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Hon. Lisa P. Jackson
Administrator
Environmental Protection Agency
EPA Docket Center (EPA/DC)
Air and Radiation Docket
Mail Code 2822T
1200 Pennsylvania Avenue NW
Washington, DC 20460

VIA ELECTRONIC SUBMISSION

Friday, November 27, 2009

Re: Docket ID No. EPA–HQ–OAR–2009–0472

Administrator Jackson:

We are pleased to provide the following comments regarding the *Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards*, 74 Fed. Reg. 49,454 (Sept. 28, 2009) (the "Proposed Rule"). In that rule the Department of Transportation and the Environmental Protection Agency (collectively, the "Agencies") propose new emissions standards and fuel economy standards in light of the harms caused by greenhouse gas ("GHG") emissions.

These joint comments focus on the sections of the Proposed Rule that discuss the interim "social cost of carbon" ("SCC") values, in particular Sections III.H.6 and IV.C.3. Our organizations have provided additional comments on other portions of the Proposed Rule, but want to emphasize our interest in the SCC given its great importance for future federal rulemakings.

We strongly support the development of a SCC that estimates and monetizes the benefits of GHG emissions reductions. Because of the large array of programs that have an effect on GHG emissions, developing a set of values that can be integrated by all federal agencies into their decisionmaking processes will help both rationalize the federal response to climate change threats and insure that the costs of GHG emissions are appropriately accounted for in regulatory impact analyses. We also support the "interagency group"[1] approach to ensure consistency across agencies.

As stated in the Proposed Rule, the SCC values described are only "interim" and "[t]he Administration" seeks comment "on all of the [relevant] scientific, economic, and ethical issues before establishing improved estimates for use in future rulemakings."[2] We make the following recommendations for how the SCC estimates can be improved:

- **Discounting:** In light of significant economic and ethical challenges raised by discounting, and the lack of a consensus around a single number or even a single

[1] *Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards*, 74 Fed. Reg. 49,454, 49,506 (Sept. 28, 2009) (hereinafter the "Proposed Rule").

[2] Proposed Rule at 49,612 and 49,676.

conceptual approach to choosing a discount rate, the only appropriate course of action is a fully transparent, exhaustive, and rigorous process to determine a range of appropriate discount rates (including time-varying discount rates that explicitly acknowledge uncertainty). To the extent that constant discount rates are used, the lower range should be extended to 2% or lower, and the upper bound should be set no higher than 4%.

- **Uncertainty and Risk:** The Final Rule must respond more fully to uncertainties and risks associated with climate change in developing the SCC. Upward adjustments in the SCC may be necessary to account for the upward skew of uncertainty. Where possible, the SCC should be expressed as a probability density function and a broader set of descriptive statistics (e.g., variance, skewness, and interquartile range), and wider sensitivity analysis should be reported. SCC estimates should account for risk aversion and risk premiums either through a positive "adder" or a reduction in the effective discount rate, and should better account for potentially irreversible catastrophic risks.
- **Global Valuations:** We strongly agree that a global value for the SCC is appropriate given the public good characteristic of GHG controls. To the extent that a domestic percentage is calculated, it must incorporate "spillover effects" where environmental harm in one country can have economic impacts in another country, especially given the special economic, diplomatic, and military place of the United States in the world.
- **Uses of the Social Cost of Carbon:** Central estimates of the social cost of carbon should not be used in optimization models, and should not replace traditional regulatory impact analysis for GHG emissions reductions. While incorporating ancillary benefits directly into the SCC is likely to prove difficult, the interagency group should provide guidance on the types of ancillary benefits typically associated with GHG reductions.
- **Final Value:** The interagency group should continue to develop more accurate estimates of the SCC; as a vital next step, individual agencies should be given significant opportunities to examine the current IAMs, including how the specifications, inputs, and assumptions within the IAMs affect outcomes. A final value should only be developed after agencies have developed considerable expertise with these models.

We look forward to continued discussion of appropriate tools to value the benefits of GHG reductions and how SCC estimates can be improved and used to promote rational and efficient steps to curb GHG reductions.

Section One: Discounting

1.1 Introduction

The discount rate is widely acknowledged to be the single most important parameter in determining the social cost of carbon.[3] The results of the interagency process presented in the Proposed Rule bear this out: The range of SCC values considered in the Proposed Rule — spanning an order of magnitude, from $5 to $56 — is due entirely to different assumptions about the discount rate. Indeed, variation among the three selected integrated

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[3] *See, e.g.,* Martin L. Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. OF ECON. & STATISTICS 1 (2009) [hereinafter Weitzman (2009)].

assessment models (IAMs) is swamped by variations within those models using plausible assumptions of discount rates.

However, the choice of discount rate is as controversial as it is crucial to the results. As noted in the preamble, the "choice of a discount rate . . . raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law."[4] The Proposed Rule provides a preliminary overview of some of these questions, but largely recognizes that it will be impossible to provide final resolution on many issues. As discussed in more detail in the next subsection, the choice of discount rate can be guided by prescriptive or descriptive considerations. Both have their proponents in the literature, but neither is entirely satisfactory. Meanwhile, an emerging literature on the uncertainty of future discount rates provides compelling arguments for using a discount rate that declines over time, rather than a single constant rate.

Weitzman puts the problem succinctly: "[T]he most critical single problem with discounting future benefits and costs is that no consensus now exists, or for that matter has ever existed, about what actual rate of interest to use."[5] The range of uncertainties and problems associated with this issue are well summed up by Dasgupta (2008): "[I]ntergenerational welfare economics raises more questions than it is able to answer satisfactorily."[6]

In light of these challenges, and the lack of anything approaching consensus around a single number or even a single conceptual approach, the only appropriate course of action for the Agencies (and for the interagency group) is a fully transparent, exhaustive, and rigorous process to determine a range of appropriate discount rates (including time-varying discount rates that explicitly acknowledge uncertainty), and use that range to derive values for the social cost of carbon.

The Proposed Rule fails to meet this standard. First, the reasoning behind the choice of discount rates is obscure, often peremptory, and limited in disciplinary scope.[7] Second, the Proposed Rule does not satisfactorily address uncertainty, or take into account its implications for the appropriate time structure of social discount rates. Third, in selecting constant discount rates of 3% and 5%, the Proposed Rule ignores significant support for extending that range to include a lower value (e.g. 1%, 1.5% or 2%) while overstating the justification for a 5% rate.

1.2 How well justified are the Proposed Rule's choices of 3% and 5%?

1.2.2 The methodology followed by the Proposed Rule

Two general approaches can be followed in determining a discount rate for use in cost-benefit analysis of intergenerational problems: a "prescriptive approach" and a "descriptive approach." The prescriptive approach explicitly contemplates the choice of discount rate as an ethical and moral question, typically using the Ramsey equation[8] as a conceptual

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[4] Proposed Rule at 49,613 and 49,677.

[5] Martin L. Weitzman, *Gamma Discounting*, 91 AM. ECON. REV. 260, 270 (2001) [hereinafter Weitzman (2001)].

[6] Partha Dasgupta, *Discounting Climate Change*, 37 J. RISK & UNCERTAINTY 141, 167 (2008).

[7] The Proposed Rule notes that "[t]he current Administration has worked to develop a transparent methodology for selecting a set of interim SCC estimates." Proposed Rule at 48,612 and 49,676. However, there is insufficient explanation for the choices inherent in the selection of the discount rate for commentators (or courts) to fully understand the Agencies rational for the discount rate chosen, undercutting the transparency of the methodology and raising potential legal issues.

[8] Frank P. Ramsey, *A Mathematical Theory of Saving*, 38 ECON. J. 543 (1928).

framework for combining economic reasoning with judgments about intergenerational equity. The descriptive approach, in contrast, takes a "revealed preference" approach, relying on observed rates of return in private markets—typically the risk-free rate of return or the market return on capital—to determine the appropriate discount rate. [9]

To the extent that the Proposed Rule adopts a methodology, it attempts to identify areas of overlap from different methods for selecting a discount rate. In particular, to justify its selection of 3% and 5% percent discount rates, the Proposed Rule relies on both descriptive and prescriptive approaches. There is a truly vast scholarly literature discussing variants on these two approaches. The Proposed Rule canvasses some of that literature, and finds some support for the 3% and 5% rates using both approaches. But the Proposed Rule also notes that there is support for both lower and higher values. While the two selected values do fall within the very wide range of values that have *some* support within the economics literature, the Proposed Rule does not give adequate explanation why these values, as opposed to the large number of other plausible values, were chosen. Instead, the Proposed Rule tends to fall back on abrupt and seemingly arbitrary references to "common" judgments among economists.

While making reference to the "questions of science, economics, philosophy, and law" that are raised by "[t]he choice of a discount rate,"[10] the Proposed Rule relies almost entirely on economic reasoning. When it cites the academic literature, those citations are drawn from the economics literature—philosophical or legal scholarship is absent.[11] While providing some exploration of economic issues relevant to the discount rate, the "highly contested and exceedingly difficult" of other disciplines are largely ignored.

The SCC is an assuredly economic concept, and the concept of discounting is grounded in that discipline. There is no question that economics has a central role to play. But neither is the choice of a discount rate a value-free "objective" decision.[12] There are many deep ethical and moral judgments that are that arise and are settled without adequate

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[9] The prescriptive/descriptive distinction is generally credited to Kenneth J. Arrow et al., *Intertemporal Equity, Discounting, and Economic Efficiency*, in CLIMATE CHANGE 1995: ECONOMIC AND SOCIAL DIMENSIONS OF CLIMATE CHANGE 129 (James P. Bruce, Hoesung Lee, and Erik F. Haites eds. 1996). We appropriate the terms but change the meanings slightly.

[10] Proposed Rule at 49,613 and 49,677.

[11] This is not because there is no significant philosophical or legal literature on discounting and intergenerational equity. *See, e.g.*, Matthew D. Adler, *Symposium: Intergenerational Equity and Discounting: Economic Growth and the Interests of Future (and Past and Present) Generations: A Comment on Tyler Cowen*, 74 U. CHI. L. REV. 41 (2007) (discussing the subject from a welfarist moral theory); Douglas A. Kysar, *Discounting, on Stilts*, 74 U. CHI. L. REV. 119 (2007) (discussing several legal viewpoints on discounting and intergenerational equity); Tyler Crown, *Policy Implications of Zero Discounting: An Exploration in Politics and Morality*, *in* MORALITY AND POLITICS 121 (Ellen Frankel Paul et al. eds., 2004) (advocating for a zero discount rate from a moral perspective); HANDBOOK OF INTERGENERATIONAL JUSTICE (Joerg Chet Tremmel ed., 2006) (discussing discounting from a human rights perspective); OWEN MCINTYRE, ENVIRONMENTAL PROTECTION OF INTERNATIONAL WATERCOURSES UNDER INTERNATIONAL LAW 251-60 (2007) (discussing intergenerational equity in the context of international environmental law); Richard L. Revesz, *Environmental Regulation, Cost-Benefit Analysis, and the Discounting of Human Lives*, 99 COLUM. L. REV. 941 (1999).

[12] *See* David Anthoff, Cameron Hepburn, Richard S.J. Tol, *Equity Weighting and the Marginal Damage Costs of Climate Change*, 68 ECO. ECON. 836, 839 (2009) ("[M]any economists and philosophers argue that an ethical approach based solely on individual preferences revealed on markets is flawed and would caution that care should be taken before inferring ethical parameters from revealed social preferences.") (citing Cameron J. Hepburn & Wilfred Beckerman, *Ethics of the Discount Rate in the Stern Review on the Economics of Climate Change*, 8 WORLD ECON. 187 (2007)); John Broome, Climate Change: Why Economics Requires Ethics, The Knox Lecture (University of St. Andrews, United Kingdom, April 19, 2007); Dasgupta, *supra* note 6.

justification in the Proposed Rule—such as the choice of a utilitarian philosophical framework implied by the use of an intertemporally additive social welfare function.

While economics can provide a crucial and useful set of frameworks for formulating the problem and identifying the underlying concepts, a full treatment of discounting must also draw explicitly on insights from science, philosophy, and law. The consequence of an overly narrow economic approach is to significantly undermine the usefulness and legitimacy of the process used to choose discount rates—leaving it more vulnerable to challenge, and less likely to serve as a lasting guidance for future Administrations.

1.2.2 Prescriptive approach

There is a large academic literature that attempts to use the prescriptive approach to derive discount rates.[13] Many attempts use the Ramsey equation as a starting point for analysis. That equation, based on an abstract model of optimal economic growth, disaggregates the discount rate into the sum of two elements: a pure rate of time preference (PRTP), denoted ρ, and the product of the elasticity of the marginal utility of consumption (μ) and the growth of per-capita consumption (g):

$$r = \rho + \mu g$$

There is significant controversy over each of these parameters, with published values varying widely. More fundamentally, ρ and μ are explicitly ethical parameters whose values cannot be simply determined by empirical analysis but instead should be the subject of careful, reasoned, and transparent deliberation. In the face of this lack of consensus, the Agencies have not adequately explained how the prescriptive approach supports the discount rates chosen.

1.2.2.1 Marginal utility of consumption and the growth rate

With respect to the elasticity of the marginal utility of consumption and the growth rate, the two parameters are not separately discussed. Because the Proposed Rule does not report its values for μ and g, it is impossible for commentators to evaluate them separately. Instead, the Proposed Rule simply reports the product, and makes the claim that 3%-5% are "standard estimates" while citing portions of the vast literature on this question. This claim—which is not accompanied by any citation or reference—seems hard to sustain.

