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Communication

The damage costs of climate change: a note on tangibles and intangibles, applied to DICE

Economic cost-benefit analysis of the costs of greenhouse gas emission abatement and climate change often points towards limited abatement. This note elucidates one reason why this result is obtained: the way in which the intangible damages are treated and the utility function is specified. On the basis of the DICE *model, it is shown that by putting the intangible damages directly into the utility function, and by assuming them to grow with per capita income, the optimal reduction increases, and in the second case more than triples, compared to Nordhaus's original results.*

Keywords: Cost-benefit; Emission abatement; Climate change

The greenhouse effect is a hot topic. One of the more intriguing and controversial results of the (neoclassical model based) research into the damages of presumably human induced climate change is that these do not justify substantial costs to reduce emissions of greenhouse gases, at least in economic terms. The main reasons for this relate to economic growth, scientific progress and time discounting. Some take this conclusion, presumably leading to unsustainable development, as the final answer;[1] others dismiss the discipline of economic science as the means to deal with this problem.[2] Our conclusion lies somewhere in between. We view the failure of economics to come up with reasonable answers to important questions such as how to 'manage' climate change as a challenge to improve the theory in order to discard counterintuitive results. To that end, we need a clear understanding of what exactly is assumed in climate–economy models, and how this influences their results. The literature identifies the costs of greenhouse gas emission control, the damage costs of climate change, the uncertainties surrounding the enhanced greenhouse effect, the rate of scientific progress, the economic development, and the discount rate as important features in the emission abatement discussion. But here we add another point: the specification of the utility function. In fact, the utility function is the input from the other social sciences into economics, and sets the normative framework of our positive models. As such, utility is a non-economic feature determining which values we choose to be important and thus determining our policy objective. Here we make this explicit.

In this note, we take two particular functions of one particular model and discuss their features. The functions are the production function and the utility function, the model is Nordhaus's DICE.[3] This does not imply that we agree on Nordhaus's approach,[4] but our point will be more clear when using a well known (and conservative) model. As the title suggests, we focus on the impact of climate change damages on these functions, and pay explicit attention to the difference between tangible and intangible damages. The next section briefly outlines the DICE model; the following section discusses the distinction between tangibles and intangibles, alters DICE, and elucidates the differences between the outcomes of our and Nordhaus's versions. The model is then further altered, and the final section concludes. The main conclusion of this note is that the utility function is another important feature in climate–economy modelling, and that therefore more attention needs to be paid to its specification.

The DICE model

The Dynamic Integrated Climate Economy model of Nordhaus is a simple one-region, one-sector, one-good Ramsey-type model, extended with greenhouse gas emissions, a climate module, and the impacts of climate change and emission abatement. In its August 1993 version, gross world output Y_t is given by

$$Y_t = A_t L_t^{(1-\gamma)} K_t^{\gamma} G_t \tag{1}$$

where

$$G_t = \frac{1-\beta_1 E_t^{\beta_2}}{1+\alpha_1 (T_t/T_B)^{\alpha_2}} \tag{2}$$

with A_t the level of total factor productivity, L_t the labour force, K_t the capital stock, E_t the rate of emission control, and T_t the temperature at time t; α_1 is the benchmark climate change cost, T_B is the benchmark climate change, α_2 determines the non-linearity of the climate change damage cost function, β_1 and β_2 are the emission control intercept and exponent, respectively, and γ is the capital elasticity of the output. Essentially, the costs of emission control and the damages of climate change are treated as budget constraints to the economy, restricting the output available for consumption and investment.

In DICE, the capital stock K grows with the difference between output Y and consumption C and shrinks through depreciation. The factor productivity and the labour force grow according to exogenous paths. Energy efficiency improves autonomously. The distribution of income over consumption and investment is determined by optimising the net present utility U:

$$U = \sum_t \frac{L_t \ln(C_t/L_t)}{(1+\delta)^t} \tag{3}$$

with δ the utility discount rate.

