FROM POVERTY TO POWER **BACKGROUND PAPER**

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Carbon Dioxide Emissions, Technology, and Economic Growth

Richard King

This paper addresses the debate about whether a combination of innovation and technology transfer will be sufficient to allow us to adapt to climate change and reduce emissions to a sustainable level, without any reduction in overall economic growth levels.

This background paper was written as a contribution to the development of *From Poverty to Power: How Active Citizens and Effective States Can Change the World*, Oxfam International 2008. It is published in order to share widely the results of commissioned research and programme experience. The views it expresses are those of the author and do not necessarily reflect those of Oxfam International or its affiliate organisations.

Background and rationale

The role of technology in responding to climate change polarises debate. Techno-optimists argue that a combination of innovation and technology transfer will be sufficient to allow us to adapt to climate change and reduce emissions to a sustainable level without any reduction in overall economic growth levels. Sceptics argue that lower growth levels, especially in the rich countries, will have to be part of the solution. This paper explores a set of questions on this topic:

1. What does the historical trend tell us about the likely future variation in the intensity and overall quantity of global carbon dioxide emissions? (Intensity is the amount of emissions produced per unit of GDP. Therefore, a country with low emissions and a small economy could have the same emissions intensity as another country with much greater emissions and a larger economy. Some countries prefer to report their emissions intensity rather than their absolute emissions, as a falling intensity can mask the fact that emissions are actually rising – if economic output is growing faster than emissions are increasing, *i.e.* CO_2 efficiency is improving. For reporting purposes, absolute emissions are more important than emissions intensity.)
2. If the global economy could operate at the intensity of the most (CO_2) efficient economies, what would happen to global emissions?

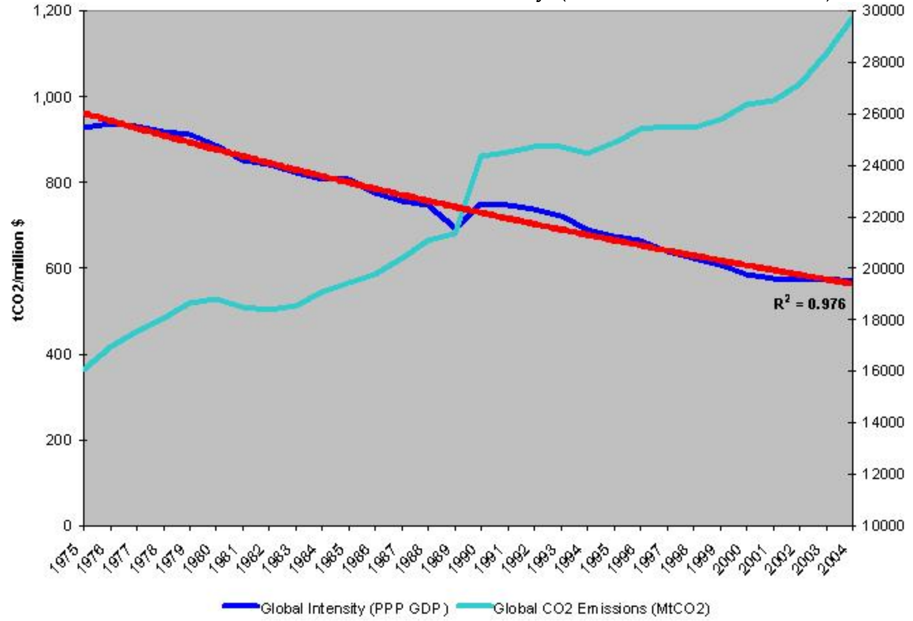
Answers to these questions could contribute to the debate over the role of technology in responding to climate change.

