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Mitigation versus compensation in global warming policy

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Abstract

Policy discussions on global warming are focused on mitigation and adaptation. Here the role of ex post compensation as a substitute for ex ante mitigation is considered. In a simple 2−period model the salient features of the global warming problem suggest mitigation is difficult to motivate. A key problem is that damages are very hard to identify even after the fact. The roles of endogenous private savings and a compensation fund as an alternative to ex ante mitigation are explored.

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1. Introduction

Global warming policy discussions have hitherto focused on *mitigation* through reductions in emissions believed to cause climate change. Yet the original Kyoto Protocol, even if fully implemented, would only delay by about 5 years the expected date at which the atmospheric concentration of CO_2 doubles; increasing it from, say, 100 years to 105 years (Wigley 1998, Reilly *et. al.* 1998). Whatever consequences will ensue from carbon dioxide doubling are not prevented through such policy, only postponed. Many studies have examined challenges of mitigation policy design, such as international coordination (Carraro 2000), uncertain damages (Wirl 2001), design of market mechanisms (Shogren and Toman 2000), empirical computation of static optima (Brown 1998) etc. What has been missing is a serious consideration of whether *ex post* compensation could be a substitute for *ex ante* mitigation initiatives. Three international agreements to date (Toronto, Rio and Kyoto) have focused only on emission reductions. No countries seem to have actively considered *ex post* policy, i.e. a fund that would pay compensation for deleterious effects of global warming, if any, arriving slightly earlier than they would have with a mitigation policy in effect.

In an economic sense the two approaches ought to be substitutes: *ex ante* measures are based on willingness to pay (WTP) to prevent expected damages, and *ex post* measures are based on willingness to accept (WTA) compensation for damages incurred. While the WTP and WTA magnitudes can differ slightly because of income effects, the two metrics both reduce to the same underlying utility change, unless the public good in question has, effectively, no substitutes (Hanemann 1991). Since the public good generated by the Kyoto Protocol is merely a short delay in possible climate changes, this latter point does not apply. In other words we can assume that there is a finite amount people would be willing to accept as compensation for the effects of climate change arriving slightly sooner than if a (costly) policy had been implemented, and the WTA amount approximately equals the maximum amount people would have been willing to pay *ex ante* for the effects-delaying measures.

Going further, one important but subtle feature of the global warming issue makes the *ex post* compensation policy seem preferable. The anthropogenic component of many pollution problems—e.g. soil and water contamination—are obvious because the presence of tell-tale chemicals is identical to the damage. But CO_2 occurs and varies naturally. Anthropogenic additions to the atmosphere will (if they do anything) produce changes in the weather. But weather is a chaotic process, and we have limited expectation of being able to distinguish natural and anthropogenic changes at the local level, even *ex post*. Any damage function we define for the purposes of determining optimal mitigation policy must take for granted a future ability to accurately identify location-specific climate changes and attribute them to anthropogenic causes. If we do not have this ability, climate policy can not be based on cost-benefit analysis.

Suppose, for instance, that as of 2030 two regions of the UK have experienced an increase in rainfall, requiring costly modifications to water management infrastructure. Suppose further that one region's change is entirely attributable to natural causes while the other was caused by the increased optical depth of the atmosphere from greenhouse gas emissions. While both changes are of interest from a water management point of view, only the latter is of interest for the purposes of decision-making on greenhouse gas policy. If we think of compensation as a substitute for a mitigation option not taken, the amount owed is limited to the extra expense of having to pay for the infrastructure sooner rather than later. But we do not currently have the ability to model location-specific greenhouse gas-induced effects on a small enough spatial and time scale to attribute, say, hydrological changes to anthropogenic rather than natural causes, and to quantify how much compensation is appropriate for not implementing a particular emissions reduction treaty. The best we can say is that, from the perspective of the present, for every *n* claims in 2030 of damages due to global warming, we expect (today) that we will be able to correctly identify π percent of them as being legitimate and quantify accurately the amount owed. Otherwise, private financial instruments like insurance and "weather derivatives" (Dosi and Moretto 2001) will serve as the main channel of compensation for climate-related damages, regardless of cause.

