The "Stern Review" and Its Critics: Implications for the Theory and Practice of Benefit-Cost Analysis

Daniel H. Cole*

> "Every cost-benefit analysis is an exercise in subjective uncertainty. If, as the *Stern Review* puts it, 'climate change is the greatest externality the world has ever seen,' then a cost-benefit calculation of what to do about it is the greatest exercise in Bayesian decision theory that we economists have ever performed."
>
> – Martin Weitzman (2007)

1. Introduction

In 2003, the UK's Chancellor of the Exchequer, Gordon Brown, appointed Nicholas Stern, an Oxford economist and former World Bank chief economist and senior vice president, as second permanent secretary at HM Treasury. Two years later, Chancellor Brown asked Secretary Stern to head up an official governmental review of the economics of climate change. The UK Treasury published the "Stern Review" on the Economics of Climate Change (Stern 2007) on October 30, 2006. It was hardly the first benefit-cost analysis on climate change ever published (see, e.g., Cline 1992; Nordhaus and Boyer 2000). It was, however, the first analysis to be issued with the imprimatur of a major government. Consequently, the Stern Review had unusually high political salience and potential to influence policy.

Unsurprisingly, politicians and NGOs that favor rapid and strong action to mitigate greenhouse gas emissions greeted the nearly 600-page "Stern Review" with uncritical adulation,

* R. Bruce Townsend Professor of Law, Indiana University School of Law – Indianapolis. The author is grateful: to Martin Weitzman for providing a late draft of his forthcoming article (Weitzman 2007) in the *Journal of Economic Literature;* to Peter Grossman and Martin Weitzman for their helpful comments on drafts of this paper; and to the participants in the 2007 Benefit-Cost Analysis Conference at the University of Washington, particularly Dick Zerbe, the conference organizer.

while climate-change skeptics summarily bashed it.[1] More serious academic critiques of the Review were not long in coming. Several well-respected economists (including Nordhaus 2006; Dasgupta 2007; Maddison 2006; Mendelsohn 2006-7; Tol 2006; Yohe 2006; and Yohe and Tol 2007) have argued that the Review's assumptions, arguments and recommendations are seriously flawed, even biased. Others (including Quiggin 2006) have given the Review more generous readings. In perhaps the most nuanced and interesting of all the reviews, Weitzman (2007) deftly criticizes the Stern Review's assumptions and analysis, but goes on to suggest why, ultimately, the Review's conclusions might be sound. Weitzman's analysis, in particular, has important implications for the practice of BCA as it applies to policies like climate change, which involve long time horizons, potentially catastrophic levels of harm, and very high levels of uncertainty.

The purpose of this paper is to explain that the disagreements over the quality of the Stern Review (among serious scholars without ostensible political or ideological agendas) largely reflect disagreements about how BCAs generally should (and should not) be done. To that end, it focuses on the Stern Review's BCA from a process-oriented perspective. What can producers and consumers of benefit-cost analyses learn from the Stern Review and its critics about the theory and practice of benefit-cost analysis? The lessons are several, including many negative lessons about how benefit-cost analyses should *not* be done. Less obvious, but just as important, are one or two positive lessons from the Stern Review. The lessons, both positive and negative, relate to the selection of parameter values, including discount rates, and methods of estimating damages.

2. A Summary of the Stern Review

The Stern Review does three things: (1) it assesses the likely costs of climate change up to 2200 under a "business as usual" (BAU) policy, where nothing is done to control emissions rates or atmospheric concentrations of greenhouse gases (GHGs); (2) it assess the costs and benefits of various levels of emissions mitigation/climate stabilization; and (3) it assess policy

[1] The Center for Science and Public Policy (Nov. 2006) and Ribo̍ń (Dec. 2006) compile some of those early responses.

options in light of the analyses in (1) and (2).

2.1 The PAGE2002 Model

In order to assess the costs of climate change, a special kind of model is required to integrate scientific and economic information about GHG emissions, atmospheric concentrations, and impacts. The goal is to simulate the process of climate change starting from GHG emissions through atmospheric concentrations to climate effects and ultimately the socio-economic impacts of climate change. The Stern Review uses an Integrated Assessment Model (IAM) called PAGE2002,[2] which was developed by Cambridge economist Chris Hope (2006). Chapter 6 of the Stern Review provides some (but not all[3]) relevant details of the PAGE2002 model and how it was employed to derive climate change damage functions under various GHG emission trajectories.

The PAGE2002 IAM measures socio-economic impacts of climate change in terms of differential per capita income growth rates under various scenarios ranging from zero climate change at one extreme to BAU at the other. Between those two limits lies a continuum of points at which GHG emissions are mitigated to one extent or another and atmospheric concentrations of CO_2 are stabilized. The precise relations between GHG emissions, atmospheric concentration levels, climate changes, and the socio-economic effects of those changes are, of course, subject to high levels of uncertainty, which increase with time. Among other uncertainties is the prospect of a nonlinear damage function resulting from extreme climate events, climate feedback mechanisms, and other large-scale discontinuities. The Intergovernmental Panel on Climate Change's (IPCC) Third Assessment Report (TAR) (2001) expressed serious concern over such impacts, and Chris Hope designed PAGE2002 precisely to incorporate them.

---

[2] "PAGE" stands for "Policy Analysis of the Greenhouse Effect" (see Stern 2007, p. 153).

[3] The failure to discuss all relevant details of the model, itself, can be considered a possible violation of "best practices" for BCA, especially given the overall importance of the choice of model to the outcome of the BCA. However, all relevant details about the model are available in Hope (2006), on which this summary of the Stern Review relies extensively.

The PAGE2002 IAM factors uncertainty into the analysis by incorporating a Monte Carlo analysis that repeatedly solves the model using 79 random variables for key parameters (Hope 2006, Appendix 1, pp. 36-7). Those variables include (among others) emissions of primary GHGs, atmospheric concentrations of GHGs, concentrations of sulphate aerosols that cool the atmosphere, regional temperature effects for eight regions of the world, nonlinear and transient damages, regional economic growth, investments in climate change adaptation measures, and the possibility of some future, large-scale discontinuity (Hope 2006, pp. 20-1). The model is run 1000 times to generate "a range of possible trajectories for GDP per capita net of climate change related damage costs" (Maddison 2006, p. 4). It then produces a probability density function of economic damage outcomes for various GHG emission levels over time.

It was precisely this ability of the PAGE2002 IAM to incorporate nonlinear damage functions, including potential catastrophic events, and nonmarket costs that evidently led the Stern Review's authors to adopt that model rather than alternative IAMs.[4] Various statements throughout the Stern Review signal an intention to estimate not only the mean expected-values of climate change damage, but higher harm-based scenarios. For example, Stern and his colleagues write that "the science and economics are particularly sparse precisely where the stakes are highest – at the high temperatures we now know may be possible" (Stern 2007, p. 34). Later, they state that "the knowledge base on which the cost of climate change is calibrated – specialized studies on impacts on agriculture, ecosystems and so on – is particularly patchy at high temperatures. In principle, the gaps that remain may lead to underestimates or overestimates of global impacts. In practice, however, most of the unresolved issues will increase damage estimates" (Stern 2007, p. 149). The Stern Review then criticizes earlier studies for limiting their analyses "to a small subset of the most well understood, but least damaging, impacts" (Stern 2007, p. 150). In effect, earlier analysts looked only where the light was better, ignoring impacts "that have the potential to inflict the greatest damage" simply because those impacts were "surrounded by the greatest scientific uncertainty" (Stern 2007, pp. 150-1). Thus, the Stern

[4] In contrast to PAGE2002, Mendelsohn et als' (1998) model does not account for nonmarket impacts or catastrophic events. Tol's (2002) model accounts for some nonmarket impacts, but does not account for catastrophic events. Nordhaus and Boyer's (2000) model accounts for some catastrophic events but not nonmarket impacts. See Stern (2007, p. 150 fig. 6.3).

Review seems to have been intended, at least in part, as a BCA of *worse*-case scenarios for climate change.[5]

In addition to facilitating the incorporation of large-scale discontinuities in the damages function, the PAGE2002 IAM had the advantage of closely tracking the scientific projections of the IPCC's TAR, falling short by only about 40 ppm of CO_2 concentration at the IPCC's mean projection under BAU of 700 to 800 ppm for the year 2100. PAGE2002's 5th percentile and 95th percentile projections were also very close to the outer bounds of the IPCC's TAR projections.[6]

Among the important projections of the IPCC's TAR, which profoundly influenced both the PAGE2002 IAM and the Stern Review's outcome was the finding that the impact of a large-scale discontinuity might exceed ordinary disasters by orders of magnitude. The chance of large-scale discontinuities is estimated to be significant only after mean temperature has risen 5ºC over pre-industrial levels, but for every 1ºC rise above that point the chance of a large-scale discontinuity increases by 10% (IPCC 2001, p. 947). PAGE2002 presumes a 10% loss to EU gross domestic product (GDP) from any large-scale discontinuity that does occur at or above temperature increases of 6ºC. In recognition that other regions of the world would suffer greater or lesser losses (or even make gains) from higher-than-expected temperature changes, expected income affects are weighted to allow for comparison and aggregation across regions (Hope 2006, pp. 23-4).

