Ramsey discounting calls for subtracting climate damages from economic growth rates☆

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Abstract

The Ramsey equation ties the utility discount rate and the elasticity of marginal utility of consumption together with per capita consumption growth rates to calculate consumption discount rates. For many applications, per capita consumption growth rates can be approximated with per capita output growth rates. That approximation does not work for climate change, which drives an ever-increasing and increasingly uncertain wedge between output and consumption growth. NAS (2017) in a central recommendation and illustrative example conflates the two. The correct, consumption-based discounting method generally decreases consumption discount rates and, thus, increases the resulting Social Cost of Carbon Dioxide (SC-CO_2).

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1. Introduction

A recent report by the National Academies of Sciences, Engineering, and Medicine (NAS, 2017) makes important contributions to the calculation of the Social Cost of Carbon Dioxide (SC-CO_2).[1] One such contribution concerns discounting—what NAS calls the "discounting module."[2] For example, NAS's Conclusion 6-1 rightly criticizes the U.S. Government Interagency Working Group on Social Cost of Carbon (2015) for using three constant discount rates, endorsing instead the "explicit connection between discounting and *consumption* growth that arises under a more structural (e.g., Ramsey-like) approach to discounting" (NAS, 2017, p. 169, emphasis added). However, Recommendation 6-1 and the illustrative toy examples following it (NAS, 2017, p. 174ff) use per capita *output* growth. That is mistaken. In practice, output-based discounting biases analyses toward higher discount rates and, thus, toward lower SC-CO_2 estimates.

2. Ramsey consumption discounting

Ramsey (1928) provides the structural foundation for much contemporary thinking about discounting. The Ramsey framework assumes a social planner

[1] This alone is an area where NAS (2017) clears up prior confusion: The more commonly used term to describe the optimal social cost of the marginal ton of CO_2 emitted is "Social Cost of Carbon" or "SCC." That is inaccurate. For example, an SCC of \$100 per ton of carbon, C, equals \$27 per ton of carbon dioxide, CO_2, as one ton of C = $\frac{44}{12}$ tons of CO_2.

[2] Yet another important contribution: splitting the daunting process of calculating the SC-CO_2 into individual modules. While often interrelated, these modules can, for the most part, be tackled independently before integrating them into a coherent whole.

who maximizes discounted utility across time. The standard utility function, $U(C_t)$, takes as its argument per capita *consumption* at time t.

Define the utility discount factor,

$$a_t \equiv \frac{1}{(1+\delta)^t}, \tag{1}$$

where δ is the utility discount rate. Further assume $U(C_t)$ takes the isoelastic form, $U(C_t) = \frac{{C_t}^{1-\eta}}{1-\eta}$, where η represents the elasticity of marginal utility of *consumption*. The famous Ramsey equation ties δ and η together with the growth rate of per capita *consumption*, g, to define the *consumption* discount rate:

$$\rho = \delta + \eta g. \tag{2}$$

Much has been written justifying, critiquing, and extending the Ramsey equation.[3] Few dispute its usefulness in social welfare calculations.[4]

[3] See, e.g., Gollier (2012) for an overview. See Broome (2012) and Kelleher (2017) for ethical perspectives, Arrow et al. (1996) for introducing the distinction between descriptivist and prescriptivist approaches to discounting into the climate debate, and references in footnote 5 for how uncertainties influence the resulting discount rates.

[4] Note that we do not go as far here as Heal (2017), who argues that the Ramsey equation does not apply because of climate damages. It does. It just requires the use of the correct g that subtracts climate damages from economic output, as we show here. One important critique and extension, also referenced by NAS (2017) in a footnote though not further elaborated on, notices that η in equation (2) conflates risk across states of nature and risk across time, in form of the elasticity of intertemporal substitution (EIS). Separating risk aversion and the EIS is a potentially important extension that, in fact, replaces the Ramsey equation altogether in determining appropriate discount rates (e.g. Epstein and Zin, 1989, 1991; Weil, 1990).

3. Consumption growth = output growth – rate of climate damages

It is possible to imagine some applications of the Ramsey framework in which g, the growth rate of C_t, can simply be set equal to the growth rate of output—i.e. projections of per capita gross domestic product (GDP). Climate is not one of these applications.

As NAS (2017) emphasizes throughout its report, the causal chain from business-as-usual growth in output to growth in atmospheric CO_2 concentrations, from concentrations to global average temperature increases, and from temperatures to final consumption is at the core of determining the SC-CO_2. But the difference between output and consumption growth rates is important both conceptually and as a source of uncertainty around g.[5]

To be sure, the NAS report has the basic methodology correct: first estimate undiscounted damages in each year based on business-as-usual growth in output; estimate annual incremental damages due to one additional ton of CO_2 emitted; discount each year's incremental damages; then sum dis-

[5]The difference is variably described as "marginal" versus "non-marginal" (e.g., Dietz and Hepburn, 2013; Foley et al., 2013) or as "exogenous" versus "endogenous" approaches to discounting (e.g., Dietz et al., 2006), with the first of each pair of terms applying to output-based growth rates and the second to consumption-based ones adjusted for climate damages. Note that general-equilibrium approaches such as Nordhaus (1992, 2017)'s DICE model naturally use the latter. NAS (2017), too, notes that outputs from integrated assessment models like DICE are in "consumption-equivalent" units (p. 167). Many others explore the role of uncertainty in determining the discount rate, which generally declines as a result. For some of the recent intellectual history see: Weitzman (1998, 2001, 2010), Newell and Pizer (2003), and Gollier and Weitzman (2010). For digestible summaries of the main arguments, see: Arrow et al. (2013, 2014) and Groom et al. (2005).