A widely cited survey finds that reasonable estimates of μ range from 1 to 2, while a reasonable estimate of per-capita growth rate over the long term would be 1.5%[14] These numbers would produce a range of 1%-3% for the product μg. Other surveys suggest that a more central estimate of the elasticity of marginal utility is μ = 1.[15] Cline (1992) uses a value of 1 for μ and 1.5% for g.[16]

In addition, while these numbers may be useful guidelines, using them to infer an "empirical" value of ρ suffers from a confusion between *social* and *individual* preferences.

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[13] *See, e.g.,* Arrow et al., *supra* note 9.

[14] *Id.*

[15] David W. Pearce & David Ulph, *A Social Discount Rate for the United Kingdom*, *in* ENVIRONMENTAL ECONOMICS: ESSAYS IN ECOLOGICAL ECONOMICS AND SUSTAINABLE DEVELOPMENT 268 (David W. Pearce ed. 1999).

[16] WILLIAM R. CLINE, THE ECONOMICS OF GLOBAL WARMING (1992).

Social preferences cannot be revealed from individual market behavior.[17] Nordhaus provides an appropriate caution on this point:

> It must be emphasized that the variables analyzed here [i.e., ρ and μ] apply to comparisons of the welfare of different generations and not to individual preferences. The individual rates of time preference, risk preference, and utility functions, do not, in principle at least, enter into the discussion or arguments at all.[18]

To restate the point slightly, there is no social-choice-theoretic or axiomatic basis for any particular correspondence between individual preferences over time or risk or consumption, and the parameters of the social welfare function used for evaluating a reduction in greenhouse gas emissions, which is necessarily embedded in the Ramsey formulation (and indeed in the computation of a social cost of carbon using IAMs).

While a value of 5% can obviously be computed by choosing a sufficiently high elasticity and/or growth rate, the claim that it is a "standard estimate" has little basis in the economics literature. The Proposed Rule includes no meta-analysis of published results on this question, nor does it review the literature in depth and provide a critical assessment of why it is using some numbers rather than others. Nor does it adequately discuss how evidence concerning individual preferences can meaningfully translated to the social preferences relevant for this rule. And yet these are crucial elements of the Proposed Rule's justification for its choice of discount rate. The inability of commentators to adequate review the Agencies choice of this fundamental parameter significantly undercuts the transparency of the final decision.

1.2.2.2 Pure rate of time preference

In a similar manner, the Proposed Rule selects 2% as a "common estimate" of the PRTP. This assertion is made without providing any rigorous justification or even a single citation. Moreover, even if the Agencies were able to demonstrate that a 2% pure rate of time preference were "common," that alone would not justify its use. Simply because an estimate is common does not mean that it represents a meaningful consensus; that value may often serve as a "place holder" in a model rather than have been the subject of meaningful analysis.[19]

While the Proposed Rule acknowledges in passing that "some observers believe that a principle of intergenerational equity suggests that [ρ] should be close to zero,"[20] that dramatically understates the case. In fact, a number of eminent economists have taken that stance. Ramsey's oft-cited view was that a positive pure rate of time preference was "a practice which is ethically indefensible and arises merely from the weakness of the imagination";[21] Arthur Pigou held that a pure rate of time preference "implies… our

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[17] To be fair, the authors of the Proposed Rule are not alone in making this mistake. *See, e.g.*, Martin L. Weitzman, *A Review of* The Stern Review on the Economics of Climate Change, 45 J. OF ECON. LIT. 703, 712 (2007) [hereinafter Weitzman (2007)] (referring to "society's revealed preference value of [ρ]").

[18] WILLIAM NORDHAUS, A QUESTION OF BALANCE: WEIGHING THE OPTIONS ON GLOBAL WARMING POLICIES 172 (2008).

[19] *See, e.g.,* Anthoff et al., *supra* note 12 (using PRTPs of 0%, 1%, and 3%, largely without justification, to demonstrate the effects of another parameter on the SCC).

[20] Proposed Rule at 49,614 and 49,678.

[21] Ramsey, *supra* note 8 at 543.

telescopic faculty is defective";[22] and Robert Solow stated that, "In solemn conclave assembled, so to speak, we ought to act as if the social rate of time preference were zero."[23]

The main argument against a zero PRTP has been elucidated clearly by Arrow: a zero pure rate of time preference would demand an unreasonably high level of saving by present generations.[24] Arrow concludes that a small but positive PRTP (his choice is 1%) is justifiable.[25] However, Koopmans (whose arguments are the basis for Arrow's) averred "an ethical preference for neutrality as between the welfare of different generations."[26] Dasgupta takes a different tack, acknowledging the force of the savings argument but also expressing support on ethical grounds for a value of ρ = 0.1 (the value used in the *Stern Review*); he resolves the dilemma by arguing for a higher value of μ. In all of these cases, the ethical implications of the choice of a PRTP are paramount and it is ethical intuitions, more than empirical or economic theory, that drives the results.

The conclusion from this discussion is not that there is a consensus for setting ρ to zero. Rather, the conclusion is that these are challenging and complex ethical and economic questions that cannot be satisfactorily settled by an offhand assertion that 2% is a "common estimate."

1.2.2.3 The appropriate use of the prescriptive approach

On the basis of its assertions that the "standard estimate" of μg is 3-5% and the "common estimate" of ρ is 2%, the Proposed Rule makes a pair of very strong claims:

> "5%, not 3%, is roughly consistent with estimates implied by inputs to the theoretically derived Ramsey equation. … It follows that discount rate of 5% is near the middle of the range of values that are able to be derived from the Ramsey equation."[27]

However, **the Proposed Rule fails to meet any reasonable standard of demonstrating this claim, which is a central pillar of its argument**. As acknowledged above, there are certainly legitimate values of μ, g, and ρ that add up to 5%. However, the Proposed Rule does not present even a single citation from the economics literature to justify its specific assertions. Nor does it grapple seriously or convincingly with the deep underlying ethical and moral judgments that are necessarily involved in the prescriptive approach.

The claim that 3% is not "consistent with estimates implied by inputs to the theoretically derived Ramsey equation" sweeps aside, without justification or examination, large

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[22] ARTHUR C. PIGOU, THE ECONOMICS OF WELFARE 25 (4th ed., 1932).

[23] Robert Solow, *The Economics of Resources or the Resources of Economics,* 64 AM. ECON. REV. PAPERS & PROCEEDINGS 1, 9 (1974) (noting that "we would simultaneously discount future *consumption* if we expect the future to be richer than the present").

[24] Kenneth J. Arrow, *Discounting, Morality, and Gaming in* DISCOUNTING AND INTERGENERATIONAL EQUITY 14 (Paul R. Portney & John Peter Weyant eds., 1999); *see also* Tjalling C. Koopmans, *Stationary Ordinal Utility and Impatience*, 28 ECONOMETRICA 287 (1960) (discussed therein). Nordhaus emphasized this same argument in his review of the *Stern Review*. Nordhaus *supra* note 18 at 179.

[25] Kenneth J. Arrow, Intergenerational Equity and the Rate of Discount in Long-Term Social Investment 17 (paper presented to the IEA World Congress, Dec. 1995) [hereinafter Arrow (1995)], *available at* www-siepr.stanford.edu/workp/swp97005.pdf.

[26] Tjalling C. Koopmans, *On the Concept of Optimal Economic Growth in* THE ECONOMETRIC APPROACH TO DEVELOPMENT PLANNING 225, 239 (1964) (quoted in Arrow *supra* note 24).

[27] Proposed Rule at 49614 and 49678.

portions of the economics literature (including the references cited above) that would support a lower discount rate. The claim that 5% is "near the middle of the range of values that are *able to be derived* from the Ramsey equation" is in fact meaningless—there is no theoretical lower or upper bound to values that could possibly be derived from the Ramsey equation. And because Proposed Rule provides no justification for any implied bounds on the parameters for the equation, even if true that 5% is "near the middle of the range," using those implied bounds, it impossible for commentators to evaluate the meaning of the value because the parameters, or the implied bounds on the parameters, are not justified (or even made explicit).

If the prescriptive approach is to be used, then the ethical considerations that arise when making intergenerational allocation decisions must form the heart of the Agencies' justification for the rate that is selected. On these grounds, the Proposed Rule is clearly insufficient.

To rely on the prescriptive model to justify the selection of the discount rate, the Final Rule must provide a reasoned explanation for why that model is chosen, and for each of the parameters that are selected. The value chosen for ρ must be justified on the basis of the relevant ethical considerations at the heart of the prescriptive method—a simple and unjustified analogy to empirical evidence concerning individuals' time preferences is insufficient. The relevance of individual time preference to distributional questions must be adequately explained. The value of μ must likewise be explained with reference both to the empirical literature on the marginal utility of income as well as the fundamental moral question of what degree of income distribution from wealthy to poor is justified. It is not the current policy of any federal agency to engage in all wealth transfers that increases aggregate utility (as measured by a μ sensitive social welfare function)—the Agencies must explain why SCC is different and justify the choice of a particular value of μ that will drive the wealth transfer.

Merely pointing to a "common estimate" or a "standard estimate" for values in the Ramsey equation is insufficient. The Agencies must show either that they are making an independent judgment on the merits of particular parameter choices, or must show that they have conducted an adequate review of the literature and selected values that are truly representative of a meaningful consensus. Given that these parameters are fundamentally assumptions, rather than empirical estimates, the frequency of some values in the literature is not an adequate proxy for widespread acceptance. The agency must examine, within the literature, which published values are merely "placeholders" and which truly represent the considered conclusion of peer reviewed experts. Moreover, because of the essential ethical and moral dimensions of these judgments, the Agencies must extend their vision beyond the discipline of economics. Only after an exhaustive analysis of the relevant literature in economics, political science, philosophy, and law, coupled either with a sophisticated meta-analysis to tease out areas of consensus or independent justification grounded in ethical consideration, can the Agencies use the prescriptive approach as a mechanism to defend the choice of particular discount rates.

1.2.2.4 Equity weighting in an inter- and intragenerational context

A final concern involves the inconsistency between the prescriptive approach for discounting (involving a nonzero value of μ) and the decision not to apply differential equity weights to the impacts on different income groups within a single generation. As the Proposed Rule recognizes, a "consistent and logical . . . application of the Ramsey framework"[28] would also require that equity weights be applied. The discount rate in the Ramsey equation is based in part on an assumption of diminishing marginal utility of consumption. Coupled with an assumption of economic growth, this leads to the conclusion that consumption today will generate more welfare than consumption at an arbitrary time in the future. But, as the Proposed Rule notes the same argument applied with equal force to individuals or groups with different levels of income at the same point in time.

The unavoidable implication is that the use of equity weights across generations justifies the use of equity weights within generations as well. Note that this logic applies not only for comparisons between rich and poor populations today, but also for comparisons between rich and poor populations in the future. The application of a discount rate to impacts on future generations is justified in the Ramsey equation by the argument that mitigating those impacts would represent a transfer from the current generation to future generations which (due to economic growth) will be richer, and thus will have a lower marginal utility of consumption. However, the future damages of climate change will be especially concentrated in poor countries: for example, low-lying areas such as Bangladesh and the small island states will be particularly vulnerable to rising sea levels. As a consequence, mitigation may be better understood as a transfer from the today's rich to the future poor — reversing the conventional logic of the standard Ramsey equation.[29]

This is not necessarily to recommend that equity weights be applied for intratemporal transfers: although there would appear to be strong ethical grounds for such an approach, the determination of those equity weights would be an enormous challenge in itself. However, the difficulty of determining those weights is no different, in principle, from the difficulty in determining the appropriate intergenerational equity weights that are assigned through the choice of μ. The Proposed Rule has provided no reasoned explanation, if one is even possible, for why diminishing marginal utility of consumption is taken into account in one context but not another.

The Proposed Rule fails to adequately explain how the prescriptive approach justified selection of 3% and 5% discount rates. If the Agencies use the prescriptive approach, the philosophical and legal questions raised by this approach must form the heart of the Agency analysis—meta-analysis of the relevant literature coupled with independent evaluation of the all parameter values chosen is needed to ground the discount rates in reasoned analysis.

1.2.3 Descriptive Approach

1.2.3.1 Overview

The descriptive approach to the choice of discount rate is motivated by the conviction that social decisions involving trade-offs over time should be guided primarily by how individuals and governments actually make such trade-offs in their own decisions—i.e. by their revealed preferences.[30] The appeal of the descriptive approach is that it does not force analysts to engage in ethically fraught decisions about wealth redistribution or how much to "purely" discount future generations. Instead, the Agencies can ground their decision in a

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[28] Proposed Rule at 49,614 n. 371.

[29] Thomas Sterner & U. Martin Persson, *An Even Sterner Review: Introducing Relative Prices into the Discount Debate*, 2 REV. OF ENVIRO. ECON. POLICY 61 (2008).

[30] But recall Nordhaus's caution, *supra* note 18, against using individual preferences as the basis for social choices.

more “scientific” approach that looks to empirical observations in the world as the basis for its decision.

In a descriptive context, the main challenge facing the analyst is: What is the appropriate market rate of discount to be used as a proxy for the social rate of discount? The apparent simplicity of this question masks considerable complexity. Among other issues, the vast literature on this topic has identified the importance of tax laws, the source of financing (investment vs. consumption), the correlation between a project’s rates of return and that of the market as a whole, and many others.[31]

In defending its chosen discount rates, the Proposed Rule cites two market proxies: the “risk-free rate of return”[32] and “the estimated post-tax average real returns to risky private investments.”[33] The risk-free rate of return is used to justify the 3% rate (adjusted for a liquidity premium); while the risky private investment rate is used to justify the 5% rate. We return to the appropriateness of those choices below.

