ENVIRONMENTAL ECONOMICS

Optimal carbon tax doubled

Cost–benefit analysis and risk assessment approaches inform global climate change mitigation policy-making processes. Now, a development in the former shows that optimal carbon tax levels have previously been underestimated by a factor of two.

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Typically, cost–benefit analysis (CBA) has suggested 'optimal' carbon tax regimes that result in a global temperature rise of around 3 °C, or even eventually (post-2100) 4 °C, above pre-industrial levels. However, risk analysis approaches indicate that these levels of temperature rise result in climate change impacts that pose a high or very high level of risk to society and ecosystems[1] (Fig. 1). Thus, the risk analysis approach has generally indicated that higher levels of climate change mitigation are needed, for example, to constrain global mean temperature rise to around 2 °C above pre-industrial. A particularly controversial aspect of CBA is the representation of consumer preferences relating to the future. These assumptions are the strongest drivers of CBA outcomes. Writing in *Nature Climate Change*, Benjamin Crost and Christian Traeger[2] describe an improved approach to determining consumer preferences in CBA — called Epstein-Zin utility — that leads to a lower level of optimal climate change (that is, the level of climate change achieved through carbon taxes set at an 'optimal' level through which economic resources are distributed in a way that maximizes welfare) and results in a temperature increase of approximately 2 °C by 2100, bringing the implications of CBA closer to those of risk assessment.

In CBA, optimal carbon taxes are derived by maximizing economic consumption over time, taking into account the combined effects of taxation and climate change damages. This insight arises from recent developments in finance that separate consumers' preferences about time and risk: Crost and Traeger call this a 'disentangled' approach[2]. Previously, CBA has mainly relied on the assumption that consumers are just as concerned about short-term fluctuations in consumption as they are about the risk of future consumption loss. In fact, observed market data do not support this assumption[3]. The data show that consumers prefer to sacrifice consumption in one period to get it back with certainty later, rather than gamble over whether the future has greater or smaller consumption. In other words, the new approach "distinguishes risk aversion from the desire to smooth consumption over time"[2] — a concept traditionally expressed as a single parameter known as the elasticity of the marginal utility of consumption. The authors' approach better fits market observations than the traditional one.