Because of the great uncertainties in the occurrence and effects of large-scale discontinuities, PAGE20002 provides wide parameter ranges. But as Hope (2006, p. 25) and Stern (2007, p. 151) both note, it is important not to ignore large-scale discontinuities in estimating the economic effects of climate change just because they are subject to great

---

[5] Weitzman (2007, p. 3) appears to agree with this assessment in noting that "the *Stern Review* consistently leans towards (and consistently phrases issues in terms of) assumptions and formulations that emphasize ... pessimistically-high expected damages from greenhouse warming – relative to most other studies of the economics of climate change." Whether or not the Stern Review's "worse-case" approach comports with (presumed) "best practices" in regulatory BCA, is a question addressed later in this paper.

[6] It is worth wondering why the Stern Review was published just months before the IPCC (2007) released its Fourth Assessment Report (FAR), which significantly altered some of the projections made in the 2001 TAR. The Stern Review's authors incorporated into their model a good deal of the science on which the FAR is based. However, they could not await the FAR's publication because they were operating under an Autumn 2006 deadline set by the Chancellor of the Exchequer.

uncertainty. Their intuition seems right: it is better to incorporate wide parameter ranges with high margins of error than to virtually ensure large errors by summarily excluding large-scale discontinuities from the damage function.[7]

2.2 Applying the Model

The Stern group ran the PAGE2002 model under two different assumed levels of climatic response to BAU (no controls on present or future emissions rates) (1) the "baseline" scenario designed to give outputs consistent with the IPCC's TAR (as in Hope 2006), and (2) a "high climate" scenario which adds the risk of nonlinear damages, resulting for example from natural feedbacks in the climate system. Obviously, the "high climate" scenario results in a higher probability of larger temperature changes and, consequently, higher expected social costs. According to Stern (2007, p. 158), "[i]n the high scenario, global mean temperature rises to an average of nearly 4.3ºC above pre-industrial levels by 2100, compared with an average of 3.9ºC above pre-industrial levels in the baseline scenario." And the temperature difference between the two scenarios increases after 2100. By 2200, the average increase in mean global temperatures increases by 7.4ºC above pre-industrial levels on the baseline scenario, and by 8.6ºC on the "high climate" scenario (Stern 2007, p. 158). The Stern Review warns that temperature increases, especially beyond 2100, should be treated as "indicative" only because uncertainty about effects increases with time (Stern 2007, p. 158). But the Review's authors ignore their own words of caution in deriving preliminary estimates of average losses in global per capita GDP in 2200 ranging from 5.3% to 13.8%, "depending on the size of climate-system feedbacks and what estimates of 'non-market impacts' are included" (Stern 2007, p. 155). They do, however, add the important caveat that "growth in GDP will have made the world considerably richer than it is now" (Stern 2007, p. 158).

The size of climate change costs is not the only important consideration. The distribution of those costs also matters. The Stern group notes (in accordance with virtually every other analyst, including, e.g., Schelling 2006a, pp. 34-5) that the costs of climate change will not be

[7] As we shall see later, Weitzman (2007) seems to agree.

distributed evenly or randomly throughout the world. Rather, the costs are expected to fall most heavily in less developed regions of the world that (a) have contributed least (so far) to GHG emissions and (b) can least afford to bear the costs of climate change. "[I]n the baseline-climate scenario with all three categories of economic impact [market, risk of catastrophe, and non-market], the mean cost to India and South-East Asia is around 6% of regional GDP by 2100, compared with a global average of 2.6%" (Stern 2007, p. 158). The inequitable distribution of climate change costs introduces an important ethical component into climate change policy, which the Stern Review does not neglect.

In deriving its damage figures, the Stern Review employs standard economic assumptions from welfare economics theory, including the assumption of diminishing marginal utility of income in evaluating risks and future welfare. But then Stern deliberately courts controversy by choosing a very low pure rate of time preference (utility discount rate) of 0.1% per year. I will postpone until the next section a discussion of the controversy over that very low rate. For present purposes, it is necessary only to understanding the proper role the utility discount rate plays in the Stern Review's calculations. In particular, we need to distinguish carefully between pure rate of time preference and the interest rate used to discount consumption (see Weitzman 2007, p. 5). In Frank Ramsey's modern formulation of Irving Fisher's dynamic general equilibrium model of the interaction of preferences and technological change

$$r = \rho + \eta g,$$

where r is the interest rate that discounts consumption, ρ is the pure rate of time preference, η is the elasticity of marginal utility or the base-case coefficient of relative risk aversion (what someone would be willing to pay today to insure against an expected future loss),[8] and g is the per-capita growth rate of consumption (Weitzman 2007, p. 5). In the Stern Review, $\rho = 0.1\%$, $\eta = 1$, and $g = 1.3\%$. Plugging these figures into the Ramsey equation, gives us a value of r (the

[8] John Quiggin (2006), explains the effect of the choice of η ("eta"): "Using eta = 1, a sacrifice of $70 per person (1 per cent of income) today would be justified if (and only if) it increased the income of our great-grandchildren in 2100 by at least $1,000. If this trade-off appears reasonable, then a value of eta = 1 is appropriate. If the future payoff required is higher (or lower) then so is the preferred value of eta."

discount rate of consumption) = 1.4%. As Weitzman (2007, p. 7) notes, Stern's choice of a very low pure rate of time preference (ρ) and a relatively low coefficient of relative risk aversion (η) results in an unusually low consumption discount rate (r). Compared to other, more conventional discount rates, the Stern Review's r = 1.4% leads to estimated damage costs 100 years from now that exceed by two orders of magnitude estimates using a more conventional r = 6% (e.g., where ρ, η, and g each = 2) (Weitzman 2007, p. 7).[9]

Based on its low parameter values, the Stern Review's analysis shows that under BAU (uncontrolled GHG emissions indefinitely into the future) the risks of climate change between 2100 and 2200 will be equivalent to about 5% of global GDP each year, and possibly as high as 20%, "forever" (Stern 2007, p. 163). As noted earlier, estimated damages would only 1/100th as large with different parameter values yielding r = 6%.

2.3 The Costs and Benefits of Carbon Mitigation/Climate Stabilization

Next, Stern assesses the economics of mitigation/stabilization. In accordance with IPCC TAR and more recent data, he finds that stabilization of GHG concentrations necessary to avoid high costs of climate change will require "deep emissions cuts of at least 25% by 2050" (Stern 2007, p. 168). Nominally, that would be a decline of 30-35 $GtCO_2$ (Stern 2007, p. 201). To achieve that goal, emissions would peak during the next 10 to 20 years, and then decline by between 1% and 3% per year (Stern 2007, p. 201). The Stern Review estimates that cutting emissions 25% by 2050 would cost approximately 1% of annual global GDP (about $1 trillion in 2050), plus or minus 3%, and would stabilize concentration levels at between 500-550 ppm of carbon dioxide equivalent (CO_2eq) (Stern 2007, pp. 168, 240). At such concentration levels, the most harmful effects (and costs) of climate change would be averted. By investing 1% of annual global GDP starting now (and continuing potentially forever), Stern (2007, p. 285) calculates

[9] As Weitzman (2007, p. 8) notes, this "no frills stripped-down variant of the Ramsey model ... is liable to a thousand and one legitimate questions and criticisms about its oversimplifications, but at the end of the day ... this exercise is highlighting fairly what really counts in the economics of climate change." For a clear and accessible discussion of alternative models for discounting and their various issues, see Moore et al. 2004).

that the world could avert costs to annual global GDP of 10% "forever." In the "worst case" scenario, climate change mitigation would yield net global costs of 3.4% of annual global GDP. In the "best case scenario," climate change mitigation would yield net global benefits of 3.9% to annual global GDP (Stern 2007, p. 242).

Finally, the Stern Review considers policy options for mitigating GHG emissions, and uncontroversially recommends a Pigouvian carbon tax or tradeable permitting system, which would establish a price of carbon at or near the social-cost level (Stern 2007, p. xviii). While the Stern Review presents a fairly comprehensive and detailed introduction to various policy options, it does not actually engage in a comparative BCA (or comparative cost-effectiveness analysis) of alternative policies for achieving its goal of climate stabilization at 500-550 ppm of CO_2eq by 2050.

