Comments on Simon Dietz and Nicholas Stern's *Why Economic Analysis Supports Strong Action on Climate Change: A Response to the Stern Review's Critics*

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The science of economics has made a number of important contributions to understanding greenhouse gases and their optimal control. From basic economic theory, economists have pointed out the need to minimize the sum of mitigation costs and climate damages (Nordhaus 1992). From this simple insight, society can derive an elegant solution to greenhouse gases. The optimal policy for society should balance marginal mitigation costs with marginal damages. Economics also provides an important perspective on time. Time is valuable and cannot be ignored. This is especially critical for a problem that has a very long time horizon. Costs borne in the present are more burdensome than costs born in the future. Finally, economics has much to offer in quantifying both the costs of mitigating greenhouse gas emissions (Weyant 2008) and the damages that climate change will cause to society (Pearce et al. 1996; Tol 2002; Mendelsohn et al. 2006).

Stern (2007) and Dietz and Stern (2008) largely reject all of these contributions by economics. They argue that "minimizing the present value of costs of climate change and costs of abatement is both misleading and dangerous." They argue that treating future costs as though they are worth less than current costs is "unethical." They reject the empirical analysis of actual impacts arguing that the impacts are unknowable. They reject the economic estimates of mitigation costs in favor of the free-lunch estimates of technologists.

Dietz and Stern argue that "strong and urgent action is in fact good economics." To make this case, they assume that the discount rate is effectively zero, that climate change poses "severe risks" far beyond any we can measure, and that the mitigation costs will be lower than the most optimistic scenario. Even then, they suggest a formal weighing of costs and damages is unacceptable and that instead society should turn to ethical principles to guide greenhouse gas policy. They invoke an "ethics of responsibility of current generations for future generations." This is climate advocacy, not good economics.

What can the current generation do for future generations? By investing in capital, infrastructure, and technology, many generations since the industrial revolution have spurred economic growth, allowing future generations to enjoy a much higher standard of living. Dollars invested in capital and new technology grow at the interest rate, providing a reward

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to savers for forgoing current consumption. The current generation should invest in climate change mitigation that earns the same rate of return as competitive investments in a myriad of market sector alternatives. Such investments will make future generations better off. But investments in mitigation that cannot even earn a positive rate of return will be worth far less to future generations than those same dollars invested in the market. Placing climate change before investments in other important nonmarket services such as conservation, health, education, security, and transportation also cannot be justified in the name of future generations. From the perspective of future generations, it is in their interest that all investments earn the same rate of return. The ethical justification for intentionally overspending on selective projects with low rates of return is weak indeed.

Economic theory and empirical facts teach us that climate policy should follow a moderate course. Mitigation should begin modestly but globally and gradually increase over time. Aggressive near-term policies in selected countries will only increase the costs to society of this long-term problem. Climate change is a serious problem, but succumbing to alarmism will not make it better.

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Thomas Sterner and U. Martin Persson

Despite 100 years of relativity theory, we continue, successfully, to use Newtonian mechanics for most practical purposes. Only in very extreme applications, with interstellar distances or speeds close to that of light, do we need Einstein's equations. The analogy may seem far-fetched but when we analyze the welfare effects of climatic changes—entailing large-scale risks and taking place over centuries—we must be particularly careful with our rules of thumb. Averages and linear approximations serve us well in ordinary benefit–cost calculations but are a risk to our thinking when applied over centuries with rapid technical and socioeconomic change. In the simple case we can say that risks and distributional effects of various projects "even out" or can be dealt with separately using other policies, but for climate change we do not have this option. We must take our theory seriously and as Dietz and Stern (2008) show, strong and urgent action can indeed be defended by good economics.

As if it were the most commonplace matter, we economists assume that growth will continue at a pace that, a century hence, will leave the world ten times (or more) better off than today. Something that is far from obvious to most noneconomists is for us just the starting point of the analysis and not something we spend too much time discussing. Still, it is a truly mind-boggling scenario. Does this mean an end to poverty as we know it or does it mean that a few billion stay close to subsistence while the average gets ten times richer and the rich even more so? Clearly it makes an enormous difference. One of the fundamental ideas of welfare theory is that welfare and utility are concave with respect to income. Admittedly we do not know the degree of concavity. But we must count the costs from climate change impacts that hit the poor differently than those that hit the rich—particularly if we have high disparities. Unfortunately, this is still not the norm in economic analyses of climate change.

