Economic Growth Lecture Note 20

12.05.2010. Christian Groth

The green-house effect and willingness to pay for insurance

Mankind is clearly better off to act to reduce CO_2 emissions substantially *now* than to risk the consequences of failing to meet this challenge. This is the conclusion in a short article by Nobel Laureate Kenneth J. Arrow.[1] Arrow believes the fundamental conclusion of the Stern Review (Stern 2007) is justified. He finds this holds true even if one, unlike the Stern Review, heavily discounts the utility of future generations. Uncertainty and risk aversion play a key role in the argument. In many areas of life high insurance premia are willingly paid to reduce risks. This should also be so in relation to the green-house problem.

This lecture note is an attempt at explaining Arrow's argument, as I understand it. The emphasis is on the analytical content in the light of concepts from our economic growth course. (I write this note under the proviso that I am certainly no specialist either in climate change analysis or in the economics of uncertainty)

1 Global climate change

The current level of CO_2 (including other greenhouse gases, in CO_2 equivalents) is today about 430 parts per million (ppm), compared with 280 ppm before the industrial revolution. Under a "business as usual" assumption the level will likely be around 550 ppm by 2035. This is almost twice the pre-industrial level, and a level that has not been reached for several million years.

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

[1] Arrow (2007). Arrow won the Nobel Prize in Economics in 1972.

The full consequences of such rises are not well known. But the negative effects on agriculture in the heavily populated tropical regions predominate. The rise in the sea level will wipe out small island countries, and for example Bangladesh will loose much of its land area. A reversal of the Gulf Stream is possible, which could cause climate in Europe to resemble that of Greenland. Tropical storms will become severe and many glaciers will disappear and with them, valuable water supplies. Two challenging factors are that the emissions of CO_2 and other gases are almost irreversible and that they constitute a global negative externality at a grand scale. As emphasized by another Nobel Laureate, Joseph Stiglitz, a third challenging factor is that postponing action is likely to increase both risks and costs. In Stiglitz' view: "[The Stern Review] makes clear that the question is not whether we can afford to act, but whether we can afford not to act" (Stiglitz, 2007). Here Stiglitz has in mind the Stern Review's indication that the costs of action are less than the costs of inaction because the marginal damages of rising temperature increase strongly as temperatures rise.

2 Risk aversion and discount rate

For a macroeconomic cost-benefit analysis two aspects are often critical. One is allowance for uncertainty and risk aversion. The other is the choice of the discount rate for evaluating utility benefits and costs of public projects in the far future vis-a-vis current utility costs.

An uncertain gain is generally evaluated as being equivalent to a single gain smaller than the expected value (the "average") of the possible outcomes. With the green-house effect mankind is facing an uncertain *damage* which should be evaluated as being equivalent to a single loss *greater* than the expected value of the possible damages. For the so-called High-climate scenario (considered by Arrow to be the best-substantiated scenario) the Stern Review estimates that by 2200 the losses in global GNP per capita have an *expected* value of 13.8% of what global GNP per capita would be otherwise, with a 0.05 percentile of about 3% and a 0.95 percentile of about 34%. With this degree of uncertainty, the uncertain loss can be considered as equivalent to a *certain* loss of about 20% of GNP per capita in year 2200.[2] On average this loss corresponds to a decrease of the expected growth rate per year of GNP per capita between now and year 2200 from 1.3% to 1.2% per year.

The Stern Review estimates that avoiding such an outcome is possible by a series

[2]How Arrow arrives exactly at the number 20% is not entirely clear to me from his short article.

of concrete measures (carbon pricing, technology policy, international collective action) aimed at stopping or at least reducing the emission of green-house gases and mitigate its consequences. Out of the Stern Review's suggested range of the estimated costs associated with this, Arrow chooses a cost level of 1% of GNP every year forever.

Regarding discounting of future costs and benefits, the Stern Review has been criticized by many for adopting too low intergenerational preference parameters, implying a too low consumption discount rate. The formula for the social planner's consumption discount rate along the optimal path (close to the steady state) in Lecture Note 19, p. 10, throws light on these disagreements:

$$r^{SP} = \rho + \theta g, \tag{1}$$

where ρ is the pure rate of time preference, θ the absolute elasticity of marginal utility of consumption, and g the growth rate of labor productivity as reflecting technical progress. The critics claim that Stern has chosen both ρ and θ too low, 0.001 and 1.0 (implying logarithmic utility), respectively.

Although Arrow believes a higher value of θ is warranted, he finds that in the present case the choice of ρ and θ is not crucial, at least not for the High-climate scenario which he favors. In Arrow's view, taking risk aversion properly into account implies that the essential conclusion of the Stern Review goes through at *any* consumption discount rate conventionally suggested by economists. This is so *in spite of* the fact that present values of projects involving costs and benefits in the far future are highly sensitive to r^{SP}.

