

What is the Economics of Climate Change? – A Response to the Discussion Paper by Sir Nicholas Stern

Geoffrey P. Hammond

Professor of Mechanical Engineering and Director of the International Centre for the Environment at the University of Bath, Bath. BA2 7AY. UK*

Summary

This response to the discussion paper by Sir Nicholas Stern, presented as the Oxonia Distinguished Lecture on 31 January 2006, builds on a recent paper by the respondent that deals with the determinants of environmental or ‘ecological’ footprints of nations from around the world (published in the United Nations’ *Natural Resources Forum* in February 2006). It showed that carbon emissions, environmental footprints, and measures of economic wealth, like the Gross National Income (GNI in purchasing power parity terms), are closely coupled. In looking to the future, the economics of climate change will ultimately be underpinned by ethical considerations. International negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have implicitly relied on the notion of an ‘Earthshare’ – that each citizen of “spaceship Earth” should in the long term be entitled to emit an equal share of ‘greenhouse’ gases at a level that will stabilise global warming at an acceptable level. But given the existing disparity of wealth between and within nations on the planet it is unlikely that humanity could converge to equal shares of carbon dioxide (CO₂) emissions in the 21st century. It is emphasised that notions like the Earthshare, and the strategy of ‘contraction and convergence’, are ethical constructs that look unlikely to be accepted by politicians in the United States. The US Congress has shown no willingness (under either the Clinton or the present Bush Administrations) to adopt climate change mitigation policies that will reduce their economic prosperity and standard of living in the foreseeable future. If future climate change negotiations are to be successful they must embrace large emitter countries like the USA, but also the rapidly industrialising countries like China, India and Brazil. These representatives of the ‘Majority South’ are unlikely to engage in such negotiations until they perceive that America is doing likewise. It is argued here that (i) the analysis of national environmental footprints and *per capita* CO₂ emissions indicates that they are principally linked to the wealth of nations; (ii) an acceptance of this link, as well as the need to safeguard economic prosperity, in international climate change negotiations may make it possible for countries like the USA and Australia to engage in future climate mitigation discussions; and (iii) insights derived from environmental footprinting, such as the need for humanity (and, more debatably, individual countries) to live within biocapacity limits, may aid such post-Kyoto negotiations. Such national biocapacity-related constraints could be included within a modified ‘contraction and convergence’ quota allocation scheme.

* Tel.: +44 1225 386168; fax: +44 1225 386928; E-mail address: ensgph@bath.ac.uk

1. Introduction

Energy sources of various kinds heat and power human development, but they also put at risk the quality and longer-term viability of the biosphere as a result of unwanted or ‘second order’ effects¹. Many of these side effects of energy production and consumption give rise to resource uncertainties and potential environmental hazards on a local, regional and global scale. Most environmental concern has recently focused on global warming¹. In the UK some 95% of carbon dioxide (CO₂) emissions, the dominant ‘greenhouse gas’ (GHG), are attributable to energy use, including transport. For a proper understanding of such issues the author² has argued that it is necessary to employ a range of analytical techniques that have been developed under the umbrella of several different scientific, engineering and social science disciplines. To do otherwise than adopt an interdisciplinary, systems approach is to run the risk of missing some important element in the broad environmental canvas. Thus, the international community needs to ensure that a global consensus is in place that seeks to balance the first and second order consequences of the available energy options, including both ‘capital’ (finite fossil fuels and uranium) and ‘income’ (renewable energy) resources. It should also strive to reconcile the pressures induced by the move towards competitive markets with the requirements of a sustainable energy strategy¹.

This response to the discussion paper by Sir Nicholas Stern³, presented as a Distinguished Lecture at the on 31 January 2006, builds on a recent paper by the respondent⁴ that deals with the determinants of the environmental or ‘ecological’ footprints of nations from around the world (published in *Natural Resources Forum*, the United Nations’ Sustainable Development Journal, February 2006). The paper was submitted in evidence to the Stern Review because of the links between the subject matter and issues such as national carbon ratios, economic development, and post-Kyoto Protocol international climate change negotiations. This piece of work was curiosity-driven, but it has a number of potentially controversial implications for the global environmental debate, and for climate change negotiations specifically. It highlights those nations that are relatively frugal or profligate in terms of their consumption of resources and environmental impacts (see Fig. 1). [Details of the analysis, as well as the uncertainties involved, are described by Hammond⁴.] Here environmental footprints are judged against that expected for a given national income or population density. The United States of America (USA) comes out of this study rather better than some environmentalists would expect. It sits exactly on the correlation line – indicating that it consumes no more than would be expected for a country of its wealth and population density. There are other nations, including the UK, who are more profligate. Likewise, although the USA exceeds its own ‘biocapacity’ (see Fig. 2), there are many other nation States that have much greater overshoot ratios. Consequently, the USA might be able to utilise such insights and data to counter the international criticism that it often receives as being a superpower that contributes to global CO₂ emissions out of proportion to its population size. Other countries, in both the northern and southern hemispheres, might then need to take a rather different view of America’s environmental impact as part of the post-Kyoto international climate change negotiations.

