ECONOMICS

Critical Assumptions in the Stern Review on Climate Change

The Stern Review's analysis of global-warming economics depends on an extreme view of economic discounting.
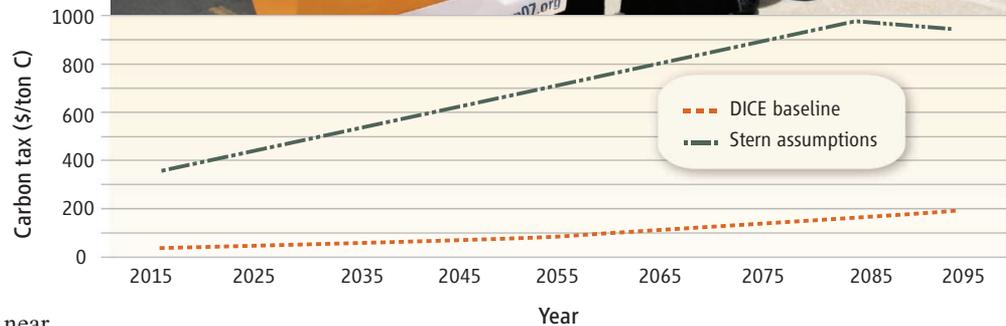
William Nordhaus

In November 2006, the British government presented a comprehensive study on the economics of climate change (1), the Stern Review. It painted a dark picture for the globe, "[I]f we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP [gross domestic product] each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more." The Stern Review recommended urgent, immediate, and sharp reductions in greenhouse-gas emissions.

These findings differ markedly from economic models that calculate least-cost emissions paths to stabilize concentrations or paths that balance the costs and benefits of emissions reductions. Mainstream economic models definitely find it economically beneficial to take steps today to slow warming, but efficient policies generally involve modest rates of emissions reductions in the near term, followed by sharp reductions in the medium and long term (2–5).

A standard way of showing the stringency of policies is to calculate the "carbon tax," or penalty on carbon emissions. A recent study by the author estimates an optimal carbon tax for 2005 of around $30 per ton carbon in today's prices, rising to $85 by the mid–21st century and further increasing after that (5). A similar carbon price has been found in studies that estimate the least-cost path to stabilize CO_2 concentrations at two times preindustrial levels (2). The sharply rising carbon tax reflects initially low, but rising, emissions-reduction rates. We call this the climate-policy ramp, in which policies to slow global warming increasingly tighten or ramp up over time. A $30 carbon tax may appear to be a modest target, but it is at least 10 times the current globally averaged carbon tax implicit in the Kyoto Protocol (shown as Stern assumptions).

What is the logic of the ramp? In a world where capital is productive and damages are far in the future (see chart above), the highest-

Comparing the optimal carbon tax under alternative discounting assumptions. The Dynamic Integrated model of Climate and the Economy (DICE model) (5) integrates the economic costs and benefits of greenhouse-gas (GHG) reductions with a simple dynamic representation of the scientific and economic links of output, emissions, concentrations, and climate change. The DICE model is designed to choose levels of investment in tangible capital and in GHG reductions that maximize economic welfare. It calculates the optimal carbon tax as the price of carbon emissions that will balance the incremental costs of abating carbon emissions with the incremental benefits of lower future damages from climate change. Using the DICE model to optimize climate policy leads to an optimal carbon tax in 2005 of around $30 per ton carbon (shown here as "DICE baseline"). If we substitute the Stern Review's assumptions about time discounting and the consumption elasticity into the DICE model, the calculated optimal carbon tax is much higher and rises much more rapidly (shown as "Stern assumptions").

return investments today are primarily in tangible, technological, and human capital. In the coming decades, damages are predicted to rise relative to output. As that occurs, it becomes efficient to shift investments toward more intensive emissions reductions and the accompanying higher carbon taxes. The exact timing of emissions reductions depends on details of costs, damages, learning, and the extent to which climate change and damages are nonlinear and irreversible.

The Stern Review proposes to move the timetable for emissions reductions sharply forward. It suggests global emissions reductions of between 30 and 70% over the next two decades, objectives consistent with a carbon tax of around $300 per ton today, or about 10 times the level suggested by standard economic models.

Given that the Stern Review embraces traditional economic techniques such as those described in (2–5), how does it get such different results and strategies? Having analyzed the Stern Review in (6) (which also contains a list of recent analyses), I find that the difference stems almost entirely from its technique for calculating discount rates and only marginally on new science or economics. The reasoning has questionable founda-

Department of Economics, Yale University, New Haven, CT 06511–8268, USA. E-mail: william.nordhaus@yale.edu

tions in terms of its ethical assumptions and also leads to economic results that are inconsistent with market data.

