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EDITORIAL

The Stern Review and the economics of climate change: an editorial essay

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The *Stern Review of the Economics of Climate Change* (Stern et al. 2006a, b; Stern 2007) has been the catalyst of an enormous amount of discussion since its release in the fall of 2006. Policy makers see it as an authoritative report that makes an economic case for rapid reduction of greenhouse gas emissions. Most economists have a different opinion of the quality of the analysis, even though there is a virtual consensus among economists that climate change is a serious externality which calls for the immediate implementation of a carbon tax or some other type of policy intervention. Economists who have glanced at the *Stern Review* typically argue, for example, that its choice of ethical parameters (rate of pure time preference, rate of risk aversion) is peculiar, biased, and potentially misleading to be point of being counterproductive (Arrow 2007; Dasgupta 2007; Varian 2006; Yohe and Tol 2007a, b). Analysts who took a closer look at the *Stern Review* tend to notice a range of other assumptions that are questionable, and many have lamented what they perceive to be inadequate documentation (Jensen and Webster 2007; Mendelsohn 2006; Nordhaus 2007a; Pielke, 2007; Tol 2006; Tol and Yohe 2006; Yohe 2006; Yohe and Tol 2007b). Some papers claim that the *Stern Review* underestimated the impacts of climate change (Neumayer 2007; Spash 2007; Sterner and Persson 2007), while other papers argue that human-induced climate change is not real (Byatt et al. 2006; Carter et al. 2006). Neither position has any empirical support. The *Stern Review* team has published a number of rebuttals to our

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concerns and those of others (Anderson 2007; Dietz et al. 2007a, b, c; Hamid et al. 2007; Stern and Taylor 2007), but we are not convinced that our concerns have been addressed adequately. To be clear, economists who have studied climate change usually conclude that an economic case for greenhouse gas emission reduction has been made; they worry only that the *Stern Review* failed to make the case because it put ideology ahead of analytics (Nordhaus 2007b; Weitzman 2007; Yohe et al. 2007).[1] We all generally agree with Weitzman's (2007) assessment: the *Stern Review* is "right for the wrong reasons".

Climatic Change is now publishing four more essays on the *Stern Review*, and here we use them to launch our discussion—one in which we occasionally defend the *Stern Review* as we reiterate and extend our earlier contributions. Terry Barker played a central role in this collection—authoring two papers and contributing editorial guidance to the other two. In the one he authored alone, Barker (this volume) argues that the *Stern Review* is an assault on neo-classical economics and utilitarianism.[2] It is not. Indeed, the *Stern Review* is firmly rooted in both traditions (Jensen and Webster 2007; Neumeyer 2007; Spash 2007). For instance, Dasgupta (2007) makes this point when he criticises the *Stern Review* for not explicitly introducing inequity aversion into its calculus. Doing so would have been only a modest deviation from the utilitarian framework within which its authors operated. It is important to note, of course, that Fankhauser et al. (1998) have shown why adding this component would have changed the results of the *Stern Review's* inherent cost–benefit analyses substantially.

Quiggin (this volume) devotes his entire essay to discounting. It is here, of course, that the *Review* attracted so much criticism from mainstream economists, including ourselves. This criticism was not generally born of the *Review's* authors' choosing a *very low* discount rate based on a very low pure rate of time preference. We expect, in fact, that many of the same authors would have been equally critical if the *Stern Review* had adopted a *very high* discount rate based on a very high pure rate of time preference. Indeed, most commentaries were critical because the *Stern Review* chose to work with only one discount rate, and a peculiar one at that, and did not explore the ramifications of alternative reflections of inter-temporal impatience.

