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Agreeing to disagree on climate policy

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Disagreements about the value of the utility discount rate – the rate at which our concern for the welfare of future people declines with their distance from us in time – are at the heart of the debate about the appropriate intensity of climate policy. Seemingly small differences in the discount rate yield very different policy prescriptions, and no consensus 'correct' value has been identified. We argue that the choice of discount rate is an ethical primitive: there are many different legitimate opinions as to its value, and none should receive a privileged place in economic analysis of climate policy. Rather, we advocate a social choice based approach in which a diverse set of individual discount rates is aggregated into a 'representative' rate. We show that performing this aggregation efficiently leads to a time-dependent discount rate that declines monotonically to the lowest rate in the population. We apply this discounting scheme to calculations of the social cost of carbon recently performed by the US government, and show that it provides an attractive compromise between competing ethical positions, and thus provides a possible resolution to the ethical impasse in climate change economics.

Climate policy | Discounting | Social cost of carbon

Abbreviations: SCC, social cost of carbon

Significance statement: The social cost of carbon – the cost to society of an additional ton of CO_2 emissions – is a crucial measure of the desirable intensity of climate policy. The models economists use to calculate it are however highly sensitive to the choice of discount rate, which measures our concern for the well-being of future generations. Different economists favor different values, and this leads to radically different policy prescriptions. We present a method for combining a diverse set of discount rates into a single 'representative' rate, and apply it to the analysis of the social cost of carbon performed by the US government. This approach may help to resolve ethical conflicts, and hence lead to consensus policy recommendations.

A central feature of the economic analysis of climate change policy is that it requires us to weigh costs and benefits that are distributed across very long time horizons. Most of the benefits of policies that aim to reduce greenhouse gas emissions will only be realized by future generations, while their costs must be born by us today. Any sensible climate policy thus needs to trade off future benefits against current costs.

Economists who study climate change have a standard tool for aggregating consequences that are distributed across time. They make use of dynamic social welfare functions of the discounted utilitarian type. Let $c(t)$ be a measure of the set of goods and services we consume at time t. Then under discounted utilitarianism a policy that gives rise to a sequence of consumption $c(t)$ is preferred to a policy that gives rise to the sequence $\tilde{c}(t)$ if and only if

$$\int_{\tau}^{\infty} U(c(t))e^{-\delta(t-\tau)}dt > \int_{\tau}^{\infty} U(\tilde{c}(t))e^{-\delta(t-\tau)}dt \qquad \textbf{[1]}$$

where τ is the current time, $U(c)$ is a utility function which is assumed to be increasing and concave ($U' > 0, U'' \leq 0$), and $\delta > 0$ is the utility discount rate, also known as the pure rate of time preference. This approach aggregates future utilities additively, but downweights welfare consequences that are distant in time by an exponentially declining discount factor $e^{-\delta t}$. The larger is the discount factor δ, the more this welfare function favors policies that benefit the present, rather than the future.

The normative justification for using the exponentially discounted utility model for dynamic welfare analysis has been forcefully laid out in the axiomatic work of Koopmans [1]. This model respects two desirable properties of dynamic choice (independence and stationarity, see e.g. [2]), as well as giving rise to optimal plans that are time-consistent – the mere passage of time does not cause us to alter the plans we made in the past. It has thus become the standard method for policy choice and evaluation in dynamic contexts, including climate change.

