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Reflections on the 2018 Nobel Memorial Prize Awarded to William Nordhaus

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> A definition is just a definition, but when the *definiendum* is a word already in common use with highly favorable connotations, it is clear that we are really trying to be persuasive; we are implicitly recommending the achievement of optimal states.
>
> — Arrow (1963, 942)

William D. Nordhaus of Yale University was one of two recipients of the 2018 Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel. He shared the prize with Paul M. Romer. In its Scientific Background essay, the Prize Committee lauded each awardee's contributions to the analysis of market failure, and to the development and extension of neoclassical growth theory, for which Robert Solow won the same prize in 1987 and whose roots trace back to a landmark 1928 paper by Frank Ramsey.[1] Whereas Romer's work explores positive externalities in the form of knowledge spillovers, Nordhaus has focused on the negative externalities associated with greenhouse gas emissions. He is credited with developing the first serious Integrated Assessment Model (IAM), a tool for understanding the complex interactions between the climate system and the global economy. Nordhaus' IAMs are also frequently used to evaluate climate policies—"to rank different policies according to their desirability" and "to devise the right dose of the right medicine", in the words of the Prize Committee (Royal Swedish Academy of Sciences 2018, 26, 2).

Although there has been much debate over the empirical assumptions underlying Nordhaus' analyses,[2] the primary topic of

[1] Strangely, the Scientific Background paper's bibliography lists F.P. Ramsey as 'A.S. Ramsey' (Royal Swedish Academy of Sciences 2018, 48).

[2] For example, Dietz and Stern (2015, 578) write: "[W]e assume that the damage function linking the increase in global mean temperature with the instantaneous reduction in output is highly convex at some temperature. Consideration of some of

interest to those in my discipline—moral philosophy—has been Nordhaus' views on discounting the future benefits of greenhouse gas mitigation. His discount rates are among the highest in the climate economics literature, and this is a key reason why Nordhaus has always labeled as 'sub-optimal' the popular precautionary proposal to limit average global temperature increases to no more than 2 degrees Celsius above pre-industrial averages.[3] I know of no moral philosopher who accepts Nordhaus' approach to discounting, and many economists also believe that it violates basic ethical principles of intergenerational fairness and impartiality.

My own view is that Nordhaus' approach to discounting is not necessarily at odds with the approach favored by moral philosophers. What *is* problematic is Nordhaus' insistence that his discounting method sheds privileged light on so-called 'optimal' climate policy. As I seek to explain in what follows, Nordhaus' approach to climate policy evaluation can shed light on one—but only one—dimension of the climate change problem. In the normal English language sense of the term, there is nothing particularly optimal about the temperature increases associated with his modeling choices.

I. NORDHAUS' APPROACH TO CLIMATE POLICY EVALUATION

Unregulated greenhouse gas emissions are a negative externality because those who emit need not take into account the cost they impose on uninvolved third-parties. More specifically, carbon dioxide is a *stock externality* in the sense that the main driver of the adverse external costs of climate change is the *cumulative total* amount of carbon in the atmosphere. Because this cumulative total is not something that any individual country can meaningfully influence on its own, countries may see no compelling reason to reduce their emissions today, *even if* they can foresee that runaway climate change will be bad for them in the far future. As Nordhaus and his co-author Zili Yang wrote in 1996:

the science, for example, on tipping points, leads us in this direction. By contrast, most existing IAM studies assume very modest curvature of the damage function. [Nordhaus'] DICE [model's] default is quadratic and it is well known that with the standard values of the functions' coefficients an implausible 18°C or so of warming is required in order to reduce global output by 50%".

[3] In his most recent book, *Climate Casino*, Nordhaus says that a 2.8 degree rise is optimal (Nordhaus 2013a, 212). Bizarrely, a slide in his Prize acceptance speech reports an increase of 4 degrees as optimal (Nordhaus 2018, 6). In *Climate Casino*, Nordhaus reports that his model treats a rise of 4 degrees as optimal *given* the assumption of low participation among the countries of the world, which increases marginal abatement costs.

