The Social Cost of Carbon

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Introduction

The effects of global climate change are diverse and potentially very large. Traditionally the policy debate has focused on the costs of mitigation, but there is an increasing interest in the economic costs (social costs) of climate change. In the UK, these are usually referred to as the Social Cost of Carbon (SCC), and can be used to assess the economic benefits of climate change policy.

The Social Cost of Carbon is usually estimated as the net present value of climate change impacts over the next 100 years (or longer) of one additional tonne of carbon emitted to the atmosphere today. It is the marginal global damage costs of carbon emissions.

In 2002, the UK Government Economic Service (GES) recommended an illustrative estimate for the SCC of £70/tonne of carbon (tC), within a range of £35 to £140/tC (for year 2000 emissions), for use in policy appraisal across Government, and that these values should be increased at the rate of £1/tC per year[1]. The GES also recommended that these values should be subject to periodic review.

In 2003, Defra (the UK Department for Environment, Food and Rural Affairs) established an Inter-departmental Group on the Social Cost of Carbon to take forward a review, and this group commissioned two research projects aimed at improving the available SCC estimates, and to explore how they could be applied to policy assessment:.

- The first project '*The Social Cost of Carbon (SCC) review – A closer look at the models'*, was led by Tom Downing (SEI). The findings of this report are included in another paper in this OECD series.
- The second project, '*The Social Cost of Carbon (SCC) Review - Methodological Approaches for Using SCC Estimates in Policy Assessment*' was led by Paul Watkiss at AEA Technology Environment, with the aim of informing Government on how best to incorporate SCC values in decision-making, given the uncertainty surrounding monetisation of global climate change.

This paper summarises the output from the second of these projects[2], focusing on the policy aspects for using the SCC. The study findings are set out below.

Review of the Use of the SCC

The UK Government, and its economic regulators, extensively use economic appraisal. The Treasury Green Book[3] provides the guidance on how to do this, and requires Government action be based on an assessment of how any proposed policy, programme or project can best promote the public interest. It specifically sets out guidance to assess whether the benefits of intervention are expected to exceed the costs. This is assessed through cost-benefit analysis (CBA), whereby all relevant costs and benefits to government and society of all options are valued, and the net benefits or costs calculated. In the context of policy appraisal, this is undertaken within Regulatory Impact Assessment (RIA). The UK has also adopted a pro-active approach on the use of economic instruments including environmental taxes, charges and subsidies, as well as market-based instruments[4].

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[1] UK Government Economic Service (GES) paper *Estimating the Social Cost of Carbon Emissions* http://www.hm-treasury.gov.uk/documents/taxation_work_and_welfare/taxation_and_the_environment/tax_env_GESWP140.cfm

[2] Paul Watkiss, with contributions from David Anthoff, Tom Downing, Cameron Hepburn, Chris Hope, Alistair Hunt, and Richard Tol (2006). *The Social Costs of Carbon (SCC) Review – Methodological Approaches for Using SCC Estimates in Policy Assessment.* Final Report to Defra. Published January 2006. http://www.defra.gov.uk/environment/climatechange/carboncost/aeat-scc.htm

[3] *Green Book, Appraisal and Evaluation in Central Government.* HMT, 2004. http://www.hm-treasury.gov.uk/economic_data_and_tools/greenbook/data_greenbook_index.cfm

[4] For guidance on economic instruments, see *Tax and the Environment: Using Economic Instruments.* HM Treasury. 2002.

This policy context provides the opportunity to use a SCC value widely in decision making. To assess the potential uses, the study reviewed and found four potential applications for a SCC across Government and agencies in the UK. These were:

- Project appraisal (project cost-benefit analysis);
- Regulatory Impact Assessment (policy cost-benefit analysis);
- Setting of economic instrument (input to the setting of taxes, charges, or subsidies);
- Long-term (sustainability) objectives or targets, particularly climate policy.