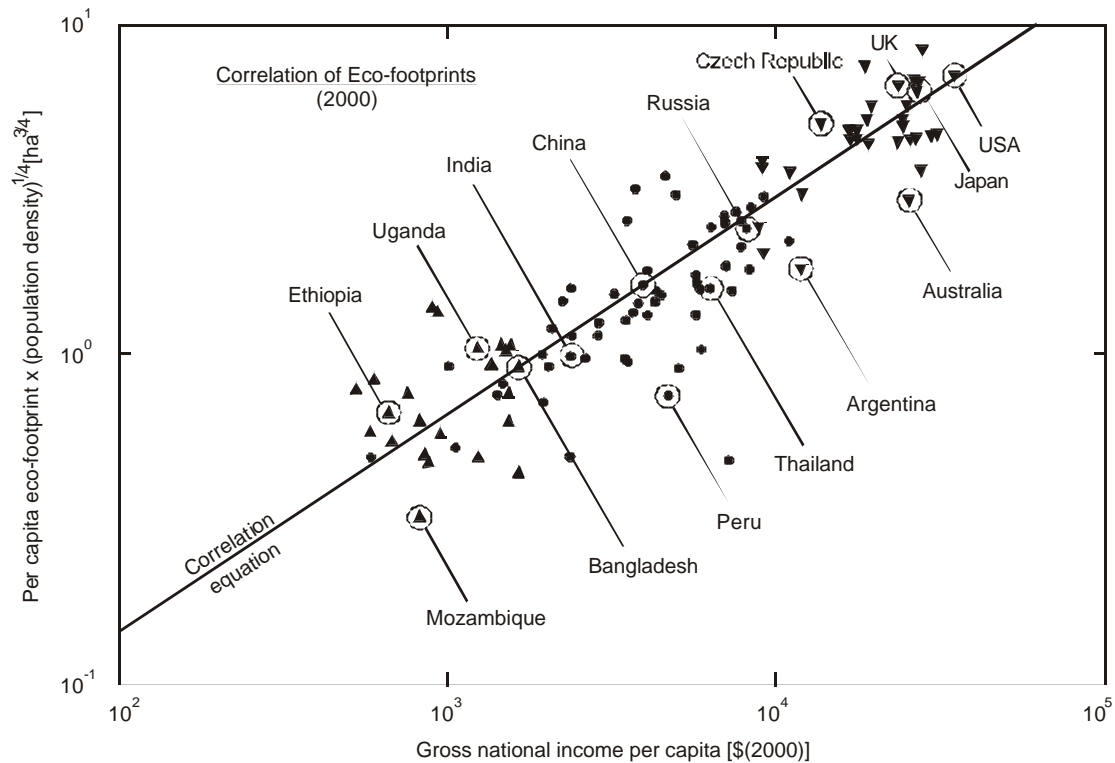


Fig. 1. The correlation of humanity's environmental footprint (selected countries identified from around the world). Source: Hammond⁴.

The above arguments are clearly linked with issues of environmental ethics and international equity. Countries like Australia and the USA might argue that being wealthy is not unethical *per se*. This runs counter to ideas such as the notion of an 'Earthshare' (of resources) for individuals or nation States that is popular amongst the environmental community. Even if the USA felt compelled at some future date to sign up to a post-Kyoto climate change regime with legally-binding targets, these could be adjusted during the long transitional or 'convergence' phase to account for the sought of insights highlighted in the *Natural Resources Forum* paper⁴. That might make it easier for the United States to engage in future climate change negotiations on a basis that it felt was more equitable. An engagement of that sort might ultimately benefit all the members of 'spaceship Earth'. It might induce the participation of the major rapidly industrialising countries of the Majority South. The only way that anthropogenic global warming is going to be tackled in the 21st Century is by restricting CO₂ emissions from present and projected coal-fired power plants in China and India.