> [T]he results of this new integrated model of climate and the economy emphasizes the implications of the fact that while climate change is a global externality, the decision makers are national and relatively small. These inherent difficulties involved in planning over a horizon of a century or more about so uncertain and complex a phenomenon are compounded by the dispersed nature of the decisions and the strong tendency for free-riding by nonparticipants in any global agreement. Countries may therefore be triply persuaded not to undertake costly efforts today—first because the benefits are so conjectural, secondly because they occur so far in the future, and third because no individual country can have a significant impact upon the pace of global warming. (Nordhaus and Yang 1996, 762)

Nordhaus views his task as discovering how much greenhouse gas mitigation would be undertaken if countries could overcome the three obstacles that, in the world as it is, 'triply persuade' them to emit profligately. For this reason, he refers to his Integrated Assessment Models as "positive", rather than normative, models. As he puts it:

> [IAMs] can be interpreted in two ways: they can be seen both, from a positive point of view, as a means of simulating the behavior of a system of competitive markets and, from a normative point of view, as a possible approach to comparing the impact of alternative paths or policies on economic welfare. (Nordhaus 2013b, 1081)

Yet despite insisting that his approach to climate policy analysis is positive rather than normative, Nordhaus continually refers to the emissions abatement path picked out by his positive analysis as the "optimal" path (Nordhaus 2008, 14, 68), and calls policies that implement that path "idealized" and "economically desirable" policies (Nordhaus 2008, 14; Nordhaus 2013a, 76). So at the very least, the rhetorical *use* to which Nordhaus puts his results is normative, and not merely positive or descriptive. Yet this indisputable fact—which I discuss further below—should not blur the point that, for Nordhaus, the path he recommends is the path that countries themselves would adopt, in light of their current policy preferences, if they could overcome collective action problems.

Nordhaus' approach to discount rates is informed by this focus on what countries themselves would do if they were fully informed about the future costs of climate change and could overcome the impulse to free-ride on others' mitigation efforts. He calls his approach "the opportunity cost approach" to discounting (Nordhaus 2013a, 188):

> Countries have a range of possible investments: homes, education, preventive health care, carbon reduction, and investing abroad. Particularly in a period of tight government budgets and financial constraints, the yields on such investments might be very high. [...] A country would be poorly served to put its scarce funds into wind farms yielding 1 percent per year when it is borrowing money in international financial markets at 5 or 10 percent. [...] [T]he discount rate should be primarily determined by the opportunity cost of capital, which is determined by the rate of return on alternative investments. (Nordhaus 2013a, 187)

To grasp the basic idea behind this way of thinking about discounting, consider a government climate change project that costs \$100 today and prevents \$1,000 in climate damages in 100 years. Nordhaus' way of judging whether this project is "economically desirable" (76) is to check whether the government could have delivered more than \$1,000 in benefits in 100 years by investing the \$100 in some alternative investment. If all other forms of investment are already effectively competing against one another and thus have the same marginal rate of return (something Nordhaus assumes), then a neat way to check mitigation against other investments is to discount the benefits offered by mitigation using a discount rate equal to the rate of return offered in capital markets. Suppose, for example, the interest rate available in capital markets is 6% per year. Then we can multiply the \$1,000 future benefit by the corresponding discount factor, $\left(\frac{1}{1.06^{100}}\right)$, and subtract the \$100 present cost of producing that \$1,000 benefit. If the result of this exercise is a positive number, that indicates the climate change project is the better of the two. If the result is a negative number—which in this case it is—then the government would do better to make a conventional capital investment instead. Indeed, the government could either invest the full \$100 to yield roughly \$40,000 worth of benefits in 100 years, or it can invest just \$2.50 today in order deliver \$1,000 in 100 years. Either way, Nordhaus claims that countries should investigate whether a climatic investment beats a conventional financial investment, and the way to determine this is by discounting the benefits of the former using the rate of return offered by the latter. Countries should then engage in the most lucrative climate projects until the remaining projects have discounted benefits equal to or less than the project's cost. Once they have done that, they have achieved the 'optimal' level of abatement and the global temperature increases associated with this level of abatement is the 'optimal' increase.

