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The level and distribution of costs and benefits over generations of an emission stabilization program

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Abstract

In the *Energy Economics* issue of May 2005, Kavuncu and Knabb (KK) develop an IAM-OLG model to analyze the costs and benefits per generation of a Kyoto type emission stabilization program. They find that the first generations are confronted with huge costs, from 8% in 2000 to 40% in 2100. Only after 2315, generations start to benefit. I believe that this result is fully driven by the assumed very high abatement costs. I add an OLG structure to the existing DICE99 model, and reproduce their results based on the same abatement costs function. Under the standard abatement costs function that comes with DICE99, however, an emission stabilization program results in early generations having costs always below 0.5%, while generations start to benefit from 2080 onwards.

JEL classification: D90; H23; Q20; Q28

Keywords: Climate change; Environmental policy; Intergenerational costs and benefits; Overlapping generations

In the *Energy Economics* issue of May 2005, Kavuncu and Knabb (KK) assess the costs and benefits of stabilizing greenhouse gas emissions as prescribed by the Kyoto Protocol. The specific objective of their paper is to study which generations will benefit, and which generations will bear the costs of such a global climate change program. For this purpose, they develop an applied economic growth model with overlapping generations (OLG), emissions, a simple climate module, and a feed back from temperature increase to decreasing welfare. The specification of

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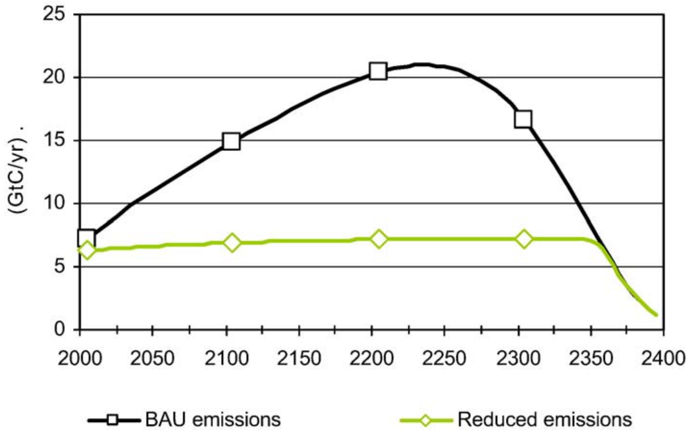

Fig. 1. Industrial CO_2 emissions in the benchmark (BAU) and in the control scenarios (S1 and S2).

generations enables KK to calculate the change in welfare induced by the emission stabilization program, measured in consumption equivalents.

KK develop a benchmark (BAU) scenario without a climate change policy, and a control scenario with stabilized emissions. Then they compare welfare levels per generation and calculate the net benefits or costs of the control policy compared to the BAU. They find the first generation, born in 2000, to face a net loss equivalent to 8% of its consumption. Control costs increase further to more than 40% for the generation born in 2100. Only generations born after 2315 benefit from the control policy.[1] The magnitude of costs over the 21st century imply that it is impossible for future generations living in the 24th century and thereafter to compensate the early generations, e.g. through government debt. A reader can easily conclude from KK's results — and KK themselves state it as a possible interpretation — that an emission stabilization program is not warranted, unless there comes a new evidence that climate change costs will be more severe, or that abatement costs are much lower, than currently anticipated.

It is at this point that I think some comment is in order. As KK are certainly aware, but many of the *Energy Economics* readers may not, in KK's model there is but one option to reduce emissions, by reducing output. The economy has no option of substituting non carbon-emitting production factors for carbon-energy, nor is there an option of substituting goods from 'clean' sectors for goods from 'dirty' sectors in consumption. To cut emissions by say 50%, an amount necessary in 2100 in the control scenario, the only option available is to reduce output by 50% as well. This abatement cost specification assumes a very high flat marginal costs curve. For all IS92 scenarios (Leggett et al., 1992) and for almost all SRES scenarios (Nakicenovic and Swart, 2000) the implied marginal costs would exceed 10,000 US$90/*tC* for the entire range of emission abatement. In contrast, marginal abatement cost estimates typically used in the relevant branch of the literature start from close to zero for low abatement levels to some hundreds of US$/*tC* for very deep cuts in emission levels (Weyant and Hill, 1999). Nordhaus and Boyer (2000), for example, for the DICE99 model, assume that in 2100, 50% emission reductions would decrease output by 0.38%, at marginal costs of about 120 US$/*tC*. Since in DICE99 costs are strongly convex, for all intermediate abatement levels, the relative discrepancy between DICE99 and KK's

[1] All KK results reported here are based on the scenarios calculated with the central parameters.