2. Towards Sustainability

2.1 *The Sustainable Development Context*

Over a period of some 15-20 years, the international community has been grappling with the task of defining 'sustainable development'. It came to particular prominence as a result of the so-called Brundtland Report⁵ published under the title 'Our Common Future'; the outcome of four years of study and debate by the World Commission on

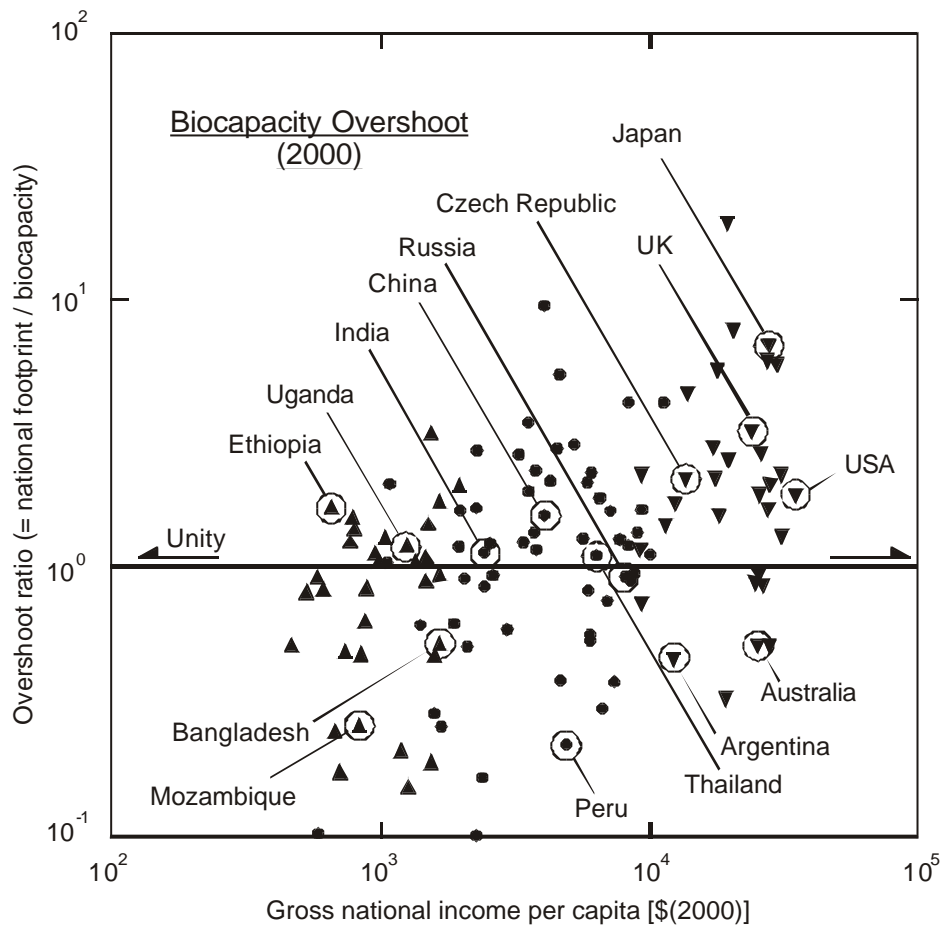


Fig. 2. Biocapacity overshoot or undershoot of nations from around the world (selected countries identified). Source: Hammond⁴.

Environment and Development led by the former Prime Minister of Norway, Gro Harlem Brundtland. This Commission argued that the time had come to couple economy and ecology, so that the wider community would take responsibility for both the causes and the consequences of environmental damage. It envisaged sustainable development as a means by which the global system would satisfy "the needs of the present without compromising the ability of future generations to meet their own needs". The notion therefore involves a strong element of intergenerational ethics. It also involves balancing of economic and social development with environmental protection: the so-called 'Three Pillars'.

Parkin⁶ and Porritt⁷ have stressed that sustainable development is only a process or journey towards a destination, which is 'sustainability'. The end-game cannot easily be defined from a scientific perspective, although Porritt⁷ argues that the attainment of sustainability can be measured against a set of four 'system conditions'. He draws these from 'The Natural Step' (TNS); an initiative by the Swedish cancer specialist, Karl-Henrick Robert (see, for example, Broman *et al.*⁸). Its system conditions put severe constraints on economic development, and may be viewed⁹ as being

impractical or 'utopian'. One of them, for example, suggests that finite materials (including fossil fuels) should not be extracted at a faster rate than they can be re-deposited in the Earth's crust on geological timescales. This may be contrasted with the present rapid rate of fossil fuel depletion on the global scale: leading to estimates for resource to production ratios of 20-40 years for oil, 40-70 years for natural gas, and 80-240 years for coal¹⁰. Upham¹¹ argues that TNS moves beyond (scientific and other) knowledge in signposting action for the business sector. He contends that it represents a political and ethical statement rather than any justifiable scientific consensus. TNS certainly implies that the ultimate goal of sustainability is rather a long way off when compared with the present conditions on the planet. Parkin⁶ suggests 2050-2100 or beyond. More recently, a significant step forward has been taken by Graedel and Klee¹² in trying to establish a quantifiable, long-term target for sustainability from an 'industrial ecology' perspective. They suggest a framework, or series of steps, to permit the establishment of the sustainable (or limiting) rate of natural resource use, which can then be contrasted with the current rate of consumption. The process is illustrated for the case of three common materials employed or emitted by industrial societies: zinc, germanium, and greenhouse gases. Unfortunately, the Graedel and Klee procedure requires the establishment of equal planetary shares of materials/emissions on a 50-year timescale. They acknowledge that the idea of an 'Earthshare' or quota of this sort is controversial, and that the chosen timescale is somewhat arbitrary. An alternative quantitative indicator that may be able to better track humanity's pathway towards sustainability is the environmental footprint analysed by the respondent⁴. It is in keeping with an interpretation of sustainable development devised by several leading international nature conservation and environmental organisations (the IUCN, UNEP and WWF¹³) as "improving the quality of human life while living within the carrying capacity of supporting ecosystems".