In order to implement this method of climate policy analysis, one needs a way to predict the relevant capital market interest rates far into the future. For this, Nordhaus enlists an economic model known as the Ramsey-Koopmans-Cass model. The standard macroeconomic approach to Ramsey analysis (as I will call it) is to suppose that the economy can be thought of as driven by the behavior of a single infinitely-lived representative agent who must choose between using income to fund consumption today or instead investing it to fund consumption tomorrow. It is supposed that there is a set of feasible *intertemporal consumption streams* of the form ${}_nC \equiv \{c_t^n, c_{t+1}^n, c_{t+2}^n, \ldots\}$ over which the agent can choose, and that she adjusts her consumption and investment decisions so as to place herself on her top-ranked stream. (Here, each c_t^n represents the agent's level of consumption at time t along stream ${}_nC$.) It is further supposed that the agent's preferences over consumption streams can be represented by a *discounted utilitarian* value function of the form:

$$V_i = \sum_{t=0}^{\infty} u(c_t) \cdot \left(\frac{1}{(1+\delta)^t}\right) \tag{1}$$

This value function ranks consumption streams by using its u-function to represent the agent's consumption-derived utility at each time, discounting utility that occurs in the future, and then summing these utility numbers across times. The representative agent is said to be *impatient* at a given time if her utility discount rate, δ, is greater than zero at that time (and thus if her corresponding utility discount *factor*, $\left(\frac{1}{(1+\delta)}\right)$, is less than 1). The utility function u is typically assumed to take the *isoelastic* form:

$$u = \frac{{c_t}^{1-\eta}}{1-\eta} \tag{2}$$

In this utility function, η is a measure of the function's curvature, which reflects both the degree to which the agent is averse to risk to her consumption levels and the degree to which she is averse to fluctuations in her consumption across time. When $\eta = 0$, the representative agent is neutral with respect to risk and also indifferent to consumption inequalities across the different times in her life. (Risk- and inequality-aversion are conceptually distinguishable from impatience, and from each other, but the standard utility function in climate economics nevertheless forges an ironclad link between risk and inequality aversion (Kelleher and Wagner 2018).) As η approaches infinity, the agent is increasingly averse to consumption fluctuations and increasingly prefers to maximize the lowest consumption level across all times she is alive.

After calibrating these two preference parameters to observed behavior in the real world, macroeconomists use their models to predict real-world future interest rates. They do this via a famous equation known as the Ramsey equation. Actually, there are two Ramsey equations. Here is the first, which can be derived from equation (1):

$$\rho_t = \delta + \eta \cdot g_t \qquad (3)$$

Call this equation the *Ramsey formula*. Here is how it works. Suppose for the sake of argument that ${}_1C$ is the business as usual consumption stream. For each time period t along stream ${}_1C$, there will be a rate of growth between the agent's consumption at t and her consumption in the very next time period, $t + 1$. Designate this rate of growth between c_t^1 and c_{t+1}^1 as g_t. Now by plugging g_t, δ, and η into equation (3), one generates period t's *consumption discount rate*, ρ_t. A consumption discount rate is a sort of 'hurdle rate'. To illustrate, suppose the consumption discount rate for period t along the business as usual consumption stream ${}_1C$ is 0.06, or 6%. This means that if it is possible for the representative agent to decrease her period t consumption by one dollar and receive a greater than 6% return on that investment in period $t + 1$, then the agent's preferences are better satisfied by investing the dollar instead of consuming it. In other words, if the prevailing rate of return on investment 'hurdles' over the agent's consumption discount rate, then the agent's preferences are better satisfied by consuming slightly less now in order to invest and consume a bit more later.

By calibrating their representative agent's discounted utilitarian preferences so that they approximate the preferences of the average real-world agent, macroeconomists observe as their model's agents move from feasible consumption stream to feasible consumption stream until they settle on a stream along which their consumption discount rates in every time period equal those respective time periods' available rates of return on investment. This gives the second Ramsey equation:

$$r_t = \delta + \eta \cdot g_t \qquad (4)$$

This equation, which is sometimes called the *Ramsey rule*, says that agents with discounted utilitarian preferences will make savings and consumption decisions so as to ensure that each time period's consumption discount rate (as given by the righthand side of (4)) equals that time period's rate of return on conventional capital investment (as given by the lefthand side of (4)).[4] The reasoning is intuitive: if equilibrium consumption discount rates did *not* equal equilibrium rates of return in all time periods, the representative agent could move to a more preferred consumption stream by adjusting her consumption or saving behavior in at least one time period. The Ramsey rule is an 'optimality condition' in the sense that if one has discounted utilitarian preferences, then a necessary condition for residing on one's most preferred consumption stream is that the Ramsey rule equation actually hold true.