Whose discount rate?. While there is a near unanimous adherence to the social welfare function defined by (1) in climate economics, there are substantial and persistent disagreements about the appropriate value of the discount rate δ. These disagreements are encapsulated by a long-standing debate between two of the most well-known proponents of the field – Nicholas Stern and William Nordhaus – who recommend values for δ of 0.1%/yr and 1.5%/yr respectively. While a 1.4% difference in δ may not seem like much, it has an enormous effect on policy recommendations. Stern [3] recommends aggressive mitigation investments, while Nordhaus' analysis [4] argues for a much less intensive climate policy. This is reflected in the fact that the value of the social cost of carbon (the estimated welfare cost of emitting one additional ton of CO_2) obtained by Stern is more than 10 times Nordhaus' value. The cause of these widely different policy recommendations can be traced largely to the different discount rates the two authors assume in their analysis [4][1]. Other commentators have also argued for their own preferred values of δ, with no convergence to a single unanimously agreed upon value in sight. Given the important effect δ has on policy prescriptions, this disagreement has led to an uncomfortable stalemate in climate change economics, which has led some to question the value of economic models of the issue [5].

Our view is that the choice of δ represents a primitive ethical judgement – it captures how much one cares about the welfare of future generations. As such, it is a parameter that is unique to each individual – much like the moral legitimacy of the death penalty or abortion rights, it is the kind of thing reasonable people can reasonably disagree about[2]. Once we adopt this position, it becomes clear

Reserved for Publication Footnotes

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[1] The Stern review initially also chose a low value of the elasticity of marginal utility (i.e. η=1, where η is defined in (5) below), thus compounding the differences between its analysis and that of Nordhaus (who uses $\eta = 2$). The postscript to the review however contains a sensitivity analysis over η. Arguably, η has more of a positive flavour than δ as it measures aversion to inequality, including contemporaneous inequality, and can thus be estimated empirically, as we discuss below. There is no conceptual difficulty with accounting for heterogeneous utility functions too (see e.g. [7, 8]), but analytic solutions for the representative discount rate are not possible in this case. We keep to the case of common utility functions in order to simplify the exposition.

[2] Remarkably, both Stern and Nordhaus enunciate this position in their writings. Stern [6]: "Value judgements are, of course, precisely that and there will be many different positions." Nordhaus [4]: "It should be clear that alternative ethical perspectives are possible...[and]

that the economist's role is not to impose his or her own preferences on society, but rather to adopt a welfare framework that aims to represent the distribution of ethical views. There are no objectively 'correct' values of δ, only different ethical positions, and each should be given some weight in policy prescriptions. The analysis of climate policy thus becomes an exercise in social choice – we need to aggregate the diverse preferences of individuals into a representative discount rate, and use this to evaluate policy options.

Discounting under disagreement

Individuals with different discount rates have different preferences over the timing of consumption. Those with high discount rates will have stronger preferences for immediate consumption, while those with low discount rates will be more willing to defer consumption into the future. Given a set of policy choices (e.g. global mitigation effort and savings rates) the total quantity of global consumption is determined by technological and climatic factors. The question remains however what the value of this consumption path is to society. In order to decide this, we need a rule for allocating global consumption between individuals with different discount rates. It is natural to require that such an allocation should be *efficient*. An allocation is efficient if it is not possible to alter it to make one person better off without making someone else worse off.

Efficient consumption allocations can be determined through the follow procedure. Let global consumption per capita at time t be $C(t)$. Suppose that a planner allocates consumption $c_i(t)$ to individual i with discount rate δ_i according to

$$\max_{c_i(t)} \sum_i w_i \int_\tau^\infty U(c_i(t)) e^{-\delta_i t} dt \text{ s.t. } \sum_i c_i(t) = C(t) \qquad [2]$$

where w_i are a set of positive Pareto weights, with $\sum_i w_i = 1$. It is well know that allocations $c_i(t)$ chosen in this manner will be efficient. To ensure equal treatment we further assume that w_i is chosen to coincide with the proportion of individuals in the population with discount rate δ_i.