The pure rate of time preference is, to some, purely an ethical parameter—a manifestation of one's value system that reflects how much less one cares about the future than about today simply because it is the future (Arrow et al. 1996; Portney and Weyant 1999). Moral philosophers have elaborate theories about what the pure rate of time preference ought to be (e.g., Broome 1992), and the *Stern Review* devotes considerable space justifying its choice of an extraordinarily low value on those theories. At the same time, however, people and government express their pure rates of time preference in their every day decisions (Nordhaus 1997). Quiggin (this volume) cites a single observation (low risk bonds) that suggests that the "market" pure rate of time preference is near zero,[3] but Frederick et al. (2002) surveyed a much wider empirical base and found very little empirical support for individual time preferences near zero. Evans and Sezer (2004, 2005) estimate social rates of pure time preference for rich countries, and find a range of 0.8–1.5.

[1] Sir Nicholas was duly promoted to become Lord Stern, Baron of (ironically) Brentford, and life peer in the House of Lords.

[2] Nelson (2008) similarly makes Lord Stern of Brentford an unlikely champion of feminist economics.

[3] Quiggin also advocates using a value of 1.0 to reflect (relative) aversion to risk—another parameter that reflects human behavior and attitudes; this is the same value used by Stern et al. (2006a, b). We note that Evans (2005) estimates a value of 1.4 using evidence from tax data and a method originally developed by Stern (1977).

By choosing a pure rate of time preference that deviates from any average of observed pure rates of time preference, the authors of the *Stern Review* essentially assert that their value is right and other people's values are wrong. Indeed, Jensen and Webster (2007), Nordhaus (2007a) and Weitzman (2007) all accuse the *Stern Review* of paternalism.

Although commissioned by HM Government, the *Stern Review* also deviates from the standard discounting procedures in the UK. Quiggin (this volume) dismisses this observation as a neat but irrelevant debating point. We disagree. If governments use one principle of time discounting for climate policy and another principle for other policies, then they are crafting internally inconsistent policy portfolios that are, themselves, unethical. Using a low discount rate for climate policy and a high discount rate for road safety or health care immediately implies, for example, that future deaths due to climate change are more important than future deaths due to road accidents or inadequate hospitals. Put another way, if governments agree with the *Stern Review*, then they should substantially increase investments in R&D, education, health care, and pensions—and taxes too.[4] Of course, Nordhaus (2007b) has shown that following this route would necessitate dramatic increases in aggregate savings that would emphatically slow the pace of economic growth for a very long time. The key to understanding his point is simply to recognize that the discount rate is fundamentally a direct representation of the opportunity cost of investment. Put another way, reducing the discount rate necessarily implies that investment in less profitable projects should and would be undertaken.

As an aside, we should note that there *are* economic circumstances under which adopting a low discount rate when evaluating the relative efficacy of a public investment satisfies efficiency criteria. In countries where the private return to capital is taxed, for example, the appropriate discount rate for public investment can fall well below the market return on private investment (and even converge to zero) if public investments (strongly) complement private investments in the sense of increasing the productivity of privately held capital (Ogura and Yohe 1977). Returns to private capital are certainly taxed at various rates across most the world. We also expect that a strong case could be made that public investment in mitigation would complement private investment across many if not all of those countries. The specific degree of complementarity has not yet been evaluated, so this argument cannot be applied. Nonetheless, the underlying ambiguity is just one of the reasons why, in our work, we did not ignore low discount rates. Instead, we explored the sensitivity of results across a wide range of possible values to get a handle on what difference it makes. To nobody's surprise, we found that it makes an enormous amount of difference—a conclusion that the *Stern Review* team, itself, recognized in its postscript (Stern et al. 2006b).

Barker (this volume) also heralds the *Stern Review's* apparent deviation from marginal calculus of neo-classical economics, but we fear that he is mistaken on two fundamental grounds. First of all, the *Stern Review* still aims at an *optimal* climate policy. We know this because the authors spend so much effort time justifying the low pure rate of time preference that they insert into the first term of the Ramsey (1928) discounting equation when they compute their estimates of climate damages.[5] Secondly, the connection between optimality and marginality has nothing to do with economics—neo-classical or otherwise;

[4] Kenny (2007) shows that the *Stern Review* also implies a massive redistribution of income across the globe.