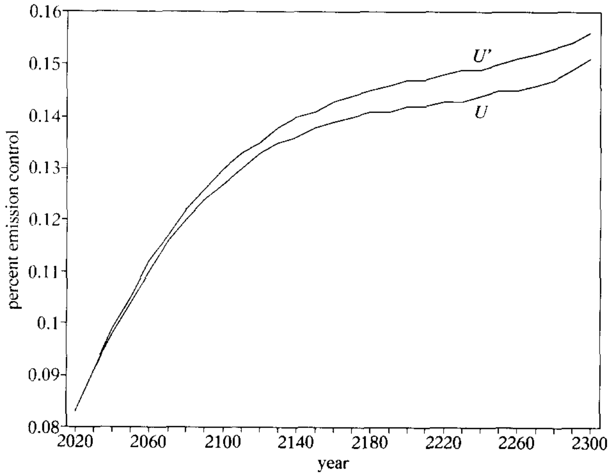

Figure 1. Optimal greenhouse gas emission control for the period 2020–2300 according to utility U, corresponding to Equation (3), and according to utility U', corresponding to Equation (4), based on Nordhaus's DICE model.

Tangibles versus intangibles

Tangible goods are those goods for which markets and thus prices exist. Intangible goods are the inputs of human welfare which are not marketed and priced. Tangible and intangible damages are defined accordingly. Nordhaus[6] states that the intangible damages of climate change are about three times as large as the tangible damages. In Equation (2), α_1 comprises both the tangibles and the intangibles, and as (1) is the economic output equation, DICE treats intangible damages exactly the same as the tangible ones. However, we might claim that intangible damages by their very nature rather affect the utility function directly (though some effects on labour productivity can be expected; these are ignored here). Intangibles consist of non-monetary inputs to the human welfare; implicitly, economic valuation methods translate the intangibles' utility into their monetary utility equivalent, and further into money. Therefore, α_1 in (2) is replaced by $0.25\alpha_1$, and utility U is replaced by

$$U' = \sum_t \frac{L_t \ln[C_t/L_t) - 0.75\alpha_1 (T_t/T_B)^{\alpha_2} Y_t/L_t]}{(1+\delta)^t} \qquad (4)$$

Note that U' is not defined for high T_t and so is only a local approximation of the 'real' utility. Figure 1 depicts the optimal emission control rate according to Nordhaus and our version of DICE over the period 2020–2300 (Nordhaus assumes no emission control up to 2020 – this assumption does not substantially influence the results). The discount rate δ is set to 3% a year, α_1 equals 1.33%, and α_2 is 2. Putting the intangible losses directly in the utility function clearly leads to stricter reductions. This can be explained as follows. The intangible damages are moved from the flexible production function to the more rigid utility function. This implies that the intangible damages are largely withdrawn from the process of economic growth and so that there is less opportunity to substitute the losses in time eg by means of altering the investments. In the DICE model with utility function (3), biodiversity and videorecorders, say, are fully substitutable; with Equation (4), only their utilities are substitutable. Apart from this, the total damage costs are implicitly raised by $0.25 \times 0.75 \times \alpha_1^2 (T_t/T_B)^4 \approx 0.3 \times 10^{-5} (T_t/T_B)^4$, which implies that the benchmark damage increases from 1.330% to 1.333%.

Further extension

It is clear from the theory of environmental economics that the intangible goods are valued higher in terms of money as the income per capita grows, ie the richer we are, the larger the share of our income we are willing to pay for the environment; in other words, the intangibles are treated as luxury goods. This should be incorporated in the utility function by a part which is convex in income per capita and a part which is at the same time concave in income per capita and convex in environmental quality, with the first part dominant for low levels income. Note that it would even be more elegant to put environmental quality directly into the utility function; this would require a major adjustment of DICE. We will not go into this tricky question here, but adjust our utility function somewhat further by

$$U'' = \sum_t \frac{L_t \ln[(C_t/L_t) - 0.75\alpha_1 (T_t/T_B)^{\alpha_2} (Y_t/L_t)(C_t/L_t)/(C_0/L_0)]}{(1+\delta)^t} \qquad (5)$$

that is, the intangible damages are assumed to be assessed for the present situation and to grow proportionally with the income per capita. According to Equation (5), the benchmark intangible damage equals 1% of the gross world product if evaluated under the current average income per capita levels, but will be valued at 2% of GWP