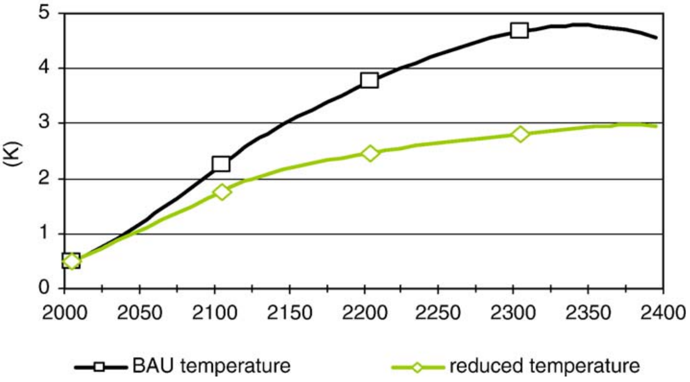

Fig. 2. Temperature increase in benchmark (BAU) and in the control scenarios (S1 and S2).

model is even larger. I therefore conclude that we do not need new evidence on abatement costs, but rather use the existing evidence to radically change the results.

To give substance to my claim, I extended the DICE99 model with an overlapping generations format to see whether indeed, (i) I could reproduce qualitatively the results by KK when assuming the drop in output proportional to emission reductions, and (ii) whether results would dramatically change under the standard DICE99 abatement costs assumptions. I refer the reader to Nordhaus and Boyer (2000, Appendix B and E) for a full description of the DICE99 model. Here I will confine myself to the extensions I made.

First I constructed a sequence of generations, each living for 4 adult periods of 10 years. Generations are denoted by t, the first period in which they enter the model. We can think of childhood as being covered by the parents' consumption decisions, so that the model describes the economic lives from age 20 till 60. The size of each generation is constructed such that the sum of the size of the generations $N(.)$ alive in period t, is equal to the population size in DICE99, $L(t)$, (1). obviously, when having multiple generations, the commodity balance has to be adjusted to account for consumption of all generations (2), where $C(t-3,t)$ refers to the consumption of generation $t-3$ in period t. Each generation is assumed to maximize welfare $U(t)$, (3), where the time discount factor $R(.)$ is taken from DICE99, leading to the first order conditions (4), for i=0,1,2, where $r(t)$ is the interest rate between period $t-1$ and t. Most distinctive of the OLG structure is the budget equation, which sets equal the value of labour income and the expenditure on consumption (5). We make three observations. First, each generation is assumed only to work during the first 3 periods of life. The fourth period is spent in retirement. Second, the first 3 generations that enter the model also receive a share in the value of the initial capital stock of 0.5, 0.35, and 0.15, respectively, which is not specified in the equations below. Third, the last three generations also pay for the last-period investments, also in shares 0.5, 0.35 and 0.15. Finally, to complete the OLG extension, we have to define wages, which are given by the first order conditions for labour (6), and the interest rate, given by the first order condition for capital (7). Together, these equations define the OLG extension for DICE99.[2]

$$N(t-3)+N(t-2)+N(t-1)+N(t)=L(t) \tag{1}$$

[2] It is implicit in the equations that carbon tax revenues are per period redistributed over generations proportional to their income in that period.

$$C(t-3,t)+C(t-2,t)+C(t-1,t)+C(t,t)+I(t)=Y(t) \tag{2}$$

$$U(t)=\Sigma_{i=0,1,2,3}[N(t)R(t+i)/R(t)]\ln[C(t,t+i)/N(t)] \tag{3}$$

$$1+r(t+1)=[R(t+1)/R(t)]\ [C(t-i,t+1)/N(t-i)]/[C(t-i,t)/N(t-i)] \tag{4}$$

$$\begin{aligned} &w(t)N(t)+w(t+1)N(t)/(1+r(t+1))+w(t+2)N(t)/[(1+r(t+1))(1+r(t+2))] \\ &\quad =C(t,t)+C(t,t+1)/(1+r(t+1))+C(t,t+2)/[(1+r(t+1)) \\ &\qquad \times(1+r(t+2))]+C(t,t+3)/[(1+r(t+1))(1+r(t+2))(1+r(t+3))] \end{aligned} \tag{5}$$

$$w(t)(N(t-2)+N(t-1)+N(t))=(1-\gamma)Y(t) \tag{6}$$

$$r(t)K(t)=\gamma Y(t)-(1-(1-\delta_K)^{10})K(t) \tag{7}$$

With this extended model, I ran the benchmark (BAU) scenario, one scenario (S1) in which total emissions (industrial plus non-industrial) were set not to exceed their 1995 levels, and one scenario (S2) in which I ran the same emission control, but with abatement costs assumed equal to output times the relative emission cuts.[3] Results are presented below.