Current situation: rising CO_2 emissions, falling intensity

Global carbon dioxide intensity has been falling at a remarkably steady rate over the past 30 years (Figure 1), reducing by an average of 1.6% p.a. between 1976 and 2004.[1] Although causation is hard to prove, this trend is inevitably a result of some combination of new technical innovations and the diffusion and transfer of these technologies throughout the world. However, this reduction in intensities has not been accompanied by an associated fall in CO_2 emissions. Rather, intensity has fallen because global GDP has grown faster than emissions have risen.

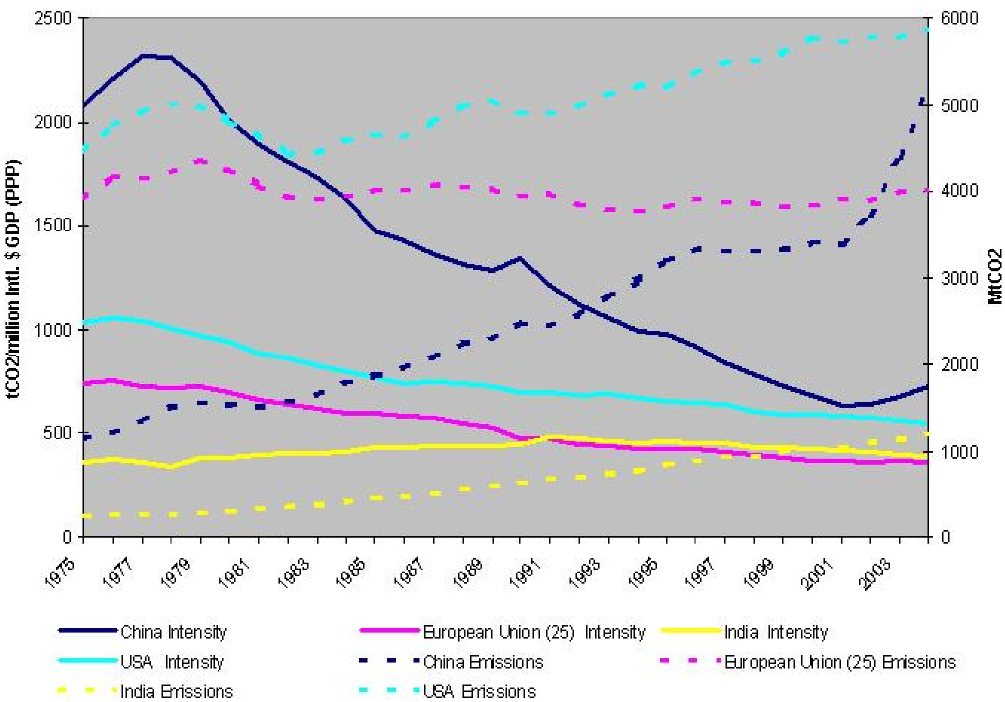
[1] Some alternative data sources suggest a recent (since 2002) marked reversal in this trend of falling intensities (*cf.* Raupach *et al.*, 2007). The data sets used and whether purchasing power parity (PPP) or market exchange rate GDP figures are used also affect the figures, although the trend is broadly similar in all cases.

Figure 1: Global carbon dioxide emissions and intensity (Source: CAIT v5, 2008)



This global picture hides a wide variation in the performance of the major emitters (Figure 2). China conforms to the global trends: despite a rapid fall in intensity, emissions have also risen rapidly. The same, though less dramatically, is true of the US (still the world's largest emitter of CO_2), whilst India has experienced both rising and falling intensities during a period of steady emissions growth, and the EU has marginally decreased both its emissions and the intensity of these over the past 30 years. The EU and US have similar intensity trajectories, with the US about 20% more intensive than EU.

Figure 2: Carbon dioxide intensities and emissions for four major emitters (Source: CAIT v5, 2008)



What if the global economy operated at the level of the most CO_2 efficient countries?