Nordhaus' approach to projecting real interest rates is actually a bit different from the standard approach I have just described. Instead of assuming a representative *agent*, he assumes a representative *society*. He knows that real-world decisions about which consumption streams to settle on are profoundly shaped by government policies (e.g. tax policy), and so instead of modeling the planning behavior of an agent (or, equivalently, an identical set of agents), Nordhaus models the decision-making of societies by using the following *social* discounted utilitarian value function:

$$V = \sum_{t=0}^{\infty} N_t u(c_t) \cdot \left(\frac{1}{(1+\delta)^t}\right) \qquad (5)$$

[4] It is unfortunately not common in the climate economics literature to distinguish between what I have called the Ramsey formula and the Ramsey rule. But they are importantly distinct propositions and should be kept distinct. For the rare paper that does so, see Dasgupta (1982, 279, 284).

With the addition of the population variable N_t, this formulation moves beyond the representative agent conceit by explicitly acknowledging that multiple agents exist at each time. In Nordhaus' model, the utility discount rate, δ, is now the rate at which *society* discounts the utility (which is still given by an isoelastic u-function) of future people. Despite these differences, the Ramsey formula (equation (3)) and the Ramsey rule (equation (4)) carry over from the representative agent framework to the one employing a social value function.[5] This is related to one of Nordhaus' key assumptions: he assumes that real-world societies have used public policy tools to bring it about that the equality expressed by (4) holds true in the real world. From this assumption, he proposes to deduce the values of η and δ that characterize these societies' policy preferences. Of course, there is an infinite number of pairs of (η, δ) that could equally well solve a Ramsey rule equation with an observable business-as-usual real interest rate on the lefthand side and an observable per capita consumption growth rate on the righthand side, and Nordhaus has modified his selections over the years (see for example Nordhaus 2008, 50). Still, his overall aspiration has remained the same:

> We note first, as discussed earlier, that the interpretation of the economic parameters is that they are designed to provide the most accurate projections rather than to be normative in nature. (Nordhaus 2008, 50)

Here, then, is how Nordhaus' models use a social value function to simulate perfect competitive markets for greenhouse gas abatement. First, he seeks to infer values for δ and η by assuming that societies optimize their conventional investments. The parameter values so inferred are *descriptive*: they describe aspects of the social policy preferences that steer the real-world macroeconomy. He then inserts these parameters into his IAM, which is independently programmed to identify the full set of feasible future consumption streams. Nordhaus then asks his model to determine which feasible consumption stream maximizes the descriptive social value function *subject to the constraint that countries do not invest in greenhouse gas mitigation*. This gives the

[5] In the context of a social discounted utilitarian value function, the Ramsey formula expresses the hurdle rate for an increment in *total* consumption, rather than an increment in the representative agent's consumption, and c_t now represents average per capita consumption.

business-as-usual consumption stream. Nordhaus' model then computes this stream's time-path of consumption discount rates, and finally the Ramsey rule is invoked once again to equate these discount rates with the business-as-usual time-path of rates of return on capital investment. Countries can now discount prospective future benefits of greenhouse gas mitigation with these interest rates in order to test climate investment projects against alternative investment opportunities elsewhere in the economy. If we assume that marginal mitigation costs in the model are given by the costs as they would be if countries were willing and able to jointly invest in meaningful greenhouse gas abatement, then by supposing that countries invest in mitigation until the discounted benefits of marginal mitigation equal present marginal abatement costs, Nordhaus' model identifies the additional mitigation that the world's countries would collectively undertake in the absence of the three barriers that currently 'triply persuade' them to underinvest in climate change mitigation.

