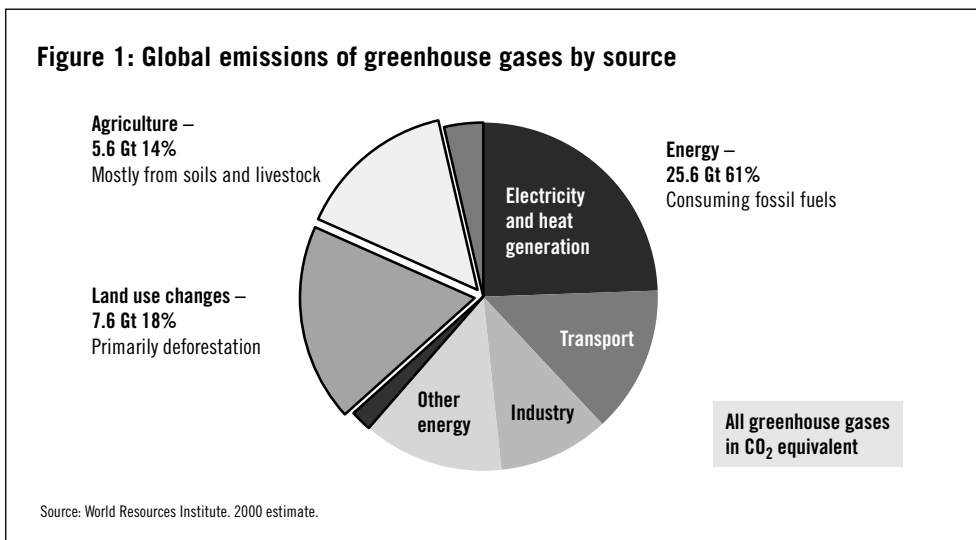


What is the Economics of Climate Change?

Nicholas Stern

The science of climate change

Climate change is a serious and urgent issue. There is now an overwhelming body of scientific evidence that human activity is causing global warming, with the main sources of greenhouse gases, in order of global importance, being electricity generation, land-use changes (particularly deforestation), agriculture and transport (see Figure 1); the fastest growing sources are transport and electricity.



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There do remain uncertainties about the nature and scale of long-term impacts, with wide margins of error. But it is clear that anything like business-as-usual will take us into dangerous territory. And the most recent science indicates that some of the risks are more serious than had first appeared. Some potential impacts could be irreversible and accelerate the process of global warming, such as the melting of permafrost, which could release huge quantities of methane. Such feedbacks could lead to global warming much greater than current projections, resulting in temperatures higher than anything in the past 50 million years.

The problem is global in its cause; greenhouse gases have broadly the same impact on the climate wherever in the world they are emitted. Effective action will require international collaboration. No region will be left untouched. But effects will differ widely around the world. Some of the greatest impacts will be felt in the poorest countries that are most vulnerable to the changes.

The basis of the science was established in the nineteenth century with the work of the French mathematician and physicist Fourier, the English physicist Tyndall and the Swedish chemist Arrhenius. Scientific work has accelerated in the past twenty years and international collaboration has been strong, particularly via the Intergovernmental Panel on Climate Change (IPCC). The evidence that climate change is in large measure anthropogenic and set on a very worrying path grows ever stronger. There are a few scientists who still dispute the argument and/or evidence, but they are a small minority and their positions become weaker as the evidence accumulates.

Recent estimates suggest that, even if emissions peak in the next decade or two and then fall sharply, the impact on global temperatures will still be very large (see Table 1). For comparison, the current concentration of greenhouse gases in the atmosphere is around 425 parts per million (ppm) of carbon dioxide equivalent (380 ppm carbon dioxide only), and it has recently been increasing by over 2 ppm each year. Because many greenhouse gases, including carbon dioxide, stay in the atmosphere for more than a century and the effects on climate come through with a lag, temperature and sea level will continue to rise during the twenty-second century, even if we stabilise emissions soon. Most of the damaging consequences of climate change are associated with water in some shape or form, including droughts, floods, storms, and sea level rise.