While the descriptive approach has its advantages, it must be conducted carefully or it runs a risk of arbitrariness. In the discounting context, some reference to “market behavior” or “revealed preferences” could justify an extremely broad range of discount rates. In the context of energy efficiency investments decisions by households, there is “relatively well established” empirical evidence of “discount rates ranging from 25% to over 100%.”[34] Alternatively, for very long time horizons, there is considerable empirical evidence of declining rates of interest.[35] There are a wide range of rates in between, including federal funds (1.92% in 2008; 5.35 in 1998), CDs on secondary markets (6-month CDs: 3.14% in 2008; 5.44% in 1998), a range of treasury bills (30-year: 4.28% in 2008, 5.58% in 1998; 20-year inflation indexed: 2.18% in 2008), or the large and highly variable rates of return for private instruments, including junk bonds, common stock, bank loans, and portfolios of derivative instruments. With this vast collection to choose from, almost any discount rate can be backed up with reference to some empirically observed number, so the Agencies must be careful to select an appropriate proxy for the type of decision that it faces.

In supporting its selection of 5% and 3% as appropriate discount rates from a descriptive standpoint, the Proposed Rule makes four explicit claims: (1) the rate of return to risky investments, e.g., equities, is an appropriate rate to use in evaluating trade-offs in consumption over time; (2) the risk-free rate of return, representing an appropriate lower bound on the discount rate, is 3%; (3) the 5% discount rate “may be preferable” to the 3% rate on the grounds that climate mitigation investments are risky; and (4) the appropriate discount rate depends on the degree of correlation between the returns from climate mitigation and the returns to the economy as a whole. In addition, the Proposed Rule’s reasoning relies implicitly (at least in parts) on a more fundamental claim that the relevant discount rate to use is the rate of return necessary to justify investment in climate mitigation projects rather than other investment opportunities.

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[31] See generally the discussion in Arrow et al, *supra* note 9 and the references cited therein.

[32] Proposed Rule at 49,614 and 49,677.

[33] *Id*.

[34] Kenneth Gillingham, Richard G. Newell & Karen Palmer, *Energy Efficiency Economics and Policy* 8-9 (Nat. Bureau of Econ. Research Working Paper 15031, June 2009).

[35] Salvador Cruz Rambaud & María José Muñoz Torrecillas, *Some Considerations on the Social Discount Rate*, 8 ENVRTL SCI. & POL’Y 343, 346-47 (2005) (surveying empirical studies).

1.2.3.2 Should the discount rate be determined by the rate of return on alternative private investments?

One argument commonly employed to justify the use of a relatively high discount rate holds that the relevant benchmark for the discount rate is the opportunity cost of capital — that is, the return from alternative projects that are foregone by the decision to invest in the public project. This view treats a ton of emissions reduction as akin to a public project with some future stream of returns. The appropriate discount rate is conceived of as the answer to the question: "What rate of return should society demand on the project in order to make it worthwhile?" The answer is typically taken to be an estimate of the available after-tax returns to capital, providing a rationale for using a discount rate of 5% or even higher.[36]

In the current context, there are at least three independent reasons to reject this argument as the basis for choosing a high discount rate in the case of climate change. First, the use of a high discount rate based on alternative rates of return relies heavily on the assumption that the returns from those alternative investments will be available in the future as compensation for the damages from climate change. Given the long intervening time period, such compensating transfers may not be feasible.[37] That is especially so given that climate damages will be concentrated in poor regions; thus the contemplated transfers must also be intragenerational, making them even less likely.

Second, in the economics literature on public finance, the conventional approach to resolve the dilemma (when contemplating a particular public project) is to apply a convex combination of the rate of return on investment and the consumer interest rate, using weights reflecting the mix of investment and consumption used to fund the project.[38] In the case of climate change, a substantial amount of abatement will be achieved through changes in consumption (i.e., increased energy conservation and substitution away from carbon-intensive goods). Hence even if we accept the premise that the discount rate should be defined in terms of the marginal returns from mitigation projects, the appropriate "opportunity cost" to use benefits from a marginal ton of emissions reduction should put considerable weight on consumer interest rates.

Third, in the case of the SCC, one can argue that the relevant discount rate should not be defined in terms of the rate of return necessary to justify an investment in mitigation. Rather, the problem should be framed as one of discounting the value of future damages (or benefits) that will affect the consumption and thus the welfare of future generations. In this view, the appropriate discount rate is the answer to the question: "How should we trade off future consumption against present consumption?" The discount rate should be pegged to the rate at which individuals are able to trade off consumption today against consumption in the future.[39] In a theoretical market equilibrium, with no distortions from taxes or other public policies, and no constraints on intertemporal transfers, an approach based on tradeoffs for consumption and one based on the opportunity cost of capital lead to the same

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[36] William Nordhaus is a strong proponent of this view. *See* Nordhaus *supra* note 18.

[37] On intergenerational transfers, see William R. Cline, *Discounting for the Very Long*, *in* DISCOUNTING AND INTERGENERATIONAL EQUITY, *supra* note 24; Joseph E. Stiglitz, *The Rate of Discount for Benefit-Cost Analysis and the Theory of the Second Best*, *in* COST-BENEFIT ANALYSIS (P. Richard, G. Layard & Stephen Glaister eds., 2d ed., 1994).

[38] A. Sandmo & J.H. Drèze, *Discount Rates for Public Investment in Closed and Open Economies*, 38 ECONOMICA 395 (1971). See also the discussion in Arrow et al., *supra* note 9, at 139.

[39] While this view is sometimes linked to the prescriptive approach to discounting, it is logically distinct from it; in the descriptive context, a consumption-based view simply implies that the relevant discount rate should reflect the interest rate used by consumers, rather than the market rate of return on productive investments.

conclusions.[40] However, under real-world conditions they do not, so that the choice between them is a germane one.

In this context, the Proposed Rule's choice of baseline becomes crucial. As the Proposed Rule states, one of the four "filters" used in preparing the interim social cost of carbon is to "use a 'business as usual' climate scenario," arguing that this approach "stems from the judgment that as a general rule, the proper way to assess a policy decision is by comparing the implementation of the policy against a counterfactual state where the policy is not implemented."[41]

Although the SCC is being considered in the context of a proposed policy (e.g., the present proposed rulemaking for vehicle fuel efficiency), it is computed expressly in the *absence* of such policies. It simply represents the value today of the future marginal damages from an additional ton of emissions, starting from a business-as-usual trajectory. In that setting, the proper role of the discount rate is to express future losses in consumption in today's present value. The reason is that when the emissions baseline used to compute the social cost of carbon is a "business as usual" (i.e. no-policy) scenario, the valuation of the damages from a marginal ton of emissions is properly defined entirely in terms of the reduced future consumption.

The rate of return on private capital that might be invested in mitigation efforts is entirely separate from that calculation. This is not to say that the rate of return available on alternative investments should be ignored. Rather, that alternative rate of return should be treated as the opportunity cost of capital — that is, it should be incorporated as a cost of investment rather than as a rate to be used in discounting future consumption.[42]

Of course, it remains to be determined what the appropriate "consumer interest rate" is. We turn to that subject next.

1.2.3.3 Is the rate of return on equities a good proxy for intertemporal trade-offs in consumption?

The Proposed Rule supports its use of a 5% discount rate on the grounds that it "fits market behavior with respect to *individuals'* willingness to trade-off consumption across periods as measured by the estimated post-tax average real returns to risky private investments (e.g., the S&P 500)."[43]

However, this rationale is open to question on two grounds. First, a typical individual holds a diversified portfolio, rather than one that is composed solely of equities. As a result, both the risk and the average rate of return are lower.

Second, the relatively high returns available on equities can be explained by a risk premium that is designed to *compensate* risk-averse investors for the possibility of lower consumption. From an individual's point of view, therefore, this compensation for risk must be distinguished from the intertemporal rate at which she is able and willing to trade off a unit of consumption today for a sure unit consumption in the future. This latter rate of intertemporal substitution is the appropriate measure of "individuals' willingness to trade-

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[40] ROBERT C. LIND ET AL., DISCOUNTING FOR TIME AND RISK IN ENERGY POLICY (1983); Stiglitz, *supra* note 37; Arrow et al., *supra* note 9, at 139.

[41] Proposed Rule 49,612-13 and 49,677.

[42] *See* Arrow et al., *supra* note 9, at 132.

[43] Proposed Rule at 49,614 and 49,677.

off consumption across periods." Arrow et al. refer to this as the "risk-adjusted return on capital," or equivalently the risk-free rate of return. We turn next to how it can be measured.[44]

1.2.3.4 What is the appropriate empirical estimate of the risk-free rate of return?

The rate at which consumers trade off consumption over time is the appropriate discount rate for use in calculating the SCC. This intertemporal trade-off for individuals is best captured by the rate of return on risk-free investments, rather than risky equities. Additionally, rates of return on government bonds can be thought of as a measure of society's willingness to trade off consumption across time periods.

The Proposed Rule suggests that "it is standard to base the discount rate on the compensation that people receive for delaying consumption, and the 3% [rate] is close to the risk-free rate of return, proxied by the return on long-term inflation-adjusted U.S. Treasury Bonds.[45]" The Proposed Rule's use of returns from long-term government bonds is one reasonable approach, although the value cited may be somewhat high; the current yield on long-term inflation-adjusted U.S. Treasury Bonds is actually below 2%.

Alternatively, another suitable proxy for the rate at which individuals trade off consumption over time is the average real return on short-term Treasury bills. Indeed, this is closer to a true risk-free rate of interest than the return on long-term Treasury bonds, which include some residual risk. The real rate of return on short-term Treasury bills has been estimated at 1% over the period from 1889 to 2000, and at the even lower value of 0.3% for the period 1926-1986.[46] The Proposed Rule should consider including this lower rate in its analysis, and if it does not include it must explain why rates of return on long-term bonds, rather than averaged return on short-terms bonds, is the more appropriate choice.

1.2.3.5 Accounting for the distribution of future marginal benefits

Among the rationales provided by the Proposed Rule for its choice of a relatively high discount rate of 5% is that a risk premium is needed in order to account for the nature of mitigation investments: "In the climate setting, the 5% discount rate may be preferable to the riskless rate because the benefits to mitigation are not known with certainty."[47]

From a theoretical point of view, however, the Proposed Rule's approach of seeking to deal with risk by adjusting the discount rate is not the right approach. Arrow *et al.* are admirably clear on this point:

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[44] As Arrow et al. write, "The rate of return on corporate capital, equities, and even bonds can be thought of as including a risk premium for various uncertainties, including the risk of inflation. The very low return on short-term government bonds has the lowest risk component and, some would argue, is closer to the risk-adjusted rate we are seeking." *Id.* at 133.

[45] Proposed Rule at 49,614 and 49,677.

[46] The 1% figure is from N.R. Kocherlakota, *The Equity Premium: It's Still A Puzzle*, 34 J. OF ECON. LIT. 42 (1996), and ELROY DIMPSON, PAUL MARSH, & MIKE STAUNTON, TRIUMPH OF THE OPTIMISTS (2002). The 0.3% figure is from CLINE*, supra* note 16 (cited by Arrow et al., *supra* note 9).

[47] Proposed Rule at 49,614. *See also id.* at 49,678 ("In the climate setting, the 5 percent discount rate may be preferable to the riskless rate because it is based on risky investments and the return to projects to mitigate climate change is also risky. In contrast, the 3 percent riskless rate may be a more appropriate discount rate for projects where the return is known with a high degree of confidence (e.g., highway guardrails).").

> There is also a general consensus about certain basic principles of discount rate analysis. Most economists believe that considerations of risk can be treated by converting outcomes into *certainty equivalents* … and discounting these certainty equivalents.
>
> …
>
> The standard treatment of risk in models involving impacts over a single individual's life is not to raise the discount rate for riskier projects, but instead to convert probabilistic consumption patterns into their certainty equivalents and then discount the result at the standard rate. The same should be true for the pure time preference component of the SRTP when discounting across generations. This component should remain unchanged with respect to risk, and the influence of risk should instead be incorporated in the stream of expected consumption effects.[48]

In other words, discount rates should not be adjusted to "compensate" for the fact that climate change impacts are uncertain. Instead, the proper way to account for risk in climate outcomes is to compute the certainty-equivalent damage, and discount that back to the present with an appropriately chosen discount rate.

A possible response to this argument is that it may not be feasible, for various reasons, to account for risk by calculating the certainty equivalent welfare loss directly, as in the theoretically correct treatment of risk. In section 2.3 below, we return to this issue in the broader context of uncertainty. As we show there, the calculation of a risk premium in the SCC is a "second-best" approach that may be used when the theoretically correct method is infeasible. In addition, the interaction between emissions and the distribution of temperatures leads to a second, distinct argument for a risk premium. Either of those factors could be incorporated through an adjustment to the discount rate, as we note in section 2.3. In that case, however, it is crucial to note that the result will be to lower the discount rate, rather than raising it.

1.2.3.6 What is the significance of correlation between climate impacts and the returns to the economy as a whole?

The Proposed Rule suggests that the appropriate choice of discount rate depends on the correlation between the impacts from a marginal ton of emissions and the general market rate of return on capital in the economy as a whole: "In principle, the correct discount rate would reflect the variance in payoff from climate mitigation policy and the correlation between the payoffs of the policy and the broader economy."[49] Specifically, if payoffs are "highly [positively] correlated with the returns from the broader economy," then a market rate should be used; if payoffs are uncorrelated then a risk free rate should be used; and if payoffs are "negatively correlated" than a rate less than the risk free rate should be used.[50] A similar result can be demonstrated in the context of the Ramsey formula.[51]

As discussed above, expressing the welfare loss in certainty-equivalence terms fully accounts for the associated risks. No adjustment to the discount rate is required. However,

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[48] Arrow et al., *supra* note 9, at 130, 136-37.

[49] Proposed Rule at 49,614 and 49,678.

[50] *See id.* at 49,614 n.369 & 49,678 n.528 (both citing Lind (1982)).