The study also reviewed how the existing SCC values had been used across each these four areas since the guidance was issued in 2002. It found there had been widespread use of the SCC estimates for the first three applications. A summary of examples is presented in the table below for different applications in different Government departments, agencies and regulators. However, the study also found that the use of the SCC values were not always consistent (for example, some analysts had used the central illustrative value of £70/tC only, whilst some used the full range £35 to £140/tC). It also identified a limited number of relevant policy appraisals which had important effects on greenhouse gas emissions, but had not used the SCC values.

Examples of the Use of the SCC value across Government in the UK.

Organisation	**Example Applications**
Defra	Regulatory Impact Assessment of the proposed F Gas regulations
	Cost-benefit analysis of UK Emission Trading Scheme
	Analysis of waste tax charges (review and consultation)
DfT	Incorporation into New Approach to Appraisal for Road Transport infrastructure appraisal
	Incorporation into National Transport Model/Social Pricing Model
	Analysis of aviation tax in Aviation White Paper (for consultation)
	Analysis of road user charging and differential charges (consultation paper)
DTI	Energy White Paper
	Regulatory Impact Assessment for Renewables Obligation II
ODPM	Proposals for Part L amendment (energy efficiency provisions) of Building Regulations
Ofgem	Energy investment appraisal (gas network extension, electricity transmission infrastructure)
EA	Assessment of Asset Management Programme 4 for Water Sector (AMP4)

Defra = Department for Environment, Food and Rural Affairs.
DfT = Department for Transport
DTI = Department for Trade and Industry.
Ofgem = Office of Gas and Electricity Markets.
OPDM = Office of the Deputy Prime Minister.
EA = Environment Agency.

Interestingly, the study found limited use of the SCC in longer-term climate change policy. The UK has adopted a long-term GHG reduction goal. This was published in the 2003 Energy White Paper[5], which set out the longer term framework for the UK's energy policy and accepted that the UK should put itself on a path to reducing carbon dioxide emissions by some 60% (from 1990 levels) by 2050. The analysis did consider the SCC in the analysis of the necessary short-term steps towards this goal (until 2020), but the value was not used explicitly (in published material) in cost-benefit analysis of the long-term goal. This is consistent with the general finding that for longer-term climate change policy, cost-benefit analysis is rarely used, and any such application are the subject of considerable debate.

[5] Our Energy Future – Creating a Low Carbon Economy. DTI, 2003.

The study also reviewed the use of SCC estimates in policy in other countries and organisations. It found limited current use with only a handful of examples. There is use of carbon switching values in the European Investment Bank for energy appraisal, with switching values of 5 Euro and 125 Euro/tC (note these are the subject of current review). There has been some historical use of social cost estimates, e.g. the European Commission previously used a value of Euro 70 - 170/tC in some appraisals, but these were replaced by the use of marginal abatement costs from the sectoral targets and European Climate Change Programme. Finally, there have been examples of the use of these types of values in sensitivity analysis, e.g. Netherlands government, World Bank.

Instead there has been a recent trend towards the use of marginal abatement cost estimates, or more specifically carbon prices (EUAs or CERs) as a 'shadow price' of carbon emissions in project and policy appraisal. The UK government appears unique in its widespread adoption and implementation of a social cost estimate in policy assessment. However, the study also found more recent interest in the economic benefits of climate change policy, as part of wider post-Kyoto considerations, notably in the EU with the recognition in the Communication on Climate Change[6], mirroring the request of the Spring Council, that '*monetised avoided impact benefits, estimated globally, but with a focus also on the European scale, will enable fully informed policy making'*.

