The Stern Review on the Economics of Climate Change

Written evidence from
Dr Chris Hope, Judge Business School, University of Cambridge
c.hope@jbs.cam.ac.uk

9 December 2005

1. My work involves the construction and use of an integrated assessment model of Climate Change called PAGE (Policy Analysis of the Greenhouse Effect). The first version of PAGE was produced in 1991 for the European Commission. It was updated in 1995 to PAGE95 and most recently in 2002 to PAGE2002.

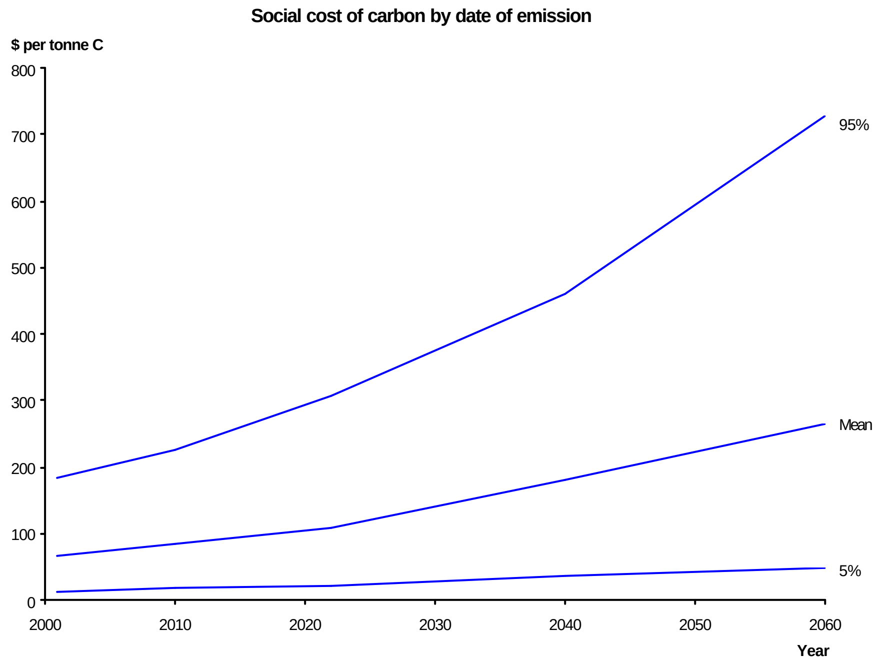
2. Integrated assessment models incorporate knowledge from more than one field of study, with the purpose of informing climate change policy. PAGE2002 is typical in using relatively simple equations to capture complex scientific and economic phenomena. This is justified because the results approximate those of the most complex climate simulations to within a few tenths of a degree, and because many aspects of climate change are still subject to profound uncertainty.

3. To express the model results in terms of a single 'best guess' could be dangerously misleading. Instead, a range of possible outcomes should inform policy. PAGE2002 builds up probability distributions of results by representing over 50 key inputs by probability distributions, making the characterisation of uncertainty the central focus.

4. The outputs of PAGE2002 include estimates of the impacts of climate change across the regions of the world and over time, how these impacts change if measures are taken to cut back the emissions of greenhouse gases, or adapt to changes in climate, and what the costs of the abatement or adaptation measures might be. In this note I shall concentrate mainly on PAGE2002 results for the social cost of carbon (SCC); that is the extra impacts caused by the emission of one extra tonne of carbon in the form of carbon dioxide. This is also the benefit of reducing carbon emissions by one tonne. It is calculated by summing up the extra impacts for as long as the extra tonne remains in the atmosphere, and discounting them back to the year of emission.

5. Using scientific and economic inputs taken mainly from the IPCC's 2001 Third Assessment Report, the mean PAGE2002 estimate for the SCC is $66 per tonne of carbon emitted in 2001, in year 2000 dollars, with a 5-95% range of $13 - 185. These estimates use the Treasury Green Book assumptions on the social rate of time preference, and an equity weight parameter (the negative of the marginal elasticity of utility with respect to income) of 1, which has the effect of giving greater weight to impacts in poor regions of the world. We see immediately just how broad the range of plausible estimates is, even with these fixed assumptions for discount rates and equity weights.