3 The social welfare function

The social (even "global") welfare function that Arrow has in mind and which is explicit in the Stern Review is

$$W_0 = \int_0^{200} u(c_t)e^{-\rho t}dt + S_{200}, \tag{2}$$

where c_t is per capita consumption at time t, $u(\cdot)$ is the instantaneous utility function, and S_{200} is a so-called scrap value function subsuming discounted utility from year 2200 to infinity.[3] The instantaneous utility function is specified as CRRA:

$$u(c_t) = \frac{c_t^{1-\theta}}{1-\theta}, \qquad \theta > 0. \tag{3}$$

[3]For analytical clarity we ignore population growth so that ρ can be seen as both the pure and the effective utility discount rate.

I have not had time to really find out the details about the scrap value function. In view of the long-run perspective of the analysis, I allow myself to simplify and assume a balanced growth path with a constant productivity growth rate, g, forever. Then g is also the permanent growth rate of per capita consumption. Thus, $c_t = c_0 e^{gt}$ for all $t \geq 0$, and we may write

$$u(c_t) = \frac{(c_0 e^{gt})^{1-\theta}}{1-\theta},$$

along the balanced growth path. It follows that

$$\begin{aligned} W_0 &= \frac{{c_0}^{1-\theta}}{1-\theta}\int_0^\infty (e^{gt})^{1-\theta} e^{-\rho t} dt = \frac{{c_0}^{1-\theta}}{1-\theta}\int_0^\infty e^{[(1-\theta)g-\rho]t} dt = \frac{{c_0}^{1-\theta}}{1-\theta}\frac{1}{\rho-(1-\theta)g} \\ &= \frac{{c_0}^{1-\theta}}{1-\theta}\frac{1}{\rho+\theta g-g} \equiv \frac{{c_0}^{1-\theta}}{1-\theta}\frac{1}{r^{SP}-g}. \end{aligned} \tag{4}$$

We write W_0 in this way in order to expose the term $r^{SP} = \rho + \theta g$ from (1).

Many economic analysts have the rate of time preference, ρ, positive, say 1-2% per year. Sometimes this discounting of future utility simply because it arrives in the future is defended by claiming it is a typical characteristic of an individual's preferences. Others find this is not a valid argument for long-horizon evaluations because these involve different persons and even as yet unborn generations. According to the Stern Review the only ethically defensible reason for choosing a positive ρ is that there always is a small risk of extinction of the human race due to for example a devastating meteorite or nuclear war. Based on this view, a value of ρ close to zero, namely $\rho = 0.001$, is chosen. Concerning θ, which measures the aversion towards consumption variation (inequality) over time, Stern chooses a value as low as 1.0, which may be considered more questionable. Stern's g is 0.014.

Arrow accepts the choice of ρ not higher than 0.001, but suggests $\theta = 2$, thereby implying a higher consumption discount rate r^{SP}. The key point is Arrow's demonstration that even for higher values of both ρ and θ, the benefits of abating or mitigating climate change now are higher than the costs.

Let W_0 in (4) denote the welfare outcome under "business as usual" and let W_0' denote the welfare outcome under the "act now policy" which replaces c_0 by $c_0' = 0.99c_0$ and $g = 0.012$ by $g' = 0.013$ (by taking $g' = 0.013 > g$ also after year 2200, we cheat a little and favor the Stern conclusion a little). A social cost-benefit analysis is now simply a calculation of the sign of $W_0' - W_0$.

4 The break-even utility discount rate

Since the benefits of the act now policy come in the future and the costs are there from date zero, a high enough utility discount rate ρ will make $W_0' < W_0$. Let us calculate the break-even point for ρ at which $W_0' = W_0$. With $\theta = 2$, we have from (4)

$$\begin{aligned} W_0' &= -(0.99c_0)^{-1}\frac{1}{\rho+g'} > W_0 = -(c_0)^{-1}\frac{1}{\rho+g} \Rightarrow \\ \frac{1}{0.99(\rho+g')} &< \frac{1}{\rho+g} \Rightarrow \rho+g < 0.99(\rho+g') \Rightarrow \\ 0.01\rho &< 0.99g' - g = 0.00087 \Rightarrow \\ \rho &< 0.087 \text{ or } \rho < 8.7\% \text{ per year.} \end{aligned}$$

As mentioned above, we cheated a little by assuming the act now policy implies a slightly higher growth rate also after year 2200. This is probably the explanation that our estimated break-even point is slightly above Arrow's which is 8.5%. In any case, as Arrow concludes, "no estimate of the pure rate of time preference even by those who believe in relatively strong discounting of the future has ever approached 8.5%". Or we could say that nobody suggests an annual social consumption discount rate r^{SP} about 11% (0.087 + 2*0.011).

The conclusion is that the act now policy passes the cost-benefit test, thus supporting the Stern Review at least on this point.

5 Final remark

There are many different opinions about the Stern Review, see for example:

http://en.wikipedia.org/wiki/Stern_Review#cite_ref-5

One issue which the Stern Review only treats in an informal and intuitive way is how to evaluate catastrophe outcomes with positive, but low probabilities. This theme of catastrophe insurance is taken up in Weitzman's review of the Stern Review (Weitzman, 2007) where further references are given.

6 References

See Lecture Note 19.

For elaborate discussions of discounting with reference to the climate change problem, also taking into account the risk of catastrophe and that uncertainty is increasing with the length of the time horizon, see Arrow (1995), Heal (1998), Hepburn (2006), and different papers by Weitzman.