[5] This equation, highlighted in Quiggin (this volume), adds the pure rate of time preference (the utility discount rate) to the product of the elasticity of the marginal utility of per capita consumption and the rate of growth of per capita consumption—a result that is derived only from an *optimal* growth model.

and it is not derived exclusively from a reliance on benefit–cost analyses. This connection is a central part of the calculus developed by Leibniz and Newton. Indeed, an "optimum" that does not meet its first-order conditions, like that in the *Stern Review*, is just bad mathematics.

Jaeger et al. (this volume) argue similarly when they protest the maximisation of Gross Domestic Product (GDP) as a policy objective. They seem to criticize the *Stern Review* team for comparing their damage estimates for climate change, calibrated quantitatively as the "equivalent" of percentage losses in GDP, with the suffering inflicted upon individuals by the major wars of the past century. To be fair, Stern et al. (2006a, b) concludes that climate change could produce "risks of *major disruption to economic and social activity*, on a scale similar to those associated with the great wars and economic depressions of the first half of the 20th century" (our emphasis). To our reading, this is not a comparison of the economic consequences of wars, depressions, and damages attributed to climate change much less a comparison confined to a single economic measure (GDP). Jaeger et al. (this volume) also rail against what they call Adam Smith's (1776; cf. Arrow and Debreu 1954) fallacy of social optimum born of the independent actions of self-interested economic agents. Alfred Pigou (1920; cf. Baumol 1972) have already shown that this is not true in the presence of externalities, a fact that is mentioned in any textbook. The *Stern Review* got this right, too, by correctly framing climate change as an externality of global proportion.

In short, as noted above and emphasized by Barker (this volume) and Quiggin (this volume), economic models do not maximise GDP or income. They focus on utility (though Stern et al. (2006a, b) go to great lengths to convert lost utility into an economic metric-reduction in the certainty equivalent consumption path). The distinction between welfare and GDP dates back to Bernouilli (1954/1738), and it is well known that GDP is a bad approximation for welfare. Ironically, a younger Nordhaus laid the foundations for the measurement of the "green" Net National Product (Nordhaus and Tobin 1972). Jaeger and colleagues have set up a strawman to fight against, but they are tilting at windmills that do not exist in the *Review*.

It is in the context of clarifying the appropriate application of utility-based approach adopted by the *Stern Review* team where we hope to have contributed to a more correct economic interpretation of the economic case for climate policy. Our disagreements with the methods and assumptions of the *Stern Review* (but not its fundamental conclusion that an economic case can be made for immediate climate policy) can be summarized in a series of succinct statements:

1. Stern et al. (2006a, b) use an extraordinarily low discount rate without reporting a sensitivity analysis (e.g., Nordhaus 2007a).
2. The time horizon in the *Stern Review* is too short for the chosen discount rate because the calculated post-2200 residuals contain up to 50% of the damages (e.g., Yohe 2006).
3. The *Stern Review*'s low discount rate does not match the equally low assumed rate of risk aversion (e.g., Dasgupta 2007; Weitzman 2007).
4. Stern et al. (2006a, b) do not separate risk aversion from inequity aversion (e.g., Dasgupta 2007).
5. Stern et al. (2006a, b) use the ill-defined "relative change in the balanced growth equivalent" as their welfare measure (e.g., Tol and Yohe 2007).
6. In the *Stern Review*, vulnerability to climate change is assumed to be constant (e.g., Sterner and Persson 2007 and Tol and Yohe 2007).

7. Stern et al. (2006a, b) assume, implicitly, that there is no learning about the climate system or the driving socio-economic system as the future unfolds (e.g., Yohe and Tol 2007a, b).
8. Stern et al. (2006a, b) confuse the costs of climate change with the benefits of emission reduction (e.g., Anthoff and Tol 2008).
9. Stern et al. (2006a, b) overestimate the impact of climate change by cherry picking (e.g., Pielke 2007).
10. Stern et al. (2006a, b) underestimate the costs of emission reduction (e.g., Tol and Yohe 2006, 2007).
11. The documentation of Stern et al. (2006a, b) is incomplete and inconsistent (e.g., Weitzman 2007), and the *Stern Review* generally violates the rules of good practice in policy analysis (e.g., Cole 2007).