Table 1: Increase in global temperature for different stabilisation levels

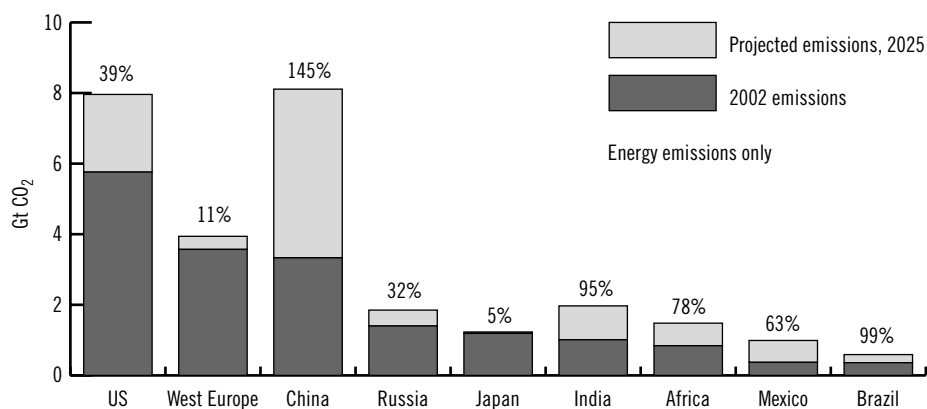
Stabilisation level (CO ₂ equivalent)	Temperature change by 2100 (relative to pre-industrial)		Temperature change at equilibrium (relative to pre-industrial)	
	Temperature change – based on IPCC 2001 climate models	Temperature change – based on 2004 Hadley Centre ensembles	Temperature change – based on IPCC 2001 climate models	Temperature change – based on 2004 Hadley Centre ensembles
	400ppm	1.2–2.5°C	1.6–2.8°C	0.8–2.4°C
450ppm	1.3–2.7°C	1.8–3.0°C	1.0–3.1°C	1.7–3.7°C
550ppm	1.5–3.2°C	2.2–3.6°C	1.5–4.4°C	2.4–5.3°C

Note: The ranges represent 90% confidence intervals
 Source: Based on den Elzen and Meinhausen (2005), 'Meeting the EU 2°C climate target: global and regional emission implications'.

The UN Framework Convention on Climate Change and the Kyoto Protocol provide a valuable basis for developing an international response but the time horizons for agreed action are short (2012) and thus the scale necessarily limited. Figure 2 shows

- (i) that rich countries dominate current emissions;
- (ii) that, without action to mitigate, emissions will rise strongly; and
- (iii) that emissions from developing countries are likely to rise more rapidly.

Figure 2: Current and projected emissions by country



Source: World Resources Institute, CAIT Energy Information Administration Reference Scenario, Energy emissions only

Taken together with the lessons from Table 1, this implies that both stronger ambition on the part of the rich countries and the involvement of developing countries will be necessary if emissions are to be substantially reduced.

The nature of the economics

Climate change, like other environmental problems, involves an externality: the emission of greenhouse gases damages others at no cost to the agent responsible for the emissions. The standard theory of externalities, under certainty, perfect competition, and with a single government, points to one of: taxation of the emitter equivalent to marginal social cost (Pigou); the allocation of property rights with trading (Coase); and direct regulation. But here we have many jurisdictions, weak representation of those most affected (future generations), long-term horizons, a global scale, major uncertainties, and important interactions with other market failures. Thus, whilst the standard theory can provide useful initial insights, we have a much deeper and more complex economic policy problem. We have a problem of intertemporal international collective action with major uncertainty and linked market failures.

This dictates the structure of the relevant economics. It must cover a very broad range, including the economics of: growth and development; industry; innovation and technological change; institutions; the international economy; demography and migration; public finance; information and uncertainty; and environmental and public economics generally.

From basic game theory, we know that, for example, policy requires the promotion of a collaborative solution to games with 'free-rider' problems: in other words, the international community, if it is to act effectively, must find a collective global way forward, building clear long-term international agreements within which markets and entrepreneurs can function. Building such agreements will require a shared understanding of their consequences, including what the agreements ask of each interested party and the equity issues involved. It will also require finding incentive structures to foster economic, social and political perspectives that can make collaboration more likely.

The nature of the problem in terms of its causes and effects implies that a broad range of ethical perspectives are likely to be involved, including issues of consequentialism, equity, fairness, justice, freedom, rights,

sustainability and stewardship. There are fundamental ethical differences among these approaches, but each would point towards a focus on similar measurable outcomes such as incomes, forms of capital and wealth, including the environment, health, education and ways of life.

There is much learning to be done about both the science and the economics. But the risks of severe outcomes and destabilising dynamics from the physical processes involved generate a powerful argument for strong and urgent action.