If we take the lowest current intensity levels among developed economies (highest GDP, lowest emissions) and apply that to the world as a whole, we arrive at a 'CO_2 gap' showing what current technology might be capable of delivering now, were all countries to use it. Using the per capita GDP/emissions scatter plot presented in Appendix I, it is possible to identify a group of countries that are amongst the top economic performers, yet have comparatively low carbon dioxide emissions. They are: France, Iceland, Ireland, Norway, Sweden, Switzerland (Group 1).

However, with the exception of Switzerland, the countries above all have fairly unique forms of electricity production (e.g. hydroelectricity in Norway and Sweden, nuclear in France, geothermal in Iceland); therefore, technology transfer alone is unlikely to achieve these levels of intensity. A second set of countries is therefore presented with fewer unique circumstances, more industrialised economies, and higher intensity levels. These represent a more obtainable goal for other economies seeking lower emission paths to development. They are: Germany, Italy, Japan, Switzerland,[2] UK (Group 2)

By calculating the average intensity of these countries' emissions in 2004 (the last year for which data are readily available) and taking global GDP in 2004 as a given, we can calculate what global emissions would have been under immediate and best case technology transfer.

In 2004, the average CO_2 intensity of the most efficient industrialised nations were:

- 247.8 tonnes of carbon dioxide per million international dollars[3] (tCO_2/Mill. Intl. $) (Group 1)
- 321.7 tCO_2/Mill. Intl $ (Group 2)

Applying that level of CO_2 intensity to global GDP, we can consider how much carbon dioxide emissions would have been reduced:

- 2004 Global CO_2 Emissions: 29,734 million tonnes of carbon dioxide ($MtCO_2$) (CAIT v5, 2008)
- 2004 Global GDP: 52,673 Billion Intl. $ (World Bank, 2007)

Therefore, applying the intensity of the most CO_2 efficient economies, 2004 global CO_2 emissions would have been:

- 13,053 $MtCO_2$ (44% of actual 2004 emissions) (Group 1)
- 16,946 $MtCO_2$ (57% of actual 2004 emissions) (Group 2)

This equates to a *reduction* in actual emissions for 2004 of:

- 16,681 MtCO2 (56% of actual 2004 emissions) (Group 1)
- 12,788 MtCO2 (43% of actual 2004 emissions) (Group 2)

Global CO_2 emissions could, therefore, be cut by circa 43% if all countries were able to shift to the CO_2 intensity of Group 2 economies. On the face of it, this makes a strong case for rapid technology transfer to kick-start the process of global emissions reductions.

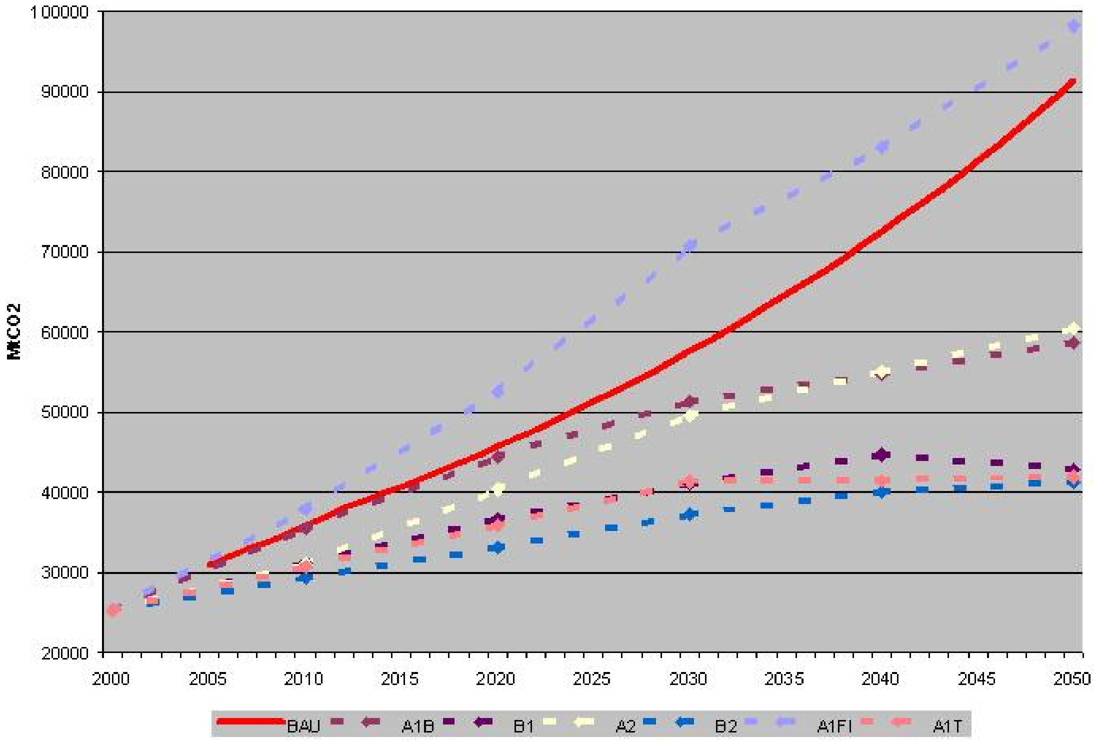
What might happen under a 'Business as Usual' (BAU) scenario?