Some background on growth economics and discounting concepts is necessary to understand the debate. In choosing among alternative trajectories for emissions reductions, the key economic variable is the real return on capital, r, which measures the net yield on investments in capital, education, and technology. In principle, this is observable in the marketplace. For example, the real pretax return on U.S. corporate capital over the last four decades has averaged about 0.07 yr^{-1}. Estimated real returns on human capital range from 0.06 yr^{-1} to >0.20 yr^{-1}, depending on the country and time period (7). The return on capital is the "discount rate" that enters into the determination of the efficient balance between the cost of emissions reductions today and the benefit of reduced climate damages in the future. A high return on capital tilts the balance toward emissions reductions in the future, whereas a low return tilts reductions toward the present. The Stern Review's economic analysis recommended immediate emissions reductions because its assumptions led to very low assumed real returns on capital.

Where does the return on capital come from? The Stern Review and other analyses of climate economics base the analysis of real returns on the optimal economic growth theory (8, 9). In this framework, the real return on capital is an economic variable that is determined by two normative parameters. The first parameter is the time discount rate, denoted by ρ, which refers to the discount on future "utility" or welfare (not on future goods, like the return on capital). It measures the relative importance in societal decisions of the welfare of future generations relative to that of the current generation. A zero discount rate means that all generations into the indefinite future are treated the same; a positive discount rate means that that the welfare of future generations is reduced or "discounted" compared with nearer generations.

Analyses are sometimes divided between the "descriptive approach," in which assumed discount rates should conform to actual political and economic decisions and prices, and the "prescriptive approach," where discount rates should conform to an ethical ideal, sometimes taken to be very low or even zero. Philosophers and economists have conducted vigorous debates about how to apply discount rates in areas as diverse as economic growth, climate change, energy, nuclear waste, major infra-

structure programs, hurricane levees, and reparations for slavery.

The Stern Review takes the prescriptive approach in the extreme, arguing that it is indefensible to make long-term decisions with a positive time discount rate. The actual time discount rate used in the Stern Review is 0.001 yr^{-1}, which is vaguely justified by estimates of the probability of the extinction of the human race.

The second parameter that determines return on capital is the consumption elasticity, denoted as η. This parameter represents the aversion to the economic equality among different generations. A low (high) value of η implies that decisions take little (much) heed about whether the future is richer or poorer than the present. Under standard optimal growth theory, if time discounting is low and society cares little about income inequality, then it will save a great deal for the future, and the real return will be low. This is the case assumed by the Stern Review. Alternatively, if either the time discount rate is high or society is averse to inequality, the current savings rate is low and the real return is high.

This relation is captured by the "Ramsey equation" of optimal growth theory (8, 9), in which the long-run equilibrium real return on capital is determined by $r = \rho + \eta g$, where g is the average growth in consumption per capita, ρ is the time discount rate, and η is the consumption elasticity. Using the Stern Review's assumption of $\rho = 0.001$ yr^{-1} and $\eta = 1$, along with its assumed growth rate ($g^* = 0.013$ yr^{-1}) and a stable population, yields an equilibrium real interest rate of 0.014 yr^{-1}, far below the returns to standard investments. It would also lead to much higher savings rates than today's. This low rate of return is used in the Stern Review without any reference to actual rates of return or savings rates.

The low return also means that future damages are discounted at a low rate, and this helps explain the Stern Review's estimate that the cost of climate change could represent the equivalent of a "20% cut in per-capita consumption, now and forever." When the Stern Review says that there are substantial losses "now," it does not mean "today." In fact, the Stern Review's estimate of the output loss "today" is essentially zero. We can illustrate this using the Stern Review's high-climate scenario with catastrophic and non-market impacts. For this case, the mean losses are 0.4% of world output in 2060, 2.9% in 2100, and 13.8% in 2200. This is reported as a loss in "current per capita consumption" of 14.4%.

How do damages that average around 1% over the next century turn into 14.4%

cuts "now and forever"? The answer is that, with the low interest rate, the relatively small damages in the next two centuries get overwhelmed by the high damages over the centuries and millennia that follow 2200. In fact, if the Stern Review's methodology is used, more than half of the estimated damages "now and forever" occur after 2800.

What difference would it make if we used assumptions that are consistent with standard returns to capital and savings rates? For example, take the Stern Review's near-zero time discount rate with a high inequality aversion represented by a consumption elasticity of $\eta = 3$. This combination would yield real returns and savings rates close to those observed in today's economy and dramatically different from those shown in the Stern Review. The optimal carbon tax and the social cost of carbon decline by a factor of ~10 relative to these consistent with the Stern Review's assumptions, and the efficient trajectory looks like the policy ramp discussed above. In other words, the Stern Review's alarming findings about damages, as well as its economic rationale, rest on its model parameterization—a low time discount rate and low inequality aversion—that leads to savings rates and real returns that differ greatly from actual market data. If we correct these parameterizations, we get a carbon tax and emissions reductions that look like standard economic models.

The Stern Review's unambiguous conclusions about the need for urgent and immediate action will not survive the substitution of assumptions that are consistent with today's marketplace real interest rates and savings rates. So the central questions about global-warming policy—how much, how fast, and how costly—remain open.

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