Some reservations about "A Shapley Value Approach to Pricing Climate Risks" by Roger M. Cooke

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Roger Cooke (2011) proposes an intriguing method to estimate the benefits of mitigating climate change. His notion is to apply the concept of revealed preference to societal judgments about climate policy and to infer that the social value of a reduction in climate risks is at least as large as the reduction in the expected value of damages. As an illustration, he assumes society has expressed a desire to exchange the risky prospect of uncertain damages corresponding to a business as usual (BAU) emission path with an alternative prospect of uncertain damages corresponding to an emission path that satisfies a risk constraint (at minimum abatement cost). One could raise questions about what it means for society to express such a preference, whether society has indeed expressed a preference for the risk constraint he assumes, and how to calculate a least-cost emission path that satisfies this constraint. Setting these issues aside, I wish to focus on a key conceptual issue in the approach: the assumption that social willingness to pay (WTP) to swap one risky prospect for another exceeds the pure premium a risk-neutral insurer would demand for the swap, i.e., the difference in the expected value of damages.

I have two reservations about this assumption. First, it is not necessarily true that a risk-averse agent would be willing to pay more than the reduction in expected damages to exchange one risky prospect for another. Second, WTP to swap one risky climate-damage prospect for another depends on the dependence of the climate risks (and the difference between the two prospects) on other risks, such as that associated with economic growth. I elaborate on each point in turn. In addition, I note that society's preference to swap a BAU emissions path for a risk-constrained path implies that its WTP exceeds the combined value of the reduction in climate risk and the abatement costs required to achieve the swap.

WTP to Reduce Risk

While it is true that a risk-averse agent will pay more than a risk-neutral agent to eliminate risk, it does not follow that a risk-averse agent will pay more to reduce but not eliminate a risk. As Cooke notes, an agent's WTP to eliminate a risk of loss exceeds the expected value of the loss by a risk premium. The risk premium is positive for a risk-averse agent and zero for a risk-neutral agent. Consider the possibility of substituting one risky prospect, D_1, with another risky prospect, D_2. An agent's WTP to eliminate the risky prospect $D_i = E(D_i) + \pi_i$, where $E(D_i)$ is the expected damage and π_i is his risk premium for prospect i. Hence the agent's WTP to swap D_1 for D_2 is equal to the difference in expected damages plus the difference in the risk premia, $E(D_1) – E(D_2) + \pi_1 – \pi_2$. For the risk-averse agent, the risk premium for the first prospect need not exceed the risk premium for the second; if it does not, his WTP to swap is not greater than the reduction in expected damages (Ross 1981).

Consider a simple example in which climate damages may be catastrophic (with value D) or minimal (with value 0). Social wealth in the absence of climate damages is W. Under a BAU emissions path, the probability of catastrophic damages is p_0; under a risk-constrained emissions path, the probability is reduced to p_1. Figure 1 illustrates a (concave) risk-averse utility function and a (linear) risk-neutral utility function both normalized such that utility in the event of no damage $u(W) = 1$ and utility in the event of damage $u(W - D) = 0$. For the BAU emissions path, the expected utility is $(1 - p_0)$ and the risk-averse agent would be willing to pay $p_0D + \pi_0$ to eliminate the risk (note that the utility of the certainty-equivalent wealth $u(W - p_0D - \pi_0) = 1 - p_0$). Analogously, for the risk-constrained emissions path the expected utility is $(1 - p_1)$ and the risk-averse agent would be willing to pay $p_1D + \pi_1$ to eliminate the risk. His WTP to swap the first risk for the second is the difference between the certainty-equivalent wealth levels, $(W - p_1D - \pi_1) - (W - p_0D - \pi_0) = (p_0D - p_1D) + (\pi_0 - \pi_1)$, i.e., the difference in expected damages plus the difference in risk premia. For the example illustrated in Figure 1, this WTP is smaller than the difference in expected damages because the risk-averse utility function is steeper than the risk-neutral utility function over the interval between $(W - p_0D - \pi_0)$ and $(W - p_1D - \pi_1)$. Clearly, the risk-averse agent's WTP for the risk swap would be larger than the difference in expected damages if his utility function were flatter than the risk-neutral utility function over the relevant interval; this would occur if p_0 were relatively small so that $1 - p_0$ was close to 1.