6. The figure below shows how the PAGE2002 estimates for the SCC vary with the date that the carbon dioxide is emitted. The values increase by about 2.4% per year; by 2060 the mean estimate has risen to $265 per tonne of carbon.



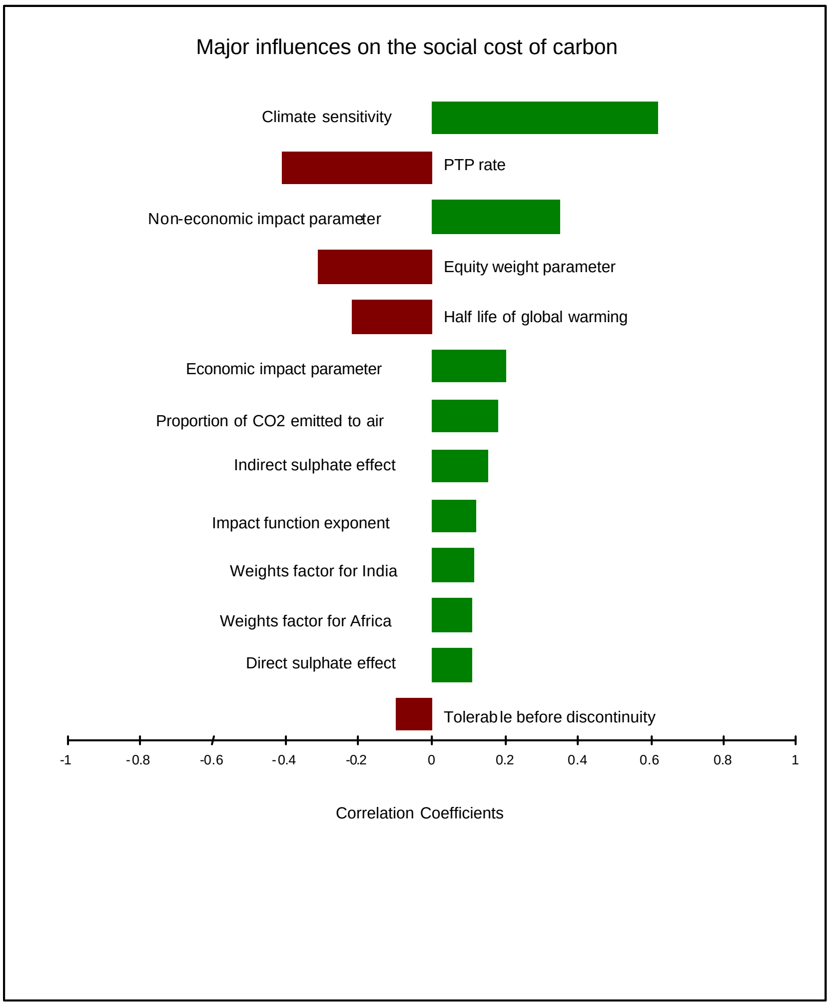
7. Allowing discount rates and equity weights to vary gives slightly different results. With pure time preference rates in the range of 1% to 3% per year, and an equity weight parameter in the range of 0.5 to 1.5, the mean PAGE2002 estimate for the SCC becomes $43 per tonne of carbon emitted in 2001, with a 5-95% range of $7 - 128. The figures are lower because the central value for the pure time preference rate, 2% per year, gives a slightly higher discount rate than the Treasury Green Book, and so the impacts that occur in the far future have less weight.

8. All of these results assume the extra tonne of carbon is emitted on top of an unconstrained emission path, scenario A2 from the IPCC Special Report on Emission Scenarios (SRES). But if climate change is taken seriously, it is unlikely that emissions will be allowed to follow this unconstrained path, which would lead to the atmospheric carbon dioxide concentration reaching over 800 parts per million (ppm) by 2100, and continuing to rise thereafter, compared to about 275 ppm in pre-industrial times and 370 ppm in 2000.

9. One constrained emission path that has been proposed aims to keep the atmospheric carbon dioxide concentration below 550 ppm, double the pre-industrial level. The mean PAGE2002 estimate for the SCC superimposed on top of this emission path is also $43 per tonne of carbon emitted in 2001, with a 5-95% range of $8 - 130, essentially identical to the result obtained for the unconstrained scenario A2. The SCC appears to be insensitive to the exact emissions scenario, within quite a wide range. Even if global emissions of all greenhouse gases and sulphates in all future years are only half the values assumed in Scenario A2 from the SRES, the mean value for today's SCC stays at $43 per tonne, essentially identical to the value under the A2 scenario.