The model developed below is a simple and preliminary exploration of this idea. A 2-period model is presented in which savings for *ex post* compensation is an option. I consider a non-recurring incident in which emissions over one interval generate costs over a subsequent interval. The optimal amount of emissions reduction is likely very small. Private savings adjusts to provide *ex post* compensation, and if mitigation is omitted altogether an offsetting addition to private savings is warranted.

2. The Model.

There are 2 periods, indexed i=1,2. Consumption each period is C_i and utility is $\ln(C_i)$. In period 1 an emission level e is chosen which generates concave benefits $B(e)$. There is also an exogenous income y and savings in the amount F. Hence

$$C_1 = B(e) + y - F\ .$$

In period 2 income is also y. There are second-period damage claims which amount to $D(e)$. Damages primarily include changes in the timing of losses due to weather variability, degradation of natural resources, new infrastructure requirements, loss of amenities, etc. If there are other damages incurred but not claimed, they can be ignored for period-1 policy purposes because they are presumably too small to notice or have benign side-effects which cancel out them out. If there are known exogenous changes in weather that will affect income the model could accommodate that by distinguishing period-2 income as, e.g., $\hat{y}$. Here income is held constant.

There is a probability π that, during period 2, the claims $D(e)$ will be attributable to emissions e. Referring to the example above, π is the fraction of n regions of the world claiming damages due to climatic changes as of (say) 2030 which we can accurately attribute to infrared absorption by greenhouse gases. If π =0, damages due to global warming, even if real, cannot be addressed by economic policy, because we cannot identify them before or after the fact. In the same way, if (say) ornamental shrubs were suspected of being a source of volatile organic compound (VOC) emissions, but no disease or harm could be attributed to it, economics would not provide any guidance for policy. Savings is available in period 2, inflated by a growth factor $R = (1+r)$ where r is the market interest rate. Taking these together we have

$$C_2 = y - \pi D(e) + RF \text{ .}$$

We ignore the possibility that there will be second-period emissions. There may or may not be, but since damages are not instantaneous they do not affect the results below. The policy problem in period 1 is

$$\text{Max (w.r.t. } e, F) \ \ln(C_1) + R^{-1}\ln(C_2) \qquad (1).$$

The first order conditions are, with respect to *e* and *F* respectively,

$$B' = R^{-1}\frac{C_1}{C_2}(\pi D')$$

and

$$RC_1 = C_2 \text{ .}$$

These yield optimal *e* and *F* (denoted *) defined as

$$B'(e^*) = R^{-1}\pi D'(e^*) \qquad (2)$$

and

$$F^* = \frac{1}{2}\left(B(e^*) + \frac{r}{R}y\right) + \frac{\pi}{2R}D \qquad (3).$$

The derivation is in the appendix. If there were no damages, period 1 emissions would be released up to the point where $B'(e) = 0$, that is, where marginal benefits today are exhausted. Mitigation is required if

$$\frac{\pi}{R}D' > 0 \qquad (4).$$

Empirical information on the relevant magnitudes in (4) can only be approximate, but these are the quantities that need to be considered.

There is mixed evidence that $D' > 0$. Early studies (see IPCC 1996, chapter 6) fell in a range of about $0-20 per ton of carbon, but did not typically account for adaptive behaviour. Ricardian analyses (e.g. Mendelsohn *et. al.* 1994, 1999, 2000; Sohngen and Mendelsohn 1998) find that, once adaptive behaviour and CO_2-fertilization is considered the net economic costs of climate change in most places are likely to be very small, in many locations there are positive benefits, and the net benefits are positive for the globe as a whole. Also, since expected warming is proportional to the log of the CO_2 concentration the damage function is unlikely to be convex, so we do not expect the sort of rising marginal damages that are associated with local contamination problems.

Even if $D' > 0$, it is multiplied into the discounted probability that we can identify, *ex post*, local damages attributable to greenhouse gases. Local meteorological changes involve fluid turbulence, and the limitations on computational modeling of such processes are so acute it is plausible to argue that π is and will remain zero. But if π is allowed to be, say, 0.5, discounting back from 2030 to 2001 at 5% yields $D' \times 0.5 \times 1.05^{-30} = 0.12 \times D'$. In studies that downplay adaptive responses to climate change the marginal damages average about \$3 per barrel of oil equivalent (Brown 1998 Figure 4). This implies mitigation should be undertaken only until the marginal benefits of fuel use have risen by \$0.35 per barrel of oil equivalent across fuel types. This would be the maximum amount we would be willing to pay for a policy that *prevents* damages due to global warming. Since mitigation efforts like Kyoto Protocol only *delay* warming by a few years, the maximum amount we are willing to pay is even less than this. We will consider below the implications of ignoring mitigation altogether.

