Response to Invited Reader Comment 1 dp 2011-22
2 October 2011

> *The main problem stems from the paper anchoring itself in the recent analysis of the SCC for US government regulatory impact assessments. This analysis was fundamentally flawed by applying constant, exogenous discount rates, as if climate change were (in any conceivable state of nature) a small problem, which would not affect consumption growth and were hence amenable to discounted cash flow analysis. This paper does not make that mistake (it uses the Ramsey rule properly), but it sets its pure rate of time preference (rho) and its elasticity of marginal utility (eta) in order to replicate the discount rates set in the US government analysis. As a result, rho and eta co-vary, so that we see, for example, the effect of different damage functional forms and parameterizations on the SCC when eta is zero but rho is 3%, when eta is one and rho is 0.95%, and when eta is 1.4 and rho is 0.14%. One cannot clearly see the effect of risk aversion, if rho co-varies. One could hold rho constant at various values, while looking at variation in eta.*

We agree with the commenter that our choice of values for η and ϱ are partially influenced by the desire for consistency with the central discount rate used in assessing climate change impacts in US regulatory impact assessments. This is a deliberate choice, as our intent is for this paper to be relevant to US policy discussions.

But there is also a good theoretical basis for our approach of calibrating ϱ and η to maintain (in the absence of climate change) a fixed average interest rate. Namely: we take as given the statement (implied by the US government SCC analysis) that risk-free interest rates will average 3% between 2015 and 2115, and we explore the different consumer preferences (in terms of elasticity of the marginal utility of consumption and rate of pure time preference) that might explain this "observed" interest rate. This interest rate might result entirely because consumers value the future less than the present (i.e., η could equal 0); or it might result entirely from consumer expectations about future wealth (i.e., ϱ could equal 0). Varying ϱ and η independently would necessitate changing the constraint provided by this observable (scenario-specified) "fact."

> *A second comment is that the range of values of eta considered is arguably too narrow. What constitutes an appropriate range is clearly debatable, and the debate is muddied by the fact that eta must simultaneously capture risk aversion and intertemporal consumption smoothing, calibration to which generally suggests different values. However, considering values of eta up to 2 and beyond to, say, 4 is certainly justifiable, especially in sensitivity analysis, as opposed to picking a central value.*

We agree that the range of η captured is too narrow, but this is a restriction that derives from the combination of (1) an average risk-free interest rate of 3%, (2) the use of a standard isoelastic model in which η stands in for both risk aversion and the inverse of the intertemporal elasticity of substitution, and (3) a (perhaps unnecessary) desire to avoid negative values of ϱ. We will consider adding an additional pair of values (e.g., $\eta = 2.0$ and $\varrho = -1.1\%$); switching to a discounting model that disaggregates different meanings of η is important but beyond the scope of this manuscript.

With respect to the commenters' minor comments:

> *In thinking about the nature of damages in section 2.5, it is worth citing Fankhauser and Tol (2005), who look at the effect of different models of economic growth on the*

way in which current climate damages to output propagate into the future via reduced investment. The basic point is that, if growth is somehow endogenous, the consequences of climate damage to current investment for future consumption are larger.

Thank you for the suggestion; we will note the Fankhauser & Tol paper in the revision.

- *Since with a CRRA utility function marginal utility tends to infinity as consumption tends to zero, the upper bound on climate damages could matter a lot to the estimate of the SCC in the event that it binds. Since it does bind at times in this paper, it is at least worth discussing uncertainty about where this upper bound could lie.*

In the original version of the manuscript, we assumed a lower bound to output of $2/person/day ($730/person/year), corresponding to the level of consumption that the World Bank defines as moderate poverty. There is, of course, considerable uncertainty about what the appropriate bound should be; and a more realistic model would likely need to allow population to decrease in response to extreme climate damages.

In the revised manuscript, we will consider the effects of different minimum output thresholds on the SCC; we will also consider the case in which the bound on per capita output is maintained by a reduction in population rather than an arbitrary increase in output.

The appropriate choice of a minimum bound to utility depends on the interpretation of this bound. On the one hand, it could be viewed as a statement about expected policy; a relatively high minimum bound could reflect a belief that humanity will assuredly act to prevent consumption per capita from falling below the level associated with this bound. This belief might lead one to choose to place the minimum bound to utility around the level associated with levels of consumptions close to the present value.

On the other hand, the minimum bound could be associated with a minimum level of consumption needed for existence. De Long (1998) estimates that world GDP per capita over the last million years has consistently exceeded ~$130. This estimates takes into account the creation of new types of goods for consumption. By contrast, Maddison (2006) employs a GDP per capita of $600 for subsistence economies, but does not take into account the creation of new categories of goods over time. (Both these values are adjusted to 2005 dollars, from 1990 dollars in the original sources.)

If one adopts this latter interpretation of the minimum bound, then the most natural way to implement it is via a Malthusian feedback on population size: if output falls below the subsistence level, then population falls until output/capita reaches the subsistence level. However, employing such an approach makes the SCC dependent upon the absolute scale used for utility. Note that the assumption of an isoelastic utility function leads to the formulation

$$U(c) = A + B\, c^{(1-\eta)} / (1-\eta)$$

If population is fixed, then the calculation of social welfare (and thus of the SCC) is not sensitive to the choice of A and B; however, if population varies among states of the world, it is. Fundamentally, this sensitivity is due to the question of whether social welfare is increased or decreased by the presence of additional individuals eking out an existence at the subsistence level. (If per capita income is $600/year, is social welfare higher if the population is 1 billion or 10 billion?) There being no positive way of answering this question, for the purposes of this manuscript, we do not explicitly implement the population feedback; this is approximately equivalent to assuming that changing the population of subsistence individuals does not affect social welfare.

By way of illustration, with $\eta = 1.4$ and $\varrho = 0.14\%$ and damage function Xc, we calculate a SCC equal to \$162/ton with a minimum per capita output of \$120, \$154/ton with a minimum per capita output of \$600, and \$142/ton with a minimum per capita output of \$3,000.

- *Given that the objective of estimating the SCC is to provide a normalized (i.e. monetized) estimate of the change in social welfare resulting from a marginal change in CO2 emissions, I don't see the reason for reporting the unadjusted Sterner-Persson SCC – it is inconsistent with what we are trying to measure.*

The primary reason for including the unadjusted Sterner-Persson SCC values is that (to our knowledge) the Sterner-Persson utility function has not previously been applied directly in SCC calculations, and the effect of current v. constant dollars on the SCC is important when applying such a utility function. We would like the considerations involved to be as transparent as possible. However, we agree that the applied value of the current dollars-denominated SCC is limited, and so in the revised manuscript we will emphasize the constant-dollars denominated SCC in the figures and restrict the current dollars-denominated values to the tables.

- *How are the standard deviations of damage function Xc, as described on page 15, calibrated?*

Since Xc is intended to be illustrative, and there is really no basis in the literature on which to calibrate the uncertainties, these standard deviations are largely arbitrary. The variance of the log normal distributions for the exponent and the calibration damages were chosen to yield a possibility of extreme poverty of slightly less than 1%, and a probability that our descendants in 2300 would be poorer than us of roughly twice this; other parameters were selected to yield reasonable indicative ranges. (For example, the percentage of consumption attributable to environmental goods was allow to span between 0 and the 15% used in Xb.)

References

J. B. DeLong (1998). Estimating world GDP, One Million B.C. - Present. http://econ161.berkeley.edu/TCEH/1998_Draft/World_GDP/Estimating_World_GDP.html

A. Maddision (2001). The world economy: a millennial perspective. OECD Publishing, 383 pp.