10. The reason why this is true is not straightforward. It is caused by the interplay between the logarithmic relationship between radiative forcing and concentration (which will tend to make one extra tonne under the A2 scenario cause less impacts), the non-linear relationship of impacts to temperature (which will tend to make one extra tonne under the A2 scenario cause more impacts), and discounting (which will tend to make early impacts more costly than late impacts). The insensitivity of the SCC to the emission path is rather counter-intuitive and is a strong argument for using an integrated assessment model, as neither a scientific nor an economic model would pick it up.

11. If the emission path does not affect the SCC, what does? The chart below shows the major influences calculated by PAGE2002; the longer the line, the larger the influence. That the major influences divide into six scientific and seven economic parameters is another strong argument for the building of integrated assessment models such as PAGE2002. Models that are exclusively scientific, or exclusively economic, would omit parts of the climate change problem which still contain profound uncertainties.



12. The two top influences are the climate sensitivity, which is the temperature rise that would occur for a doubling of carbon dioxide concentration, and the

pure time preference rate. The climate sensitivity is positively correlated with the SCC, so a rise leads to a higher SCC; the pure time preference rate is negatively correlated with the SCC, so a rise leads to a lower SCC, and so on.

13. As an example of the changes that new scientific information can bring, the journal *Nature* has recently published a new likelihood-weighted probability distribution for the climate sensitivity, with a mean value of 3.6 degC, and a 5-95% range of 2.4 to 5.4 degC. Using these values for the climate sensitivity in PAGE2002, instead of the 1.5 to 5.0 degC range given by the IPCC, increases the mean value of the SCC from $43 to $68 per tonne of carbon emitted in 2001, with a 5-95% range of $11 - 202.

14. The PAGE2002 model includes a range of greenhouse gases, not just carbon dioxide, and can calculate the social cost of each of them. Using the same assumptions as in paragraph 5, the mean PAGE2002 estimate for the social cost of methane is $280 per tonne emitted in 2001, in year 2000 dollars, with a 5-95% range of $80 – 750. In the future, the social cost of methane increases faster than carbon dioxide, by 3.6% per year. This is because of the short atmospheric lifetime of methane; any extra methane emitted today will have disappeared from the atmosphere before the most severe climate change impacts occur, but emissions that occur later will not. The PAGE2002 estimate for the social cost of SF6 is $800 000 per tonne emitted in 2001, in year 2000 dollars, with a 5-95% range of $160 000 – 2 100 000.

15. What are the policy implications of these results? If the social cost calculations are complete, efforts to cut back the emissions of greenhouse gases should continue as long as the marginal cost of the cutbacks is lower than the social cost of the impacts they cause. If taxes are used, they should be set at the social cost. If tradable permits are used, their price should be the same as the social cost; if their price turns out to be lower than the social cost, the total allocation of permits is too large and vice versa. In any comparison between greenhouse gases, the ratio of the social costs is the correct figure to use.

16. Of course, the outputs from PAGE2002, and other integrated assessment models, are only as complete as the scientific and economic information that goes into the model. PAGE2002 does make an attempt to cover all five reasons for concern about climate change identified by the IPCC, including a rudimentary treatment of large-scale discontinuities such as the melting of the West Antarctic ice sheet. It does not include the security implications of any large-scale migration caused by climate change. The social cost calculations presented here also assume that impacts in poor countries are given the same weight as impacts in the UK, or more weight if equity weights are used; this is not necessarily consistent with our behaviour in other policy areas.

17. My main purpose in this short note has not been to promote any one estimate of the social cost of greenhouse gases. As I have shown, the social cost of carbon is influenced by many factors, which are still subject to great uncertainty, and the same is true of other greenhouse gases. Rather, I have tried to demonstrate that integrated assessment models such as PAGE2002 can perform a useful service by taking the best information from the detailed

scientific and economic research, and revealing its policy implications. They can also highlight just how much we still have to learn about the economic implications of climate change, and enable different views on economic and scientific parameters, such as discount rates, equity weights and climate sensitivity, to be rigorously explored.