Using the average annual reduction in global emissions intensity over the period 1975-2004 (1.6%) (Figure 1) as a guide to likely future Business as Usual (BAU) intensities, and using IMF

[2] Because Switzerland's electricity generation portfolio is not particularly unique, it is also eligible for inclusion in Group 2.
[3] International dollars are the monetary unit associated with purchasing power parity (PPP) exchange rates; US dollars are associated with market exchange rates.

projections of growth in the global economy (up to 2012, after which a conservative constant 4% annual growth rate is used), we can estimate what future global emissions might look like under a BAU scenario.[4] Under this BAU pathway, emissions continue to rise dramatically since economic growth consistently outstrips intensity reductions. To give an indication of the validity of this projection, the global projections for fossil fuel derived CO_2 emissions from the IPCC's six 'marker' scenarios[5] are also illustrated (Figure 3). The IPCC projection that the BAU pathway most closely resembles is A1FI. The assumptions on which this model is based include rapid economic growth, a global population that reaches 9 billion in 2050 and then gradually declines, the quick spread of new and efficient technologies, income and way of life converging between regions, and extensive social and cultural interactions worldwide, all with an emphasis on the use of fossil fuels.

Figure 3: Possible global carbon dioxide emissions under a 'Business as Usual' scenario, with IPCC 'marker' scenarios



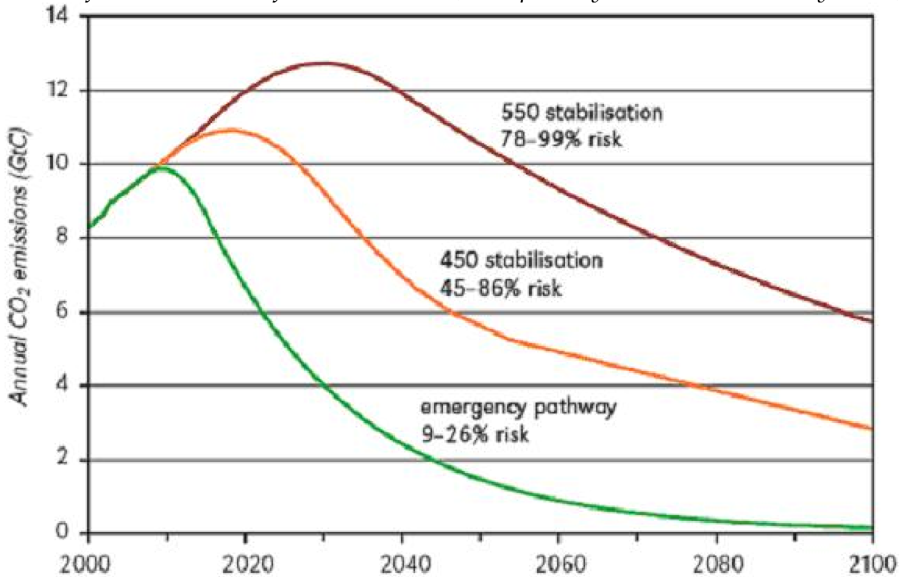
By comparison, Figure 4 illustrates several other emission scenarios. The 'emergency pathway' illustrates the trajectory of future emissions required to reduce the risk of exceeding two degrees Celsius relative to pre-industrial levels to 9-26 per cent. This would involve the rate of growth in emissions beginning to decline in 2007, emissions peaking in 2010, and the maximum rate of emissions reductions being achieved in 2015 and continuing throughout the century. This would result in CO_2 concentrations peaking at 410 ppm and reducing to 355 ppm by 2100 (Baer and Mastrandrea, 2006).