The economics of climate change

Hitherto, the economics of climate change has been focussed on modelling the implications of growth for emissions, examining and modelling the economics of technological options, calculating 'social costs of carbon', and exploring tax, market and other structures. Many elements of the foundations have been established. From the essential perspective of the international collective action problem, we must now focus on the analysis that individual countries will need to assess their own policy positions, together with an analysis of how to generate strong international action. If that analysis and understanding are shared and jointly endorsed, international agreement is much more likely.

Climate change and growth

In coming to a view on their own role, governments have an understandable focus on the growth of their economies and the health, environment and ways of life of their populations. Growth and climate change are highly inter-related: for instance, how will growth drive the sources of greenhouse gas emissions? How will climate change affect growth, both in the short and long run? How will growth processes involve and affect people in different circumstances? And how could the mitigation of greenhouse gases affect growth?

Current greenhouse gas emissions are on a dangerous path; energy-related emissions are forecast to grow, if we continue with business as usual, by over two per cent per year over the next thirty years, compared with a requirement to start falling within a decade or two if greenhouse gas levels are to stabilise even at a relatively high level (for temperature consequences, see Table 1) such as 450–550 ppm. The existing stock of

greenhouse gases is largely the result of past emissions from rich countries. They are the source of most of the problem, yet the impacts on developing countries will be of particular severity. However, most of the future emissions growth is likely to be in developing countries. If they are to play their part in international action, many would argue that equity demands that we find a way of tackling climate change that does not undermine growth and poverty reduction in these countries. At the same time, all countries will want to understand how the costs of mitigation will impinge on them, and in particular will seek to maintain or enhance their prospects for growth.

We also need to understand how growth may be affected by environmental deterioration in the absence of greenhouse gas control. Climate change has profound implications for the environment in which social and economic activity takes place, and can thus have similarly important effects on prosperity and human development. In human terms, developing countries are likely to be worst affected. They will be hit not only by increased variability (for example, suffering a greater incidence of both drought and flood) but also by a more adverse overall environment as temperatures rise. They will have to deal with this despite low incomes and often slim margins for adjustment. This combination presents a very serious challenge.

The importance of adaptation

Adaptation has the potential to reduce the impact of climate change. Over the next thirty years, substantial climate change is already inevitable, since mitigation will have only a minor effect on stocks of greenhouse gases in this time frame. So adaptation is an essential policy response, and the international community must find ways of supporting adaptation, especially in the most vulnerable countries. The origins and impacts of climate change (caused by the rich world, but affecting most seriously the poor) make the arguments for strong development assistance here still more compelling. In large measure, policies to promote adaptation, e.g. in terms of diversification of opportunities, will be closely related to those for development more generally, but some specific extra investment in terms of infrastructure, crop varieties and other areas and are likely to be important.

There are limits to the ability to adapt to fundamental and rapid climate change, in the sense that the human and economic costs could become

very large. Adaptation is particularly difficult when the precise nature and incidence of effects are uncertain. Adaptation and mitigation are not alternatives; we must pursue both. But the costs of each will influence the choice of policies for both.

Options for mitigation

Climate change is driven by greenhouse gas emissions from energy use, agriculture and deforestation. Effective action on mitigation is likely to require action including all three areas and in all sub-sectors of them; the Review will investigate a broad range of possibilities.

Energy accounts for about two-thirds of emissions. Reductions in emissions from this source depend largely on changes in the links from economic activity to energy intensity, and from energy intensity to carbon intensity. Measures to reduce the energy required per unit of output and income include altering the mix of economic activities and promoting energy efficiency. Reducing carbon per unit of energy will be largely down to technologies, many of which are already available, with more under development. They are nearer in power generation than in transport, and the demand for transport is growing still more rapidly than the demand for power. Our Review will investigate how far a focus on energy saving and on technologies could both cut through the many inefficiencies in the supply and use of energy and promote an era of discovery and innovation.

The policy framework to manage demand and pull new technologies through to the marketplace is crucial. For the development and deployment of many of the relevant technologies, the private sector will play a central role. It will require market structures and incentives that are *clear*, *long term* and *credible*. Innovation will be essential. The design of policy will require an understanding of the way in which fossil fuel markets work: the rent from the ownership of exhaustible natural resources is a central element, as is oligopolistic behaviour. Thus assessing the impact of tax and market measures is complex.