3. Critiques of the Stern Review

We now turn our attention to the critics of the Stern Review. Our focus will be on those criticisms that have the most salience for the general theory and practice of regulatory BCA. We will not, for example, attempt to assess or resolve complaints that Stern misinterpreted or misapplied scientific data (see, e.g., Carter et al. 2006). We take it as given any set of "best practice" standards for BCA would require use of the best available information inputs with due care to avoid errors.[10] We further assume that the Stern group endeavored to comply with this requirement in good faith.[11] If good-faith errors of scientific fact have occurred, then that authors

[10] It is, perhaps, the first "best practice" standard of regulatory BCA to exercise due care in avoiding the problem of "garbage in, garbage out."

[11] Yohe and Tol (2007, p. 39) allege that the Stern Review "subjected academic standards to political goals." Similarly, Nordhaus (2006, p. 5) suggests that "the *Review* should be viewed as a political document"rather than "an academic study." Such statements fall short, however, of alleging deliberate manipulation of inputs or procedures. In any case, neither Nordhaus nor Yohe and Tol provide any evidence of deliberate manipulation. The use of a low pure rate of time preference is not necessarily evidence that the Stern Review authors were massaging the numbers to yield an outcome they preferred. Even if we disagree with $\rho = 0.1\%$, the Stern Review sets forth legitimate reasons – aside from instrumental political values – to support that value.

certainly should correct them in a supplemental BCA. We also we take for granted that any discrepancies between the science-basis of the Stern Review and IPCC's FAR (2007) should be dealt with in a supplemental BCA, prepared under auspices of HM Treasury, using the same PAGE2002 IAM or explaining why the new data require a change in the model. Having cabined simple factual errors and subsequent improvements to the knowledge base, we can proceed to address what is truly significant in the Stern Review for the theory and practice of regulatory BCA.

Relevant critiques of the Stern Review focus on its damage estimates and assumptions about parameter values, including the pure rate of time preference (ρ), the choice of the η, and the rate of growth in per capita consumption.

3.1 Problems with the Stern Review's Damage Estimates

Yohe and Tol (2007, p. 40 Table 1) provide several "reasons for concern" about the Stern Review's damage estimates, including the fact that they exceeded other studies' damage estimates by 3 standard deviations. In part, this is a function of Stern's (2007) assumption of more pessimistic scenarios. In addition, Mendelsohn (2006-7, p. 44) notes that many of Stern's damage estimations did not take account of possible adaptation measures, such as dams and sea walls, that might reduce the level of harm. Mendelsohn also points out that Stern assumed large nonmarket damages, without supporting evidence. Most problematically, Stern did not specify assumed valuations for human lives and other nonmarket goods, rendering the Review's damage estimations impossible to assess or replicate. This omission must violate any conceivable set of "best practice" standards for BCA.

3.2 Is ρ = 0.1% too low?

The single most controversial aspect of the Stern Review undoubtedly has been the choice of 0.1% as the pure rate of time preference (ρ). The reason, of course, is that this choice dramatically effects the overall outcome of the BCA. As noted earlier, the Stern Review's low ρ, when combined with a low coefficient of relative risk aversion (η = 1) yields a low interest rate

(r = 1.4%) for discounting future consumption, which magnifies future damages by two orders of magnitude over a more conventional 6% interest rate for discounting future consumption. As Yohe and Tol (2007, p. 39) observe, "[m]oving from a discount rate of 0.1 percent to 1 percent would lower damage estimates by nearly 60 percent; moving to 2 percent by roughly another 20 percent, and moving to 3 percent by another 15 percent. As a result, damages calculated from the same underlying data with a 3 percent discount rate would produce damage estimates between 10 and 20 percent of the estimates reported in the *Review*."

In fact, the choice of a very low pure rate of time preference in the Stern Review results in damage estimates under BAU far higher than those derived in any other economic study of climate change ever conducted. Tol (2005) conducted a meta-analysis of 28 published studies providing a total of 103 estimates of marginal damage costs of carbon dioxide emissions. The utility discount rates in those 28 studies generally ranged between 1 and 3 percent (with some cases of hyperbolic discounting). Among those studies, Tol (2005, p. 2072) found that the utility discount rate/pure rate of time preference has a

> stark[] influence on the central estimate but particularly on the uncertainty. If we use a pure rate of time preference of 3% – corresponding to a social rate of discount of 4-5%, close to what most western governments use for most long-term investments – the combined mean estimate is \$16/tC (ton of carbon), not exceeding \$62/tC with a probability of 95%. Lower social rates of discount lead to higher estimates but particularly to greater uncertainty, but even for a 1% pure rate of time preference the combined mean is \$51/tC. Even lower discount rates may be morally preferable, but are clearly out of line with common practice.[12]

Compare Tol's (2005) combined mean estimates with the Stern Review's (2006, p. xvi) estimate of \$85/tCO_2eq under BAU. No wonder the Stern Review calls for quicker and steeper reductions

[12] The last sentence of the quote from Tol (2005) is intriguing. If a lower discount rate is "morally preferable" but "out of line with common practice," which should be adjusted, the "morally preferable" discount rate or the common practice? As we shall see later, Weitzman (2007) presents a strong (but not necessarily convincing) ethical argument that the discount rate should be made to comport to convention.

in GHG emissions than any previous BCA. This is not to say, however, that the Stern Review's cost-estimate is necessarily wrong. As Tol (2005, p. 2067) himself notes in his meta-analysis:

> The current generation of aggregate estimates may understate the true cost of climate change because they tend to ignore extreme weather events; exclude low probability/high consequence scenarios, such as a shut-down of the thermohaline circulation ... or a collapse of the West-Antarctic ice sheet...; underestimate the compounding effect of multiple stresses; and ignore the costs of transition and learning.

Each of the factors missing from the earlier studies is present and accounted for in the Stern Review. That must justify a higher cost-estimate. How much higher? Tol (2006, p. 979) does not tell us, but concludes that the Stern Review "overestimates the impacts of climate change, and therefore the benefits of emission reduction."[13]

William Nordhaus (2006) agrees with Tol's assessment, and concludes that the Stern Review's choice of a very low ρ, more than any other factor, explains why the Stern Report's results differ so dramatically from those of other climate change BCAs, including his own:[14]

> The *Review* proposes using a social discount rate that is essentially zero. Combined with other assumptions, this magnifies enormously impacts in the distant future and rationalizes deep cuts in emissions, and indeed in all consumption, today. If we were to substitute more conventional discount rates

[13] In the popular media, Tol was even more damning of the Stern Review's conclusions: "'If a student of mine were to hand in this report as a Master's thesis, perhaps if I were in a good mood I would give him a 'D' for diligence; but more likely I would give him an 'F' for fail.... There is a whole range of very basic economics mistakes that somebody who claims to be a Professor of Economics simply should not make'" (Cox and Vadon 2007). Tol's more sober scholarly criticisms do not seem to support such a conclusion.

[14] Nordhaus (2006, p. 16) also argues that the selection of a pure rate of time preference of 0.1% "is inconsistent with its utility curvature assumption [η] of 1," but this argument assumes implausibly, and inconsistently with the assumptions of the Stern Review, that population growth is zero.

> used in other global-warming analyses by governments, by consumers, or by businesses, the *Review*'s dramatic results would disappear...."[15]

Of course, Nordhaus has a dog in this fight. He has been conducting economic analyses of climate change for nearly 20 years, and his more recent studies have utilized a 3% discount rate, declining to 1% per year over 300 years. The Stern Review expressly argues that Nordhaus's studies using the DICE IAM (among other IAMs) have systematically underestimated the costs of climate change under a BAU scenario (Stern 2007, pp. 149-52).[16] By attacking the Stern Review's relatively low parameter values, Nordhaus (2006) is defending his own choices, which after all are more consistent with the rest of the literature (perhaps in part because of the influence of Nordhaus's work).[17]

It is not just the choice of a low pure rate of time preference that bothers reviewers. Mendelsohn (2006-7, p. 43) rightly complains that the Stern Review fails to apply its discount rate consistently throughout the analysis. It discounts the costs and benefits of climate change under BAU, but fails to discount the costs of mitigation. "To be consistent," Mendelsohn notes, "the opportunity cost of investing in mitigation must also be valued using the same discount rate as was used to determine the cost of climate change. Because investing in mitigation substitute for investing in other activities that can earn the market rate of interest, society loses the income that it could have gained from other valuable projects."