Thus for Nordhaus, 'optimal' climate policy is the policy that each of the world's countries would *itself* support, given its *actual* current policy preferences, if all the countries could work together to nullify the impulse to free-ride on the efforts of others. Importantly, Nordhaus admits that he is only projecting what countries *would* do under more favorable circumstances, rather than opining on what countries should *morally* do. For example, in criticizing the ethically-informed approach to discounting and climate policy analysis adopted by Nicholas Stern's British government-commissioned *The Economics of Climate: The Stern Review* (Stern 2007), Nordhaus (2007, 692) says, "[I] find the ethical reasoning on discount rates in the *Review* largely irrelevant for the actual investments and negotiations about climate change".

But then since Nordhaus studiously avoids ethical analysis, it is very unclear why he feels entitled to assign the label "optimal" to the outcome of his quasi-predictive exercise and to associate that outcome with "idealized" and "economically desirable" policy (Nordhaus 2008, 14; Nordhaus 2013a, 76). At times, Nordhaus has acknowledged this problem for his frequent policy-prescriptive declarations. In a paper that has been cited much less frequently than his much more famous review of the *Stern Review*, Nordhaus acknowledges that his model is simply "an algorithm for finding the outcome of efficient competitive markets" and that unless more robust ethical assumptions are incorporated into it—something Nordhaus himself has always refused to do—then the model's "optimal" outcome is actually "purely algorithmic and has no compelling normative properties" (Nordhaus 2013b, 1111).

II. "IF I COULD REWIND THE CLOCK TWENTY YEARS, I WOULD HAVE WRITTEN THIS DIFFERENTLY."

In 2012 Nordhaus was a commentator at John Broome's Tanner Lectures on Human Values at the University of Michigan. Broome is a former-economist-turned-leading-moral-philosopher, and he has been one of philosophy's staunchest critics of Nordhaus' approach to climate economics. At one point, Nordhaus stood in front a whiteboard on which Broome had previously drawn a diagram very similar to figure 1. Nordhaus then said:

> Now, so then we have the business-as-usual point [point BAU], and the idea here being that that's inside […] the frontier because of inefficiencies—in this particular case climate externalities. Then we have what I think of as the Pareto region here. […] Those are in principle places where you could improve the consumption of both future and present generations. […] So, John [Broome] is correct to say that the policies that were emphasized in the *Stern Review* and in my work were ones that were up here to the northwest of the Pareto region. […] Now in my own work, if I could rewind the clock twenty years, I would have written this differently—I would have emphasized differently, which is [to say] that there are two kinds of things going on here: one is going to the frontier [starting from point BAU], which you can think of as climate policy; and then where you are on the frontier, which is distributional policy. (Broome and Nordhaus 2012, 37:10–43:00 min.)

Broome drew his diagram in part to illustrate what happens when emitters are permitted to emit without any regard for the external costs they create. One thing that happens is that emitters' greenhouse gas emissions lead to *Pareto inefficiency*. When an economist says that a situation is Pareto *efficient*, it means it is not possible to make any person better off (as compared to that situation) without thereby worsening someone else.[6] By that definition, every point on figure 1's *consumption possibility frontier* is Pareto efficient: for every such point, P, if the economy were located at P, any move away from P would involve making at least some party worse off than they were at P. Conversely, a point is Pareto *inefficient* when it lies below the

[6] Economists use "Pareto optimal" and "Pareto efficient" synonymously.