Given this allocation rule, which discount rate should we use to evaluate global consumption streams $C(t)$? In order to answer this question we need to find a representative agent whose preferences over global consumption streams will be derived endogenously from the efficient sharing rule defined in (2). This approach was pioneered by [7], and has been generalized by us in [8]. Formally, we solve for the efficient allocations $c_i^*(t)$ that solve the optimization problem in (2). These solutions will depend on the global consumption stream $C(t)$ and on time, i.e. $c_i^*(t) = c_i^*(C(t), t)$. We can then define the group's instantaneous welfare from global per capita consumption $C(t)$ through

$$V(C(t), t) = \sum_i w_i U(c_i^*(C(t), t)) e^{-\delta_i t}. \qquad [3]$$

This function captures the group's preferences over global consumption streams $C(t)$. The utility discount rate of the representative agent is then given by minus the elasticity of marginal welfare with respect to time:

$$\delta^*(C(t), t) = -\frac{\frac{\partial^2 V}{\partial C \partial t}}{\frac{\partial V}{\partial C}}. \qquad [4]$$

To simplify the analysis[3], assume that agents' utility functions $U(c)$ take the widely used iso-elastic form:

$$U(c) = \begin{cases} \frac{c^{1-\eta}}{1-\eta} & \eta \neq 1 \\ \ln c & \eta = 1 \end{cases} \qquad [5]$$

Here $\eta \geq 0$ is the elasticity of marginal utility, which measures aversion to consumption inequality. To understand its interpretation, imagine that a rich person with consumption c donates \$1 to a contemporaneous poor person who has consumption $c/2$, but that only a fraction x of this transfer arrives in the poor person's pocket. With the utility function (5) this transfer is socially desirable if $x > (1/2)^\eta$. Thus for $\eta = 1$ half of this 'leaky' transfer needs to reach the poor person in order for it to be socially beneficial, but for $\eta = 2$ only a quarter of the transfer needs to arrive. In general, the larger is η, the more averse to consumption inequality we are, and the more we are willing to pay to decrease inequality. We will discuss estimated values for η below.

With the iso-elastic utility function (5) the group's discount rate can be shown to be given by (see derivation in the Appendix):

$$\delta_\eta^*(t) = \frac{\sum_i \delta_i (w_i e^{-\delta_i t})^{\frac{1}{\eta}}}{\sum_i (w_i e^{-\delta_i t})^{\frac{1}{\eta}}}. \qquad [6]$$

For this utility function the group's discount rate does not depend on $C(t)$. It is simply a weighted sum of the individuals' discount rates, with time dependent weights $y_i(t) := (w_i e^{-\delta_i t})^{\frac{1}{\eta}}$.

Defining the expectation operator $\mathsf{E} x_i := \sum_i x_i y_i(t) / \sum_i y_i(t)$, and differentiating (6) with respect to time we find

$$\frac{d}{dt} \delta_\eta^*(t) = -\frac{1}{\eta} \left(\mathsf{E}\delta_i^2 - (\mathsf{E}\delta_i)^2 \right) < 0. \qquad [7]$$

Also, letting $i = L$ index the agent with the lowest discount rate, we have

$$\lim_{t\to\infty} \delta_\eta^*(t) = \lim_{t\to\infty} \frac{\delta_L + \sum_{i\neq L} \delta_i (w_i/w_L)^{\frac{1}{\eta}} e^{-(\delta_i - \delta_L)t/\eta}}{1 + \sum_{i\neq L} (w_i/w_L)^{\frac{1}{\eta}} e^{-(\delta_i - \delta_L)t/\eta}} = \delta_L. \qquad [8]$$

Thus although each member of the group has a constant discount rate δ_i, the efficient discount rate for the group as a whole is time-dependent, and declines monotonically to the lowest rate in the population.

Disagreement and the social cost of carbon

In this section we demonstrate how the theory of discounting under disagreement can be applied to the analysis of climate policy. We focus on the effects of discounting on estimates of the social cost of carbon (SCC), perhaps the most important summary statistic in climate change economics. As mentioned above, the SCC measures the welfare cost of an additional unit of CO_2 emissions on current and future generations. In a 'first-best' world it coincides with the optimal tax rate on CO_2 emissions. The SCC has been the subject of several studies commissioned by national governments, including a recent one by the US Environmental Protection Agency (EPA) [9, 10] which we will use as a point of comparison in our analysis.