2.2 Allowing for Uncertainty, Taking Precautions

Underpinning the notion of sustainable development are a set of guiding principals. Four of these have been incorporated into European law in the Maastricht Treaty (Clause 130r)¹⁴, albeit in a rather ill-defined form. There it states that European Union policy on the environment should be "based on the precautionary principle and on the principles that preventative action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay ...". But this principle has caused some controversy amongst the scientific community, and between it and environmentalists generally. The application of the principle has often been seen (for example, by *The Economist* magazine^{7,15}) as a mechanism for restricting innovation and driving up regulatory costs. This misrepresents the precautionary approach in terms of what is sometimes viewed as its extreme, or 'strong', formulation. Lewis Wolpert (Professor of Anatomy at UCL) has also disparaged the principle¹⁶; arguing that it is not scientifically based. This is quite true, but that is rather to miss the point. It is simply a set of guidelines of the type that engineers are well accustomed to employing in industry; 'art' or practice as opposed to pure science. Indeed environmental campaigners like Jonathon Porritt⁷ and Greenpeace see the precautionary approach "as the most effective way of combining science and ethics"^{7,15}.

A pioneering study¹⁷ undertaken by the European Environment Agency (EEA) examined lessons for precautionary action from hazards caused by human activity

over the period 1900-2000. They reviewed some fourteen case studies where early warnings were evident of significant environmental damage to species and ecosystems. These cases were drawn from both European and North American experience, and included 'acid rain', ionizing radiation, and halocarbons and ozone depletion. The EEA scientific team then used these histories to devise a set of twelve 'late lessons' about how the precautionary principle should be applied in future when considering the adoption of new technologies. In the present context of energy use and climate change, the most important of these lessons were that:-

- 'Blind spots' and gaps in the scientific knowledge should be identified.
- More robust, diverse and adaptable technologies should be promoted so as to minimise the costs and maximise the benefits of innovation.
- Claimed justifications and benefits should be systematically scrutinised alongside the potential risks.
- A range of options for meeting needs should be evaluated alongside the option under appraisal.
- Full account should be taken of 'lay' and local knowledge as well as relevant specialist expertise in the appraisal process.
- Risk and uncertainty should be acknowledged and form part of the process of technology assessment and public policy-making.
- 'Paralysis by analysis' should be avoided by acting to reduce potential harm when there are reasonable grounds for concern.
- Adequate long-term environmental and health monitoring and research should be provided to ensure early warnings.

The EEA team recognised that many of these lessons are clearly interlinked.

Practising engineers typically operate in an industrial setting that requires them to design products and systems on the basis of what the management thinker Igor Ansoff termed 'partial ignorance'¹⁸. They are therefore unable to foresee, or take account of, the second-order, side-effects of their endeavours. Technology assessment systems therefore need to be put in place that will identify any potentially harmful side-effects of particular technologies *before* they are introduced into the market place. This would be consistent with the 'precautionary principle', and with the late lessons identified by the EEA¹⁷. It is only in this way that humanity can ensure that its development is sustainable.

3. Climate Change, Environment and Development

3.1 Human-induced Global Warming

Global warming is regarded by many scientists and policy analysts as being one of the most challenging phenomena to threaten human development. The UK Natural Environment Research Council has usefully summarised the current state-of-the-art in

climate change research¹⁹, including the certainties and uncertainties. Anthropogenic global warming is an inevitable side-effect of the generation of heat and power by (mainly) burning fossil fuels that gives rise to CO₂ emissions. They are thought to be the principal cause of solar forcing of the climate system: the so-called 'greenhouse effect'. The resulting climate changes were identified as potentially a major, planetary-scale hazard in the 1970s, although the phenomenon is still the subject of debate amongst and within various nations, professionals, and interest groups. Low carbon, sustainable energy technologies are at the heart of moves towards sustainability with a warming climate. But conflicts between energy market liberalisation and the needs of sustainable development are becoming increasingly evident – energy efficiency measures requiring high, not low, prices to stimulate their take-up.