But why did Stern (2007) choose such a low utility discount rate in the first place? Was it a politically motivated choice to inflate cost estimates so as to justify more rapid and extreme measures to control GHG emissions? While the Stern Review is replete with expressions of

---

[15] Nordhaus's assertion about the "social discount rate" is potentially misleading. Usually, when economists discuss the "social discount rate," they are talking about r (the discount rate of consumption) rather than ρ (the pure rate of time preference). The Stern Review's pure rate of time preference (or utility discount rate) was "essentially zero," but its social discount rate was actually 1.4%.

[16] Other critics have made similar arguments about Nordhaus's model. See, e.g., Cline (2004); Ackerman and Finlayson (2005); Quiggin (2006).

[17] In an e-mail message he sent to Sir Nicholas Stern, Nordhaus reportedly stated that the Review "it's a great study, but it's 50 years ahead of its time.... Since everybody else is 50 years behind the times, if you average the two, you might come out just right" (Leonhardt 2007).

concern that earlier studies had under-estimated the costs of climate change, Stern certainly does not attempt to justify the choice of a low discount rate on this basis alone. Rather, he follows the lead of several other prominent economists such as Frank Ramsey, Amartya Sen, and Robert Solow, in presenting affirmative and legitimate *ethical reasons* against anything higher than a minimal discount rate for estimating the costs of climate change (Stern 2007, p. 45). Ramsey (1928, p. 261) famously argued that discounting is "ethically indefensible and arises merely from the weakness of the imagination." Even if discounting is a "brute fact," as the late David Pearce (2003, p. 122) pointed out, because people "do discount for time and for space," that "brute fact" would not contradict Ramsey's point. The decision to discount and the choice of a social discount rate is not just a matter of positive economics but normative ethics. Sir Nicholas Stern, for one, thinks that people should not discount for time and space. In fact, the only reason the Stern Review uses a 0.1% pure rate of time preference rather than zero rate is the slim risk of human extinction during the course of the current century (Stern 2007, p. 47).

The bottom-line question is whether the Stern Review's pure rate of time preference is so low as to violate some presumed "best practice standard." As a matter of theory and practice, this is a difficult question to answer. The choice of social discount rate is inherently subjective, and as Portney and Weyant (1999, p. 4) have observed, "[t]hose looking for guidance on the choice of discount rate could find justification [in the literature] for a rate at or near zero, as high as 20 percent, and any and all values in between." Thus, the Stern Review's choice of a discount rate close to zero does not seem invalid *per se*. That it deviates from the literature does not make it wrong, only deviant. We might conclude that deviance from an accepted norm would violate a duty of BCA producers not to impose their own values paternalistically on society.[18] But it is not at all clear that such a norm exists.[19]

[18] Weitzman (2007, pp. 8-9) makes this point.

[19] We will return to this question in the following section.

3.3. Is $\eta = 1$ too low?

One prominent critic of the Stern Review, Partha Dasgupta (2007) has no complaint with Stern Review's selection of 0.1% for the pure rate of time preference. This is unsurprising as Dasgupta himself has suggested that the discount rate for climate change might be zero or even negative, if costs are severe enough to require reductions in consumption (Dasgupta, Mäler, and Barrett 1999). Moreover, Dasgupta notes that there is precedent for Stern's choice of a low pure rate of time preference. William Cline's (1992) pioneering economic analysis of global warming set ρ at zero (Dasgupta 2007, p. 5).[20]

However, Dasgupta is highly critical of the Stern Review's choice of η (the elasticity of marginal utility or coefficient of relative risk aversion). "To assume that [η] equals 1 is to say that the distribution of well-being among people doesn't matter much, that we should spend huge amounts for later generations even if, adjusting for risk, they were expected to be much better off than us" (Dasgupta 2007, p. 6). A high η would "imply greater sensitivity to risk and inequality in consumption" (Dasgupta 2007, p. 6).

To give a feel for how changing the η alters consequences, Dasgupta provides the following example. If the rate of return on investment is 4% per annum, then under the Stern Review's assumptions of $\rho = 0.1$ and $\eta = 1$ the social saving rate ought to be 97.5%, which is so out of line with social practice as to be ridiculous. If, however, we altered the Stern Review's assumptions so that η equaled 3, the optimum saving rate would fall to a more reasonable (but still pretty darn high) rate of 25% of net aggregate output. Dasgupta (2007, p. 6) notes that the Stern Review contains no sensitivity analysis for its set of assumptions about the values of ρ, η, and g.[21] From the perspective of "best practices" for BCA, this is probably his most significant

[20] In fact, Cline (1992) adopted parameter values all of which were very close to those chosen by Stern (2007). In Cline (1992), $\rho = 0\%$, $\eta = 1.5$, and $g = 1\%$, which in the Ramsey model yields $r = 1.5\%$, a mere one-tenth of one percent above the Stern Review's value for r. And Weitzman (2007, p. 13) notes that, like Stern (2007), Cline (1992) reached "strong activist conclusions."

[21] In addition to his critique of the Stern Review's choice of η, Dasgupta (2007, pp. 6-7) makes a salient observation about the public choice implications of the Review's conclusion that the world should spend 1% of global GDP annually to combat climate change. He reasonably assumes that all of the spending would come from the world's developed countries, and that 1% of global GDP would equal

complaint.

John Quiggin (2006, p. 15) takes issue with Dasgupta's argument about the Stern Review's valuation of η based on a presumed 4% market rate of return on investment. According to Quiggin, "the fact that we see more rapid growth with lower rates of net saving seems to imply that there must exist many projects with rates of return greater than or equal to 4 percent." In addition, "[i]n an economy where most growth in consumption arises from technical progress, the optimal rate of saving is far lower than that derived by Dasgupta. Finally, "[a] more direct way of refuting Dasgupta's argument is to observe that the major premise must be false. If there existed an infinite supply of projects with riskless returns of 4 per cent, the rate or return on riskless bonds would have to equal 4 per cent, rather than the 1 to 2 per cent observed in practice."

Whatever we might conclude about Dasgupta's argument that the Stern Review's η is too low, he has performed a valuable service in focusing attention on a relatively neglected element in the composition of r, the discount rate of consumption. The η actually combines three distinct valuations into a single number: (1) the measure of risk aversion; (2) a judgment about the extent of static income inequality among different people; and (3) a judgment about the extent of dynamic income inequality for a single individual over time. The inferences about each one of

---

1.8% of developed countries GDP. But, he notes, that figure would be "some seven times the annual global aid budget." Implicit is the assumption that spending to mitigate global climate change constitutes foreign aid. This assumption is strongly supported by Tom Schelling's assessment of climate change as a political-economic issue. According to Schelling (2006a and 2006b), spending to counteract climate change constitutes foreign aid because the primary (if not exclusive) "investors" would be developed countries, while the primary (though not exclusive) beneficiaries would be developing countries, which are expected to bear the brunt of climate change costs.

Assuming, with Dasgupta and Schelling, that spending on climate change mitigation would constitute foreign aid (entirely or predominantly), a key question becomes how to persuade voting publics in developed countries to instruct their governments, collectively, to increase foreign aid spending so dramatically. Dasgupta suggests that simply stating it as a moral imperative is unlikely to be effective. But, of course, the Stern Review does not simply make a moral argument about the need for more spending to minimize the social costs of climate change; its argument is first and foremost economic. If spending more now can reduce costs down the road (after those costs are discounted to present value), then the choice is a matter of both economic efficiency and ethics. Whether or not developed countries would internalize enough of those efficiency gains to make the additional investment in foreign aid worthwhile remains questionable.

these judgments affects the valuations of the others and the overall valuation of η.[22] According to Weitzman's (forthcoming 2007) interpretation, the authors of the Stern Review seem to want a low η for some purposes, but a higher η for others. This is obviously problematic, and it points out the potential difficulties, for BCAs generally, of reposing various judgments or valuations in a single number, η.

3.4 It's the r, stupid!

As a practical matter, neither the choice of ρ (pure rate of time preference) nor η (coefficient of the relative rate of risk aversion), alone, is all that important. Rather, it is the combination of those factors along with g (the assumed growth rate of per capita consumption), in the Ramsey equation, which determine r – the interest rate at which future consumption is discounted. As Weitzman (2007) usefully reminds us, it is the r that ultimately matters most in BCA.

As we have seen, the Stern Review selects the following values: $\rho = 0.1\%$, $\eta = 1$, and $g = 1.3\%$ to yield $r = 1.4\%$. Weitzman (2007, p. 2) agrees with Nordhaus (2006) and Tol (2006) that "[t]he discount rate we choose is all important and *Stern's* results come from choosing a very low discount rate."[23] But whereas Nordhaus and Tol focused on the ρ, Weitzman focuses more appropriately on the r. He notes that if we assume that $\rho = 2\%$, $\eta = 2$, and $g = 2\%$, then $r = 6\%$. If we assume instead that $\rho = 0\%$, $\eta = 3$, and $g = 2\%$, then r still = 6%. Thus, we can derive the same consumption discount rate, whether ρ equals 2% or 0%, by adjusting the η and/or g (Weitzman 2007, p. 6).