Just as distribution is a big question mark—so is resource allocation. If average income goes up ten times—does that mean the average person consumes ten times as much of everything? Clearly not. We cannot eat ten times more food and we should not use more gasoline. Skiing and coral reef tourism will probably decline rather than increase. Other items will change all the more. Countless new gadgets may one day appear equally important as the cell-phone or Ipod today. New services, ecological, social or spiritual, will transform our societies and their culture, influencing even the fundamentals of interpersonal relationships. In all this, there is much change in what we prosaically would call relative prices. If a third of biodiversity is gone but we are otherwise ten times richer—is it not plausible that the value of ecosystem services may have increased beyond current imagination?

When the *Stern Review* challenged the conventional wisdom and called for strong and immediate action on climate change, reactions were initially fierce. However, the ensuing debate has shown a new consensus in the making. Dietz and Stern (2008), rightly in our opinion, highlight the combined weight of ethical considerations and the large-scale risks that climate change poses. Similarly Weitzman (2007), as well as Yohe et al. (2007), focuses on risk and uncertainty, endorsing the policy conclusions of the *Stern Review* on the basis of buying greenhouse insurance. Sterner and Persson (2008), as well as Heal (2008) and Neumeyer (2007), have drawn attention to the role of limited substitutability, changing relative prices and underestimated ecosystem damages. As Geoffrey Heal (2008) puts it, there are "many ways in which we can make a case for strong action now, and few in which we can deny it."

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John P. Weyant

My response to Dietz and Stern (2008) focuses on two main subjects: (1) what I actually concluded about greenhouse gas mitigation policies, and (2) what I actually concluded is the biggest uncertainty regarding mitigation costs.

First, I do not favor a "wait and see" policy on greenhouse gas mitigation as opposed to an "act now" policy. I believe we need to act now, but that the most effective set of actions includes immediate low-cost mitigation measures, as well as energy technology R&D and work on the development of new institutions and policies to mitigate greenhouse gas emissions. Because we are just learning how to reduce greenhouse gas emissions, at every step along the way we need to balance the additional costs of acting too hastily against the additional risks resulting from climate change. If mitigation costs turn out to be higher than expected in the near term and the benefits less, that may well lead to less aggressive mitigation policies and more vulnerability in the longer term. Moreover, it is not necessary to completely commit to an aggressive long-term target today. We can first reduce greenhouse gas emissions significantly at a low cost and learn how to do it and then make the final decision on our destination when better information on impacts will presumably also be available. Thus, rather than "wait and see," I favor a policy architecture in which we try a lot of everything—mitigation, policies designed to speed the adoption of lower-GHG-emitting technologies, R&D on new lower-GHG-emitting technologies, and adaptation to climate change as it occurs—rather than putting too many eggs in the dramatic early mitigation basket. In my view, the latter has a risk associated with it that is not recognized by Dietz and Stern.

Second, I believe the risk on the mitigation-cost side relates directly to how both the "top down" and "bottom up" projections of GHG mitigation costs should be interpreted. These two types of projections are extremely useful, but highly idealized. The implementation of both approaches has generally assumed that GHG emissions reductions all over the world are taken wherever, whenever, with whatever GHGs, and however it is least costly to do so. Besides assuming an immediate worldwide consensus on what to do, how to do it, and who should pay for it, this assumes that we can design polices to not only internalize the carbon externality perfectly but also to: (1) overcome the innovation market failure that results from private companies not being able to recoup close to all the benefits resulting from their R&D investments, (2) correct the market failures resulting from, for example, imperfect information and lack of adequate financing for implementing the available options and (3) prevent politicians from spending any revenues collected from GHG taxation or permit auctions on low-value programs unrelated to GHG mitigation. In the top-down approaches, we at least make highly idealized assumptions about these details, but in the bottom-up approaches we essentially assume that policies exist and can be implemented to result in the least cost program. Thus, by using bottom-up cost projections directly as in input to policy, we implicitly give policy advice without specifying the policies to be used. Can we really figure out all the implementation details quickly enough to avoid large excess costs (far above the societal costs included in most model simulations) from making dramatic reductions in GHG emissions in the next couple of decades? Thus, my high (say 10 percent of GDP) short-run potential mitigation cost projection for stabilization results primarily from institutional pessimism rather than technological pessimism.