Review of SCC values and uncertainty

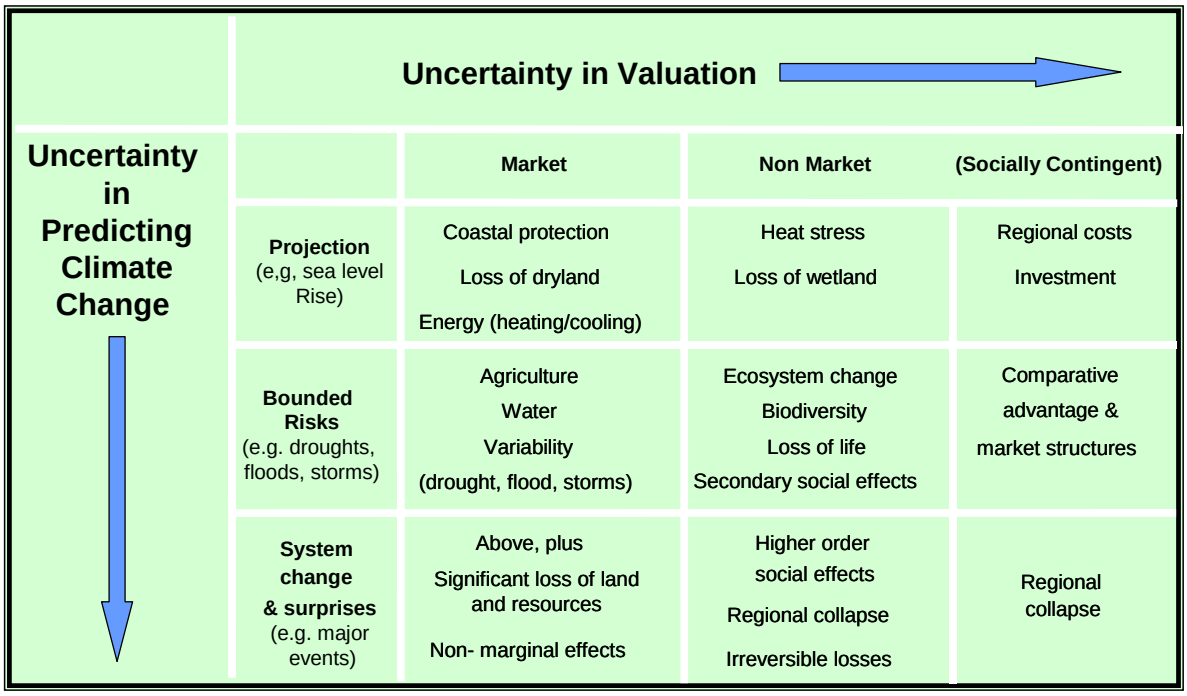
The two projects reviewed the SCC literature and examined reasons for the differences in literature values. The review indicates that with typical assumptions about discounting and aggregation, many central estimates of the marginal damage cost of carbon dioxide emissions are lower than the current GES illustrative value of £70/tC. This reflects a trend in the literature towards lower SCC values in recent years. However, the literature studies do not cover all the impact categories of climate change, and most researchers consider the possibility of negative surprises to be more likely than positive ones. The studies therefore assessed the coverage of the valuation studies to investigate the extent to which they may under-estimate the total SCC. This was undertaken using a risk matrix, in relation to the uncertainty of climate change impacts (vertical axis) and the uncertainty in valuation (horizontal axis), as set out below.

Mapping the literature studies onto this matrix[7], it was found that most studies/models cover only the top left hand corner of the matrix. Very few studies cover any non-market damages, or the risk of potential extreme weather (floods, storms, etc). None cover socially contingent effects[8], and very few the potential for longer-term effects and catastrophic events. Therefore the uncertainty in the SCC values concerns not only the 'true' value of impacts that are covered by the models, but also uncertainty about impacts that have not yet been quantified and valued. Perhaps most importantly, it indicates that values in the literature are a sub-total of the full SCC, though it is not known by how much.

[6] 'Winning the Battle Against Climate Change (SEC(2005)180.
http://europa.eu.int/comm/environment/climat/pdf/staff_work_paper_sec_2005_180_3.pdf

[7] Note even this risk matrix des not fully capture all dimensions of the SCC. It is clear that there will be different time dimensions associated with the different categories of impacts – to illustrate system change and surprises at the bottom are likely to be longer-term effects. There is also no evidence on the relative importance or probability of the various grid cells. For simplicity, all nine boxes above have been drawn of equal size – it is simply not known how important relative categories of impacts (or even benefits) will be in reality, nor the probability of the occurrence of different impacts. Nonetheless, the matrix provides a useful tool to start to interrogate the coverage of the literature estimates.