[51] Weitzman (2007), *supra* note 17, at 713.

even if a certainty-equivalence approach is infeasible, likely correlations between returns to the overall economy and climate damages do not lend support to the choice of a relatively high discount rate (e.g. 5%).

The choice of the 5% discount rate essentially treats a decision whether to reduce GHG emissions as an investment in a diversified portfolio — one that exactly tracks the market rate. To the contrary, there are strong reasons for concluding that a substantial fraction of the benefits from abatement are uncorrelated or even negatively correlated with the returns to the economy as a whole.

As Weitzman points out, the IAMs typically build in an assumption of perfect correlation — but this is done purely for mathematical and computational convenience rather than as the result of any reasoned argument. After weighing the question, he concludes that the correlation is likely to be less than one:

> Is there any economic rationale by which greenhouse-warming damages are as much uncorrelated as they are correlated with aggregate economic activity? The answer, when you think about it, is yes. … The parts of an economy likely to be most impacted by global warming involve its "outdoor" aspects (broadly defined) like agriculture, coastal recreational areas, and natural landscapes (including the existence value of ecosystems, species, and so forth). Climate-affected "outdoor" activities may be differently impacted by greenhouse warming than "indoor" economic activities constituting the bulk of the economy.[52]

To the extent that many of the effects of climate change will involve non-market impacts — the decimation of coral reefs, for example, or widespread extinction of terrestrial species — they may be substantially unrelated to the returns in the economy as a whole. If a substantial share of the damages from climate change are expected to be uncorrelated to returns in the economy as a whole, the discount rate should move toward the risk-free rate.

In addition, the relationship between reductions in GHG emissions and economic growth reflects *causation* as well as correlation. Severe climate change could bear negatively and directly on overall economic productivity. For example, sea level rise could threaten large parts of the coastal United States, especially low-lying areas like Florida. In effect, such a causal relationship will be a source of negative correlation between the benefits of mitigation and broader market returns. In climate scenarios with greater temperature change, total damages from climate change will be higher, but total economic activity will be lower (*ceteris paribus*)—marginal damages and therefore marginal benefits of mitigation will be high (due to convexity of damages) while the returns to the broader economy will tend to be low (the productivity effect).

If the Agencies wish to use a market rate of return, all of these complexities must be analyzed in greater detail. Because of the special relationship of GHGs to the market rate of return and to a large range of goods and services (both market and non-market), a simple application of a market rate of return is not justified—a much fuller account of how GHG reductions fit into an optimal portfolio of investments is needed than the extremely skeletal discussion in the Proposed Rule.

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[52] *Id.*

1.3 The Case for Time-Varying Discount Rates

The conventional approach to discounting is to apply a constant discount rate per unit of time. However, the pervasive uncertainty about the appropriate discount rate—evident in the Proposed Rule itself and in the previous section of these comments—provides a very strong rationale in favor of applying differential discount rates over time.[53] A recent strand of papers in the economics literature has shown that uncertainty over the choice of discount rate mandates the use of lower discount rates for costs and benefits that occur later in the future.[54] This uncertainty over discount rates can be viewed in either a static or dynamic sense, and its implications are relevant for both the prescriptive and descriptive approaches described above. Regardless of how it is defined, such uncertainty translates into a "certainty equivalent" or "forward" discount rate that falls over time.

1.3.1 The effect of static uncertainty on the appropriate discount rate

The wide range of proposed discount rates in the literature, and even proposed methods for determining the discount rate, underscores the fundamental uncertainty in this area.

First, there is static uncertainty about the appropriate "best" or "true" discount rate. Such uncertainty could arise from disagreement on the appropriate ethical judgments embedded in the Ramsey equation or disagreement over the appropriate rate of return to use in principle (i.e., a risk-free rate versus the market return on capital).

This "current lack of consensus about the correct discount rate for all future time periods" was captured by Weitzman, in his survey of the "professionally considered gut feeling" amongst 2,160 economists.[55] The survey results are summarized in the table below:

Discount rate (Rounded to nearest whole percentage)	Number of responses
-3	1
-2	1
-1	1
0	46
1	236

[53] An alternative, although less well-established, argument for differential discount rates can be made squarely within the context of the prescriptive approach to discounting. The premise is that each generation weights its own utility more highly than that of subsequent generations, but does not distinguish among those other generations. Arrow refers to this stance as *agent-relative ethics*, and finds some empirical support for it in surveys, where respondents distinguish little between returns one and two centuries from now. Arrow (1995), *supra* note 25, at 17-20. In the context of the Ramsey formulation, this would suggest a positive pure rate of time preference between each generation and the following one—but a zero pure rate of time preference applied among subsequent generations. In practical terms, this would yield a higher discount rate in the near term than in the more distant future.

[54] Martin L. Weitzman, *Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate*, 36 J. ENVTL. ECON. & MGMT. 201 (1998) [hereinafter Weitzman (1998)]; Weitzman (2001), *supra* note 5; Richard Newell & William Pizer, *Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuation?*, 46 J. ENVTL. ECON. & MGMT. 52 (2003); Christian Gollier & Martin L. Weitzman, *How Should the Distant Future Be Discounted When Discount Rates Are Uncertain?* (Working Paper, Nov. 2009), *available at* http://www.economics.harvard.edu/faculty/weitzman/files/discountinglongterm(2).pdf.

[55] Weitzman (2001), *supra* note 5, at 266.

2	454
3	427
4	362
5	227
6	136
7	71
8	44
9	28
10	44
11	15
12	25
13	12
14	5
15	8
16	3
17	2
18	3
19	1
20	4
25	2
26	1
27	1

Total responses = 2,160

This distribution of responses shows a high degree of uncertainty about what the correct rate should be, even assuming a constant discount rate in the future.

The significance of this uncertainty stems from the mathematical fact that if two discount rates are deemed equally likely, it is not the average discount *rate* that should be applied but rather the average discount *factor* at each future point in time.[56] (The discount factor in time *t* expresses the present value of a payment of $1 in *t* years; under the assumption of a constant discount rate *r*, this factor is given by $\delta = e^{-rt}$.) Suppose one thinks that discount rates of 3% and 5% are equally likely, and wishes to discount the value of $100 a century from now. The value of $100 using the lower discount rate is $100e^{-100*0.03}$ = $4.98; the value of the same amount using a discount rate of 5% is $0.68. The average of those two values is therefore $2.83 — corresponding to an *effective* discount rate of 3.6%.[57] Intuitively, more weight is placed on the lower discount rate as the time horizon increases, because the effect of the higher rate declines much more rapidly. It follows that when a range of discount rates is considered, the effective discount rate is lower for costs and benefits that occur further in the future — approaching the lower bound of the range.

Weitzman concludes that the decline in effective social discount rates "warrants inclusion of this sliding-scale feature in any serious benefit-cost analysis of long term environmental projects, like activities to mitigate the effects of global warming."[58] A more recent working paper by Weitzman and Gollier confirms this finding in a very general theoretical model. They state their result succinctly: "When future discount rates are uncertain but have a

[56] Weitzman (1998), *supra* note 54.

[57] A simple calculation verifies that $100e^{-100*0.036}$ = 2.83.

[58] Weitzman (2001), *supra* note 5, at 271.

permanent component, then the 'effective' discount rate must decline over time to its lowest possible value."[59]

1.3.2 The effect of dynamic uncertainty on the appropriate discount rate

Whether or not there is reasonable consensus about the correct discount rate today, the appropriate rate may change over time in ways that are not known in advance. In the prescriptive approach, such dynamic uncertainty could stem from uncertainty about future growth rates (g in the Ramsey formula). Relatively slow growth implies a smaller increase in consumption and thus a smaller decrease in marginal utility over time, implying a lower rate of discount.[60]

Alternatively, dynamic uncertainty could be due to changes over time in economic circumstances, productivity, and market rates of return. Accounting for this type of uncertainty is the focus of Newell and Pizer.[61] Newell and Pizer extend Weitzman's approach in a key direction. They argue that the future discount rate is not only uncertain from *today's* standpoint, but that such uncertainty remains in the future (e.g., because of continued variation in the underlying fundamentals driving productivity and economic growth). In making this argument, Newell and Pizer place Weitzman's insight in an explicitly descriptive framework.

Their methodological approach is to compile a long time series of data on long-term U.S. government bond yields and use it to estimate the underlying behavior of real interest rates. On the basis of this empirical exercise, they conclude that a random walk model of bond rates (in which the best predictor of future rates is the current rate) explains the data better than a mean-reverting model (in which rates may exhibit periods of low or high values but tend to return to a stationary mean value). Newell and Pizer then use their empirical estimates to simulate a large number of future paths for the discount rate. Along each path, they calculate the discount factor at each point in time, and average those factors across all simulated paths. Finally, they use those average discount factors to compute the *certainty-equivalent* forward discount rates in the future— that is, for any given time t in the future, the discount rate that should be applied between t and $t+1$.

We present the quantitative results of their simulation below. Here, we focus on the broader implications of their analysis. Three findings emerge from their data and empirical analysis: (i) real interest rates on U.S. government bonds over the past two centuries have varied between roughly 2% and 8%; (ii) interest rates have fallen over time, with recent rates being at the low end of the observed range; and (iii) long-term interest rates appear to follow a random walk, meaning that future rates are likely to be in a range above and below current rates. These findings suggest that future discount rates will vary from somewhat below to somewhat above their already historically low levels. When combined with Weitzman's insight about averaging discount factors rather than rates, this translates into forward discount rates for long periods into the future that are even lower than current rates, i.e., on the order of 0.5% to 2%.

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[59] Gollier & Weitzman, *supra* note 54.

[60] Arrow et al., *supra* note 9, at 137.

[61] Newell & Pizer, *supra* note 54.

Indeed, Newell and Pizer's conclusion strongly echoes that of Weitzman and Gollier and Weitzman: "appropriate future certainty equivalent discount rates will decline towards the lower bound of possible future discount rates."[62]

1.3.3 Implications for the choice of differential discount rates

Whether conceptualized as static or dynamic, the implications of this "sliding-scale" approach are dramatic. We present three examples.

On the basis of his survey results and the logic of averaging discount factors rather than rates,[63] Weitzman suggests the following set of appropriate discount rates for use over different future time periods:

Immediate future (0-5 years): 4%

Near future (6-25 years hence): 3%

Medium future (26 -75 years): 2%

Distant future (76 -300 years): 1%

Far distant future (301+ years): 0%

Note that each value represents a marginal or *instantaneous* discount rate appropriate during a particular time period, rather than the *average* discount rate. In other words, 2% is the discount rate that should be applied *between* years 26 and 75 — not the discount rate that should be applied to the entire period of time between now and any particular year in that range. We shall return to the latter concept (which corresponds to the average discount rate, and which Weitzman refers to as the *as-if-constant* discount rate) in the next section.[64]

For their part, Newell and Pizer simulate 100,000 future paths of the long-term government bonds rate, assuming it follows a random walk process, as discussed above. Their analysis leads to the following marginal discount rates:[65]

100+ years: 2%

200+ years: 1%

300+: 0.5%.

Notably, Newell and Pizer assume a starting rate of 4%, significantly higher than the current bond rates at the time of their analysis (~3%). The latter rate, of course, would be more consistent with their random walk model—and would lead to even lower forward rates.[66]

[62] *Id.* at 69.

[63] Weitzman (2001), *supra* note 5, at 261.

[64] Note that in our simple example in section 1.3.1, used to develop the intuition behind the Weitzman result, what we called the "effective" discount rate corresponded to an average or as-if-constant rate.

[65] Newell & Pizer, *supra* note 54, at 69.

[66] Recall that their random walk model suggests that the best predictor of future rates is the current rate, in their case 3%. Newell and Pizer explain that they chose 4% because forecasts suggested that interest rates were set to rise, and for expositional purposes they wished to "mak[e] a fair comparison with a constant interest rate." *Id.* at 64 n.27. Although they did rise briefly, current rates are below 3%.

Finally, the use of declining discount rates has also been embraced in regulatory settings in the real world. In particular, the UK's Green Book (2003)[67] includes the following declining long-term discount rates:

0-30 years: 3.5%;

31-75 years: 3.0%;

76-125 years: 2.5%

126 to 200 years: 2.0%;

201 to 300 years: 1.5%

After 300 years: 1% percent.

1.3.4 The treatment of time-varying discount rates in the Proposed Rule

To its credit, the Proposed Rule includes a consideration of the Newell-Pizer method, applying a random-walk process to starting discount rates of 3% and 5%. The Proposed Rule also considers a mean-reversion process. As noted above, however, Newell and Pizer find persuasive evidence for a random walk, making that model the preferred one for use in determining the SCC.

As might be expected, the results of the Newell-Pizer method are dramatic. When it is applied to a 3% starting rate, the resulting model-weighted mean value of the SCC is $55 per ton of CO_2 — much higher than the value of $33 that arises from the use of a constant 3% discount rate.[68]

However, the Proposed Rule accords this estimate second-class status. While it is included in the range of SCC values cited in the Proposed Rule, it is left out of the averaging used to determine the central or "preferred" SCC value of $20. No reason is given other than the recent publication dates of the Newell-Pizer paper: "The Newell-Pizer approach … is a relatively recent contribution to the literature, and estimates are included with the aim of soliciting comment."[69] As we indicate strongly below, the Newell-Pizer approach ought not only to be included—it ought to be the *principal* methodology for calculating the social cost of carbon.

