and the State of Michigan. He is the winner of the 2007 Julian Simon Prize. He was a visiting fellow with the American Enterprise Institute, and the Julian Simon Fellow at the Property and Environment Research Center in Bozeman, Montana. He has represented the U.S. at the Intergovernmental Panel on Climate Change and in the negotiations leading to the UN Framework Convention on Climate Change. His degrees, all in electrical engineering, are from the Indian Institute of Technology, Bombay, and Michigan State University..

He is the author of *Clearing the Air: The Real Story of the War on Air Pollution*, and *The Precautionary Principle*, and *The Improving the State of the World*, all published by the Cato Institute. Opinions and views expressed by Dr. Goklany are his alone, and not necessarily of any institution with which he is associated.

Douglas Southgate

Douglas Southgate specializes in the study of environmental problems in developing countries and has been a faculty member in the Department of Agricultural, Environmental, and Development Economics at Ohio State University (USA) since 1980.

Southgate has written numerous chapters and journal articles on public policies contributing to tropical deforestation, the economics of watershed management and related topics. Southgate is also the author of four books, including *The World Food Economy* (Blackwell

Publishing, 2006). Southgate has consulted in 15 African, Caribbean, and Latin American nations.

Brent Sohngen

Brent Sohngen is an environmental and resource economist, and has been a faculty member in the Department of Agricultural, Environmental, and Development Economics at Ohio State University (USA) since 1996.

Sohngen has written numerous articles and book chapters on the economics of climate change, forestry markets, and tradable pollution permits. In addition Sohngen has participated as an author on the Intergovernmental Panel on Climate Change. Sohngen is currently developing models to assess the implications of climate change on global demands for agricultural and forestry.

Wolfgang Kasper

Wolfgang Kasper is an *emeritus* Professor of Economics of the University of New South Wales. He worked first in Germany and Malaysia, and from 1973 in Australia, as well as in the USA and most of East Asia. Apart from his academic teaching, he has a long record of research and consulting for international businesses and governments. His main interest has been industrial (re)location and institutional economics, i.e. the role of customs, laws and regulations in shaping economic life. He was an early voice for economic reform in Australia and New Zealand, and has written widely on the role of secure private property rights, small government and economic freedom in promoting prosperity. In 1988, Kasper was elected to the *Mont Pelerin Society*, an international academy dedicated to the promotion of freedom. The author gratefully acknowledges helpful pointers and astute criticism from one anonymous reviewer; all errors of fact and judgement of course remain his alone.

Members of the Civil Society Coalition on Climate Change

The Civil Society Coalition on Climate Change comprises 41 member organisations from 33 countries.

Alabama Policy Institute, USA
http://www.alabamapolicy.org

Alternate Solutions Institute, Pakistan
http://asinstitute.org

Asociación de Consumidores Libres, Costa Rica
http://www.consumidoreslibres.org

Association for Liberal Thinking, Turkey
http://www.liberal-dt.org.tr

Bluegrass Institute for Public Policy, USA
http://www.bipps.org

CGC Forum, China
http://www.cgcforum.org

Cathay Institute of Public Affairs, China
http://www.jiuding.org

CEDICE, Venezuela
http://www.cedice.org.ve

Centro de Innovación y Desarrollo Humano, Uruguay
http://www.cidhu.org

CEPOS, Denmark
http://www.cepos.dk

CEPPRO, Paraguay
http://www.ceppro.org.py

CIIMA-ESEADE, Argentina
http://www.eseade.edu.ar/ciima/ciima.asp

CORE, USA
http://www.core-online.org

European Center for Economic Growth, Austria
http://e-growth.eu

Free Market Foundation, South Africa
http://www.freemarketfoundation.com

Frontier Centre for Public Policy, Canada
http://www.fcpp.org

Fundacion Atlas 1853, Argentina
http://www.atlas.org.ar

Fundacion Libertad, Panama
http://www.libertad.org.ar

Hayek Institute, Austria
http://www.hayek-institute.at

IEEP, Ecuador
http://www.ieep.org.ec

Imani: The Centre for Humane Education, Ghana
http://www.imanighana.com

Initiative of Public Policy Analysis, Nigeria
http://ippanigeria.org

INLAP, Costa Rica
http://www.inlap.org

Institut Constant de Rebecque, Switzerland
http://www.institutconstant.ch

Institute for Free Enterprise, Germany
http://www.iuf-berlin.org

Institute for Market Economics, Bulgaria
http://www.ime-bg.org

Institute of Economic Analysis, Russia
http://www.iea.ru

Institute of Public Affairs, Australia
http://www.ipa.org.au

Instituto de Libre Empresa, Peru
http://www.ileperu.org

Instituto Liberdade, Brazil
http://www.il-rs.com.br

International Policy Network, UK
http://www.policynetwork.net

Istituto Bruno Leoni, Italy
http://www.brunoleoni.it

Jerusalem Institute for Market Studies, Israel
http://www.jims-israel.org

John Locke Foundation, USA
http://www.johnlocke.org

Liberalni Institute, Czech Republic
http://libinst.cz

Libertad y Desarrollo, Chile
http://www.lyd.com

Liberty Institute, India
http://www.libertyindia.org

Lion Rock Institute, Hong Kong
http://www.lionrockinstitute.org

New Economic School, Georgia
http://www.nesgeorgia.org

New Zealand Business Roundtable, New Zealand
http://www.nzbr.org.nz

Tennessee Center for Policy Research, USA
http://www.tennesseepolicy.org

Civil Society Report on Climate Change

While global warming very likely is real and may well cause problems, the debate has become distorted by alarmists who claim that unless drastic and urgent action is taken, catastrophic climate change will decimate humanity. In response, some politicians and activists have called for dramatic reductions in emissions of these gases. Realising that such restrictions are not attractive to many poorer countries, the carrot of foreign aid is being offered and the threat of trade restrictions mooted. But are such policies the best way to address climate change?

This report, commissioned by a coalition of 41 civil society organizations across the world, seeks to offer a balanced assessment of the problem of climate change and to evaluate various policies.

Among the findings in this report are:

- An increase in global mean temperature in the range of 1 to 4°C would likely cause some changes to the geographical pattern of agriculture and forestry, but the costs of adaptation need not be substantial.
- If adaptation is not unduly restricted, production of food and other agricultural products, as well as forestry products, will keep pace with growing human demands.
- Human ecology and human behaviour are the key determinants of the transmission of infectious disease. Obsessive emphasis on climate is unwarranted because, given suitable economic circumstances, straightforward strategies are available to ensure the public health.
- Average decadal mortality and mortality rates due to extreme weather events have declined substantially since adequate record-keeping began in the mid-20th century.
- As with infectious and vector-borne disease, mortality from extreme weather events is far more strongly affected by the technologies deployed by humans – such as the construction of houses, roads, and dams – than by climate.
- Many actors in the climate debate seek private benefit at public expense, a well-established economic phenomenon known as rent-seeking.
- The main UN agencies with a remit to address climate change, the IPCC and UNFCCC, are not impartial. The policies they advocate to address 'dangerous climate change' – dramatic short-to medium-term reductions in emissions of greenhouse gases – would be enormously costly and not very effective.

CGC Forum, China

Initiative of Public Policy Analysis, Nigeria

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