[4] This is obviously a highly approximate process, and recent evidence that the global emissions intensity is now rising suggest global emissions may rise more than projected here.

[5] IPCC scenarios are grouped into six categories based on the assumptions used in their calculations. For each of the six scenario groups an illustrative marker scenario is provided.

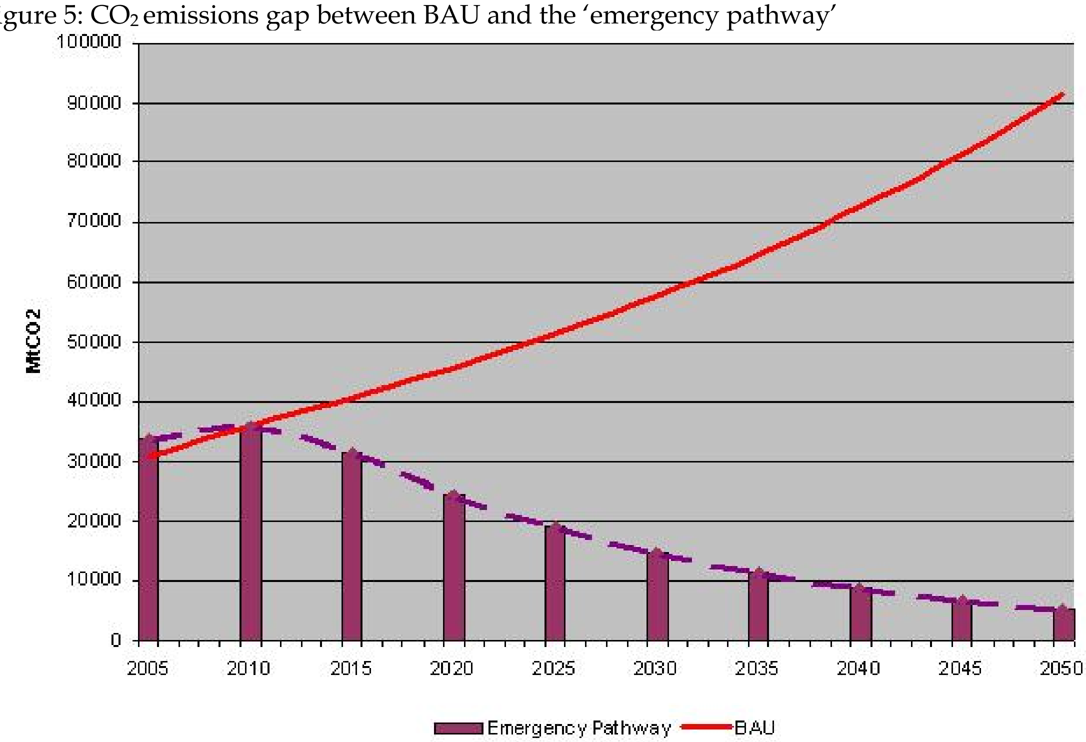
Figure 4: Carbon dioxide emission predictions (Source: Roach, 2007)