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Global Climate Change: A Challenge to Policy

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Last fall, the United Kingdom issued a major government report on global climate change directed by Sir Nicholas Stern, a top-flight economist. The Stern Report amounts to a call to action: it argues that huge future costs of global warming can be avoided by incurring relatively modest cost today.

Critics of the Stern Report don't think serious action to limit carbon dioxide (CO_2) emissions is justified because there remains substantial uncertainty about the extent of the costs of global climate change and because these costs will be incurred far in the future. They think that Stern improperly fails to discount for either uncertainty or futurity.

I agree that both futurity and uncertainty require significant discounting. However, even with that, I believe the fundamental conclusion of Stern is justified: we are much better off to act to reduce CO_2 emissions substantially than to suffer and risk the consequences of failing to meet this challenge. As I explain here, this conclusion holds true even if, unlike Stern, one heavily discounts the future.

A PERSONAL INTRODUCTION TO GLOBAL WARMING

I first heard of the effect of industrialization on global temperatures long before the present concerns became significant: in the fall of 1942, to be precise. I was being trained as a weather officer. One course, called "dynamic meteorology," taught by Dr. Hans Panofsky at New York University, dealt with the basic physics of weather systems (pressure variations, the laws determining the strength of winds, the causes and effects of precipitation, and similar matters). One of the first things to understand was what determined the general level of temperature. The source of terrestrial temperature is, of course, solar radiation. But heating of the Earth from the Sun's rays causes the Earth to emit radiation at frequencies appropriate to its temperature, that is, in the infra-red low-frequency portion of the electromagnetic spectrum. Since the Earth radiates into empty space, where the temperature approximates absolute zero, it would appear that in equilibrium the Earth should come to that temperature also, as is indeed the case with the Moon.

What makes the difference is the Earth's atmosphere. The vast bulk of the atmosphere is

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made up of nitrogen and oxygen, transparent to both the visible radiation coming from the Sun and the infrared radiation emitted by the Earth, and hence without effect on the equilibrium temperature. However, the atmosphere also contains, we learned, a considerable variety of other gases in small quantities. These "trace gases" include most notably water vapor, carbon dioxide, and methane, though there are many others. These trace gases have the property of being transparent to radiation in the visible part of the spectrum but absorbent at lower frequencies, such as infrared. Hence, the effect of these gases is to retain the outgoing radiation and so raise the temperature of the Earth to the point in which life can flourish. The effect is strictly parallel to the use of glass in greenhouses, also transparent to visible radiation but not to infrared; hence, the widespread term, "greenhouse effect."

Where do these trace gases come from? The water vapor comes from the passage of air over the large expanses of water in the Earth's surface, particularly when the water is warmer than the air. The carbon dioxide and methane have come from some non-biological sources, such as volcanic eruptions, but also from the respiration of animals and from organic wastes. (Vegetation, on the contrary, absorbs CO_2.)

Our instructor then added one more observation. CO_2 is a by-product of combustion. There are fires due to volcanoes and lightning, and mankind has lit fires for 500,000 years, but the pace of combustion has vastly increased since the Industrial Revolution. So, concluded Dr. Panofsky, we can expect the world temperature to rise steadily as CO_2 continues to accumulate and at an increasing rate with the growth of industry. This was not presented as a jeremiad or as controversial. Indeed, we were clearly being told this rather to vivify the somewhat arid set of facts we had to learn than to move us to action.

As any economist accustomed to general equilibrium theory might guess, the implications of a given increase in greenhouse gases for the weather are mediated through a very complex interactive system with both positive and negative feedbacks. Elaborate climate models have been developed, each admittedly falling short of catching some significant aspect. (Economists will understand.) Nevertheless, serious studies have lead to a considerable consensus, although with a wide range of uncertainty. I will draw upon the most recent report, prepared by a team directed by Sir Nicholas Stern for the United Kingdom Prime Minister and Chancellor of the Exchequer. The mean levels of different magnitudes in this report are comparable to those in earlier work, but the Stern Review is more explicit about ranges of uncertainty.