counted incremental damages across all relevant future years to arrive at the SC-CO_2 estimate. Yet this sound guidance is undermined by NAS's mistaken claim in Recommendation 6-1 and subsequent illustrative example that the growth rates relevant to the Ramsey equation are the business-as-usual *output* growth rates, rather than the growth rates along the ultimate *consumption* path that gets perturbed by the extra pulse of CO_2.[6]

4. A consumption-based toy example

NAS (2017) confirms this likely inadvertent misapplication of the Ramsey equation in a toy example intended to guide "practical assessments of the SC-CO_2" (p. 174ff).[7] Assuming $\delta = 1.1$, $\eta = 0.88$, and output growth rates of 1, 2.2, and 3.3%, respectively, NAS uses equation (2) to derive consumption discount rates of 2, 3, and 4%, respectively.[8] But this is permissible only if there is no wedge between growth in output and growth in consumption. Climate change is just such a wedge, and a potentially increasing and increasingly uncertain one at that.

[6] In fact, NAS (2017) is clear that the reason for using the Office of Management and Budget's 3 rather than 7% discount rate is that "the 3.0 percent rate is intended to reflect the rate at which society discounts future *consumption*" (p. 160, emphasis added), and it refers to "the rate of growth in consumption" (p. 176), in its reference to U.S. Government Interagency Working Group on Social Cost of Carbon (2015) justifying a 2.5% discount rate.

[7] On p. 175 the NAS report argues that the growth rates are to emerge from the "socioeconomic" module, whose task is to project growth rates in business-as-usual real GDP per capita over the coming decades (NAS, 2017, pp. 72-74).

[8] Not to be overly precise, but since it will matter for comparison with Tables 1, the exact rates thus calculated are 1.98, 3.04, and 4.00%, respectively.

To illustrate this point, we combine the NAS's toy example assumptions with Hsiang et al. (2017)'s headline figure suggesting economic losses of 1.2% per 1^{o}C rise in average surface temperatures. For purely illustrative purposes, we take those latest and, in many ways, most comprehensive, econometrically-based results for the United States and heroically extrapolate them to global climate damages. We look to RCP 4.5 and 8.5 for rough temperature projections for 2100 of 3 and 5^{o}C, respectively (IPCC, 2013). A simple application of the "1.2% per 1^{o}C" result suggests damages of between 3.6 and 6% of economic output by 2100. Those, in turn, translate into adjusted annual *consumption* growth rates below *output* growth rates. Using equation (2) yields consumption discount rates below those from NAS's toy example (Table 1).[9]

Table 1: Consumption discount rates after accounting for assumed climate damages of 1.2% of output per 1^{o}C of average surface warming, with $\delta = 1.1$ and $\eta = 0.88$

	1.0% GDP growth rate	2.2% GDP growth rate	3.3% GDP growth rate
RCP4.5	1.94%	3.00%	3.96%
RCP8.5	1.92%	2.97%	3.94%

Sticking with NAS's toy example, we can now re-calculate SC-CO_2 figures. Reflecting damages up to 2100, Table 2 shows the ratio, in percent, in 2015 SC-CO_2 figures of consumption-based growth rates over output-based ones. Depending on the scenario for climate damages, values increase from between

[9]See footnote 8 for comparison.

102 to 103.5%.

Table 2: Ratio of SC-CO_2 calculated based on consumption growth rates adjusted for climate damages compared to SC-CO_2 based on (erroneous) per capita GDP growth rates, with $\delta = 1.1$ and $\eta = 0.88$

	1.0% GDP growth rate	2.2% GDP growth rate	3.3% GDP growth rate
RCP4.5	102.00%	102.03%	102.06%
RCP8.5	103.39%	103.44%	103.48%

Note the purely illustrative nature of these numbers: δ and η, for example, are based on values that NAS calibrates to yield round output-based discount rates in its toy example. In practice, that is decidedly *not* how either factor should be calibrated, whether one uses descriptivist or prescriptivist approaches to discounting (Arrow et al., 1996; Dasgupta, 2008; Heal, 2009). Also note that, assuming $g > 1$, results are naturally more sensitive to changes in η than to changes in δ. For example, using U.K. Treasury (2003)'s suggested values of $\delta = 1.5$ and $\eta = 1$, our toy 2015 SC-CO_2 ratios range from 102.2 to 103.3%—with no variation across different growth rate assumptions, as $\eta = 1$ negates those differences. Using instead Dasgupta (2008)'s $\delta = 0.1$ and his upper bound for $\eta = 4$, without changing the range of g, yields ratios of between 103.4 and 113.1%.

To further illustrate the role of uncertainty, we can calculate certainty-equivalent consumption discount rates ρ_{ce_t}, in any given year t, via:

$$\rho_{ce_t} = -\frac{\ln a_t}{t}, \tag{3}$$

where a_t is defined by equation 1. For example, the certainty-equivalent rate based on the NAS report's erroneous output-based growth rate used in its toy example is 2.89% in 2035 ($t = 20$) (see NAS, 2017, p. 176, footnote 20). The adjusted, consumption-based rate $\rho_{ce_{20}} = 2.85\%$. The difference increases over time. By 2100, the two rates are 2.70 and 2.65%, respectively.

5. Conclusion

For discounting far-distant futures, small changes in the discount rate can matter—a lot. A proper application of the Ramsey framework calls for the use of consumption-based growth rates, g. That is particularly important for climate applications, as unmitigated climate damages drive an ever-increasing wedge between business-as-usual output and damage-adjusted consumption projections. Moreover, estimating climate damages introduces potentially large uncertainties in projecting g, leading to lower certainty-equivalent discount rates and, thus, higher SC-CO_2.

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