N.B. Units in this illustration are gigatonnes of carbon. In all following figures the emergency pathway is presented in units of million tonnes of carbon dioxide (multiplied by 11/3 then divided by 1,000)



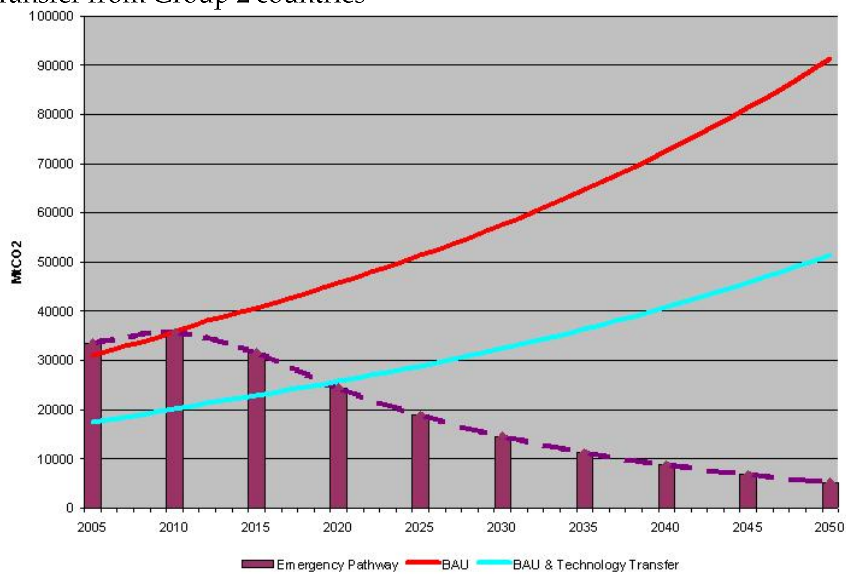
Using the 'emergency pathway' above and the BAU emissions resulting from the past global intensity trend, the massive emissions gap can clearly be seen (Figure 5). Therefore, compared to what is necessary to avoid dangerous levels of climatic change, current global levels of innovation and technology transfer are clearly insufficient to deliver the reductions required to avoid warming above two degrees. Does this mean that we have to forego economic growth (as it is currently manifest) on the global scale if we are to avoid dangerous climate change, or would a rapid acceleration of technology transfer be sufficient?

Figure 5: CO_2 emissions gap between BAU and the 'emergency pathway'



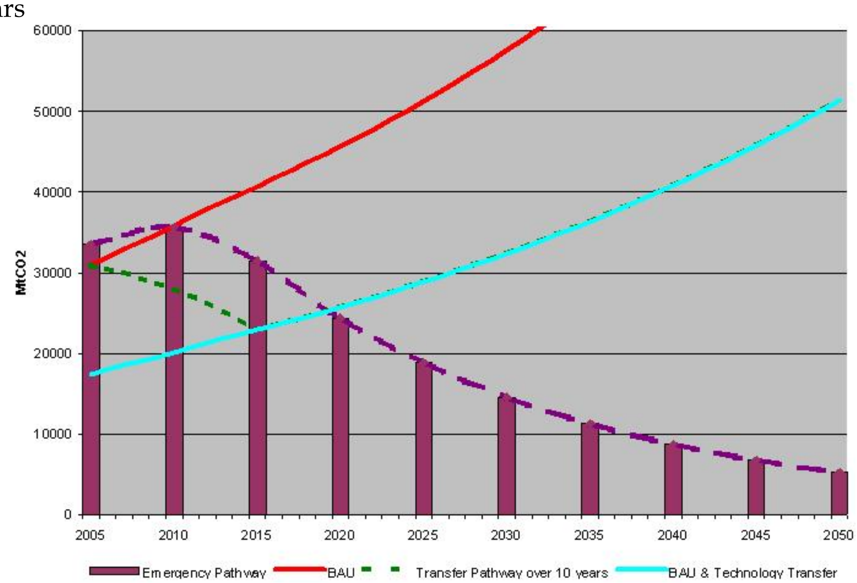
Consider another scenario. What if the same (current) rate of global innovation as presented above, in section one, were to be preceded by the levels of technology transfer presented in section two (Group 2 countries)? Although the overall trajectory is unchanged, immediate global technology transfer followed by unaltered levels of economic growth and innovation would reduce global carbon dioxide emissions to a level that would buy us a little more time in which to find a sustainable way of aligning ourselves with the emergency pathway (Figure 6).