WTP to reduce a risk depends on how the risk is reduced. One distinction is that between 'self-protection' (reducing the probability of loss) and 'self-insurance' (reducing the magnitude of the loss) (Ehrlich and Becker 1972). The example in Figure 1 is a case of self-protection, for which WTP need not increase with risk aversion. In contrast, if the benefit of the risk-constrained emissions path were to reduce the magnitude of damages, rather than their probability, then any risk-averse agent's WTP for the risk swap would exceed the reduction in expected damages (Dionne and Eeckhoudt 1985). More generally, if the risk under the BAU pathway is second-order stochastically dominated by the risk under the risk-constrained pathway (i.e., the former is obtained from the latter by an increase in expected damage and/or a sequence of mean-preserving spreads; Rothschild and Stiglitz 1970), then any risk-averse agent's WTP will exceed the reduction in expected damages. (Note that having greater variance is a necessary but insufficient condition for one risk to be obtained from another by a sequence of mean-preserving spreads.)

Dependence among Climate Damages and Other Risks

The previous section concerns a model in which there is only one risk – that of climate damages. Society faces many additional risks, including uncertainty about economic growth and about the abatement costs incurred along a risk-compliant emissions path. As these risks may be probabilistically dependent, it is possible that climate risk tends to offset other risks to well-being. If so, reducing climate risks can have two, offsetting effects: a reduction in expected damages and an exacerbation of total risk. In this case, WTP to reduce climate risk can be less than the reduction in expected damages.

To illustrate, assume climate damages are binary; with probability 1/2 damages will be equal to D and with probability 1/2 they will be zero. In addition, assume that economic growth is uncertain and that future wealth will be W + G or W – G with equal probability. If climate damages are positively dependent on economic growth (so that damages are more likely to occur when economic growth is strong) then the climate risk helps to offset the growth risk. For simplicity, assume the two risks are perfectly dependent so that the prospects for future wealth are as illustrated in Figure 2. Under the BAU emissions path, wealth will be (W + G – D) if economic growth is strong and climate damages occur or (W – G) if growth is weak and no damages occur. Assume that climate risk is eliminated under the risk-constrained pathway, so that wealth is (W + G) or (W – G). Given these assumptions, the certainty-equivalent wealth for the BAU emission path is $W - D/2 - \pi_B$ and that for the risk- constrained pathway is $W - \pi_C$, where π_B and π_C are the corresponding risk premia. WTP to swap the risk under the BAU pathway for that under the risk-compliant pathway is $D/2 + \pi_B - \pi_C$, which is larger than the reduction in expected damages (D/2) if and only if the risk premium for the BAU pathway exceeds that for the risk-compliant pathway. This need not be the case. For example, if D = 2G then there is no risk under the BAU pathway (wealth net of climate damages is W – G), the risk premium $\pi_B = 0$, and WTP to swap risks is less than the reduction in expected damages.

The dependence among climate damages, economic growth, and uncertainty about abatement costs is not clear. Many integrated-assessment models assume that climate damages are proportional to the size of the economy, and so damages and economic growth are positively dependent. In this case, WTP to reduce climate damages could be less than the reduction in expected damages, as in the previous example. On the other hand, lower-income economies are thought to be proportionally more vulnerable to climate change because larger shares of their economies are in climate-sensitive sectors (e.g., agriculture). This observation suggests that economic growth reduces the likely magnitude of climate damages, implying a negative dependence. Abatement costs of meeting a risk-compliant emissions path may be positively dependent on economic growth if higher growth requires larger emission reductions, or negatively dependent if economic growth is stimulated by development of greenhouse-friendly energy or other technologies.