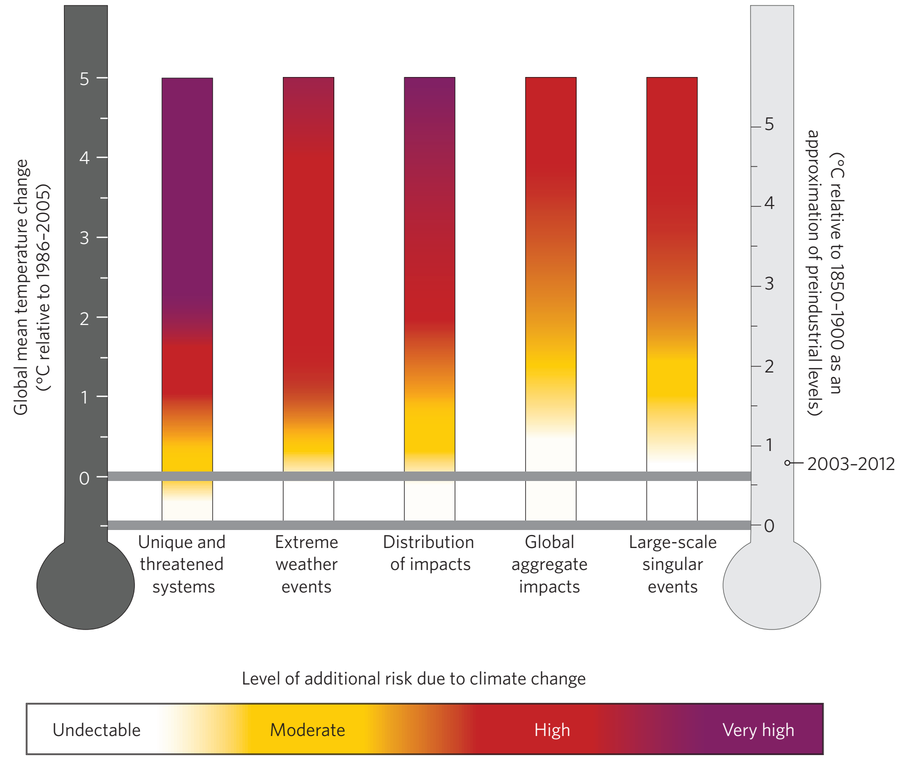

Figure 1 | A global perspective on climate-related risks. Risks associated with reasons for concern[1] are shown for increasing levels of climate change. The colour shading indicates the additional risk due to climate change when a temperature level is reached and then sustained or exceeded. Undetectable risk (white) indicates no associated impacts are detectable and attributable to climate change. Moderate risk (yellow) indicates that associated impacts are both detectable and attributable to climate change with at least medium confidence, also accounting for the other specific criteria for key risks. High risk (red) indicates severe and widespread impacts, also accounting for the other specific criteria for key risks. Purple, introduced in this assessment[1], shows that very high risk is indicated by all specific criteria for key risks. Risk assessment criteria encompass large magnitude, high probability, or irreversibility of impacts; timing of impacts; persistent vulnerability or exposure contributing to risks; or limited potential to reduce risks through adaptation or mitigation. Reproduced with permission from refs 1 and 14.

Crost and Traeger apply this approach within the DICE2007 model[4], an integrated assessment model of climate and the economy used mainly to inform climate policy in the US. The result is a doubling of the optimal carbon tax and emission abatement, resulting in a peak and decline of global temperature trends, which remain close to 2 °C in 2100 and peak at about

2.3 °C above pre-industrial levels between 2100 and 2150.

Using the traditional approach, with a pure rate of time preference — the marginal rate of substitution between present and future consumption — of 1.5%, DICE indicates carbon taxes of around 40 US$ per tonne of carbon (tC) at present, rising to around 100 US$ per tC by 2050 and leading to emissions of 8.5 Gt yr^{-1} in 2050 with carbon emissions continuing to rise until 2100. Using the authors' approach, present carbon taxes of around 100US$ per tC rise to over 200 US$ per tC by 2050, resulting in an abatement rate of 45% by 2050 and emissions of 7 Gt yr^{-1} in 2050. Global emissions peak decades earlier (in the 2030s), optimal peak global temperature is reduced by 1 °C (from 3.7 °C to 2.5 °C) and optimal CO_2 concentrations are reduced by 120–160 ppm.

The study by Crost and Traeger follows other recent advances in CBA that incorporate uncertainty analysis. Future optimal policies depend on the realization of damages, considering all possible damage outcomes. Damage uncertainty and risk aversion are considered jointly, as recommended by Kopp and colleagues[5].

In particular, the researchers explore the implications of uncertainty about the characteristics of the damage function. The analysis indicates that uncertainty about the form of the function — explained by the lack of observed climate impacts for a temperature rise exceeding 1°C and the tendency of climate impacts projections to focus on temperature increases of 2–3°C — leads to larger optimal taxes. Previous studies[5–9] have also emphasized the influence of the form of the damage function on the optimal level of taxes.

The uncertain damage function exponent follows a normal distribution centred on a value of 2 with a standard deviation of 0.5. A standard DICE2007 climate modelling approach is used, and thus does not encompass uncertainty in climate sensitivity (the equilibrium temperature response to doubling of atmospheric CO_2 concentration), which is set to 3.08. In fact, the dynamical approach required a simplification of the climate model in DICE2007, but the model still performs as well as the original DICE2007 in projecting climate change responses.

The approach used by Crost and Traeger complements existing work that has shown how the traditional approach to CBA needs to incorporate fat-tailed distributions of the damage function exponent and the climate sensitivity to reflect low probabilities of climate catastrophe[7,8,10,11]. These studies also found that optimal carbon taxes were significantly underestimated in the standard CBA approach, but for different reasons.

Ackerman *et al.*[12] adopted a different approach from the incorporation of Epstein-Zin utility into DICE, and also found that emission abatement was more than doubled by 2075. Both studies illustrate the importance of interdisciplinary research in combining insights from different research communities.

Most existing integrated models used in CBA adopt the same generic treatment of consumer preferences. Although Crost and Traeger based their study on an analysis with DICE2007 only, the implication of their work is that most CBA approaches have hitherto greatly underestimated optimal carbon taxes and hence the optimal level of global temperature rise. Incorporation of fat-tailed distributions for climate sensitivity and climate damages[7,8,10,11] as well as declining discount rates[13] — all recommended by economists[9], but not used in this study — would be expected to further increase optimal carbon taxes and further decrease optimal global temperature rise. ❑

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