The British Government's former Chief Scientific Adviser, Robert May (later Lord May of Oxford, the immediate Past President of the Royal Society), advocated²⁰ action to reduce carbon dioxide emissions on the basis of the 'precautionary principle' discussed above. Not out of conviction that anthropogenic climate change is currently proven, but because its possible effects over the next century may be damaging and large-scale. Carbon dioxide released into the atmosphere from the burning of fossil fuels is thought to persist for around a hundred years. This precautionary approach is something that could usefully be reinforced by the Stern Review in the light of the persistent doubts about the causes of climate change, particularly in North America.

3.2 The Environmental Footprints of Nations from Around the World

Environmental or 'ecological' footprints have been widely used in recent years as indicators of resource consumption and waste absorption transformed on the basis of biologically productive land area required per capita with prevailing technology. They represent a partial measure of the extent to which the planet, its regions, or nations are moving along a sustainable development pathway. Such footprints vary between countries at different stages of economic development and varying geographic characteristics. Over recent years, the World Wide Fund for Nature (WWF) has supported a study²¹ to determine the environmental footprints of most countries in the world, and consequently of the whole planet. Its influential Living Planet Report 2002 covered 146 countries with populations greater than 1 million²¹ (see Fig. 3⁴). WWF then carried out footprint assessments based on six consumption categories: 'food and forestry products' were subdivided into those accruing from cropland, grazing land, forest and fishing grounds. A number of specific countries have been identified by the respondent⁴ from amongst the data points illustrated in Fig. 3. These have been chosen from across the different geo-economic groups, but are otherwise arbitrary. Some of the most dominant nations in terms of population size and economic wealth are amongst those highlighted. The headline findings from the WWF study²¹ were that the global environmental footprint grew by 80% over the period 1961-1999, and that the Earth had already overshot its 'carrying capacity' by some 20% at the end of the Millennium. Humanity had, by this time, reached a population size of a little over 6 billion (compared with about 3 billion in 1960). Projections by the WWF suggest that humanity might require around two Earth-sized

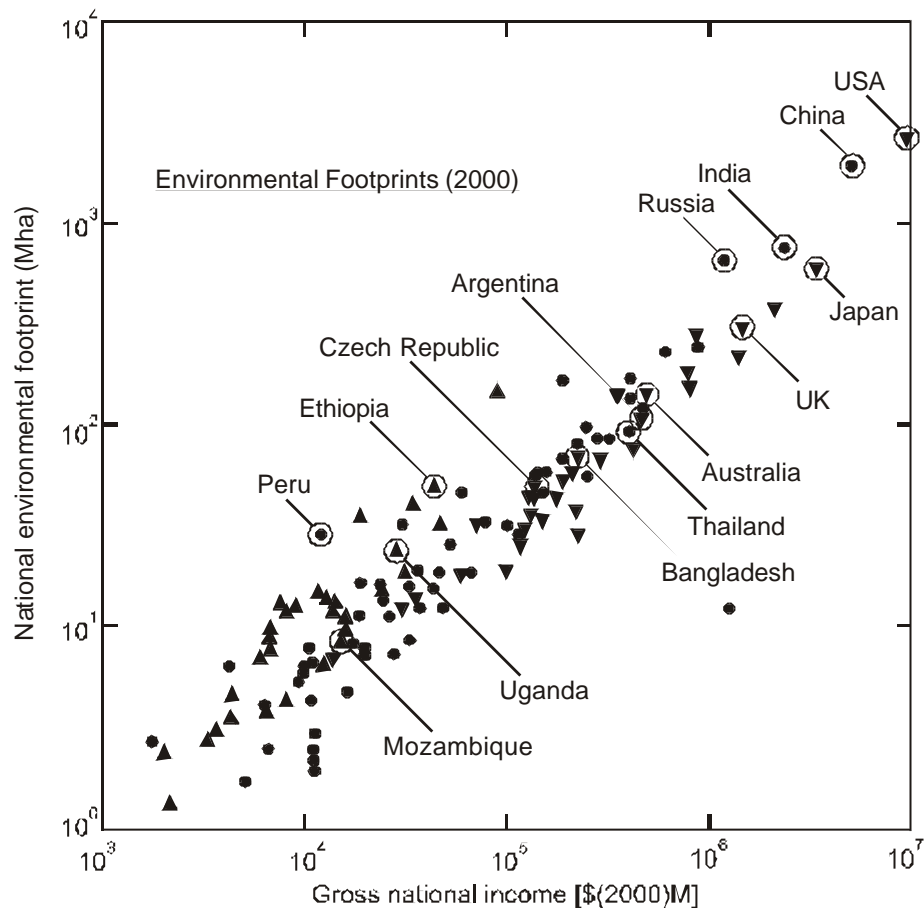


Fig. 3. Environmental footprints associated with the nations of the world with population sizes over 1 million (selected countries identified). Source: Hammond⁴.

planets to meet its resource demands by 2050²¹. That could only be achieved by exploiting fossil fuels laid down over geological timescales.