Key policy instruments shaping incentives include taxes, trading based on the allocations of property rights, and regulation. Where aggregate emissions targets are used, they will determine the sum of rights to emit. These property rights can be allocated over different time horizons and across countries, firms and individuals in different ways, resulting in different distributions of wealth and income. But, if they are to be effective,

they must provide the foundations for credible markets. Currently, all three of these instruments play a role in energy and environmental policy in most advanced countries. We will examine how they should be combined, and which institutional structures can support their effective use.

But we must go beyond incentives and the institutions that can support them and examine the possibilities for changing preferences and the behaviour they generate. This can happen through information, discussion and education. It has been a key element in several policy approaches that involve externalities, including recycling, water conservation, alcohol and smoking.

We must also ask how quickly current patterns of energy production and use can and should be shifted—and whether this can be done in a way that strengthens, rather than weakens, economic growth. We must examine the adjustment costs of moving towards low-carbon economies, including effects on the competitiveness of particular industries and the overall economy along the various possible paths.

Management of the issues of growth, pace of adjustment and competitiveness is likely to be more successful if groups of countries act together so that their economies adjust to changes in relative prices over a similar time period. Sectors in some industries subject to global competition might also benefit from international cooperation. In deciding on their positions on how to participate in international action and on how to implement their own responsibilities, countries will bring in criteria beyond implications for growth and competitiveness. These include, in the case of energy policy, security of supply and access to energy in developing countries. Decisions are likely to vary across countries since, *inter alia*, objectives, natural resource endowments, technologies, market structures and institutions may differ. Many measures to promote energy security, such as low-carbon technologies in electricity and energy efficiency, are likely also to promote reduction in emissions of greenhouse gases. A switch to coal on the other hand (if not combined with carbon capture and storage) might promote the former and damage the latter.

Both for equity reasons and from domestic financial pressures, developing countries are likely to seek external finance for the investments involved in their contribution to mitigation. The magnitude of the challenge and limits to overseas aid indicate that scaling up market mechanisms for promoting such investments is likely to be crucial. These are

likely to involve not only power generation, but also transport, agriculture and deforestation.

The role of uncertainty

Uncertainty is a key element of most aspects of climate change. The criteria by which decisions are assessed must take careful account of the degree of uncertainty, the long time horizons and the range of possible outcomes. The possible outcomes that need to be considered, which include major irreversible changes to the climate, are likely to be considerably beyond human experience hitherto. Such uncertainty over the scientific, economic and social consequences of climate change makes it especially challenging for international collective action to agree on greenhouse gas emission targets.

The pervasiveness of uncertainty will also influence the choice of instruments in terms of taxes, markets, property rights and regulation. For instance, are prices or quantities—tax or quotas—more appropriate policy instruments in the face of the uncertainty and asymmetric information involved? Uncertainty will also affect the pace and degree of action; how should we act when we know that we will be able to learn more in the future, when some possible effects are irreversible, and when some infrastructure investments are irrecoverable? And the existence of major uncertainty implies that taking simple approaches to discounting the future will be misleading and wrong. We will have to go back to the first principles of welfare assessment.

Responding to the global challenges: the basis for international action

Any effective response to the challenge of climate change must be based on an international understanding that its origins, impact, scale and urgency require action that is *global* and *collective*. In order to make sensible choices in building international agreement, all countries will need to understand the implications for them of adaptation to and mitigation of climate change in terms of their growth, competitiveness, security, public finances and environment. Most countries will, and should be, concerned also about the implications for others. The UK is no exception.

Thus analysis of these implications is crucial to inform and underpin international negotiations and agreements. It must offer a clear and, where

possible, quantitative understanding of the likely impacts of different courses of action in different countries and regions, and on different generations. Given their complexity, it will take some time to produce a strong body of research on some of these issues. But some broad directions and ‘orders of magnitude’ are already emerging. It is important for this economic and social analysis to proceed side-by-side with the science.

The *sustainability* of agreements will be crucial, given the potential damage that free riding can inflict on mitigation by others. A combination of methods is likely to be appropriate, including: international standards; treaty obligations supported by emissions quotas and/or taxes; technological lock-ins through infrastructure and other investments; placing climate change at the centre of the whole set of international engagements; public pressure, nationally and internationally; and the education of current and future generations. Building on the science, the economic analysis must provide *shared understanding* of the nature of the economic problems it generates, *inform* the international participants of the implications for them, and other parties, of different arrangements and find ways of *sustaining* a collaborative response to the challenge.

The Review will consider these issues, and will also look at how individual countries and regions, particularly the UK and EU, can play an effective role in fostering and promoting cooperation within this wider international context. International action requires both *leadership* and a *collaborative spirit*.