The current level of CO_2 (plus other greenhouse gases, in CO_2 equivalents) is today about 430 parts per million (ppm), compared with 280 ppm before the Industrial Revolution. With the present and growing rate of emissions, the level could reach 550 ppm by 2035. This is almost twice the pre-industrial level, and a level that has not been reached for several million years.

POTENTIAL CLIMATE CHANGE AND ITS IMPACTS

Most climate change models predict that a concentration of 550 ppm would be associated with a rise in temperature of at least two degrees Centigrade. A continuation of "business as usual" trends will likely lead to a trebling of CO_2 by the end of the century, with a 50% chance of exceeding a rise of five degrees Centigrade, about the same as the increase from the last ice age to the present.

The full consequences of such rises are not well known. Some of the direct effects are obvious: implications for agriculture (not all bad; productivity in Canada and northern Russia will rise, but negative effects predominate where moisture is the limiting factor and especially in the heavily populated tropical regions), and a rise in sea-level, which will wipe out the small island countries (e.g., the Maldives or Tonga) and encroach considerably on all countries. Bangladesh will lose much of its land area; Manhattan could be under water. This rise might be catastrophic rather than gradual if the Greenland and West Antarctic ice sheets melt and collapse. In addition, temperature changes can change the nature of the world's weather system. A reversing of the Gulf Stream, which could cause climate in Europe to resemble that of Greenland, is a distinct possibility. There is good reason to believe that tropical storms will become more severe, since the energy which fuels them comes from the rising temperature of the oceans. Glaciers will disappear, indeed have been disappearing, rapidly, and with them, valuable water supplies.

ARE THE BENEFITS FROM REDUCING CLIMATE CHANGE WORTH THE COSTS?

The available policies essentially are ways of preventing the greenhouse gases from entering the atmosphere, or at least reducing their magnitude. Today the source of 65% of the gases is the use of energy; the remainder arises from waste, agriculture, and land use. A number of behavioral changes would mitigate this problem: (1) shifting to fuels which have higher ratio of useful energy to CO_2 emissions (e.g., from coal to oil or oil to natural gas); (2) developing technologies which use less energy per unit output; (3) shifting demand to products with lower energy intensity; (4) planting trees and reducing deforestation, since trees absorb CO_2; or, (5) pursuing an unproven but apparently feasible policy of sequestering the CO_2 by pumping it directly into underground reservoirs. We can go further and simply restrict output.

Two factors deserve emphasis, factors that differentiate global climate change from other environmental problems. First, emissions of CO_2 and other trace gases are almost irreversible; more precisely, their residence time in the atmosphere is measured in centuries. Most environmental insults are mitigated promptly or in fairly short order when the source is cleaned up, as with water pollution, acid rain, or sulfur dioxide emissions. Here, reducing emissions today is very valuable to humanity in the distant future. Second, the scale of the externality is truly global; greenhouse gases travel around the world in a few days. This means that the nation-state and its subsidiaries, the typical loci for internalization of externalities, are limited in their remedial ability. (To be sure, there are other transboundary environmental externalities, as with water pollution in the Rhine Valley or acid rain, but none nearly so far-flung as climate change.) However, since the United States contributes about 25% of the world's CO_2 emissions, its own policy could make a large difference.

Thus, global climate change is a public good (bad) *par excellence*. Benefit-cost analysis is a principal tool for deciding whether altering this public good through mitigation policy is warranted. Economic analysis can also help identify the most efficient policy instruments for mitigation, but I leave that to other essays in this issue.

Two aspects of the benefit-cost calculation are critical. One is allowance for uncertainty (and related behavioral effects reflecting risk aversion). To explain economic choices such as insurance or the holding of inventories, it has to be assumed that individuals prefer to avoid risk. That is, an uncertain outcome is worth less than the average of the outcomes. As has already been indicated, the possible outcomes of global warming in the absence of mitigation are very uncertain, though surely bad; the uncertain losses should be evaluated as being equivalent to a single loss greater than the expected loss.