The Stern Review's $r = 1.4\%$ is comparatively low because the selected rate of time preference is very low *and* the value chosen for the coefficient of the relative rate of risk

[22] I am grateful to Marty Weitzman for his assistance in unpacking these discrete aspects of the η, and the complications that can (but do not necessarily) arise from their combination into a single numeric value.

[23] He does not argue, however, that Stern was wrong to adopt such a low pure rate of time preference, but only notes that "*Stern* follows a decidedly-minority paternalistic view (which, however, includes a handful of distinguished economists" (Weitzman 2007, p. 6).

aversion, $\eta = 1$, is "the lower bound of just about any economist's best-guess range" (Weitzman 2007, pp. 6-7). Weitzman points out that under an alternative $r = 6$, the Stern Review's present discounted value of damages from climate change over the next 100 years would be lower by two orders of magnitude. And so, "what really counts in the economics of climate change [is] the hidden discounting assumptions whose role tends to be more obscured than informed by the big IAMs" (Weitzman 2007, pp. 7-8).[24] Of course, this is not just a criticism of the Stern Review and its choice of parameter values. Rather, it is a challenge to the entire practice of economic analysis of climate change. But it is especially relevant to the Stern Review simply because its authors assumed parameter values that ignored how people are observed to act. As Weitzman (2007, pp. 8-9) puts it:

> *Stern*'s worldview tends to blow off market-based observations and behavioral influences as being (for a variety of reasons including market incompleteness) largely irrelevant to long-run discounting, which should instead be based primarily on the 'ethical' value $\rho \approx 0$ that *Stern* imposes on *a priori* grounds.... While there may be *something* to *Stern*'s position about the limited relevance of market-based inferences for putting welfare weights on the utilities of one's great-grandchildren, and there might be *some* sporadic support for *Stern*'s preferred taste parameters scattered throughout the literature, I ultimately find such an extreme stance on the primacy of $\rho \approx 0$, $\eta \approx 0$ unconvincing when super-strong policy advice is so dependent upon nonconventional assumptions that go so strongly against mainstream economics.[25]

[24] It is not at all clear why Weitzman believes that the discounting assumptions in Stern (2007) or other models have been "hidden." They are debatable to be sure, and they certainly seem to drive the outcomes not only of Stern (2007) but Nordhaus and Boyer (2000) as well, among other economic analyses of climate change.

[25] Later in his review, however, Weitzman (2007, pp. 15-6) shows that observed economic behavior creates problems not just for Stern's (2006) choice of parameter values but "threatens all such formulations."

In essence, Weitzman's argument is about the values of convention and prudence in BCA: analysts should not rest strong and socially costly policy recommendations on conclusions from analyses that depend so heavily on unconventional assumptions, especially when those assumptions run counter to observed economic behavior.[26] In addition, Weitzman seems to be making an important point about the role of economic analysts: it is not their job to impose their own values and preferences on society. Their job, rather, is to input the best available data in a responsible fashion, and analyze that data using models based on prudent assumptions that are broadly consistent with the way people are actually observed to behave. Then, they can present the results to policy-makers, whose job it is to make decisions that either comport with or "go ... strongly against mainstream economics."[27] If I am interpreting him correctly, Weitzman is making a strong ethical argument about how BCAs should and should not be done.

3.5 Or, is it the g?

Although Weitzman strongly criticizes the Stern Review for its assumptions and analytical weaknesses, he is not so quick as other reviewers to denounce its conclusions or policy recommendations. To the contrary, he suggests that the Stern Review's value of r may end up "being more right than wrong when full accounting is made for the uncertainty of the discount rate itself, which is arguably the most important uncertainty of all in the economics of climate change" (Weitzman 2007, p. 9). Why? Because "[t]he very same force of compound interest that makes costs and benefits a century from now seem relatively insignificant, and that additionally creates the 'majority tilt' of a pain-postponing climate policy ramp of emissions

[26] However, as Newell and Pizer (2001, p. 13) point out, "there are few if any observable market rates for investment horizons more than 30 years in the future, making the interest rate beyond those horizons even more uncertain than it otherwise might be." Given the lack of "observable market rates" for investments with longer times horizons and the likelihood that uncertainty over future interest rates militates in favor of lower discount rates (see Weitzman 2007, p. 9), to what extent can the Stern Review really be faulted for ignoring "observed economic behavior" in selecting a value of ρ?

[27] The roles of analyst and policy-maker are somewhat obscured in the Stern Review because, in his position as second permanent secretary of HM Treasury Sir Nicholas Stern was not *just* an analyst but a policy-maker as well.

reductions starting from a low gradual base [as in Nordhaus's model], also forces us to recognize the logic that over such long periods we should be using interest rates at the lower end of the spectrum of possible values" (Weitzman 2007, pp. 9-10). Specifically, Weitzman (2007, p. 27) suggests that uncertainty over which discount rates to use for the costs and benefits of climate change a century from now might reduce the value of *r* from 6% to as low as 2%, which not far above the Stern Review's value of *r*.

Weitzman proceeds to factor uncertainty into the Ramsey equation. I will not reproduce his formal modeling here, but his argument boils down to this: the kinds of parameter values Stern (2007) and Cline (1992) assume may be justified because the damages of climate change over the next century may not coordinate well with aggregate economic activity. The economic sectors most likely to be harmed by climate change, such as agricultural, outdoor recreation, and natural landscapes (including nonmarket ecosystem values) are not "highly correlated with technological progress in computer power, furniture making, or better pharmaceuticals a century from now." This presents a big problem for those who favor basing the discount rate on the economy-wide return on capital. The only other option, of course, is to base the discount rate on the risk-free rate of return, which "is close to the *Stern* interest rate."

The "moral" Weitzman draws "is that the nature of the impacts of climate change determine whether we should end up closer to using the risk-free rate or the economy-wide return on capital." But "trying to forecast costs and benefits of climate change scenarios a hundred years or so from now is more the art of inspired guesstimating by analogy than a science (imagine forecasting today's world a century ago) (Weitzman 2007, pp. 14-16).[28] Is Weitzman suggesting that the state of the art of economic analysis is not yet up to the task of dealing with problem as potentially large and long-term as climate change? The last three sections of Weitzman's review suggest that the answer to this question is a qualified "yes."

The problem in a nutshell is the wide range of possible temperature increases under the IPCC's (2007) most current climate change models, including a 3% possibility that temperature increases will exceed 6ºC by 2150. Weitzman (2007, p. 18) notes that "any honest economic modeler would have to admit"complete uncertainty about the social, economic, and

[28] Shelling (2006a, pp. 33-4) makes a similar point.

environmental effects of such a temperature increase because "such high temperatures have not existed for some tens of millions of years." Even if their probability is low, high temperature increases – the kind of "worse-case" scenarios which the Stern Review emphasized – could result in what Weitzman (2007, p. 19) calls "low-*g* disasters" (especially if *g* is defined to include the existence value of ecosystems). The possibility of such disasters make prediction uncertain in the Knightian sense. As Weitzman (2007, p. 19) explains, "[w]ith an evolutionary stochastic process like global climate change, the world is not standing still long enough for us to accumulate the relevant information to accurately assess tail probabilities." We don't even know how much we don't know about the probabilities. The structural uncertainties, Weitzman (2007, p. 22) notes, are highly likely to matter more than the risk for "whomever wants to model optimal-expected-utility growth under endogenous greenhouse warming."

Weitzman (2007, pp. 22-4) lauds the Stern Review for treating seriously the possibility of rare, high-temperature, "low-*g*" catastrophes, but thinks that Stern (2007) should have dealt with them such catastrophes forthrightly, rather that "through the back door with unreasonably low values of ρ and η."[29] Presumably, this means that damage estimates should be increased or the value of *g* should be lowered based on some, admittedly error-prone, calculation of the anticipated effects of high-temperature changes on consumption levels. But Weitzman also doubts the ability of Stern, or any other economic analyst, to perform such calculations given the current state of economic science. And, like other reviewers, he faults the Stern Review "for giving readers an authoritative-looking impression that seemingly-objective best available-practice professional economic analysis robustly supports it conclusions, instead of more openly disclosing the full extent to which the *Review*'s radical policy recommendations depend on controversial extreme assumptions and unconventional discount rates that most economists would consider much too low" (Weitzman 2007, p. 28).