In order to estimate the SCC we need an integrated model of the climate-economy system which captures how the trajectory of future global temperatures changes in response to an additional unit of CO_2 emissions, how these climatic changes impact the global economy over time, and finally how these impacts alter global consumption and welfare. We will make use of a version of the well known DICE integrated assessment model [4]. In order to make our analysis directly comparable to the EPA's, our version of DICE makes use of

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provide vastly different prescriptions about desirable climate change policies." Both authors nevertheless perform their analysis with a single preferred value of δ.

[3] See [7] and [8] for a general analysis with arbitrary, possibly heterogeneous, utility functions.

[4] The version of DICE used by the EPA makes use of 5 socio-economic scenarios, and a large Monte Carlo sample from the probability distribution for the climate sensitivity parameter derived in [11]. The final SCC values reported are an average over all scenarios and Monte Carlo samples for a given value of the consumption discount rate. Our analysis uses an identical methodology. Note however that the final summary values of the SCC adopted by the EPA average estimates from three different integrated assessment models – DICE, PAGE, and FUND. We just use the DICE model, as it is freely available and easy to implement. SCC estimates from the DICE model fall between those from the other two models.

the same socio-economic scenarios and model parameterization as their study[4], with one important difference. The EPA used constant values of the *consumption discount rate* in its analysis. For deterministic consumption streams and iso-elastic utility, the consumption discount rate $\rho(t)$ is related to the utility discount rate δ through

$$\rho(t) = \delta + \eta g(t) \qquad \textbf{[9]}$$

where $g(t)$ is the mean consumption growth rate up to time t (see e.g. [2]). This is the rate that is used to discount changes in consumption $c(t)$, rather than changes in utility $U(c(t))$ which are discounted at the rate δ. Since $g(t)$ is in general non-constant in the DICE model, even if δ is a constant as is conventionally assumed, the consumption discount rate cannot be constant. Our analysis will thus make use of the formula (9), in which the consumption discount rate is derived from explicit welfare assumptions and the rate of consumption growth that emerges endogenously from the DICE model, rather than assuming an *ad hoc* constant rate.

In order to operationalize the discounting formula (9) we need to specify values for δ and η. We consider three different schemes for δ: First we use Stern's value of $\delta = 0.1\%$, then Nordhaus' value of $\delta = 1.5\%$, and finally we consider the efficient discount rate under disagreement $\delta = \delta^*_\eta(t)$ from (6), where we assume equal weights on the Stern and Nordhaus values of δ. The value of η can be estimated from a variety of empirical sources, including income tax schedules [12], asset markets [13], and behavioral surveys [14]. While the empirical literature is not without its problems, $\eta = 2$ is often taken as a reasonable starting point [15], with values between 1 and 3 being recommended for sensitivity analysis [16]. We adopt this approach, and compute the SCC for $\eta \in [1, 3]$ for each of our three choices for δ using the EPA's version of the DICE model. Our results are displayed in Figure 1. For reference we also plot the value of the SCC for the three constant consumption discount rate scenarios used by the EPA: $\rho(t) \in \{2.5\%, 3\%, 5\%\}$.

As the figure makes clear, the values of the SCC computed with the efficient discount rate $\delta^*_\eta(t)$ lie between those computed with the Stern and Nordhaus values of δ for each value of η. The SCC values under disagreement are derived from a procedure that is both equitable and efficient, and thus achieve a successful compromise between opposing viewpoints.