The determinants of environmental footprints in some 113 countries from around the world have recently been evaluated by the respondent⁴ using the WWF footprint data. Dimensional analysis techniques from engineering and the physical sciences are employed to determine the relative significance of population density, economic wealth, and pollutant emission intensity. Variations about the resulting power-law correlation (see Fig. 1 above) suggest the extent to which individual nations are currently frugal or profligate in terms of their resource use and environmental impacts. The scatter associated with footprints, or closely related parameters, also indicates the uncertainty inherent within the international datasets needed to compute them, as well as differences in local climate and terrain. Nevertheless, national footprints reflect the need for humanity to live within the regenerative capacity of the biosphere in order to ensure ‘environmental sustainability’. Fossil fuel consumption typically accounts for between some 33% and 60% of national environmental footprints for low-income and high-income countries respectively. Clearly there are other factors that could influence the size of footprints, including variations in local climate, different terrains and soil productivity, but for which there are not suitable international indicators or readily available datasets.

The environmental footprint of a country is strongly dependent on national economic wealth and only weakly on population density (see Fig. 1). This contradicts the hypothesis by the controversial environmentalist and statistician Bjørn Lomborg that societies become greener as they accumulate wealth. He based this assertion on a comparison of the now largely discredited *Environmental Sustainability Index* (ESI), developed at Yale Law School for the World Economic Forum at Davos, with the Gross National Income of countries from around the world. The ESI employs 67 variables, many quite unrelated to a nation's environmental condition, and simply linked together by equal weights. The environmental footprint data analysed by the respondent⁴ suggests that nations above the resulting power-law correlation curve (shown in Fig. 1) are generally profligate in terms of their use of natural capital, whilst those below the curve are relatively frugal. Countries such as Bangladesh, China, Russia and the USA fall almost exactly on the footprint power-law curve (Fig. 1), whereas Argentina, Australia, Mozambique and Peru are seen to be more sparing in their use of natural capital. In contrast, the Czech Republic, Ethiopia, Uganda and the UK exhibit relative profligacy. Nation states that are placed above and below the curve are distributed across the spectrum of socio-economic groups. The dominance of fossil fuel consumption in the footprints of (particularly) high-income countries obviously means that these states rely on resources laid down over geological timescales. Such energy technologies will need to be replaced by nuclear or renewable energy sources, coupled with measures aimed at improving significantly energy efficiency, over the longer term as fossil fuels are depleted.

The comparison between national footprints and the biocapacities of individual countries in Fig. 2 provides a means of illustrating how much a nation state overshoots its 'carrying capacity'. In line with the findings of the WWF study²¹, that the planet had overshoot its footprint by some 20% in 2000, many countries display an overshoot ratio greater than unity. The USA is one of these, but it is exceeded by many other nations, including the Czech Republic, Japan and the UK (and likewise the European Union generally). China, India and Uganda have environmental footprints that are roughly in balance with their available productive areas. But sparsely populated countries, such as Argentina and Australia (the continental part of Oceania, together with Tasmania), as well as many of the developing countries, including Bangladesh, Mozambique and Peru, can be seen to live well within their carrying capacity.

4. The International Response

4.1 *The Ethical Dimension*

The debate that preceded the Kyoto Protocol focussed on alternative ways of allocating greenhouse gas (GHG) emission quotas, including cumulative national emissions (or 'grandfather rights'²²); favoured by many developing countries, but against which the industrialised countries score poorly. Environmentalists have tended to argue that ecological burdens, including CO₂ emissions that are believed to be the main stimulant for global warming, should be shared in *per capita* terms. This alludes to what economists view as the 'strong' interpretation of sustainability⁷, which requires that life-supporting natural capital is maintained on such a *per capita* basis –