Before reaching that conclusion, however, we respond briefly to another issue raised in the Proposed Rule: namely, the observation that the Weitzman and Newell-Pizer approaches define the underlying uncertainty in discount rates in different ways, and the accompanying request for comment on the advantages and disadvantages of each. [70]

As should be clear from our discussion so far, the difference in the two approaches noted in the Proposed Rule maps into our distinction between "static" and "dynamic" uncertainty. If forced to choose one, the Newell-Pizer approach would appear to have the upper hand, due to its careful use of historical data, its demonstration that time-varying discount rates are

[67] The Green Book provides appraisal and evaluation guidelines for central government appraisals. It constitutes binding guidance for departments and executive agencies. H.M. TREASURY OF THE UNITED KINGDOM, THE GREEN BOOK: APPRAISAL AND EVALUATION IN CENTRAL GOVERNMENT (2003), *available at* http://www.hm-treasury.gov.uk/ data_greenbook_index.htm. Its use of declining discount rates cites work by Weitzman and by Gollier. *Id.* at 98.

[68] Similarly, applying a random walk model to a starting point of 5% results in a doubling of the SCC value, from $5 to $10.

[69] Proposed Rule at 49,615 n. 378 and 49,679 n. 534.

[70] *Id.*

rigorously justified on strictly descriptive grounds, and its development of a rigorous analytical methodology that can be readily applied to the computation of SCC values in the current context.

However, the choice between the "Weitzman approach" and the "Newell-Pizer approach" is in many respects a false one because they both point to the same conclusion: in the presence of uncertainty over the appropriate discount rate, future costs and benefits should be discounted at a rate that declines over time. Indeed, the recent contribution by Gollier and Weitzman (which is not cited in the Proposed Rule) provides a simple yet elegant theoretical model that firmly establishes the generality of the intuition that runs through both Weitzman and Newell-Pizer.

Finally, we note that there are other strong arguments for differential discounting in the *prescriptive* setting that are less well developed but are worth exploring. These include the "agent-relative" ethical approach discussed in footnote 53 above, and the role of uncertain growth rates in the Ramsey equation.

1.3.5 Conclusion regarding declining discount rates

The core logic behind a declining rate — Weitzman's insight about the proper averaging of discount factors — is incontrovertible. The Newell and Pizer analysis demonstrates that even in the context of a descriptive approach to discounting, guided by a rigorous empirical analysis of the best available data, a declining interest rate is not only justified but has significant implications for policy. While the Newell and Pizer analysis may be a recent contribution to the literature, that does not diminish its significance or the validity of its conclusions. In addition, the qualitative conclusions of both Weitzman and Newell-Pizer are reinforced in a general theoretical setting by Gollier and Weitzman.

The use of a discount rate that declines with time is also motivated by a strong epistemological argument, stated forcefully by Weitzman and directly relevant to the interagency review process that lies behind the Proposed Rule:

> There does not now exist within the economics profession, nor has there ever existed, anything remotely resembling a consensus [on the appropriate discount rate]. ... No committee of "experts" will likely to be able to resolve the dilemma—no matter how deeply they delve into it. Therefore, it follows, we should be operating from within a framework that incorporates the irreducible uncertainty about discount rates directly into our benefit-cost methodology.[71]

Weitzman's epistemological argument holds equally well in the context of the dynamic uncertainty about future discount rates that is analyzed by Newell and Pizer. In sum, the evidence from the economics literature is compelling: economic theory, backed up by empirical analysis, provides a very strong basis for using a discount rate that declines over time to a low rate.

However, one potential criticism remains to be considered: the problem of *time-inconsistency*. This criticism arises in the superficially similar setting of "hyperbolic discounting." That term refers to the observed behavioral tendency of individuals to apply a higher discount rate between now and the near future than between adjacent periods in the future. Cropper and Laibson argue that if this approach were applied to public investment

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[71] Weitzman (2001), *supra* note 5 at 261.

projects, it would lead to incoherent investment plans over time. Instead, they suggest simply lowering the required rate of return.[72]

In the next section, we will discuss this latter "shortcut" of choosing a lower constant rate. However, it is important first to explain why the Cropper and Laibson critique does not apply to the rationale for declining discount rates presented here. Although the time profiles of the discount rate may appear similar, the underlying logic is not. In the case of hyperbolic discounting, the differential rates are continuously re-applied at each decision point, as each future period of time turns into the present. That updating is the source of the time inconsistency. In effect, hyperbolic discounting involves a *certain* pattern of discount rates ("high today, low tomorrow") that the planner nonetheless *systematically fails to anticipate*.

In contrast, the logic of declining discounting as presented in the literature cited here is that there is *systematic uncertainty* (i.e., risk) about the appropriate future interest rate that the planner *properly anticipates*. In the Weitzman-Gollier-Newell-Pizer approach, a discrete investment decision must be made today, in the absence of full information about the future discount rate, that will continue to yield returns far into the future. No issue of time inconsistency arises, because by the time we reach the future the decision will have already been made. Declining discount rates merely provide an aid to current decision-making in the face of risk. Nothing in this approach says that we must apply the same discount rate when making future investment decisions: to the contrary, in that setting we may learn more about the "true" discount rate over time, and adjust our decisions accordingly.[73]

We recommend that, in light of both static and dynamic uncertainty around the discount rate, and based on the most recent economic analysis of these questions, a declining differential discount rate should be used to estimate the net present value of future harms, using the Newell-Pizer methodology.

As noted above, the Newell-Pizer approach requires that an initial starting value for the discount rate be chosen. A reasonable choice would be the current real rate of return on long-term U.S. Treasury bonds, which is in the range of 2.5% to 3%. ("Current" could be defined with respect to a reasonable rolling average, e.g., 1-2 years, taking into account the unusual present economic conditions.) This choice is justified on several grounds. First, as argued above, long-term government bonds are widely recognized to be a reasonable measure of the low-risk rate of return corresponding to intertemporal trade-offs in consumption. Second, the Newell-Pizer methodology, including the specific parameter estimates necessary for performing the simulations and computing the forward discount rates, is derived from time series of long-term government bond yields. Third, the use of a current rate of return (rather than a historical average) is the theoretically appropriate approach in the context of a random walk process for interest rates.

Alternatively, a range of initial rates could be used as the starting point for the Newell-Pizer approach. If this approach is used, however, it must first be recognized that the application of the Newell-Pizer methodology *relies on empirically estimated parameters describing the evolution of real rates of return for a particular financial instrument*. As a consequence, *those parameter values will, in general, vary across different financial instruments*.

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[72] Maureen Cropper & David Laibson, *The Implications of Hyperbolic Discounting for Project Evaluation* (World Bank Policy Research Working Paper Series 1943, 1998).

[73] One is reminded of Keynes's famous comment: "When the facts change, I change my mind. What do you do, sir?"

In simple terms, the parameter values used by Newell and Pizer in their simulations (and adopted in the Proposed Rule) were based on an empirical analysis of the real returns from long-term government bonds. Therefore, the appropriate starting point is the current return from such bonds. In contrast, the evolution of real rates of return on, say, equities will follow a different pattern. Using the Newell-Pizer parameter values to simulate future rates of return starting at 5% is equivalent to answering the question: "What would we expect future real rates of return on long-term government bonds to look like, if the current real rate of return on such bonds was 5%?" With the brief exception of the early 1980s, however, the real rate of return on long-term government bonds has not reached that level since around 1870 (according to the data presented by Newell and Pizer). Thus while that is a logically coherent question, it is hardly a germane one.

The choice of starting point cannot be made independently of the underlying financial instrument used to estimate real returns over time. The simulated paths are extensions of a particular time series, and thus correspond to a particular financial instrument. This point appears to have been overlooked not only in the Proposed Rule but also by Newell and Pizer themselves.[74]

Moreover, this point has important practical implications. Real rates of return on equities vary by much more than rates on long-term government debt reflecting the greater risk that merits their higher average rate of return. As a result, the distribution of those returns over time will look very different. Since the Weitzman-Gollier-Newell-Pizer approach to discounting is driven by the lower end of the range, this will make a big difference to the results. Using an initial interest rate corresponding to the return on risky investments (i.e., 5%), but then simulating the evolution of that rate using parameters derived from long-term government bond rates, will lead to a significant upward bias in the effective certainty-equivalent discount rates — effectively attenuating the underlying uncertainty in returns that is the whole point of the Newell-Pizer approach in the first place.[75]

In conclusion, if an alternative starting point is to be used, corresponding to a different financial instrument*, the entire empirical analysis must be repeated with new data in order to estimate the appropriate parameter values*. This conclusion applies with equal force to the 5% starting point used in the Proposed Rule, as it does to any potential additional starting point.

Given the practical difficulties associated with carrying out this empirical task, as well as the inherent appeal and reasonableness of using long-term government bonds as a proxy for the rate at which consumers make trade-offs over time, **we recommend that a single starting point be used for the Newell-Pizer method, defined by the current real rate of return on long-term government bonds.** Note that while this appears to rely on a "single" value for the discount rate, the Newell-Pizer methodology effectively ranges over a

[74] This argument might appear to limit us to using the 4% starting point in the original Newell-Pizer article. However, recall that they acknowledged the appropriateness of a 3% initial point, and essentially used a 4% rate for expositional purposes. Indeed, as noted in the text, Newell and Pizer themselves do not appear to have realized the inconsistency inherent in applying their derived parameter values to an alternative starting point: they demonstrate the results of their methodology using starting points of 2% and 7%. Newell & Pizer, *supra* note 54, at 66. Alternatively, perhaps they realized the inconsistency, but continued despite it in order to demonstrate the implications of their methodology.

[75] Similarly, using the parameter estimates from the Newell-Pizer approach and applying them to a starting point of, say, 1%—corresponding to the real rate of return on short-term Treasury bills—would exaggerate the effect of uncertainty and lead to effective discount rates that were too low.

distribution of discount rates. Thus there is less rationale or need for using multiple initial values in this setting, relative to the case of constant discount rates.

1.4 Choosing a Set of Constant Discount Rates

Despite the compelling logic of declining discount rates, the Proposed Rule nonetheless states a clear preference for choosing a set of constant discount rate as a "preferred approach."[76] In this section, we bring together a range of arguments relevant to how that set should be determined.

We recommend that if the Final Rule includes a range of constant discount rates, that range should extend below 3% to include values of 2% or lower. On the other end of the range, a more appropriate upper bound would be 4%.

1.4.1 Prescriptive and descriptive arguments

The discussion in Sections 1.2.2 and 1.2.3 above have covered the relevant ground already. Here we focus on a few salient conclusions drawn from that discussion. First, using a prescriptive approach, the strong ethical arguments for a very low pure rate of time preference, combined with plausible values for the elasticity of marginal utility and long-term future growth rates, clearly provide support for considering a discount rate of 2% or even 1.5%.

Second, in the context of a descriptive approach, an appropriate measure of the discount rate is the rate at which consumers can trade off consumption over time. Proxies for this rate include the real rate of return on inflation-adjusted long-term government bonds (currently around 2%) and the real rate of return on short-term Treasury bills (historically about 1% or less). These values provide a basis for using a discount rate below 3%.

Meanwhile, the appropriate upper bound rate is below the after-tax rate of return on equities, for several reasons. First, the rate of return on equities includes a premium to as compensation for the lower certainty equivalence, given the riskiness of stock market return; moreover, individuals typically hold diversified portfolios with less risk and lower return. This pair of observations suggests that the rate at which individuals trade off consumption is less than the rate of return on equities alone.

Furthermore, the uncertainty (more properly "risk") over the temperature changes resulting from a ton of GHG emissions does not justify a higher discount rate. To the contrary, incorporating this climate risk into the discount rate would lead to a lower discount rate (i.e., a negative risk premium), for three reasons: to account for risk aversion (via what we called a "second-best" approach); to account for the argument that climate risk is substantially uncorrelated with the returns to the economy as a whole; and to account for the increase in the variance of the distribution of temperature impacts (and thus the risk) that results from higher atmospheric concentrations.

These arguments provide a strong basis for setting the upper value of discount rates below the market rate of return as proxied by the real return on equities, and thus below the 5% rate used in the Proposed Rule.

1.4.2 Implications of uncertainty for the set of constant discount rates

As argued above, the principal implication of uncertainty over discount rates is to use the sliding-scale approach advocated by Weitzman and by Newell and Pizer. Nonetheless, if the

[76] Proposed Rule at 49,679

Agencies choose a set of constant rates, then the appropriate response to uncertainty over discount rates is to use a low constant rate.

This conclusion emerges directly from an earlier paper by Weitzman, in which he concludes that "there is a well-defined sense in which the 'lowest possible' interest rate should be used for discounting the far-distant future part of any investment project."[77]

Again, Gollier and Weitzman provide the core intuition for this result:

> Intuitively, future risk should induce prudent consumers to sacrifice more for the future. This is the Keynesian notion of precautionary saving. This is translated into using a smaller discount rate.[78]

Indeed, this implication has been recognized outside the relatively small economics literature cited here. For example, Sunstein and Weisbach argue that the uncertainty on discount rates, using the specific example of climate change, implies that the discount rate should be "near the very lowest expected rate of return over the long run" and continue that "if an agency uses a high rate, or averages the high and the low, it should be legally vulnerable on the ground that it has acted arbitrarily."[79]

There are several practical implications of this conclusion. Weitzman has concluded that "if we were forced to choose a single constant-equivalent discount rate *r* to represent the entire siding scale schedule for a point-input continuous-output investment then it would be less than 2 percent per annum."[80]

More generally, we can use the sliding-scale results presented in the previous section to compute what Weitzman refers to as the "*constant-equivalent* rate": the discount rate corresponding to the appropriate average discount factor at a given point in time. The results of this calculation, corresponding to the marginal or instantaneous rates presented by both Weitzman and Newell and Pizer (presented on p. 19 above), are given below:[81]

Time of impact	Weitzman	Newell-Pizer
40 years	2.8%	3.7%
100 years	2.1%	3.0%
200 years	1.5%	2.1%
300 years	1.4%	1.6%
400 years	1.3%	1.3%

[77] Weitzman (1998), *supra* note 54, at 201. Note that in this paper Weitzman consciously blurred the distinction between *instantaneous* and *average* rates by considering the limiting result as the time horizon grew to infinity.