Finally, Weitzman (2007, p. 25) urges caution in approaching these kinds of problems in economic analyses. "A responsible policy approach neither dismisses the horror stories just because they are two standard deviations away from what is likely nor gets stampeded into

[29] This assertion appears to impute bad faith to the Stern Review authors. But, as noted earlier, they specified ostensibly legitimate reasons for their choices of parameter values.

overemphasizing false dichotomies as if we must make costly all-or-nothing investment decisions right now to avoid theoretically-possible horrible outcomes in the distant future." Thus, he recommends a "middle course" that rejects the Stern Review's call for an "all-out war" on GHG emissions, but combines Nordhaus's gradual implementation of increasingly stringent GHG emission reductions with more serious research into low-probability, high-magnitude ("low-*g*") events "and what might be done realistically about them should they start to materialize" (Weitzman 2007, p. 26). For now, we simply "lack a commonly-accepted usable economic framework for dealing with these kinds of thick-tailed extreme disasters, whose probability distributions are inherently difficult to estimate (which is why the tails must be thick in the first place)" (Weitzman 2007, p. 26).

4. Implications for the Theory and Practice of BCA

What are the implications of the Stern Review and its critics for the theory and practice of BCA? I think there are several potential lessons, which are listed below and only briefly discussed in no particular order of importance (although I will have something to say about the relative importance of various lessons).

4.1 On Confidence and Caveats

BCAs about problems and policies at the frontiers of scientific knowledge are bound to be controversial and error prone, especially where time horizons are long and uncertainty looms large. In some cases, they are likely to be little more than shots in the dark. In such circumstances, authors should be especially parsimonious about the conclusions they draw and the recommendations they make. Nearly all reviewers agree that the Stern group pretended to greater confidence in their comparatively radical conclusions and recommendations than the facts and analysis warranted. While the Stern Review contained several warnings about the problems associated with forecasting the costs and benefits of climate change and mitigation, it did not heed its those warnings when presenting its conclusions and recommendations.

4.2 On the Inherently Political Nature of BCAs and the Importance of Sensitivity Analyses

The Stern Review is a political and ethical document, as much as an economic study. Several reviewers consider this a significant fault, as if BCAs should be, or could be, neutral. In fact, all BCAs are, to one extent or another, political or ethical documents. Given the inherently subjective elements of BCA – from the valuations of nonmarket goods (including human lives) to the choice of value parameters (including discount rates) – and given that those subjective elements invariably influence outcomes, each and every BCA is inevitably informed by the ethical, political and/or ideological predilections of its author(s). A chief virtue of BCAs as a decision tool is that they make those predilections transparent (at least as compared to other decision tools) because, according to "best practices," authors are supposed to make their assumptions, including choices of parameter values, explicit.

The authors of the Stern Review did not comply fully with this "best practice" standard. They specified certain parameter values, including the utility discount rate. Although the rate they chose ignored observed economic behavior and specified a discount rate based on paternalistic ethical values, at least they were explicit about it and provided reasoned arguments to support it. They were not explicit, however, about their valuations of nonmarket goods, including human lives. Those valuations, just like the discount rate, are subjective and therefore subject to manipulation for political purposes. That's why it is so important for BCA authors to state and support them explicitly.

Because of the potential for subjective elements including parameter values and valuations of nonmarket goods to effect the outcome of BCAs, the Stern Review certainly should have included a sensitivity analysis. Sensitivity analysis is helpful in demonstrating the relative robustness of outcomes across alternative valuations. The failure of the Stern Review authors to include one in their original BCA was a significant omission, to say the least. In response to their critics, they eventually did prepare what Martin Weitzman (2007, p. 7) has called "a halfhearted sensitivity-analysis postscript." That sensitivity analysis purported to demonstrate the robustness of the Review's conclusions but succeeded only in demonstrating their high sensitivity to the choice of parameter values (something that critiques of the Stern Review already had demonstrated).

4.3 On Discounting

Perhaps the most obvious lesson from the Stern Review and its critics (at least for those who have not already learned it) is that choices of parameter values (including discount rates, coefficients of relative risk aversion, and per capita consumption growth rates) can greatly influence the outcome of BCAs. Unfortunately, the Stern Review and its critics also remind us of just how far away we remain from being able to specify a consensus "best practice" for selecting parameter values. Many (though not all) reviewers complain that the Stern Review's choice of a 0.1% pure rate of time preference is too low. This assessment is supported by two reasons: (a) such a low discount rate ignores how people actually behave in markets; and (b) it deviates significantly from some "conventional range" of discount rates in the BCA literature. These assertions are both true, and yet they are insufficient to justify a conclusion that Stern's (2007) choice of discount rate was "wrong" or violated some "best practice" of BCA.

It is obviously true that market participants display implicit discount rates higher than that adopted by the Stern Review, but that is neither a necessary nor a sufficient reason for governments to adopt similarly high discount rates in framing policies to deal with long-run social-cost problems, particular where those problems are largely the result of the short time horizons and high discount rates of market actors. Moreover, as Stern (2007) rightly points out, the choice of discount rate in regulatory BCA is not just a question of mimicking the market; it is an ethical judgment.

But is it the job – or the right – of a BCA author to make ethical or political judgments that can determine the outcome of the BCA? Some critics of the Stern Review suggest not. They believe that the author of a BCA should avoid imposing his or her own ethical values on policymakers. Rather, the author should input the best available data, crunch the numbers in the most neutral way possible, and present the unvarnished results to those officials who are responsible for making policy. Otherwise, the author of the BCA inappropriately usurps the role of policymaker.[30] This is a sensible argument, but, as I suggested above, I do not believe it is

[30] As noted earlier (n. 23), given Stern's position in HM Treasury, it is not entirely clear that he was "usurping" the role of policy-maker.

entirely possible for any author of any BCA to avoid imposing their values on the BCA in ways the affect the outcome simply because of the subjective judgments that each BCA inevitably entails. In other words, every author of every BCA is, to a greater or lesser extent, a would-be policymaker. This is as true of Nordhaus and his 3% discount rate as it is of Stern and his 0.1% discount rate.[31]

As for the "conventional range" of utility discount rates, it is true that the Stern Review's choice of a 0.1% pure rate of time preference is lower than the rates chosen in most other BCAs. Does this deviance render it illegitimate? Well, standard practices can, and sometimes do, become norms that govern decisions. But Portney and Weyant (1999) found no such norm governing decisions about discount rates for BCAs.[32] And even if there were a generally accepted range of discount rates for BCAs, prominent economists have argued that climate change represents a special case – a long-run phenomenon subject to relatively great uncertainties, including uncertainty about the discount rate itself, which could lead to reductions in the growth rate of per capita consumption – requiring lower-than-usual discount rates (see Weitzman 2007; Dasgupta, Mäler, and Barrett 1999).

Tom Schelling (2006b) presents a very different reason for believing that climate change

---

[31] Nordhaus (2007) has recently revised his DICE model. Among the most significant changes, Nordhaus reduced the pure rate of time preference (ρ) in "DICE-2007" from 3.0% to 1.5%. In addition, he set the elasticity of the marginal utility of consumption (η) at 2 (Nordhaus 2007, p. 13). Significantly, Nordhaus (2007, p. 16) expressly recognizes that the same real interest rate would be achieved by combining ρ=0.1% (*a la* the Stern Review) and η=2.9. Unfortunately, Nordhaus (2007) does not specify a value of g (the per-capita growth rate of consumption), so we cannot directly compare his discount rate of consumption with that of the Stern Review. Earlier versions of the DICE model assumed values of g declining from 2.3 percent in 2000 to 1.1 percent by 2050. Taking the average of these numbers, g=1.7%, would yield r=4.6%, well above the Stern Review's r=1.4%. Consequently, Nordhaus's estimates of future damages from climate change and future benefits of GHG mitigation remain far below those of the Stern Review, despite Nordhaus's halving of ρ. Not surprisingly, therefore, Nordhaus (2007, p. 29) still finds the Stern Review's recommendations too costly by far. Where Stern (2007) recommends spending 1% of global GDP to mitigate GHG emissions, Nordhaus (2007, pp. 36-7) recommends spending only one-tenth as much (about $9 per capita), which would reduce expected global mean temperature increases by 1.7ºC over the next century. Nordhaus's bottom line policy recommendation remains the same: a slow and gradual ramping up of GHG emissions reductions.