Fig. 1 shows emissions under BAU and under control. DICE99 assumes that industrial emissions increase almost threefold and then drop quickly after 2250. After 2350, emissions are at their 2000 level, and no abatement is required. Under BAU, the global average surface temperature increases by almost 5 K, while under emission stabilization the temperature increase is limited to about 3 K by 2400 (Fig. 2). The S1 and S2 scenarios show the same increase to output related to the prevented temperature increase, of about 0.5% by 2100, 2% by 2200, and 3% between 2300 and 2400. The scenarios S1 and S2, however, differ sharply in their abatement costs. Scenario S1, based on the DICE99 parameters, shows abatement costs of less then 0.5% for the whole time range 2000–2400. Consequently, consumption levels under the control policy exceed consumption levels under BAU after 2100. All generations, born after 2080, benefit from the control policy (Fig. 3).

Scenario S2, however, based on KK's assumption on abatement costs shows a heavy burden. Output decreases by about 50% in 2200, and the benefits of prevented temperature related damages cannot outweigh the costs (Fig. 4). This picture, indeed, more or less resembles the findings by KK.

I conclude that KK's analysis is overly pessimistic in assuming very high costs for emission abatement. When taking a more common abatement cost function, we still find that early

[3] That is, in Eq. (B.5) in Nordhaus and Boyer (2000) I pick $b_1=b_2=1$.

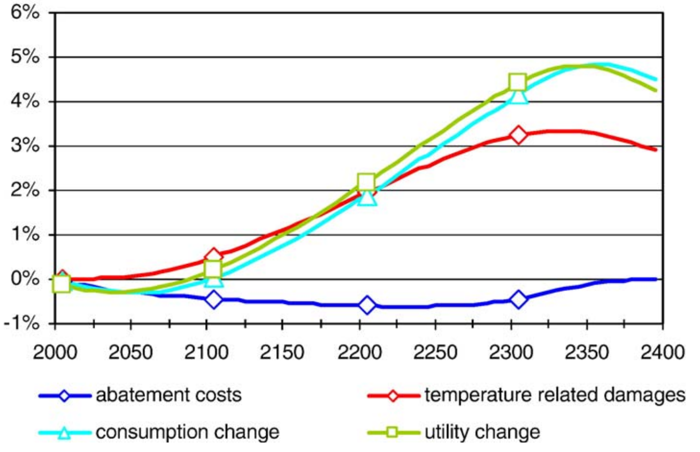

Fig. 3. Changes in output due to abatement costs, and temperature related damages. Changes in total consumption per period and in utility per generation. Comparing S1 with BAU.

generations will have to pay for an emission control policy, but their costs are much lower, and the benefits of future generations are of a much larger magnitude. Qualitatively, the analysis presented here confirms the results of KK, but, quantitatively, my results are very different. Finally, I want to make one comment on a methodological issue. Comparing the change in consumption and the change in utility, measured in consumption equivalents, it is clear that utility changes lag consumption changes by about 15 years, which is equal to the lag between the first period a generation enters the model, used as its label, and the average period in which a generation lives. The OLG structure does not seem to add much to the insights. The basic DICE99 model without OLG would have produced almost the same result, not in utility changes per generation (which is then not available), but in consumption changes per period, which is a very similar graph.

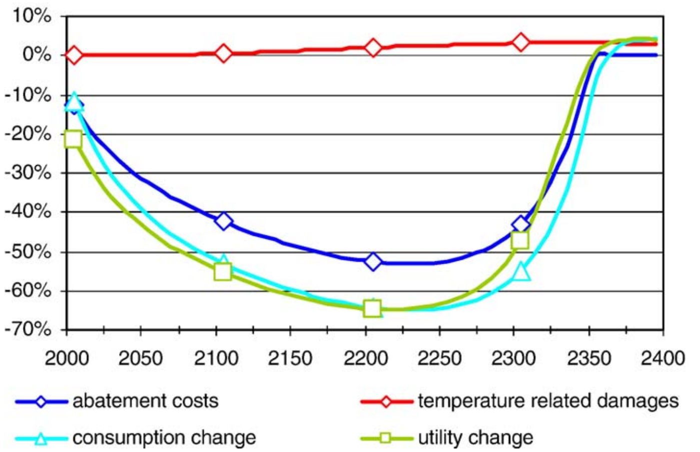

Fig. 4. Changes in output due to abatement costs, and temperature related damages. Changes in total consumption per period and in utility per generation. Comparing S2 with BAU.

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