[78] Gollier & Weitzman, *supra* note 54, at 9.

[79] David A. Weisbach & Cass R. Sunstein, *Climate Change and Discounting the Future: A Guide for the Perplexed* (Reg-Markets Center Working Paper No. 08-19; Harvard Public Law Working Paper No. 08-20; Harvard Law School Program on Risk Regulation Research Paper No. 08-12, 2008).

[80] Weitzman (2001), *supra* note 5, at 270.

[81] These numbers were calculated by using the marginal discount rates presented in *id.* at 270 tbl.2, and in Newell & Pizer, *supra* note 54, at 65 tbl.2, to compute discount factors at specific points in time; the average or constant-equivalent rates were then computed from the discount factors.

Although the Weitzman and Newell-Pizer series differ, in both cases they are dominated by constant-equivalent discount rates that are well below 3% for the distant future. Indeed, according to Weitzman's estimates (based on an exhaustive survey of economists) the appropriate constant discount rate is already less than 3% even for costs or benefits only 40 years in the future. In the results from Newell and Pizer (based on careful empirical analysis of a long time series of data), the 3% benchmark is passed after a century — and that is given a starting point of 4% that is above current interest rates on long-term government bonds. Moreover, the constant-equivalent discount rate reaches 2% or less on time scales of one or two centuries—well within the relevant range for evaluating the impacts from climate change.

Of course, it is still preferable to use a range of discount rates rather than a single number. However, the powerful conclusion to be drawn from this discussion is not that a single constant number should be chosen. It is that on the basis of the evidence in Weitzman and Newell and Pizer alone, there is a very strong basis for using discount rates below 3%—certainly as low as 2%, and perhaps as low as 1.5% or less—to evaluate the impacts of climate change.

1.4.3 Evidence from surveys and other sources

Given the central importance of the discount rate to the estimated SCC, the complexity of the issues surrounding the determination of the discount rate, and the corresponding uncertainty about the appropriate rate, it is important to demonstrate that the values selected in the interagency review process are broadly consistent with the views of other experts.

1.4.3.1 Findings of outside expert panels

As noted elsewhere, the ongoing interagency review process referred to in the Proposed Rule is not alone in assessing the social cost of carbon. A recent National Academy of Sciences study, published in October of this year, has also taken a careful look at the social cost of carbon. Many of its findings are discussed elsewhere in these comments. Of particular relevance here, however, is the range of discount rates used by the study authors in their report: 1.5%, 3%, and 4.5%.[82] The study does not describe the rationale for those numbers. However, their appearance in such a carefully written and peer-reviewed study is notable, and suggests support for including a value lower than 3% if a range of discount rates is to be considered.

1.4.3.2 Evidence from Weitzman's survey of economists

A second source of information about what might be "reasonable" choices of constant discount rates comes from Weitzman's survey of over two thousand economists as to the "appropriate real discount rate to be used for evaluating environmental projects over a long time horizon," with explicit reference to global warming.[83] The results were presented in full in section 1.3 above. Here, we simply pause to note a few salient facts. First, the mean of the distribution was 4%, with a standard error of 3; although as already noted it was strongly skewed. Second, and perhaps more interestingly, the *mode* of the distribution was 2%, with slightly more economists choosing that number (on an integer basis) than the

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[82] NAT'L RES. COUNCIL, NAT'L ACAD. OF SCI., HIDDEN COSTS OF ENERGY: UNPRICED CONSEQUENCES OF ENERGY PRODUCTION AND USE 219 (2009).

[83] Weitzman, *supra* note 5, at 271.

runner-up, 3%. Third, slightly more respondents selected 1% than chose 5% (236 to 227, or roughly 11% of respondents in each case). Fourth, well over half (58%) of the responses fell in the range of 2% to 4%.

These data do not prove anything by themselves, and are not a substitute for reasoned and rigorous analysis. However, they do add considerable weight to the claims that 2% belongs solidly in the range of reasonable discount rates, and more generally that a range of 2% to 4% would be squarely in line with the "professionally considered gut feeling" of economists.

1.4.3.3 Evidence from a recent expert survey

A recent study[84] conducted by researchers at New York University School of Law surveyed the opinions of economists who had published articles related to climate change in one of the top twenty-five economics journals during the past fifteen years.[85] The study found disagreement on the appropriate methodology to account for the intergenerational aspects of climate change. Nearly an equal number of respondent choose "alternative discounting methodologies (such as hyperbolic discounting)" as constant rate discounting.[86] Participants were also asked their views on appropriate discount rates, if constant rates were used. Interestingly, there was a relatively restricted interquartile range—the middle 75% of participants selected discount rates in the range of 1%-3.9%. Estimates of central tendency were also fairly similar: median (2.4%), mode (3%), and mean (2.89%). These figure tend to show a strong convergence around a fairly restricted number of discount rates toward the lower end and below of the values considered by the Proposed Rule.

Section 2: Uncertainty

Any attempt to assess the damages from climate change is subject to a vast array of uncertainties. A recent report by the National Academy of Sciences concluded that uncertainty pervades each link in the estimation of the economic damages from increased emissions—namely, the effect of emissions on climate; the effect of climatic changes on regional physical impacts; and the effect of impacts on damages:

> [Climatic changes from emissions], which include the extent of ice sheet melting and shifts in regional distribution of precipitation are still subject to considerable uncertainty. … [W]hile natural scientists mostly agree on the climatic variables whose impacts should be studied, there is less consensus on what are significant impacts that should be examined. Moreover, even those impacts thought to be significant (e.g., species loss) respond to changes in climate in ways that are poorly understood.[87]

In addition to the uncertainties around emissions, climatic response, and physical impacts mentioned in the quote, estimating the SCC is also subject to a wide range of economic

[84] J. Scott Holladay, Jonathan Horne & Jason A Schwarz, *Economists and Climate Change: Consensus and Open Questions* (Institute for Policy Integrity Policy Brief No. 5, 2009).

[85] See generally *id.* for more detail on the methodology used.

[86] 37.5% choose constant rate discounting, 36.8% choose alternative, with 16.7% choosing "moral inquiries unrelated to discounting." *Id.* It is also worth noting that a majority of respondents did not agree that that constant rate discounting—the approach adopted by the Proposed Rule—was preferred. Further, if it is defensible to assume that more of the respondents who preferred moral inquires would, if forced to choose between constant or alternative methodologies, prefer the alternative methodologies, then there is more support for alternative discounting treatments, like declining discount rates, than for constant rate discounting.

[87] HIDDEN COSTS OF ENERGY, *supra* note 82, at 185.

uncertainties, including disagreement over discount rates and underlying parameters such as the elasticity of marginal utility; uncertain forecasts of economic growth, technological change, and population; and difficulty monetizing known environmental effects.

The Proposed Rule recognizes that scientific knowledge about climate change's speed and severity is imperfect, and that economic models of climate change's impacts are incomplete. Accounting for these uncertainties within the SCC is one of the most important challenges facing the interagency group.

2.1 Uncertainty in IAMs

As with any mapping exercise, creating an IAM requires simplifying the realities of climate change. IAMs represent sophisticated attempts to aggregate what is known about the effects of climate change, but they do not limit uncertainty and their tentative nature of their results is widely recognized. Again, the National Academy study is incisive:

> IAMs adopt reduced-form approaches which reduce these complex relationships into simplified response surfaces, in the process oversimplifying the complexities of the underlying science. In addition, IAMs typically … consider only relatively narrow sets of impacts or types of damage.[88]

As the Proposed Rule states, "existing IAMs do not currently individually account for and assign value to all of the important physical and other impacts of climate change that are recognized in the climate change literature."[89] However, uncertainty and risk are not the same. Whereas "risky" denotes events whose probabilities are known, like the numbers on a roulette wheel, "uncertain" denotes events of unknown probability.[90] Efforts to project the path of climate change, and to map its implications for the world economy, must take account of a host of *uncertain* factors, making the task attempted by IAMs uniquely difficult.[91] Some aspects of climate change are likely to continue to resist reduction to parameters with known ranges for quite some time.[92]

The uncertainties that inhere in an IAM do not undermine the usefulness or importance of climate change projections, or of a calculation of the SCC, but those uncertainties should be treated as core features of those projections and calculations.

Scientific understanding of climate change continues to improve,[93] and IAMs must continually be updated to reflect most recent understandings. New discoveries can have

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[88] *Id*.

[89] Proposed Rule at 49,616.

[90] Howard C. Kunreuther & Erwann O. Michel-Kerjan, *Climate Change, Insurability of Large-Scale Disasters, and the Emerging Liability Challenge*, 155 U. PA. L. REV. 1795 (2007).

[91] Weitzman (2009), *supra* note 3, at 1 ("What is the essence of the economic problem posed by climate change? . . . [D]eep structural uncertainty in the science coupled with an economic inability to evaluate meaningfully the catastrophic losses from disastrous temperature changes.").

[92] *See, e.g.*, Gerard H. Roe & Marcia B. Baker, *Why Is Climate Sensitivity So Unpredictable?*, 318 SCIENCE 629, 631 (2007) ("foreseeable improvements in the understanding of physical processes, and in the estimation of their effects from observations, will not yield large reductions in the envelope of climate sensitivity. This relative insensitivity of the probability distributions to{sigma}f is also a likely reason why uncertainty in climate sensitivity estimates has not diminished substantially in the past three decades.").

[93] *See, e.g.*, O. Hoegh-Guldberg, et al., *Coral Reefs Under Rapid Climate Change and Ocean Acidification*, 318 SCIENCE 1737, 1738 (2007) (depicting chemical processes that connect CO2 emissions to ocean acidification and thereby to the impairment of carbonate shell formation which provides a baseline for ocean food chains); Victoria J. Fabry, *Ocean Science: Marine Calcifiers in a High-CO2 Ocean*, 320 SCIENCE 1020, 1021 (2008) (discussing limits of

profound effects on a model. For example, recent evidence that the absorptive capacity of oceans moving forward may be significantly less than previously thought[94] suggests a faster rate of translation from CO2 emissions to atmospheric stocks. This may also be an example of nonlinear climate responses that are difficult to predict because of unknown "tipping points."[95]

In general, fully capturing the damages from climate change remains a challenge for IAMs. One problem is simply the mismatch between projected temperature changes under a business-as-usual emissions trajectory, and what is known about damages. As the National Academy report concludes,

> Estimates of total climate damage also depend critically on the degree of temperature change that is being assessed. With the exceptions of the Titus (1992) and Tol (2002b) assessments of a 4°C and 1°C temperature increase respectively, all the other studies … focus on a benchmark warming scenario of 2.5-3.0°C, corresponding to best estimates of eventual temperature change from a doubling of GHG concentrations. … Yet in the absence of substantial mitigation action, projections of baseline GHG emissions tend to imply estimates of likely temperature increases that are significantly greater than that associated with a doubling of GHG concentrations. For example, the IPCC [Fourth Assessment Report] references plausible projections … of about 5-6°C and a likely range from just under 4°C to over 8°C. But little is known about the precise shape of the temperature-damage relationship at such high temperatures.[96]

In other words, as Richard Tol has pithily observed, "the research stops just when things start to get bad."[97] This lack of knowledge has important consequences for the estimation of the SCC: differences in the specification of the damage function across IAMs account for an order-of-magnitude difference in the resulting SCC estimates.[98]

Beyond the *levels* of damages, the nonlinearity of climate responses remains a particular challenge. As noted already, the distribution of damages from GHG emissions is highly skewed, with a long righthand "fat tail" of relatively low-probability but potentially catastrophic events including fundamental disruptions in ocean circulation, irreversible sea level rise of several meters, or severe biodiversity loss.[99] Recent work by Weitzman has

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scientific understanding of how ocean acidification could affect basic links in ocean food chains); Wayne Hsiung & Cass Sunstein, *Climate Change and Animals*, 155 U. PA. L. REV. 1695 2007) (reporting that even without including non-use values, the estimated economic impact of biodiversity loss is tremendous).

94 S. Khatiwala et al., *Reconstruction of the History of Anthropogenic CO2 Concentrations in the Ocean*, 462 NATURE 346-349 (2009) (finding that rate of CO_2 emissions absorption by oceans has slowed substantially in past 30 years).

95 Timothy M. Lenton et al., *Tipping Elements in the Earth's Climate System*, 105 PROCEEDINGS OF NAT'L ACAD. SCI. 1786 (2008).

96 HIDDEN COSTS OF ENERGY, *supra* note 82, at 213.

97 Comments of Richard S.J. Tol at a panel on the social cost of carbon, New York University Law School, November 10, 2009.