[32] To be clear, Portney and Weyant (1999) is a collection of papers by various authors. My reference here and throughout this paper is to the Introduction that Portney and Weyant wrote for the book.

is a special case. In his view, discounting is inappropriate for assessing the costs and benefits of climate change because those who bear the costs are not the same people, generally speaking, who will receive the benefits. The costs of climate change, now and in the future, will fall disproportionately on people in developing countries; but the costs of mitigating GHG emissions to stabilize the climate and reduce the costs of climate change, under the Kyoto Protocol or any other reasonably conceivable program, will be borne predominantly by the citizens wealthier, developed countries. Thus, efforts to mitigate climate change are in the nature of a foreign aid program, like the Marshall Plan, NATO, or disease eradication campaigns in Africa. As such, discounting is inappropriate. Schelling (2006b, p. 52) writes that "[t]he alleged inborn preference for earlier rather than later consumption is exclusively concerned with the consumer's impatience with respect to his or her *own* consumption."[33] And he goes on to note that

> decisions to invest in greenhouse gas-emissions abatement for the benefit of future generations are not "saving decisions" – not decisions about postponing one's own consumption – but are instead decisions about redistributing income, one's own income. To invest resources now in reduced greenhouse gas emissions is to transfer consumption from present-day people – whoever those people are who are making these sacrifices – for the benefit of people in the distant future. It is very much like making sacrifices now for people who are distant geographically or distant culturally (Schelling 2006b, p. 53).

If Schelling is right about this, then Stern (2007) and Cline (1992) were right to adopt low values of ρ. However, this does not mean that Schelling necessarily would concur in their conclusions or recommendations. In fact, Schelling (2006a) favors a gradual approach to GHG reductions over time.

A final response to the argument from convention is that the Stern Review's 0.1% pure rate of time preference is not unprecedented among climate change BCAs. The pioneering economic analysis of Cline (1992) adopted a pure rate of time preference of 0.0%. Taken

[33] Italics in original.

together, the ethical arguments of Ramsey (1928) (among others), the conceptual arguments of Schelling (2006b), Portney and Weyant's (1999) evaluations of practice, and Cline's (1992) application counsel against a conclusion that there is a "best practice," convention or social norm that the Stern Review violated in adopting a 0.1% pure rate of time preference.

Even if there were such a norm, its violation would not, by itself, make much difference to the overall BCA. As Weitzman (2007) demonstrates, it is not the pure rate of time preference (ρ) alone that is significant, but the combination of parameter values for ρ, η, and g that together determine r, the consumption rate of discount. The pure rate of time preference is only one element of the larger Ramsey equation. And it is the product of that equation, r, which ultimately has significance for the BCA.

Three concerns about the Stern Review's discount rate remain, however, which relate to other arguable conventions, social norms or "best practices" of BCAs.

First, in selecting a pure rate of time preference the Stern Review summarily ignored HM Treasury's (2003) own *Green Book* of discount rates. Interestingly, the *Green Book*'s schedule closely tracks Nordhaus and Boyer's (2000) model, with a range of discount rates that decline from 3.5% (for costs and benefits between year 0 and year 30) to 1% (for costs and benefits arising after 300 years). Stern (2007, p. 47) makes only a single, oblique reference to HM Treasury's *Green Book*, and does not provide anything like a sufficient explanation as to why it chose to ignore the discount rates *mandated* by its own authorities. This should be deemed a violation of a "best practice" standard according to which agencies must follow their own rules, unless they provide a complete and transparent explanation justifying deviation. Not doing so generates at least two problems: (a) it creates the appearance (at least) that something fishy is going on in the BCA; and (b) it unjustifiably erodes the authority of government policymakers.

Second, whatever discount rate is chosen, it must be applied consistently to the future costs and benefits of GHG mitigation, as well as the future costs and benefits of harm from climate change. According to Mendelsohn (2006-7), the Stern Review failed to discount the costs of mitigation. This is an obvious flaw, which the Stern group should correct in a supplemental BCA.

Third, over the last decade or so it has become common for government agencies, at least in the United States, to prepare BCAs that include multiple calculations using various discount

rates (see, e.g., EPA 1997). This practice has the benefit of presenting policymakers with more information and a clearer understanding (a) that they have a choice of parameter values and (b) how that choice effects expected valuations of future costs and benefits and ultimate outcomes. The Stern Review's authors might at least have presented alternative calculations using HM Treasury's official schedule of declining discount rates in addition to its own preferred parameter values. Given the inherently subjective nature of those values, I would support the establishment of a "best standard" requiring not just sensitivity analyses, but alternative sets of complete calculations under various parameter values.

The same effect can be obtained – and arguably is obtained in the case of climate change BCAs – by the independent generation of multiple BCAs assessing the same social problems and policies utilizing different parameter values. The Stern Review is not, after all, the only economic analysis we have of climate change. The fact that other BCAs of climate change exist (e.g., Cline 1992; Mendelsohn *et al.* 1998; Nordhaus and Boyer 2000) reduces the significance of the omissions, miscalculations, and idiosyncracies, of any one set of analyses, conclusions and recommendations. The various economic analyses, and their critiques, are all out there for policymakers to learn from and use in "the marketplace of ideas."[34] In this respect, the Stern Review's "deviance" could be viewed as an advantage – a significantly different (but not necessarily wrong) view of the same problem addressed in other BCAs.

However, the Stern Review, as an official government document produced under auspices of HM Treasury, arguably carries special weight. That can be the only reason for the extraordinary media attention its publication received, in stark contrast to other economic analyses of climate change produced by independent academics. The Stern Review's government backing creates the risk that the Review could influence public policy more than other economic analyses, not because of its relative merits but because of its pedigree. This undoubtedly creates a potential problem for unwary consumers of BCAs, but its implications, if any, for the theory and practice of BCA are unclear. Perhaps we can take solace in the fact that

---

[34] *Keyishian v. Board of Regents*, 385 U.S. 589 (1967). The phrase is often mistakenly attributed to Justice Oliver Wendell Holmes's dissent in the earlier case of *Abrams v. US*, 250 U.S. 616 (1919). While Holmes clearly articulated the notion, using expressions like "free trade in ideas," he did not actually write the phrase "marketplace of ideas."

after the initial surge of public and media enthusiasm over the Stern Review, it has not significantly influenced policy in Britain or elsewhere, but has taken its place alongside other economic analyses in the relative obscurity of academic discussions such as this one.

4.4 What's a Human Life or a Functional Ecosystem Worth?

Even if the Stern Review's exceptionally high damage estimates are completely explained by the choice of parameter values, its failure to plainly specify assumed valuations of nonmarket goods, including human lives, is a glaring omission that certainly violates "best practices."[35] Given the presumed importance of those values for the damage estimate, their absence from the analysis is both perplexing and troubling. A reader of the Stern Review has no way of determining whether (a) the authors' valuations are based on existing studies or their own best guesses, (b) the valuations deviate significantly from those supported in the literature, and (c) total damage estimates are calculated properly based on those valuations. Lacking valuations of nonmarket damages, no subsequent analyst could even attempt to replicate the Stern Review's damage assessment. It is a given that any good BCA should provide enough information for other analysts to replicate its results. In this respect, at least, the Stern Report is not a good BCA.

4.5 Finally, A Couple of Positive Implications of the Stern Review

The implications of the Stern Review for the theory and practice of BCA are not entirely negative. Arguably, it has made one or two highly valuable positive contributions to the field. For one, it has demonstrated the potential importance of paying attention not only to the mean of expected values of present and future costs and benefits but also to low-probability, high-magnitude (potential "low-*g*") events at the tails of damage distribution curves. As Weitzman (2007) notes, events that are highly unlikely may nevertheless be so significant for future consumption growth rates that they simply must be accounted for in economic analyses.

---

[35] Valuations of nonmarket goods, including human lives, are not important for every BCA. However, where a BCA depends heavily on such valuations, as the Stern Review clearly does, then it becomes essential for those valuations to be clearly and fully presented.

Nordhaus and Boyer (2002) paid some attention to potentially catastrophic climate-change events, but the Stern Review is the first to focus its entire BCA beyond the mean estimate of damages. This lesson may not have great importance for economic analyses of standard, run-of-the-mill government policies and projects, but for arguably special cases like climate change, which combine unusually long time-horizons with very high levels of Knightian uncertainty, worse-case scenarios should be treated seriously. This is, in a sense, an instantiation of the precautionary principle (at least in a weak version).

A second positive lesson from the Stern Review for the practice of BCA is not to be found in the Review itself, but in Sir Nicholas Stern's willingness to engage his critics. As noted earlier, one of the major failings of the Stern Review, as originally published, was the absence of a sensitivity analysis to demonstrate the robustness of its conclusions across alternative parameter values. Stern responded by adding a sensitivity analysis to the Review as a postscript. Weitzman (2007, p. 7) may be right that Stern's postscript was a "half-hearted" effort to placate the critics, but at least Stern did it (and, of course, it was the right thing to do). Stern has also made himself available for conferences and meetings that have been more or less devoted to tearing apart his Review. For example, on February 15, 2007 Sir Nicholas participated in a conference at Yale, where he confronted some of his staunchest critics, including William Nordhaus and Robert Mendelsohn. Not every author of every BCA would have been so brave or open to disputation.