This list of concerns, notwithstanding, we think that there are sound economic arguments for greenhouse gas emission reduction that can inform both the long-term goals of climate policy and the short-term steps that should be taken immediately.

Interestingly, Hasselmann and Barker (this volume) ultimately propose the creation of a technocratic body that would decide global climate policy in both time-frames. We are, at the same time, concerned that creating such a global governing body from scratch would be a political impossibility and amused that they do not see the Conference of the Parties (the COP) of the United Nations Framework Convention on Climate Change as the politically feasible incarnation of their idea (subject to the constraint of participation by all nations). While we may all wonder whether or not the COP will ever function effectively as a body entrusted to set global climate policy, recent negotiations have pushed on adaptation and mitigation fronts to frame responses to climate risks. Indeed, the COP is now working within the risk-management approach of the sort espoused by Barker (this volume) because IPCC (2007) achieved unanimous government consent to the conclusion that:

> "Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity, and attitudes to risk."

This assertion makes it clear that the nations who participate in the IPCC/UNFCCC process now profess that policy makers need a new decision-support paradigm.[6] In IPCC (2007), this assertion is followed by statements that noting the wide range of published estimates of the social cost of carbon, the sources of this range, the inherent inability to quantify all impacts, and the resulting difficulty in comparing the global benefits and costs of mitigation and, by inference in some cases, the more locally defined benefits and costs of adaptation.

In the past, we have confronted this complication by exploiting the fact that atmospheric concentrations of greenhouse gases depend on cumulative emissions over time. As a result, achieving any targeted concentration limit (and thus a corresponding range of possible temperature increases and associated climate risks) is fundamentally an exhaustible resource problem. The long-standing Hotelling (1931) result therefore applies, at least to a first approximation: to maximize the discounted value of welfare derived from an exhaustible resource (that is, to minimize the discounted costs of limiting cumulative

[6] Barker (this volume) argued that this need was recognized starting with the Second Assessment Report in IPCC (1995), but it was not until the Working Group III plenary in May of 2007 and the Synthesis Report plenary the following November that this conclusion was elevated to plenary approved language.

emissions over the long-term), simply calculate the appropriate initial "scarcity rent" (in this case, an initial price for carbon) and let it increase over time at the rate of interest. To be more specific, the Hotelling (1931) result means that it is enough to specify an initial price of carbon (or perhaps setting targeted permit price for a cap and trade system) as long as it is understood that this rent will increase persistently and predictably at the rate of interest. This initial price should be designed to get the attention of the business community and to show political leadership in the face of a serious problem. It need not, however, be set so high that it would cause undue economic harm in the short-run. Allowing the carbon price to increase year after year even while acknowledging that adjustments for new knowledge about climate risk will have to be accommodated over time would give the policy traction—this is our representation of the long-term context within which the iterative process now accepted by the COP can function.

We now add some texture to this representation by focusing attention on three different sources of economic justification for climate policy: efficiency, equity, and risk. The efficiency justification for emission abatement is a simple externality argument with which no economist would quibble. The impacts caused by climate change are an unintended and uncompensated side-effect of economic transactions that emit greenhouse gases. To restore efficiency, this externality must be internalized by a carbon tax, if the impacts are predominantly negative, or carbon subsidy, if the impacts are predominantly positive. The empirical literature on the economic impacts of climate change finds that impacts are largely negative (Smith et al. 2001 and Smith and Hitz 2003). Although positive impacts have been identified, these are limited in time, space and size. Since estimates of the marginal damage cost of carbon dioxide emissions are indeed predominantly positive (Tol 2005), greenhouse gas emissions should be taxed.

An argument for emission abatement based on equity is much more difficult to make. On the surface, it is easy. Rich people emit much more carbon dioxide than do poor people, particularly on a per capita basis, and poor people are much more vulnerable to climate change. Climate change therefore constitutes an unacceptable transfer of wealth from poor to rich. Some may find this simple framing of the issue convincing, but its economic underpinnings are not particularly persuasive. If greenhouse gas emission reduction is relatively expensive and potentially ineffective over the next several decades at least, helping poor people to adapt to climate change would be cheaper, easier, and may have positive spillovers on development in general (Schelling 1995 and Tol 2005).