Abatement Costs

Cooke's proposal attempts to infer a lower bound on WTP to reduce climate damages based on the reduction in expected damages. When society expresses its preference to follow a risk-constrained rather than a BAU emissions path, that implies that it judges the benefit to exceed the value of the climate-risk reduction plus the abatement costs associated with shifting to the risk-compliant path. If the value of the climate-risk reduction could be adequately characterized, the lower bound on WTP could be increased by adding the abatement costs to the value of the reduction in climate risk (appropriately accounting for the dependence among climate, abatement-cost, economic-growth, and other risks). For comparison with other estimates of the social cost of carbon, the resulting estimate of WTP to swap the BAU emission path for the risk- constrained path and its abatement costs should be added to the expected marginal damages under the risk-constrained path.

Conclusion

Cooke's proposed approach to pricing climate risks is a useful complement to existing approaches. For application, it requires more attention to characterizing the difference in climate risks under the BAU and risk- constrained emission paths as well as the dependence among climate and other significant risks to social well-being such as risks to economic growth and abatement costs. This attention is required because the key assumption, that a risk-averse agent's WTP to swap one risk for another exceeds the difference in expected damages, is not valid for all risk swaps. Policies that reduce the risk of small-probability catastrophic damages are likely to satisfy conditions under which the assumption is valid. The approach could also be refined to incorporate the abatement costs required to achieve the risk swap.