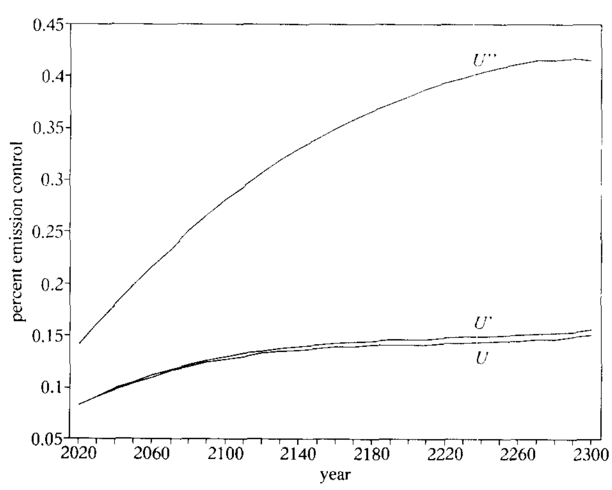

Figure 2. Optimal greenhouse gas emission control for the period 2020–2030 according to utility U, corresponding to Equation (3), according to utility U', corresponding to Equation (4), and according to utility U'', corresponding to Equation (5), based on Nordhaus's DICE model.

if evaluated under doubled levels of income per capita. Note that assuming the tangible damages to grow linearly with per capita income is a conservative choice. Figure 2 depicts the optimal emission control rates for Nordhaus's and our two versions of the utility function. The optimal abatement almost triples for the new specification (5), which can be explained by the fact that we raised the damage costs substantially over time. Just like with utility specification (4), the utilities of biodiversity and videorecorders can be substituted according to Equation (5), but the more videorecorders there are, the higher biodiversity is valued.

Conclusion

This note argues that, besides the costs of greenhouse gas emission reductions, the damages of climate change, the uncertainties surrounding climate change, the rate of scientific progress, the economic development and time discounting, the treatment of climate change damages is another important factor in evaluating optimal abatement policies.

It is shown that putting the intangibles in the utility function rather than in the production function of the DICE model, leads to a higher optimal abatement. Further assuming that the intangible losses grow proportionally with per capita income more than triples the optimal abatement. In conclusion, the specification of the utility function is of major importance in evaluating the optimal greenhouse gas emission control, and should therefore receive more attention in the economic global warming debate. This note does not go into questions of non-substitutability between utilities, of stock versus flow variables and damages, and of reversibilities and irreversibilities. In addition, the discount rate and risk minimization behaviour are left out of the discussion. Fascinating research awaits us.

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[2]F.L. Toth, 'Measurements for measures: current economic analyses of climate change', in Y. Kaya, N. Nakićenović, W.D. Nordhaus and F.L. Toth, eds, *Costs, Impacts, and Benefits of CO_2 Mitigation*, IIASA, Laxenburg, 1993.

[3]W.D. Nordhaus, *The DICE Model: Background and Structure of a Dynamic Integrated Climate-Economy Model of the Economics of Global Warming*, Cowles Foundation Discussion Paper 1009, New Haven, 1992; see also *op cit*, Ref 1.

[4]See R.S.J. Tol, *The Damage Costs of Climate Change: Towards More Comprehensive Calculations*, Institute of Environmental Studies W93/18, Vrije Universiteit, Amsterdam, 1993; but also W.R. Cline, *The Economics of Global Warming*, Institute for International Economics, Washington, DC, 1992; and M. Grubb, 'The costs of climate change: critical elements', in Y. Kaya, N. Nakićenović, W.D. Nordhaus and F.L. Toth, eds, *Costs, Impacts, and Benefits of CO_2 Mitigation*, IIASA, Laxenburg, 1993.

[5]See *op cit*, Ref 3.

[6]See *op cit*, Ref 1.