The SCC is a declining function of η in our simulations, with differences in the value of δ having a large effect for small values of η, and a smaller effect for larger values of η. This can be understood by examining the formula for the consumption discount rate in (9)[5]. Since $\rho(t)$ is increasing in η, climate damages that are distant in time are heavily discounted for large values of η. This gives rise to low values of the SCC. For large enough η the weight placed on future climate damages is already small for $\delta = 0$, so changing the value of δ has a comparatively small absolute effect on the SCC, as this modifies an already small quantity. The relative effect of a change in δ on the SCC is however still significant for large η, with the Stern value being 74% larger than the Nordhaus value even for $\eta = 3$. Regardless of the exact value of η, the efficient discount rate under disagreement can thus be used to resolve empirically meaningful disputes about the value of δ.

Conclusions

As many economists have emphasized (e.g. [19, 16]), ethical judgements are intrinsic to climate change policy, and nowhere do they play a greater role than in the question of how to discount the far future. As with all ethical judgements, there is a plurality of legitimate viewpoints about the appropriate value for the utility discount rate. While public reasoning and debate can help us refine our positions, the outcome of this process is unlikely to result in a unique consensus. As Amartya Sen has noted [20]: "Even the most vigorous critical examination can still leave conflicting arguments that are not eliminated by impartial scrutiny". How can rational policy recommendations be made in an environment characterized by such persistent and quantitatively important disagreements?

We have argued for a social choice based approach to climate policy that reflects the diversity of opinion on ethical matters. This has both pragmatic and philosophical advantages. Pragmatically our approach provides a formal mechanism for avoiding impasses caused by ethical disagreements. Everyone's opinion counts, and no one can claim that policy recommendations are derived from morally high-handed modeling assumptions. Philosophically, our method draws on a long democratic tradition in social choice theory that assigns each preference an equal weight in public decision making to arrive at a consensus that is acceptable to all.

We hope that the techniques we have identified will help to resolve debates about 'the' appropriate value of the discount rate, and instead allow research attention to focus on empirical questions such as the specification of the damage function in integrated assessment models, and comprehensive quantifications of the uncertainty in the technological and climatic components of these models [21]. While ethical assumptions are important drivers of the policy recommendations from integrated assessment models, this should not be seen as a strike against them. Ethical positions will always be irreducibly diverse, but we may nevertheless respectfully agree to disagree.

Appendix: Derivation of the representative discount rate

We can solve the maximization problem in (2) by the method of Lagrange multipliers. The Lagrangian is

$$\max_{c_i(t)} \sum_i w_i \int_\tau^\infty U(c_i(t)) e^{-\delta_i t} dt - \lambda(t)(\sum_i c_i(t) - C(t)) \qquad \textbf{[10]}$$

where $\lambda(t)$ is a sequence of Lagrange multipliers. The first order conditions for the efficient allocations $c^*_i(t)$ yield

$$c^*_i(t) = U'^{-1}\left(\frac{\lambda(t) e^{\delta_i t}}{w_i}\right), \qquad \textbf{[11]}$$

and the constraint $\sum_i c_i(t) = C(t)$ implies that

$$\sum_i U'^{-1}\left(\frac{\lambda(t) e^{\delta_i t}}{w_i}\right) = C(t) \qquad \textbf{[12]}$$

Now assume that $U(c)$ is an iso-elastic utility function, as in (5). Then $U'^{-1}(x) = x^{-\frac{1}{\eta}}$. Substituting this relationship into (12) allows us to solve for $\lambda(t)$ in terms of $C(t)$. This expressions for $\lambda(t)$ may in turn be substituted into (11) to find that

$$c^*_i(t) = \frac{(w_i e^{-\delta_i t})^{1/\eta}}{\sum_i (w_i e^{-\delta_i t})^{1/\eta}} C(t). \qquad \textbf{[13]}$$

Substituting this expression into (3), we find that the group's instantaneous welfare at the optimal allocation can be written as

$$V(C(t), t) = \frac{C(t)^{1-\eta}}{1-\eta} \beta(t) \qquad \textbf{[14]}$$

where the group's effective discount factor $\beta(t)$ is given by

$$\beta(t) = \left(\sum_i (w_i e^{-\delta_i t})^{1/\eta}\right)^\eta \qquad \textbf{[15]}$$