Stern's willingness to engage his critics reminds us that economic analysis is a dynamic, iterative process, where the cycle of analysis and criticism leads to improved analyses and further criticisms. In other words, no BCA is an island. And all *ex ante* economic analyses are provisional. Stern (2007, p. 144) explicitly recognizes this fact in acknowledging that his economic model of climate change is merely "one contribution to [a] discussion."

5. Conclusion

The Stern Review and its serious academic critics should all be read by anyone interested in benefit-cost analysis as a discipline. They raise serious issues about the practice and practicability of BCA for long-run policies (including BAU) with potentially severe

consequences under high levels of Knightian uncertainty. Stern (2007) takes a strong position that such uncertainty is not an excuse for inaction, especially where the stakes are enormous, as is arguably the case with climate change. Despite numerous flaws in his analysis and his process, I tend to agree with him about that most important point. Stern's (2006) postscript provides something of a concise summation of this entire meta-review of the Review and its critics: "We must be transparent and clear. If you take little account of the interests of future generations you will care little about climate change. But ethical positions cannot be dictated by policy analysts...." If only Stern had taken his own words more to heart, reviews such as this would be celebrating the Stern Review more and criticizing it less.

6. References

Ackerman, Frank and Ian Finlayson. Oct. 2005. The Economics of Inaction on Climate Change: A Critique (unpublished paper on file with the author; available on-line at http://www.hm-treasury.gov.uk/media/E79/F2/climatechange_ tufts_2.pdf).

Carter, Robert M, C.R. de Freitas, Indur M. Goklany, David Holland, and Richard S. Lindzen. 2006. The Stern Review: A Dual Critique: Part I: The Science. *World Economics*, 7:167-198 (available on-line at http://meteo.lcd.lu/globalwarming/Carter/WE-STERN.pdf).

Cline, William R. 1992. *Optimal Carbon Emissions over Time: Experiments with the Nordhaus DICE Model*. Washington, D.C.: Institute for International Economics.

Cline, William R. 2004. Meeting the challenge of global warming. In B. Lomborg (Ed.), *Global Crises, Global Solutions*. Cambridge: Cambridge University Press.

The Center for Science and Public Policy. Nov. 2006. The Stern Report: Some Early Criticisms. Washington, D.C.: The Center for Science and Public Policy (available on-line at http://ff.org/centers/csspp/pdf/20061104_stern.pdf.)

Cox, Simon and Richard Vadon. 2007. Running the rule over Stern's numbers. BBCNews. Jan. 26, 2007. (available on-line at http://newsvote.bbc.co.uk/mpapps/pagetools/print/news.bbc.co.uk /2/hi/science/nature/6295021.stm).

Dasgupta, Partha, Karl-Gören Mäler, and Scott Barrett, Intergenerational Equity, Social Discount Rates, and Global Warming. 1999 In P.R. Portney and J.P. Weyant (Eds.), *Discounting and Intergenerational Equity* (pp. 51-77). Washington, D.C.: Resources for the Future.

Dasgupta, Sir Partha. 2006. Commentary: The Stern Review's Economics of Climate Change, *National Institute Economic Review* No. 199 (pp. 4-7).

EPA. 1997. *The Benefits and Costs of the Clean Air Act, 1970-1990.* Washington, D.C.: Environmental Protection Agency.

HM Treasury. 2003. *The Green Book – Appraisal and Evaluation in Central Government*. London: HM Treasury (available on-line at http://www.hm-treasury.gov.uk/media/05553/Green_Book_03.pdf).

Hope, Chris. 2006. The marginal impact of CO2 from PAGE2002: An integrated assessment model incorporating the IPCC's five reasons for concern. *Integrated Assessment Journal,* 6:19-56 (available on-line at http://journals.sfu.ca/int_assess/index.php/iaj/article/view/227).

Intergovernmental Panel on Climate Change. 2001. Third Assessment Report (available on-line at http://www.ipcc.ch/pub/reports.htm).

Intergovernmental Panel on Clamate Change. 2007. Fourth Assessment Report (available on-line at http://www.ipcc.ch/).

Leonhardt, David. 2007. Amid the Ivy, A Battle About the Climate. *New York Times*, Feb. 21, 2007 at C1.

Maddison, Dr. David. 2006. Further Comments on the Stern Review. (Unpublished manuscript on file with the author; available on-line at http://www.economics.bham.ac.uk/maddison/Stern%20Comments.pdf).

Mendelsohn, Robert O. 2006-7. A Critique of the Stern Report. *Regulation*, Winter (available on-line at http://www.cato.org/pubs/regulation/regv29n4/v29n4-5.pdf).

Mendelsohn, Robert O., Wendy Morrison, Michael E. Schlesinger, and Natalia A. Andronova. 1998. Country-specific market impacts of climate change. *Climatic Change*, 54:553-569.

Moore, Mark A., Anthony E. Boardman, Aidan R. Vining, David L. Weimer, and David H. Greenberg. 2004. "Just Give Me a Number!" Practical Values for the Social Discount Rate. *Journal of Policy Analysis and Management* 23:789-812.

Newell, Richard and William Pizer. 2001. Discounting the benefits of climate change mitigation. Washington, D.C.: Pew Center on Global Climate Change (available on-line at: http://www.rff.org/Documents/RFF-RPT-disbenefits.pdf).

Nordhaus, William D. and Joseph G. Boyer. 2000. *Warming the World: economic models of global warming*. Cambridge, Mass.: The MIT Press.

Nordhaus, William D. 2007. The Challenge of Global Warming: Economic Models and Environmental Policy. (Unpublished manuscript on file with the author; available on-line at: http://www.econ.yale.edu/~nordhaus/DICEGAMS/DICE_mss_040407.pdf).

Nordhaus, William D. 2006. The *Stern Review* on the Economics of Climate Change. (Unpublished manuscript on file with the author; available on-line at: http://www.econ.yale.edu/~nordhaus/homepage/SternReviewD2.pdf).

Pearce, David, et. al. 2003. Valuing the Future: Recent Advances in Social Discounting. *World Economics*, 4:121-141.

Portney, Paul R. and John P. Weyant. 1999. Introduction. In P.R. Portney and J.P. Weyant (Eds), Discounting and Intergenerational Equity (pp. 1-11). Washington, D.C.: Resources for the Future.

Quiggin, John. 2006. Stern and the critics on discounting (unpublished manuscript on file with the author; available on-line at http://johnquiggin.com/wp-content/uploads/2006/12/sternreviewed06121.pdf).

Ramsey, Frank. 1928. A Mathematical Theory of Saving. *Economic Journal*, 38:543-549.

Riboń, Leonardo. Dec. 2006. Review of the Reactions Generated by the Release of the Stern Review: The Economics of Climate Change. Global Sustainability, an institute of RMIT University (available on-line at http://www.global.rmit.edu.au/GS@RMIT%20Review%20of%20Reactions%20to%20Stern%20Dec06.pdf).

Schelling, Thomas C. 2006a. What Makes Greenhouse Sense. In T.C. Schelling, *Strategies of Commitment and Other Essays* (pp. 27-44). Cambridge, Mass.: Harvard University Press.

Schelling, Thomas C. 2006b. Intergenerational and International Discounting. In T.C. Schelling, *Strategies of Commitment and Other Essays* (pp. 27-44). Cambridge, Mass.: Harvard University Press.

Stern, Nicholas. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge: Cambridge University Press (available on-line at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm).

Tol, Richard S.J. 2006. The Stern Review of the Economics of Climate Change: A Comment. *Energy & Environment*, 17:977-981.

Tol, Richard S.J. 2005. The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. *Energy Policy*, 33:2064-2074.

Tol, Richard S.J. 2002. Estimates of the costs of climate change – part II: dynamic estimates, *Environmental and Resource Economics* 21:135-160.

Weitzman, Martin. 2007. The Stern Review of the Economics of Climate Change. *Journal of Economic Literature* __:___-___.

Yohe, Gary. W. 2006. Some thoughts on the damage estimates presented in the *Stern Review* - An Editorial. *The Integrated Assessment Journal*, 6:65-72.

Yohe, Gary W. and Richard S.J. Tol. 2007. The *Stern Review*: Implications for Climate Change. *Environment*, 49: 36-42.