98 HIDDEN COSTS OF ENERGY, *supra* note 82, at 264.

99 Two points are worth making here. First, "catastrophic" and "abrupt" are not synonyms, although they are often lumped together and indeed coincide for some impacts (e.g., the reversal of the North American thermohaline circulation). *See id.* at 208. Second, in at least some estimates the "low" probability associated with catastrophic events is not all that low. Weitzman, for example, estimates a 5% chance of eventual warming

demonstrated the fundamental impact such "fat tails" can have on cost-benefit analysis: in the presence of risk aversion, along with the undeniable structural uncertainty about the climate system, the expected welfare damages from climate change are theoretically infinite — suggesting that the conventional cost-benefit analysis based on intertemporal models of consumption smoothing over time (i.e., IAMs) is poorly equipped to handle them.[100] Indeed, in a simple but general theoretical framework, Naevdal and Vislie find that in the presence of thresholds in damage functions, the magnitude of damages dwarfs even the choice of discount rate in determining the optimal stabilization target.[101]

Similarly, drawing on Weitzman's analysis, the National Academy study finds that IAMs are poorly equipped to incorporate such effects:

> [T]he possibility of extreme events is not well handled by IAMs in calculating the marginal damages of CO_2. … Clearly, the nature of the probability distribution of catastrophic outcomes matters, and is handled only imperfectly by the WTP calculations [in the DICE model] or by the Monte Carlo simulations performed to capture uncertainty in the key parameters of IAMs. The key problem here is that low-probability extreme-impact events located in the fat tails, which are extremely difficult to quantity, might drive the results of cost-benefit analysis.[102]

Again, these issues are critical to the computation of marginal damages that enter into the estimation of the SCC.[103]

Furthermore, the representation of such catastrophic impacts in IAMs may also be highly sensitive to subtle interactions among different model parameters, and thus not adequately captured by conventional sensitivity analysis that varies one value at a time. The 2007 iteration of DICE, for instance, addresses uncertainties by evaluating the significance of each of eight "major uncertainties" on the model's outputs, but this yields only an ordinal ranking of significant "known unknowns," one of which is the temperature-climate sensitivity coefficient. However, as has since been observed, while simply varying this coefficient does not change the model's conservative outputs, varying *both* this coefficient and the shape of the damage function can generate scientifically more extreme scenarios.[104]

An important characteristics of the uncertainties of climate change is that they are not balanced. The negative implications of the uncertain factors related to climate change tend

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of 11°C or higher along a business-as-usual trajectory, drawing on distributions of climate sensitivity in the IPCC's Fourth Assessement Report, although it should be noted that Weitzman's estimates are not universally accepted. *See* Weitzman (2009), *supra* note 3, at 1.

100 *See id*.

101 Eric Naevdal & Jon Vislie, *Climate Change, Catastrophic Risk and the Relative Unimportance of Discounting* (Univ. of Oslo Dep't of Econ. Memo. 28/2008, 2008), *available at* http://www.oekonomi.uio.no/memo/2008/pdf_filer/Memo-28-2008.pdf.

102 HIDDEN COSTS OF ENERGY, *supra* note 82, at 210-11.

103 *Id*. at 213 ("The expected value of damages may be more sensitive to the possibility of low-probability catastrophic events than to the most likely or best-estimate values.")

104 *Compare* WILLIAM NORDHAUS, THE CHALLENGE OF GLOBAL WARMING: ECONOMIC MODELS AND ENVIRONMENTAL POLICY 105-108 (2007), *available at* http://nordhaus.econ.yale.edu/dice_mss_072407_all.pdf, *with* Frank Ackerman et al., *Fat Tails, Exponents, and Extreme Uncertainty: Simulating Catastrophe in DICE* (Stockholm Env't Inst. Working Paper WP-US-0901, May 11, 2009) *available at* http://www.sei-us.org/WorkingPapers/WorkingPaperUS09-01.pdf.

to outnumber and outweigh positive implications—a point noted by the IPCC's Fourth Assessment Report and by EPA.[105] Uncertainty in the SCC estimates, then, is not only variance about a central estimate, but a skew upward in the SCC value. While the Proposed Rule acknowledges the IPCC's position that negative uncertainties likely dominate, it also suggests that, "in the opposite direction," technological change could outpace expectations, thereby causing the SCC to represent an overstatement of future damages.[106] For the most part, however, technological change relevant to climate policy is likely to involve innovation in mitigation and sequestration technologies—thereby lowering the *costs of abatement*, but not the *damages from emissions* that are captured by the SCC.[107] Moreover, the SCC estimate uses a business as usual baseline, implying a negligible economic incentive to invest research and development in carbon abatement and sequestration technologies, and thus no obvious source for such technological innovation. Even if the baseline is altered to one with a market incentive to innovate (a cap or carbon tax regime), it is far from clear that uncertainties around technological development truly counterbalance climate uncertainties.

We recommend that the Final Rule acknowledge that uncertainty in the SCC is skewed upward, towards a higher SCC. The Agencies may consider an "uncertainty premium" to attempt to quantify residual upward uncertainty as a percentage of the SCC.

2.2 Quantifying Risk in the SCC through PDFs and Sensitivity Analysis

A SCC that reflects only a central estimate of the harms associate with GHG emissions will miss an extremely important feature of the problem of climate change—the high level of variance around the expected harm, including risks of extreme or catastrophic consequences. Use of probability density functions (PDFs) and sensitivity analyses where appropriate can help capture of this important element of the climate change problem.

PDFs are better suited than a central estimate to integrate a variety of risks and uncertainties and convey the results of an analysis fully and concisely; they have become a widespread too for depicting SCC values.[108] A PDF records the outcomes of a Monte Carlo

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[105] Proposed Rule at 49,611 and 49,676 (quoting IPCC Fourth Assessment Report, "It is *very likely* that globally aggregated figures underestimate the damage costs [of climate change] because they cannot include many non-quantifiable impacts."); EPA, TECHNICAL SUPPORT DOCUMENT ON BENEFITS OF REDUCING GHG EMISSIONS (2008); *see also* EPA, EPA-420-D-09-001, DRAFT REGULATORY IMPACT ANALYSIS: CHANGES TO RENEWABLE FUEL STANDARDS PROGRAM 689 (2009) (noting that "the current trajectory for [global] GHG emissions is higher than typically modeled" and the "current regional population and income trajectories…are more asymmetric than typically modeled," such that actual climate change and vulnerability to climate change is likely much greater than captured by current SCC estimates).

[106] Proposed Rule at 49,680.

[107] To the extent that a reduction in marginal costs increases the efficient amount of abatement, technological change in abatement and sequestration could lower the social cost of carbon *along an efficient trajectory*. However, as noted in the text, the Proposed Rule explicitly considers a baseline or business-as-usual trajectory, deliberately rejecting any attempt to compute an economically efficient policy path. Moreover, even along an efficient trajectory the contemplated effect would be indirect, mediated by the reduction in emissions triggered by the fall in costs. In simple terms, it results from a movement along the marginal damages curve, rather than a shift in that curve. Such an indirect effect does not seem to be what the Proposed Rule has in mind as a "counterbalance" to the enormous uncertainties on the damages from climate change.

[108] *See* Richard S.J. Tol, *The Social Cost of Carbon: Trends, Outliers, and Catastrophes*, 2 ECON.: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL 25 (2008), *available at* http://www.economics-ejournal.org/economics/journalarticles/2008-25; Richard S.J. Tol, *The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, 33 ENERGY POL'Y 2064 (2005) (reporting results of meta-analysis that consolidated dozens of SCC estimates into a meta-PDF).

simulation, which iterates a mathematical function or model repeatedly. By "simulating" the behavior of that model's interacting variables not just once, but many times, this process serves to indicate both the possible range of that function's outcomes and their relative likelihood. A PDF thus suggests the value or values that appear most frequently, while also providing an indispensable statistical context for those values.

Sensitivity analyses are similarly standard features of SCC estimations.[109] A sensitivity analysis examines the nature of an individual variable's influence on the expression of a full equation of interacting variables. This makes it especially useful in the climate change context, where it is critical to understand not only which variables dominate others in terms of their significance to the model as a whole, but also under what conditions particular variables or groups of variables are more or less significant.

While the Proposed Rule includes a range of SCC values, two drawbacks of its approach make it inferior to the use of an explicit distribution. First, the range in the Proposed Rule is a set of model-weighted means from three IAMs under various assumptions about discounting. By taking means within each model, and then averaging across models within each methodological approach, the Proposed Rule loses a great deal of relevant information about the underlying distributions of SCC values. A collection of means is no substitute for a fuller presentation of the underlying nature of the distributions, which is critical in understanding and interpreting the damages from climate change.[110]

Second, the Proposed Rule compounds and exacerbates the problem by computing an additional "preferred" central estimate of $20/ton that is the simple average of the SCC values derived under assumptions of constant discount rates of 3% and 5%. We have already commented on that particular choice of discount rates. The additional point here is that by averaging only those two SCC values and including the result in its reported range, the Proposed Rule accords undue weight to the constant-discount approaches and effectively biases the range of SCC values downward: instead of four values of $6, $10, $34, and $55 (implying a simple average of $26), the Proposed Rule includes a fifth value of $20.

In sum, the Proposed Rule's approach obscures a wealth of information that is both useful and important to policymakers, including the relative probability of different values and other features of those values' statistical context.[111] Including this information gives a more accurate picture of the SCC and avoid obscuring the fundamentally risk-management characteristic of climate policy. [112]

We recommend, to the extent possible, that the SCC be expressed as a PDF. At the very least, for each distinct methodological assumption (i.e., each approach to the discount rate), the Final Rule should report a broader set of descriptive statistics in addition to the model-weighted mean (e.g., variance, skewness, and interquartile range). Moreover, the central estimate should draw on all the relevant modeling

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[109] *Id.*

[110] *See* HIDDEN COSTS OF ENERGY, *supra* note 82, at 211 ("Clearly, the nature of the probability distribution of catastrophic outcomes matters.").

[111] Howard Kunreuther et al., *Ambiguity and Underwriter Decision Processes*, 26 J. ECON. BEHAV. & ORG., 337, 342-44 (1995) (discussing how insurers makes sense of statistical information about the effects of climate change).

[112] *See* David Anthoff, Richard Tol & Gary Yohe, *Risk Aversion, Time Preference, and the Social Cost of Carbon*, 4 ENVTL. RESEARCH LETTERS 1 (2009) (identifying uncertainty as a dominant variable in SCC estimation); Weitzman (2007), *supra* note 17, at 719 (arguing that analysts must pay greater attention to uncertainties, because they dominate risk in terms of their implications for climate change outcomes).

runs, rather than only a subset of them. Finally, the Final Rule should carry out and report on a wider sensitivity analysis on key variables.

2.3 Treatment of risk-aversion and accounting for risk premium

The Proposed Rule solicits comment on whether low-probability catastrophic risks oblige inclusion of a risk premium in the SCC value.[113]

As discussed above, the theoretically correct treatment of risk computes the certainty-equivalent welfare loss directly. However, that approach may not be feasible. It may be impractical to calculate certainty equivalence when surveying model results in the published literature. Alternatively, if the damages are expressed directly in terms of income (i.e., GDP), then the certainty-equivalence approach requires that a concave utility function be specified, raising difficult parameterization questions (discussed above).

If the certainty equivalence approach is not employed, another method must be used to account for the riskiness in the distribution of climate damages. Two alternative approaches can be used. The first is to compute a risk premium as an "adder" to the derived SCC values. Conceptually, this risk premium represents the difference between the welfare from expected damages in monetary terms and the expected welfare given the distribution of damages —that is, the difference between the expected GDP impacts and the certainty equivalent of those GDP impacts. A second approach to incorporating risk in such a second-best setting is to adjust the discount rate.

The key point to make is that the direction of the adjustment—whether through a discrete "adder" or an adjustment to the discount rate—must be in the direction of *increasing* the SCC estimates. This result reflects the well known fact of risk aversion, which dictates that people are generally willing to pay to avoid variance of investment returns.[114] So long as there is positive risk aversion, the certainty-equivalent welfare loss from the risky distribution of impacts associated with an increase in emissions will be greater than the welfare loss from the expected (mean) impact of the same increase in emissions.[115]

The practical implication is that the greater the difference between the certainty-equivalent welfare loss and the expected welfare loss (i.e. the greater the variance and the level of risk-aversion), the higher is the appropriate "risk adder" and the *lower* is the appropriate risk-adjusted discount rate.

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[113] Proposed Rule at 49,680.

[114] *See* Sonia Quiroga & Ana Iglesias, *A Comparison of the Climate Risks of Cereal, Citrus, Grapevine and Olive Production in Spain*, 101 AGRICULTURAL SYSTEMS 91, 98-99 (2009) (specifying risk premium in relation to risk aversion among Mediterranean agricultural producers); Howard C. Kunreuther & Erwann O. Michel-Kerjan, *Climate Change, Insurability of Large-Scale Disasters, and the Emerging Liability Challenge*, 155 U. PA. L. REV. 1795 (2007) (discussing calculations for insurance policies amid climate change); Alicia N. Rambaldi & Phil Simmons, *Response to Price and Production Risk: The Case of Australian Wheat*, 20 J. FUTURES MARKETS 345 (2000). *See also See* Joseph E. Aldy et al., *Designing Climate Mitigation Policy* 14 (Res. for the Future Disc. Paper 08-16, May 2009) (noting that proper risk premium estimate is the subject of dispute, and that is varies with estimates of the marginal utility of consumption net of climate damages); Anthoff et al. supra note 112(distilling from historical data values for the elasticity of marginal utility with respect to consumption, and identifying salience of uncertainty in SCC calculation).

[115] This is a consequence of Jensen's Inequality and the concavity of the utility function.

Note that, contrary to the conjecture made in the Proposed Rule, **any adjustment to the discount rate for risk should reduce the discount rate, not increase it.**[116]

Finally, it is worth pointing out an additional and entirely distinct argument in favor of a negative risk premium. An increase in emissions spreads the distribution of temperatures, increasing risk and lowering welfare. Not only is there a probability distribution concerning the impact of a ton of emissions; that distribution is itself a function of concentrations. The higher the atmospheric concentration, the greater the variance around impacts of a ton of GHG emissions.[117] As a consequence, an increase in emissions has the effect of spreading out the temperature distribution. In the presence of risk aversion, this increase in risk will reduce utility. In other words, a marginal ton of emissions imposes an additional welfare loss by increasing the riskiness of the temperature distribution.[118] The effect of this increase in spread is distinct from the mere presence of risk discussed above. The practical implication is that an additional risk premium should be computed and incorporated into the estimates of the SCC, either by adjusting the discount rate downward or as a discrete "adder" for the SCC. What is more, the rationale for this additional risk premium remains even if the presence of underlying risk is accounted for directly, through the use of certainty equivalence.[119]

We recommend that if the riskiness of temperature impacts is not accounted for directly through the curvature of the utility function, a risk premium (either a positive "adder" or a reduction in the effective discount rate) should be used. In addition, we recommend that the SCC take into account the relationship between marginal GHG emissions and the variance of temperature impacts through the integration of an additional risk premium into the SCC (again, either as an "adder" or a reduction in the discount rate).