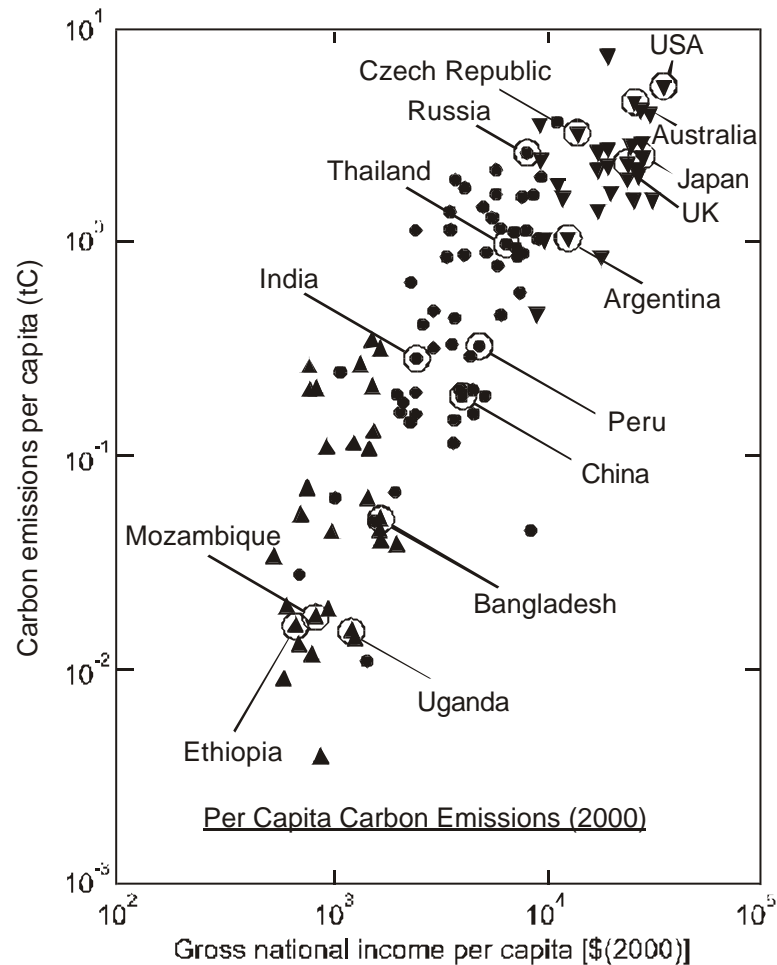


Fig. 4. National carbon emissions inventory on a *per capita* basis (selected countries identified). Source: Hammond⁴.

the Earthshare. This challenge is reflected in Fig. 4, where carbon emissions are contrasted with GNI for the countries in the author's dataset. *Per capita* emissions are closely associated with economic wealth, and hence with the United Nations Development Programme (UNDP) ranking according to their Human Development Index (HDI). Industrialised countries, particularly the USA, emit a large fraction of total greenhouse gases, and might be required to significantly curtail their carbon emissions in any future mitigation regime. This would place severe constraints on economic development in North America, Australia and New Zealand, the European Union, and Japan. It is for this reason that Australia and the USA, for example, have been reluctant to ratify the Kyoto Protocol with its modest overall GHG reduction target of 5% for the so-called Annex 1 (industrialised) countries on a 2008-2012 timescale against a 1990 baseline.

Recently the Royal Commission for Environmental Pollution in the UK (RCEP²²) has advocated a target of a 60% reduction in CO₂ emissions by 2050, and perhaps 80% by 2100, in order to stabilise global warming at an acceptable level. They support a strategy of 'contraction and convergence'²³ whereby nations' GHG emission quotas

converge to the same *per capita* level, and then all quotas would contract at the same rate to a sustainable target some time in the 22nd Century. On that timeline, many of the other environmental effects that contribute to global and national footprints will have come to the fore. In the transitional, or ‘convergence’, phase quotas for the developed countries would fall, while those of poorer developing nations would rise with economic wealth and (hopefully) well-being; thereby removing ‘grandfather rights’.

This respondent would be very sympathetic to seeing long-term carbon emission quotas allocated and secured on an equitable basis. But the question must be asked as to whether it is realistic to expect the wealthy countries of the world to sacrifice their economic well-being for the greater good of humanity. Is the notion of an ‘Earthshare’ simply a utopian dream? In the spirit of ‘satisficing’, it may therefore be necessary for all to put off the timescale for achieving an equitable allocation until some rather distant future. Insights derived from environmental footprinting highlighted in the respondent’s *Natural Resources Forum* paper⁴, such as the need for humanity (and, more debatably, individual countries) to live within biocapacity constraints, may aid the post-Kyoto negotiations. They may put into perspective the future GHG burden sharing arrangements between the wealthy nations of the northern hemisphere and the Majority South. This could be achieved by including national biocapacity-related constraints within a modified ‘contraction and convergence’ quota allocation scheme.

4.2 A New American Century?

It is evident from the WWF national footprint data²¹ presented in Fig. 3 that the greatest environmental impact is associated with the USA. It has both a large population and high per capita income. This has resulted in criticism from amongst some environmentalists. A commonly heard, and true, statement is to the effect that the USA contributed about 23% of humanity’s carbon emissions in 2000 with only 4.5% of the world’s population. However the Peoples Republic of China is not far behind in terms of the absolute size of its environmental footprint. In fact both China and India, the two most populous countries in the world (with 21.0 and 16.4% global population shares respectively), have a greater impact than any of the other so-called industrialised countries, such as Japan, the Russian Federation, and the United Kingdom (UK). Developing nations with small populations and low incomes inevitably have the lowest environmental footprint or impact on the planet.