[8] Socially contingent damages describe those large scale dynamics related to human values and equity that are poorly represented in damage estimates based on cost values, e.g. regional conflict, poverty, famine.



The SCC Risk Matrix (Source: Downing and Watkiss, 2003[9])

The study also reviewed the key parameters that affect the SCC estimates. These are important as they often reflect political or ethical judgments. It is clear that much of the variation in SCC estimates (for the sub-totals assessed so far) arise from a few key parameters in the choice of decision perspectives, most importantly:

- Discount rate used. The choice of discount rate has a very large effect on any values, because most impacts of climate change occur in the future. Clearly higher discount rates lead to lower values.
- Approach to weighting impacts in different regions (equity weighting). Most impacts in the medium term occur in developing countries, and so the decision on whether to use compensation values or instead adjust estimates using a form or distributional or equity weighting has a significantly bearing on the results. Greater use of equity weighting increases the values.
- Study time-horizon. Aggregate models suggest that net impacts of climate change may be positive in the short term, but turn negative for more severe climate change (even without major events). Extending the time horizon, even with discounting, can substantially increase the SCC for current emissions (note different discounting assumptions can make this even more important). Constraining the time-scale (e.g. to only 100 years) will conversely lead to lower values.
- Mean vs. median. Both the mean and the median have been used as a measure of central tendency for different SCC estimates. For skewed distributions they give substantially different results even with the same underlying data. As the SCC estimates are right skewed (mean>median), than the choice of central value can increase or decrease the values (e.g. models/studies which report median values give lower estimates than those that report mean values as the central estimate).

[9] Downing, T., and Watkiss, P. (2003). The Marginal Social Costs of Carbon in Policy Making: Applications, Uncertainty and a Possible Risk Based Approach. Paper presented at the DEFRA International Seminar on the Social Costs of Carbon. July 2003.

A number of other parameters are potentially important, though there is less evidence to examine their impact. These include the non-marginal nature of some effects (and whether marginal damage cost values are applicable), the assumptions on the substitutability of different effects (strong or weak sustainability, and assumptions about trading off agricultural gains against say ecosystem loss), adaptation assumptions (many of the models now build in adaptation to provide a net social cost, and adaptation is assumed to be optimized), and ancilliary effects. All these areas are potential important in future research.

Stakeholder consultation

The study undertook stakeholder consultation focusing on two major groups 1) climate change impact/valuation experts and 2) government economists (as users). It undertook direct interviews and held a major workshop. The study also had an expert peer review panel and steering group. The consultation aimed to elicit views on the use of the SCC in policy, to assess the preferred approaches to deal with risk and uncertainty, and to reveal views on the key parameters (discount rate, equity etc) appropriate for policy applications.

Overall, the consultation suggested that a shadow price of carbon emissions should be maintained for project and policy appraisal across UK Government, and that this value should be consistent with longer-term (climate) policy goals. The consultation also suggested that any value should be implemented consistently across all applications. There was, however, considerable resistance by some consultees to the use of the values in cost-benefit analysis of longer-term climate policy, though nearly all groups recognised the need for some form of benefits analysis in this decision making context.

There was also some consensus on the choice of key parameters, and this was progressed further within the study steering group to produce firm guidance as follows:

- To use a declining discount rate scheme (the Green Book declining scheme), which starts at 3.5% (social rate of time preference) and declines to 1% over three hundred years. Note the declining discount rate recommended in the UK is currently the subject of consideration in the Stern review;
- To use equity weighting for deriving SCC values. There was a wider and more divergent set of views on equity weighting. While there was a general agreement that some form of equity weighting was appropriate, there was debate the exact form and degree. Importantly, some commentators highlighted that equity weighting in climate change policy is not consistent with the current rate of spending on foreign aid in the UK, nor was consistent with other international policy e.g. agriculture[10].
- To use the mean value as the most appropriate measure of central tendency – in line with principle of maximising expected utility and at least conveying some of the risk of unpleasant surprises (note the study also trimmed data, where necessary to remove some outliers, to provide a trimmed mean) .