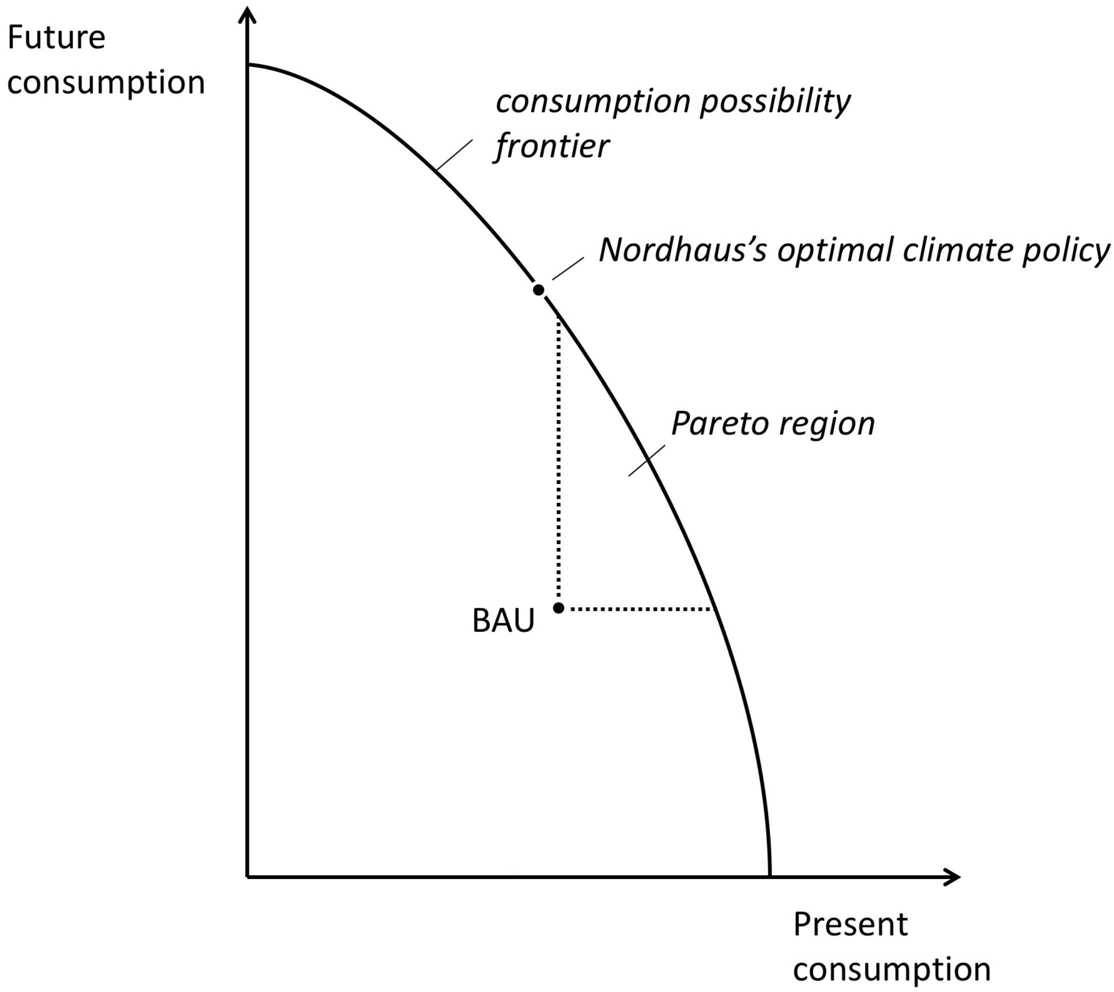

Figure 1. Illustrating Intergenerational Consumption Possibilities

consumption possibility frontier; in that case, it is possible to move to the frontier in a way that improves at least one person without making anyone else worse off. Call such a move a *Pareto improvement*.

Now consider figure 1's point BAU. Note first that any point on or under the consumption possibility frontier represents a consumption stream with just two time periods—*present* and *future*. Being under the frontier, the consumption stream represented by BAU is Pareto inefficient: it is possible to move to a new consumption stream that makes at least one time-period's people better off without making anyone else worse off—a Pareto improvement. The full set of consumption streams offering Pareto improvements falls within what Nordhaus termed the Pareto region. When greenhouse gasses are completely unregulated and untaxed, those who suffer the bad effects of greenhouse gas emissions might well be willing to pay much more for meaningful abatement than the emitters would be willing to accept by way of compensation to reduce their emissions. This because the emitters will emit right up until their declining marginal private benefit of the emitting activity equals the marginal private costs of that activity, at which point those who suffer the external costs of the activity may be experiencing so much pollution that they are willing to pay a lot to prevent some of it. And that is why Broome drew the BAU point as lying under the consumption possibility frontier.

Suppose BAU represents our current economy's status quo consumption stream. In that case, there are Pareto-improving trades that could make both present and future people better off. Such trades involve exchanging resources across time: future generations would be willing to forego some material wealth in exchange for an improved climate. If they were possible, a series of such intertemporal trades would shift the economy from BAU to a point on the consumption possibly frontier that is within the Pareto region. And indeed Nordhaus describes just such a policy in his review of the *Stern Review*: we can take out a loan today to compensate ourselves for undertaking climatic investments, and the loan can be kicked down the road until future generations arrive to pay it off (Nordhaus 2007, 695).