The US Congress has shown no willingness (under either the Clinton or the present Bush Administrations) to make changes in their economy that might result in a significant reduction in its relative wealth. This is in spite of the fact that the USA was instrumental in embedding the ‘cap-and-trade’ approach into the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Congress in general perceives that the sort of (albeit very modest) GHG emission reduction targets included in the Kyoto Protocol will place severe limits on fossil fuel use that will lead to significant falls in economic prosperity in countries around the world. If future climate change negotiations are to be successful they must embrace large emitter countries like the USA, but also the likes of Brazil, China, and India. It is the two latter nations that are likely to have the most dramatic impact on growing global CO₂ emissions in the 21st Century and beyond, due to their projected increased use of coal-fired power stations. These ‘Majority South’ countries are unlikely to positively

engage in such international climate change negotiations until they perceive that America is doing likewise.

A key feature of the post-Kyoto climate change negotiations will be the interaction between the USA, China and India. America may remain the world's only superpower out to about 2020, but the sheer size of the newly industrialising countries of China and India will mean that they will progressively become major players in the international arena as their economic, political and military strength inevitably grows. The Stern Review needs to take account of these important changes in the global power balance. Describing Australia and the USA as "free-riders" in the context of climate change negotiations is unlikely to secure their involvement.

4.3 *Targets versus Technology*

The present US Administration, together with the arch-liberal Commonwealth Government in Australia, has championed a new 'Asia-Pacific Partnership on Clean Development and Climate' that was established in the summer of 2005 with six founding partners: Australia, China, India, Japan, South Korea and the USA. This regional group represent over half the world's economy, population, energy use, and GHG emissions. It seeks to transfer clean, more efficient technologies, build technical capacity, and reduce the carbon intensities of countries around the Asia-Pacific rim. But it does not envisage legally-binding GHG emission reduction targets of the sort incorporated into the Kyoto Protocol, and against which progress could be monitored. It would be helpful for the Stern Review to set out the arguments for and against GHG reduction targets and the adoption of low carbon technologies as alternative strategies to combat climate change. Likewise the debate must be engaged in relation to the drivers for innovation; market-driven mechanisms versus technology-forcing policies imposed by governments. Such debates will inevitably be part the process of drawing together the USA and the wider world into any post-Kyoto negotiations.

5. Concluding Remarks

Recent analysis of the environmental footprints of nations around the world by the respondent⁴ has shown that they are largely dependent on their *per capita* wealth and population densities. It is certainly important that Northern industrialised countries play their full part in maintaining environmental sustainability as they currently emit the bulk of pollutants into the atmosphere. But sustainable development must also be viewed in a global context. The task facing the nearly 80% of the world population that live in developing countries is daunting. They have, in many cases, rapidly growing populations, which will drive up energy consumption and environmental pollution. This will feedback to the whole planet, and thereby alter the climate in the wealthier nations. Consequently developing countries need assistance from developed ones to promote economic growth in the South (which will, in time, induce a "demographic transition") and improve their energy systems. Environmental sustainability would certainly be aided by the transfer of best practice energy technologies from richer to poorer regions. An example of this is the recent European Union-China agreement on the transfer clean coal power generation technology. Such arrangements will ultimately be in the interests of all the citizens of 'spaceship Earth'.

In looking to the future, the economics of climate change will ultimately be underpinned by ethical considerations. International negotiations under the United

Nations Framework Convention on Climate Change have implicitly relied on the notion of an 'Earthshare' – that each planetary occupant should in the long term be entitled to emit an equal share of 'greenhouse' gases at a level that will stabilise global warming at an acceptable level. But given the existing disparity of wealth between and within nations on the planet it is unlikely that humanity could converge to equal shares of CO₂ emissions. It is emphasised that notions like the Earthshare, and the strategy of 'contraction and convergence' (advocated by the RCEP), are ethical concepts that seem unlikely to be accepted by, for example, politicians in the United States. The US Congress has shown no willingness, under either Democrat or Republican Administrations, to make changes in their economy that would result in a significant reduction in its standard of living. If future climate change negotiations are to be successful they must embrace main emitter countries like the USA, but also the large, populous, and rapidly industrialising nations such as Brazil, China, and India. These representatives of the 'Majority South' are unlikely to engage in international climate change negotiations until they perceive that America, in particular, is doing likewise. It can be argued that (i) analysis by the respondent⁴ has shown that national environmental footprints and *per capita* CO₂ emissions are closely linked to wealth; (ii) an acceptance of this relation, and of the need to safeguard economic prosperity, in international climate change negotiations may make it possible for the USA and Australia (who amongst the so-called Annex 1, industrialised countries have not ratified the Kyoto Protocol) to engage in future climate mitigation discussions; and (iii) insights derived from environmental footprinting, such as the need for humanity (and, more debatably, individual countries) to live within biocapacity limits, may therefore facilitate successful post-Kyoto negotiations. The latter could be achieved by including national biocapacity-related constraints within a modified 'contraction and convergence' quota allocation scheme. It may put into perspective the future GHG burden sharing arrangements between the wealthy nations of the northern hemisphere and the Majority South.

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