The other critical aspect is how one treats future outcomes relative to current ones. The issue of futurity has aroused much attention among philosophers as well as economists. At what rate should future impacts—in particular, losses of future consumption—be discounted to the present. The consumption discount rate, δ, can be expressed by the following simple formula:

$$\delta = \rho + g\eta$$

where ρ is the social rate of time preference, g is the projected growth rate of average consumption, and η is the elasticity of the social weight attributed to a change in consumption.

The parameter η in the second term accounts for the possibility that, as consumption grows, the marginal unit of consumption may be considered as having less social value. It is analogous to the idea of diminishing marginal private utility of private consumption. This component of the consumption rate of discount is relatively uncontroversial, although researchers disagree on its magnitude. The appropriate value to assign to η is disputed, but a value of 2 or 3 seems reasonable (the Stern Review uses 1, but this level does not seem compatible with other evidence).

Greater disagreement surrounds the appropriate value for ρ, the social rate of time preference. This parameter allows for discounting the future simply because it is the future, even if future generations were no better off than we are. The Stern Review follows a considerable tradition among British economists and many philosophers against discounting for pure futurity. Most economists take pure time preference as obvious. Tjalling Koopmans pointed out in effect that the savings rates implied by zero time preference are very much higher than those we observe. (I am myself convinced by this argument.)

Many have complained about the Stern Review adopting a value of zero for ρ , the social rate of time preference. However, I find that the case for intervention to keep CO_2 levels within bounds (say, aiming to stabilize them at about 550 ppm) is sufficiently strong as to be insensitive to the arguments about ρ . To establish this point, I draw on some numbers from the Stern Review concerning future benefits from keeping greenhouse gas concentrations from exceeding 550 ppm, as well as the costs of accomplishing this.

The benefits from mitigation of greenhouse gases are the avoided damages. The Review provides a comprehensive view of these damages, including both market damages as well as non-market damages that account for health impacts and various ecological impacts. The damages are presented in several scenarios, but I consider the so-called High-climate scenario to be the best-based. Figure 6-5c of the Review shows the increasing damages of climate change on a "business as usual" policy. By the year 2200, the losses in GNP have an expected value of 13.8% of what GNP would be otherwise, with a .05 percentile of about 3% and a .95 percentile of about 34%. With this degree of uncertainty, the loss should be equivalent to a certain loss of about 20%. The base rate of growth of the economy (before calculating the climate change effect) was taken to be 1.3% per year; a loss of 20% in the year 2200 amounts to reducing the growth rate to 1.2% per year. In other words, the benefit from mitigating greenhouse gas emissions can be represented as the increase in the growth rate from today to 2200 from 1.2 % per year to 1.3% per year.

We have to compare this benefit with the cost of stabilization. Estimates given in Table 10.1 of the Stern Review range from 3.4% down to -3.9% of GNP. (Since energy-saving reduces energy costs, this last estimate is not as startling as it sounds.) Let me assume then that costs to prevent additional accumulation of CO_2 (and equivalents) come to 1% of GNP every year forever.

Finally, I assume, in accordance with a fair amount of empirical evidence, that η, the component of the discount rate attributable to the declining marginal utility of consumption, is equal to 2. I then examine whether the present value of benefits (from the increase in the GDP growth rate from 1.2% to 1.3%) exceeds the present value of the costs (from the 1% permanent reduction in the level of the GDP time profile). A straightforward calculation shows that mitigation is better than business as usual—that is, the present value of the benefits exceeds the present value of the costs—for any social rate of time preference (ρ) less than 8.5%. No estimate for the pure rate of time preference even by those who believe in relatively strong discounting of the future has ever approached 8.5%.

These calculations indicate that, even with higher discounting, the Stern Review's estimates of future benefits and costs imply that current mitigation passes a benefit-cost test. Note that these calculations rely on the Stern Review's projected time profiles for benefits and its estimate of annual costs. Much disagreement surrounds these estimates, and further sensitivity analysis is called for. Still, I believe there can be little serious argument over the importance of a policy of avoiding major further increases in combustion by-products.

Letters commenting on this piece or others may be submitted at submit.cgi?context=ev.

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