What I have just laid out is the background behind Broome's claim "that the problem of climate change can be solved without anyone making a sacrifice" (Broome 2010, 102). Broome conceives of the "problem of climate change" as consisting in what economists call a *Pareto-relevant externality*, or an externality that keeps the economy operating underneath the consumption possibility frontier, which leaves all people worse off than they could otherwise be (Buchanan and Stubblebine 1962; Baumol and Oates 1988, 16). On this understanding, the problem of climate change consists in the fact that there exist paths of emissions abatement that, when coupled with a corresponding intertemporal transfer of resources, could move the economy onto the frontier. Once on the frontier, any further problem concerns whether or not "it is better to have more resources in the hands of the poor and of future generations, rather than in the hands of the current rich". And "[t]his matter of distribution has little to do with climate change", according to Broome (2012, 46).

Thus in at least one sense, Broome and Nordhaus agree that (as Nordhaus puts it) climate policy concerns "going to the frontier" whereas distributive policy concerns the evaluation of "where you are on the frontier" once the economy gets there (Broome and Nordhaus 2012, 39:15 min.). They also seem to agree that it is strongly worth considering routes to the frontier that could win political support in the world as it is. The key difference, it seems to me, is that while Broome is trying to convince present *people* to undertake a climate policy that will make them no worse off, Nordhaus is trying to convince *governments* to undertake a climate policy that comports with their revealed intertemporal preferences. As Nordhaus puts it when justifying his approach to climate economics in his review of the *Stern Review*, "When countries weigh their self-interest in international bargains about emissions reductions and burden sharing, they will look at the actual gains from bargains, and the returns on these relative to other investments" (Nordhaus 2007, 692). Yet the fact remains that if one wishes to separate climate policy and distributional policy in the way Nordhaus claims he does, and if one wishes to restrict oneself to climate policy only, then one cannot insist that any given policy-induced route to the consumption possibility frontier is more 'optimal' than another.

Even if Nordhaus is wrong to label his particular route to the Pareto frontier as 'optimal' a key redeeming point is that Nordhaus' non-normative approach to discounting is precisely what Broome needs to help identify the Pareto-relevant climate externality in the first place. This is because monetized climate damages can be interpreted as future people's willingness to pay to prevent those damages. (If one stands to lose $100 from climate change along a business as usual climate-economy pathway, then one should be willing to pay up to $100 to move to a new pathway that avoids those damages.) By discounting future marginal damages using the real interest rates that would result along the business as usual pathway, one converts future willingness to pay to prevent those damages into present-dollar terms. And it is the present value of future people's willingness to pay that must be compared with present people's willingness to accept compensation if one wishes to illuminate the Pareto-relevant climate externality.

III. CONCLUSION

Neither Broome nor Stern believes that one must renounce one's moral compass in order to flag the important fact that much greenhouse gas mitigation can be Pareto-improving (see Stern 2015, 202–205). Yet it is precisely Nordhaus' descriptive approach to discounting—or perhaps some alternative but still descriptive approach—that is required to reveal the full extent of the Pareto-relevant climate externality. It therefore seems possible to reconcile Nordhaus' broad approach to discounting with the alternative ethical approach championed by Stern and allied moral philosophers.[7] That alternative ethical approach aims to identify the point on the consumption possibility frontier that is (in some sense requiring further elaboration) *morally* optimal. It seems to me that each of these approaches to climate economics can shed light on a policy-relevant aspect of the overall climate change problem. But if this is right, it is also true that Nordhaus' 'optimal' policy largely reflects one person's sense of which aspects should be emphasized in real-world policy discussions, rather than an impartial finding from a prize-winning economic model.

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[7] This reconciliation resembles to some degree the one proposed in Howarth (2003) and perhaps also in Posner and Weisbach (2010). But neither puts things as I have, and I think there remain differences of interpretation between us. For an analysis more along the lines I've given here, and to which I am indebted, see Goulder and Williams (2012).

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