Additional Modelling and Potential SCC Values

In working through practical case study on policy applications, the study found that the basic SCC output from most of the models was not sufficient. There is a need for models to generate a number of sets of values to properly match up with economic appraisal uses in practice. These are:

- The need to consider the SCC values for emissions in different future time periods, i.e. it is not sufficient to work with a single year 2000 emission for appraisal.

[10] Note there are possible reasons why climate change and standard domestic/international policies may differ for equity weighting. These are: climate change is intergenerational (and there is no reliable mechanism of intergenerational transfers); it is non-marginal; and it is international. An additional issue is that the equity weights to be employed in each period depend upon the assumption about growth rates in different countries, and whether it is assumed that per capita incomes are converging. Under convergence, the impact of equity weights is significantly reduced (and this requires dynamic (or time varying) equity weighting).

- The need to consider the social costs for different greenhouse gases, not just carbon, recognising that because of discounting, it is not appropriate to take existing values for carbon and using global warming potentials to derive social costs for other gases such as methane.
- The need to consider how the SCC changes with different scenarios, and different mitigation policies.

Some additional work was undertaken to investigate the first of these (and some limited analysis on the second and third). A set of values was derived using two of the leading Integrated Assessment Models – FUND and PAGE. The analysis with both models uses the parameters agreed for the UK policy analysis from the peer review and steering group, i.e. it applies Green Book declining discount rates and equity weighting, and reports the mean as the central estimate. It is stressed that these decision parameters are based on a global decision context committed to reducing the threat of dangerous climate change and includes a modest level of aversion to extreme risks, relatively low discount rates and equity weighting. Alternative assumptions would produce very different estimates.

Example outputs for the SCC over time – using the parameters agreed for the UK policy analysis

	SCC Estimates - Year of Emission						
£/tC	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Existing UK SCC							
Low	35	45	55	65	75	85	95
Central	70	80	90	100	110	120	130
High	140	150	160	170	180	190	200
FUND Mean (1%)	65	75	85	95	97	129	
FUND 5%	-53	-46	-46	-41	-47	-40	
FUND 95%	309	378	482	458	498	575	
PAGE CC Mean	46	61	77	102	127	157	187
PAGE 5%	9	12	14	20	27	30	34
PAGE 95%	130	159	215	270	324	418	513

Note values for FUND and PAGE are based on declining discount scheme in the Green Book and assume equity weighting. The FUND model results exclude some bounded risks, and exclude major climatic system events and socially contingent effects. The PAGE model results include some (but not all) major climatic system events but exclude any socially contingent effects. Values for FUND trim 1% of values as outliers.

This analysis showed that the mean values from the IAMs are lower than the current central SCC illustrative guidance for a year 2000 emission, but that the IAM values increase much more quickly over time, and overtake the SCC values after 2030. In interpreting and comparing the values (and underlying models), it is also essential to note that these SCC estimates from the IAMs still do not include consideration of the full risk matrix – they exclude socially contingent effects and major events, and also only have a partial coverage of bounded risks and non-market impacts.

Study Recommendations

The final area of the study was to make recommendations on the use of the SCC values for policy. The key recommendations on the use of the SCC values were:

1. Benefits of climate change policy should be considered when setting long-term targets and goals.

Some benefits can be directly estimated as monetary values, but a wider framework is needed to take all relevant effects into account. Single monetary estimates of the SCC should be avoided for such policy decisions. The framework should include a disaggregated analysis of economic winners and losers by

region and sector, and a disaggregated analysis of the impacts of climate change including key indicators such as health and ecosystems. The full risk matrix identified in the study (including risk of major change) should be considered, and the analysis should include extensive uncertainty analysis. Green Book recommendations (i.e. declining discount rates) should be used for assumptions on discounting, but with sensitivity analysis. The uncertainty analysis should also consider equity assumptions. Benefits analysis should consider ancillary effects, but the analysis of these should be kept separate in the assessment. This is an informed process leading to a long-term goal.