References

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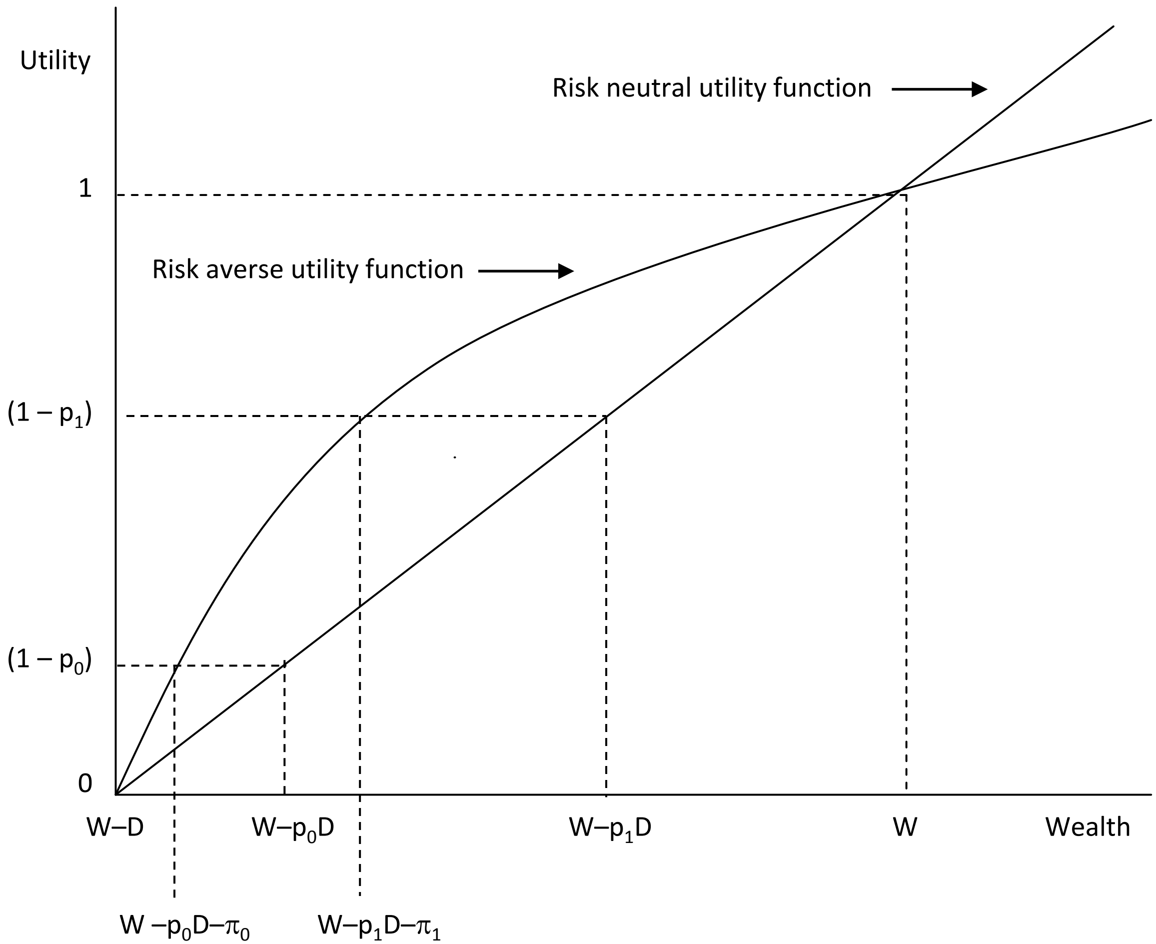
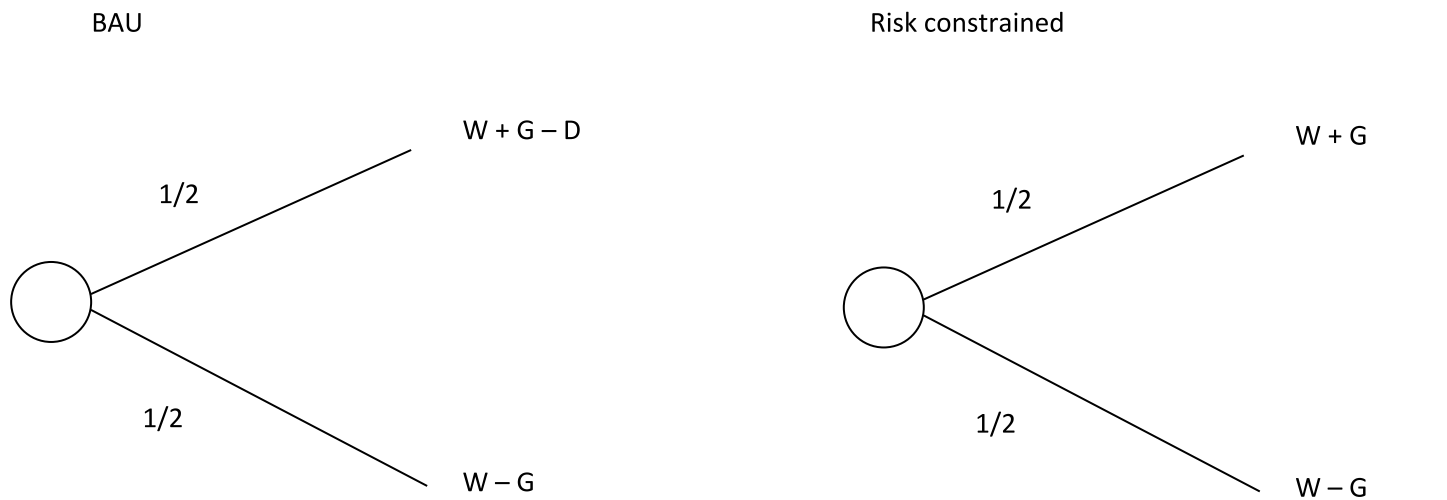

Utility
Risk neutral utility function
1
Risk averse utility function
(1 – p1)
(1 – p0)
0
W–D
W–p0D
W–p1D
W
Wealth
W –p0D–π0
W–p1D–π1

Figure 1



$CE_B = W - D/2 - \pi_B$

$CE_C = W - \pi_C$

Figure 2