The first part of equation (3) is the savings for consumption smoothing and the second part is the (endogenous) fund to compensate for the effects of first-period emissions. If there were no damages ($D = 0$) or they are positive but unidentifiable *ex post* ($\pi = 0$) then from (3) the optimal savings level would be $(B + ry/R)/2$. The expectation of identifiable second-period damage claims implies savings should rise by $\pi D/2R$, or expected identifiable damages discounted by twice the discount factor. In their discussion of the recent emergence of a market for weather derivatives, Dosi and Moretto (2001) tentatively suggest it may reflect concerns about future global warming, but it may also be tied to energy sector deregulation and other contemporary commercial developments.

Fullerton (1995) has pointed out that there are fixed costs to implementing any tax, including environmental ones, and sometimes the benefits are not sufficient to merit that form of policy intervention. If it is preferable to ignore mitigation altogether, emissions stay at the unregulated level $\bar{e} = B'^{-1}(0)$ and the extra damages are $[D(\bar{e}) - D(e^*)]$. The required increment to savings to cover net social costs of emissions (denoted N) is

$$\pi R^{-1} N(\bar{e} - e^*) = \pi R^{-1}[D(\bar{e}) - D(e^*)] - [B(\bar{e}) - B(e^*)].$$

This is a "compensation fund" that must be added to private savings in period 1. Here discounting works in favour of the *ex post* compensation policy since the higher is R, the less expensive is the original outlay. A high discount rate is usually seen as a problem for justifying mitigation since the damage reductions are far in the future, prompting some analysts to look for rationale for using small discount rates (see e.g. Weitzman 2001). No such alternative approaches are needed, since the market discount rate is the appropriate one for planning savings. For damages expected 30 years hence, a 5% discount rate implies the amount invested in a compensation fund should be $0.12\pi N(\bar{e} - e^*)$. The presence of π again reduces the appropriate amount of the fund.

If we assume away all future uncertainty regarding the detectability of damages we have $\pi = 1$. By (4), mitigation may still not be practical, especially if D' is (near) zero. But the compensation fund remains warranted.

3. Discussion and Conclusion

In a standard static pollution model, mitigation is the natural policy to consider, and the details of interest to economists are normally limited to computation of the optimum and designing market-based instruments. The willingness to pay for emissions reduction should (nearly) equate to the amount of compensation deemed adequate for not reducing emissions. But with global warming we will likely not be able to distinguish natural and anthropogenic weather changes at individual locations, even *ex post*. This paper explores, in a preliminary way, the implications of this for global warming policy. The expectation that we will have only a limited probability of being able to quantify meritorious damage claims reduces the optimal *ex ante* mitigation level to small amounts. Endogenous private savings and financial instruments will provide *ex post* compensation for damages, and if mitigation is not pursued these funds can be topped up to reflect the public WTA compensation for the risk of damages appearing earlier than otherwise. Ordinary market discount rates are adequate for computing such amounts, which by definition imply a constraint on the amount agents are WTP for mitigation *ex ante*.

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Appendix

Consumption in the 2 periods is, respectively, $C_1 = B(e) + y - F$ and $C_2 = y - \pi D(e) + RF$.

Maximize $\ln(C_1) + \ln(C_2)$ with respect to *e* to get

$$\frac{1}{C_1}B' - \frac{1}{C_2}\pi D' = 0 \Rightarrow B' = \frac{C_1}{C_2}\pi D'.$$

Maximize with respect to *F* to get

$$-\frac{1}{C_1} + \frac{R}{C_2} = 0 \Rightarrow RC_1 = C_2.$$

Use the definitions of C_i and the above to get

$$RB(e) + Ry - RF = y - \pi D(e) + RF$$

which rearranges to $F = \frac{1}{2}\left(B(e) + \frac{r}{R}y + \frac{\pi}{R}D\right)$