2. Detailed policies follow from, and should be consistent with the long-term goal, once set.

The aim should be to ensure the target is achieved in the most cost-effective way, and there is a need for consistency in appraisal across policy areas to achieve this. Any values should be used consistently across all applications in Government.

Overall, this is a two-tier approach, with different types of analysis for long-term targets (based on a wider framework) and short-term economic appraisal (using shadow prices for day-to-day appraisal across government).

It is highlighted that there is already a 2050 target in the UK. The implications of the recommendations are that once a long-term policy is set, then the value for appraisal at lower levels should be based on the marginal abatement costs (MAC) to achieve the target, i.e. to ensure that the target is achieved cost-effectively. However, it was found that there is no agreement on the MAC of the UK 2050 CO_2 target (indeed, a review in the study of the abatement costs of long-term CO_2 reductions revealed that estimates differ by over an order of magnitude, and some studies even vary in sign). For this reason, the study adopted a pragmatic recommendation to use both MAC and SCC estimates to try and derive a set of shadow prices for day to day appraisal.

These recommendations have not been adopted in the UK, and further guidance on the appropriate approach to valuation, and values for use in appraisal, are likely to emerge as a result of the current Stern Review on the Economics of Climate Change being undertaken by UK Treasury and due to report in autumn 2006.

Research recommendations

The study identified a number of research priorities. The most important priority is to fill the gaps in the risk matrix – both in terms of getting better information on sector and regional values, and extending the analysis to the important omissions of major events and socially contingent effects.

Some specific research areas are identified below.

- To extend the existing models and outputs. It would also be extremely useful to run the models to look at the marginal social costs of climate change in different time periods, and for different pollutants (e.g. CO_2, CH_4, N_2O). Additional model runs with IAMs would be useful to test different future policies (towards stabilisation targets for CO_2 equivalents of 400 ppm, 450 ppm, etc), with different assumptions relating to baselines, discount rates, equity weighting, and uncertainty analysis in relation to climate sensitivity. There is a general need for the models to move towards more dynamic analysis of assessment, both for impact assessment (the dynamic processes of vulnerability and adaptation) and valuation. Finally to review some of the valuation estimates with respect to non-marginal nature of some effects (and whether marginal damage cost values are applicable),
- Further work on global assessments with detailed sectoral studies and regional integrations. This is necessary to progress a disaggregated analysis of the estimates by region and by sector. This could

involve a collation of individual studies, but in the longer term, a specific research project. Note it is essential that any such analysis adopts consistency (e.g. scenarios, climate data, socio-economic scenarios, interactions, to allow cross comparison). This would allow investigation of cross-linkages and interactions between sectors and regions.

- To capture the main missing elements of the risk matrix. This would extend the analysis of bounded risks (e.g. in relation to floods, storm damage) and non-market valuation (e.g. health and ecosystems). Further to undertake scoping studies to assess the potential magnitude of major events, e.g. Greenland ice sheet, etc. Some preliminary work has been undertaken, but this is a major area for future studies to focus, both for the timing of events (and relationship with different stabilisation levels) and the impacts. These are likely to have a major impact on the values. Finally, to progress the understanding of, and potential magnitude of socially contingent impacts, particularly looking at specific hot-spots such as Africa, Bangladesh, low lying islands.
- To further the analysis of adaptation costs. Many IAMs include adaptation, and it would be useful to separate out adaptation and damage costs. There is also a need to undertake a wider review and analysis of the literature on adaptation costs.
- Finally, work to bring all the impact and valuation data together in a form useful for policy analysis (i.e. a multi-analysis framework). Future policy considerations will need to balance impact analysis, monetary benefits, and work with significant uncertainty and sensitivity analysis to allow informed decisions. There is a need to develop a framework to maximise the usefulness of all the information for policy makers.

A more detailed research agenda expanding these themes has been prepared by the author and is available on request[11].

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