Figure 6: CO_2 emissions scenarios: BAU, 'emergency pathway', and BAU proceeded by technology transfer from Group 2 countries



It is clearly unrealistic to transform all economies to the CO_2 intensity of the most efficient countries overnight. Suppose this took 10 years: Figure 7 illustrates the results of shifting global emissions on to the Group 2 pathway at a rate of 10% per year. This graph is highly approximate, given the heroic assumptions involved in generating it, but it is noteworthy that in the intervening period it follows a near parallel course to the emergency pathway, that is, it is the kind of pathway the world must follow to avoid dangerous climate change.

Figure 7: CO_2 emissions scenarios with a gradual transfer of technology from Group 2 countries over ten years



Obviously, if following these 10 years of technology transfer we then reverted to the original exponential trajectory, little would have been achieved – we would just continue along the path of rising emissions and impending climatic doom. So the message is clear: if global economic growth is to continue unabated, there is an urgent need not only to diffuse existing technologies throughout the world, but also to use the time bought by this process to ramp up innovations in clean technologies.

Conclusion

This paper has illustrated that:

1. Despite a consistently falling global intensity[6], CO_2 emissions continue to rise.
2. If intensity continues to fall at the same rate of 1.6% per annum, and the global economy grows as predicted, global carbon dioxide emissions are very likely to exceed levels that represent a decent chance of preventing further dangerous climatic changes.
3. If current levels of innovation persist, and technologies currently present in the most CO_2 efficient economies could be dispersed globally, then we stand a much-improved chance of having time in which to develop cleaner technologies, a necessity if we are to avoid dangerous climate change without foregoing economic growth.

Assumptions and further research

This exercise has, of necessity, made a number of assumptions and inferences, some of which are more problematic than others. The validity of its central finding would be greatly enhanced, if further research were able to:

1. Incorporate both CO_2 and other greenhouse gases emissions, especially those created by agriculture and land use change, which, by some estimates, account for as much as a third of southern countries' greenhouse gas emissions (Baer *et al.* 2007).
2. Separate out different sectors to take account of the different sectoral compositions of developed and developing economies, and thereby acknowledge that the whole world cannot switch to low emission service economies.
3. Use more nuanced projections than those that are based on simplistic models of the global economy beyond 2012 and exponential trajectories. The current paper is limited by its simplistic assumptions that the global economy will grow at four per cent per annum after 2012, and that emissions intensities will continue to fall by 1.6 per cent year on year.
4. Reconcile changes in estimates of the global economy based on different PPP values.
5. Develop a clearer understanding of whether the recent reversal of the long-term trend of declining global intensity represents is temporary or a more pronounced reversal. If the latter is true, the urgency of mitigating greenhouse gas emissions is even greater than presented in this paper.

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[6] Raupach *et al.*'s (2007) data suggest that there is a very real possibility that this long-term intensity trend has recently reversed, making the situation even more urgent than it is if the long-term trend of declining intensities continues.

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Richard King is Policy Research Assistant at Oxfam GB.

For further information on the issues raised in this paper, please email enquiries@oxfam.org.uk

Appendix I: Per capita GDP/emissions