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[5] Technically, since our computation of the SCC averages over many scenarios for global consumption we should examine the certainty equivalent consumption discount rate $\hat{\rho}(t) = \delta + \eta g(t) - \frac{1}{2}\eta^2\sigma^2(t)$, where $\sigma^2(t)$ is the variance in consumption growth at time t (see e.g. [15]). In practice the variance term is much smaller than the other two terms in the standard parameterization of the DICE model, and can be neglected for qualitative purposes. This is not however a generic result, and relies largely on the assumed functional form for the DICE damage function at large temperatures. See [17] for a discussion of the effect of the choice of damage function on the variance term in the discounting formula. The literature contains an extensive analysis of how uncertainty in the consumption growth rate can also give rise to a consumption discount rate $\hat{\rho}(t)$ that declines with time [15, 18].

The group's discount rate $\delta^*_\eta(t)$ is then determined by (4) which reduces to

$$\delta^*_\eta(t) = -\frac{1}{\beta}\frac{d\beta}{dt}. \qquad [16]$$

Straightforward algebra then yields the expression for $\delta^*_\eta(t)$ in (6).

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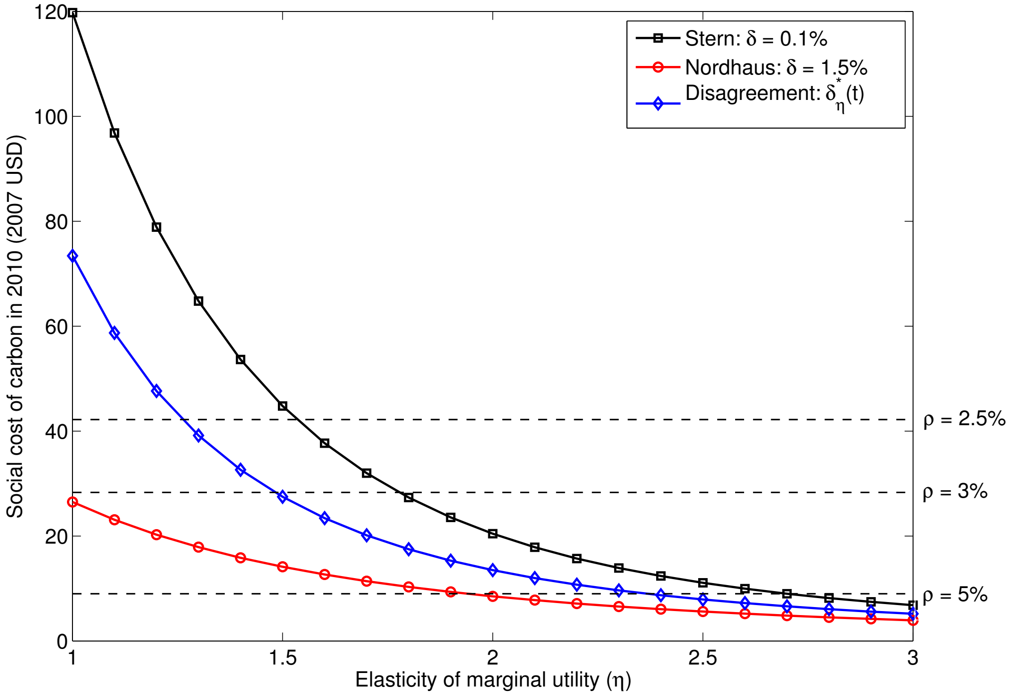

Fig. 1. The SCC as a function of η for two constant utility discount rates (Stern (black): $\delta = 0.1\%$, Nordhaus (red): $\delta = 1.5\%$), and for the efficient discount rate under disagreement (blue) given by $\delta^*_\eta(t)$ in (6). The values of the SCC under the three constant consumption discount rate scenarios used by the EPA are indicated by the dashed lines.