The risk argument for emission abatement is again straightforward. Moomaw et al. (2001) have estimated that we have sufficient reserves of fossil fuel to make Planet Earth intolerably hot. It follows that we will have to stop burning fossil fuels before they run out. IPCC (2007) has meanwhile highlighted growing evidence that we may commit ourselves to severe impacts with only a few degrees of warming; even though the likelihood may be small, the now accepted risk calculus suggests that some attempts should be made to reduce those critical probabilities. This implies that the maximum allowable amount of carbon dioxide emissions is smaller than the potential amount of emissions. The constraint on allowable cumulative emissions is therefore binding, and we are back in the Hotelling (1931) world and we are again calling for a carbon tax.

We now have two sound economic arguments for using a carbon tax to frame the approach to long-term climate policy and one argument that is definitely not an argument for a carbon subsidy. Uncertainties about future emissions, climate change, and climate impacts sustain a wide range of estimates of the social cost of carbon which can, for present purposes, be interpreted as the appropriate Pigouvian tax for current emissions (Tol 2007); even with a 3% pure rate of time preference, the median estimate here is $20 per tonne of

carbon. The downside risks of climate change are poorly understood, though, and these estimates do not include many possible impacts (Yohe and Tirpak 2008). While reasonable people disagree how much of a risk premium should be placed on top of the Pigou tax, it should be clear that no reasonable person would argue that this premium should be zero. An estimate of 50% is not out of the question, especially given a non-zero likelihood of catastrophic damage in some regions of the world. This would make $30 per tonne of carbon ($8 per tonne of CO_2) an economically justifiable point of departure (increasing at the rate of interest over time) for framing the current view of the long-term.

What about the short-term—the first iteration in the process identified in IPCC (2007)? To inform this decision, one might compare what it would take to make natural gas more attractive than coal for pending investments to add new generating capacity in the USA over the next few decades (Yohe et al. 2007). Much of this capacity is currently planned as conventional coal-fired technology, but a CO_2 price of only $18 per tonne of carbon ($5/tCO_2) would be sufficient to make new gas-fired generators as economical as new coal-fired plants (based on the present value of fixed and variable costs). This number is much lower for new plants than the $100/tC ($27/tCO_2) required to inspire existing plants to switch because the lower cost of building a new gas plant compensates for some of its higher fuel cost, but it would be sufficient to avoid significant "locked in" carbon intensive investments in future capacity. To make a large step toward near zero carbon technologies (e.g., carbon capture and sequestration) would require a somewhat higher CO_2 price—estimated at around $90/tC ($25/tCO_2) by several sources and included in Pacala and Socolow (2004) as one possible "wedge" of emissions reduction. Even so, since power generators last 30 to 40 years, a carbon tax that increases predictably over time, as the Hotelling result requires, could make CCS technologies attractive even if the precise "tipping point" is not reached until some years after the new plant starts operating.

The point we want to underline here is that these economic arguments can be made without resorting to dodgy modeling or peculiar assumptions. Taxing greenhouse gas emissions now makes perfect economic sense. However, climate policy will always be unpopular in some circles. Lobbying against carbon taxes or other forms of regulation will continue to be intense because concerns about their economic costs will persist. Therefore, the case for climate policy should be based on sober, even-handed, and high-quality research. A claim, like Terry Barker's, that the economic case for climate change constitutes a revolution in the discipline makes it easy to dismiss the arguments for climate policy as wild-eyed fantasies of burning textbooks. Shoddy analysis and questionable assumptions, like Lord Stern of Brentford's, only provide easy ammunition for those with vested interests in preserving the current fossil fuel economy, and all of this is completely unnecessary. Standard economic tools applied under standard economic assumptions call for greenhouse gas emission abatement today.

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