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[116] Risk aversion implies that the future stream of income required to compensate future generations for the damages from a marginal ton of emissions will be greater than the expected loss of consumption. Hence present generations would need to set aside a greater sum today in order to provide that compensation. To incorporate that effect into the discount rate requires a *lower* discount rate, i.e., a negative risk premium. The logic is precisely the same as in Gollier and Weitzman's explanation of their results, cited elsewhere in the text: "Intuitively, future risk, should induce prudent consumers to sacrifice more for the future….This is translated into using a smaller discount rate." Gollier & Weitzman, *supra* note 54, at 9.

[117] Climate sensitivity is defined as the equilibrium change in mean global temperature resulting from a doubling of the atmospheric CO_2 concentration. Its distribution is skewed, with a longer right tail: in the estimates surveyed by the IPCC, the medians of the distributions are clustered around 3, with 5-to-95% uncertainty ranges running from 1.5 to 6 or higher. Gerald A Meehl, Thomas F. Stocker, et al., *Global Climate Projections*, *in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENT PANEL ON CLIMATE CHANGE 798-99 box 10.2 (Solomon et al., eds. 2007). An increase in emissions shifts the temperature distribution to the right. This rightward shift in the temperature distribution is smaller at lower temperature changes because those temperatures represent lower levels of climate sensitivity. The same increase in emissions will lead to greater temperature changes on parts of the distribution subject to greater sensitivity. (This point is due to Steve Rose).

[118] It might be argued that in the case of a marginal change in emissions, these effects of risk aversion will be of second-order magnitude. However, because we are not considering an optimal trajectory, there is no applicable first-order condition and therefore the envelope theorem does not apply.

[119] This conclusion is logically consistent with the argument made above that a positive risk premium is not a theoretically appropriate way to incorporate the riskiness of climate outcomes. In that case, the distribution of outcomes is (implicitly) assumed to remain the same, so that the welfare effect is correctly captured by certainty equivalence. In contrast, the increased spread in the distribution of temperature changes that results from an increase in emissions has an independent effect on welfare. Even if the expected value of future consumption were unchanged, this increase in the spread would lower the certainty-equivalent value of that consumption.

2.4 Accounting for Option Value

The pervasive uncertainties in connecting emissions increases to temperature changes noted above combine with the shape of the distribution of the climate sensitivity to generate a distribution of damages that is highly skewed, with a long "fat tail" of high damages. We have already noted that these low-probability, catastrophic events are not well handled by IAMs.

One solution to this analytical weakness would be to address it directly, by improving the treatment of catastrophic risk in the IAMs and then recalculating the SCC. This is an important area for research and represents an important potential contribution by the Agencies. We note that the SCC values presented in the Proposed Rule are explicitly "interim" values, suggesting that there is a role for further analysis of this sort. **We recommend that the final estimates of SCC be based on improved versions of the major IAMs that directly incorporate catastrophic risk.**

Until that work can be completed, however, this gap in the capabilities of IAMs provides an argument for augmenting the estimated SCC values. We sketch one possible approach here, acknowledging that it is speculative and offering it in the spirit of a suggested way forward rather than a definitive judgment.

The starting point for our discussion is that some of the potential impacts from climate change are likely to be irreversible, once certain thresholds or "tipping points" are crossed. A potential example is the release of methane from thawing Arctic permafrost, which may (in sufficient amounts) trigger a positive feedback loop that cannot be halted.

The twin elements of *uncertainty* and *irreversibility* provide the preconditions for the application of real options theory. Intuitively, the continued release of GHG emissions along the current business-as-usual trajectory moves the climate system closer to one of these unknown thresholds. Moreover, those emissions (in the case of carbon dioxide) remain in the atmosphere for roughly a century. At the same time, we continue to learn about the climate system. If we learn (some time in the near future) that the true climate sensitivity is toward the upper end of its currently estimated distribution, by then it will be effectively impossible (or at the very least extremely costly) to "take back" the emissions released in the interim.

By contrast, a policy that reduces emissions today preserves the option to act even more aggressively in the future if conditions warrant. In other words, emitting a marginal ton today closes an option to delay that emission (through abatement) until the magnitude of damages is better understood. This "option value" should properly be accounted for in estimating the benefits of emissions reductions—and therefore the damages of increased emissions, which foreclose the option.[120]

One practical means of incorporating option value into the SCC estimates would be to adjust the discount rate. In the real options theory of investment, an option value associated with

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[120] *See* Jon Anda, Alexander Golub & Elena Strukova, *Economics of Climate Change: Benefits of Flexibility*, 37 ENERGY POLICY 1345 (2009). *See also* Gary Yohe, Natasha Andronova, & Michael Schlesinger, *To Hedge or Not to Hedge Against an Uncertain Climate Future?,* 306 SCIENCE 216 (2004). Meanwhile, Pindyck takes the contrary view that real options theory supports delaying rather than accelerating investment in emissions abatement; however, he assumes linear benefits from abatement (rather than nonlinear and potentially irreversible responses). *See* Robert S. Pindyck, *Irreversibilities and the Timing of Environmental Policy*, 22 RESOURCE & ENERGY ECON. 233 (2000). Anda et al. *supra* consider the distributions of both marginal abatement costs and marginal abatement benefits (damages) in finding a significant option value associated with more aggressive emissions reduction policies.

delaying irreversible investment can be represented as an increase in the effective "hurdle rate" that the expected returns on the investment must meet to be worthwhile.[121]

In the case of climate change, the "investment" that is delayed is the additional ton of emissions. The logic of real options theory suggests that the option value associated with delaying emissions can be represented through the discount rate. In this case, however, since the "investment" provides a current benefit in return for an uncertain stream of damages in the future, incorporating option value will *reduce* rather than increase the effective discount rate.

We recommend that the Agencies explore the ideas presented here to see whether a practical method can be found of incorporating option value through a lower social discount rate.

Section 3: Global Valuations

The Proposed Rule rightly concludes that "the global measure [of SCC valuation] is preferred."[122] This conclusion reflects three premises: climate change relates to a global public good; greenhouse gas emissions and the damages they inflict are inescapably international; and the United States is seeking international agreement to reduce emissions worldwide. The Proposed Rule, however, also reports an estimate of the percentage of global impacts that will be felt in the United States. If the Final Rule also presents this value, it should reflect the full range of pathways through which international events can affect the United States, including increased risks to national security, the transnational spread of infectious diseases, and market disruptions.

3.1 The Importance of Using a Global SCC

There are a variety of reasons that a global SCC is vastly more appropriate for use in federal rulemaking than a purely "domestic" SCC. Perhaps most obvious is the set of technical difficulties associated with attempting to determine what portion of global climate change effects will have impacts on the United States. Beyond these types of practical considerations, for reasons of economic rationality, basic moral principles of comity and justice, and international relations, a global SCC should remain the preferred approach.

As the Proposed Rule recognizes, the control of GHG emissions presents a public good problem. A public good is one that is both non-rivalrous and non-excludable. These types of goods will be under-provided by markets because they are subject to free-rider problems. While everyone may benefit from a public good, compensating the supplier of the good is extremely difficult. As a non-rivalrous good, the marginal cost of an additional user is zero; as a non-excludable good, there is no way for suppliers to restrict access to the good.

Climate stability is a classic public good. The enjoyment of climate stability by one person does not interfere with the enjoyment of climate stability by another person. In addition, once climate stability is provided, there is no way to "exclude" anyone from enjoying its benefits. Under these conditions, we can expect, and in fact have seen, under-provision of this good. From an economic perspective, there is too little investment in climate stability.

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[121] See Avinash K. Dixit, *Investment and Hysteresis*, 6 J. ECON. PERSPECTIVES 107 (1992) for an accessible treatment. *See also* Kevin A. Hassett and Gilbert E. Metcalf, *Energy Conservation Investment: Do Consumers Discount the Future Correctly?*, 21 *Energy Policy* 710 (1993), for a practical application of this approach in the case of consumer investment in energy-efficient durable goods.

[122] Proposed Rule at 49,612 and 49,676.

A classic solution to a public good problem is through government provisions. National defense is typically thought of as a public good, and the typical solution is for the government to "supply" defense and then charge the "consumers" through a mandatory tax. All potential beneficiaries are subject to the tax, which can be levied on the basis of the aggregate (rather than marginal) costs of provision—solving both the non-excludability and non-rivalry problems.

Climate stability is a special case because it is a *global* public good—there is no single national actor that can provide climate stability. Overcoming this public good problem requires the coordination of many sovereign states, all of which are subject to the same free-rider incentives that exist for individuals. Even if all states recognize the value of climate stability, they have incentives to allow other countries to incur the costs because the benefits are enjoyed globally.

The use of a "domestic" SCC is not sensible because it only partially solves the global public good problem. Were all countries to use domestic SCC values to set internal controls, there would be sub-optimal protection of climate stability—the global SCC is not a population-weighted average of domestic SCCs, but instead the aggregate of all of the harms associated with climate change.

If the purpose of cost-benefit analysis is to identify economically efficient rules, a domestic SCC will lead to incorrect results. GHG emissions cause a whole range of externalities that can occur anywhere in the globe; excluding some portion of those externalities from the cost-benefit calculus guarantees that efficient emissions controls will not be achieved. To the extent that a domestic SCC is used, it should not be incorporated into cost-benefit analysis, but rather could inform *distributional* analysis of who benefits from a proposed rule. Only to the extent that such distributional considerations override efficiency concerns would the domestic SCC be used to set GHG policy.

However, basic moral principles of comity and justice would prevent the global character of the distribution of benefits of GHG reductions to trump efficiency as an appropriate standard. GHG emissions cause significant harm to other countries—the prevention of cross-border harm is a basic principle of international environmental law.[123] For the United States to knowingly set pollution levels in light of only domestic harm, while recognizing that its pollution is directly imposing environmental risk—including catastrophic risks—to other countries, would be a violation of basic norms of comity between countries and corrective justice. The United States would be knowingly causing foreseeable harm to other countries, without compensation, and without any just cause. Given that the nations most at risk from climate change are often the poorest countries in the world, such a policy would also violate basic and widely shared intuitions about egalitarian justice.

Finally, the United States is engaged in an international process to control GHG emissions. The role of the United States as a leader in achieving a global treaty to reduce the impacts of climate change is clear; in recognition of that role, President Barack Obama has announced that he will attend international negotiations in Copenhagen, Denmark on December 9. Use of a domestic SCC could undercut the negotiating posture of the United States by signaling a refusal to recognize that GHG emissions generated in the United States can cause important harms well beyond its borders.

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[123] *See* PHILIPPE SANDS, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW 241 (2003, 2d. ed) (noting that "the responsibility not to cause damage to the environment of other states or of areas beyond national jurisdiction has been accepted as an obligation by all states[;] . . . there can be no questions but that [this principle] reflects a rule of customary international law").

We recommend the continued use of a global SCC in federal rulemaking.

3.2 Spillover Effects and the Domestic SCC

The mesh of the global economy is woven tightly enough to guarantee that disruptions in one place can have consequences around the world. As recently demonstrated, financial crises transmit around the world at a breakneck pace.[124] The nature and volume of travel and other commerce has accelerated greatly the speed with which diseases pass from region to region,[125] and policies undertaken in one country can spur quick and momentous responses in others.[126] In short, few if any disruptions arising from climate change can reasonably be expected to have merely a local or domestic impact.

National security is of particular concern in this regard. Analysts in government and academia have increasingly begun to realize that the United States has a stake in preventing the geopolitical instability associated with climatic disruptions in other regions of the world.[127] Climate effects like droughts, food shortages, and rising sea levels could trigger refugee crises and regional conflicts—both with the potential for violence. Additionally, U.S. dependence on foreign sources of oil carries very real security implications; the effects of climate change and or shifting fuel portfolios can have effects abroad that profoundly affect the U.S. economy.

Similarly significant, though less obvious, are the potential spillovers that U.S. industry could feel from a loss of biodiversity that is already occurring,[128] and is all but certain to accelerate under whatever climate change scenario unfolds.[129] Even leaving aside the non-

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[124] Steven L. Schwarz, *Systemic Risk*, 97 GEO. L.J. 193, 249 (2008) (observing that financial collapse in one country is inevitably felt beyond that country's borders).

[125] Richard D. Smith, *Responding to Global Infectious Disease Outbreaks: Lessons from SARS on the Role of Risk Perception, Communication, and Management*, 63 SOC. SCI. & MED. 3113, 3113-14 (2008) (noting that globalization is matched by acceleration in spread of global disease).

[126] *See* Timothy Searchinger et al., *Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land Use Change*, 319 SCIENCE 1238–1240 (2008) (noting linkage between U.S. biofuels policy and responsive land use changes in other countries); *see also* Timothy D. Searchinger & R.A. Houghton, *Response*, 322 SCIENCE 372 (2009) (addressing critical points raised in Vinod Khosla, *Biofuels Clarifying Assumptions*, 322 SCIENCE 371 (2009)); Hyungtae Kim, Seungdo Kim & Bruce E. Dale, *Biofuels, Land Use Change, and Greenhouse Gas Emissions: Some Unexplored Variables*, 43 ENVTL. SCI. & TECH. 961 (2009).

[127] *See, e.g.*, John M. Broder, *Climate Change Seen as Threat to U.S. Security*, N.Y. TIMES, Aug. 8, 2009; *Climate Change and Global Security: Challenges, Threats, and Global Opportunities: Hearing Before the S. Comm. on Foreign Relations*, 111th Cong. (2009) (statement of Vice Admiral Dennis McGinn), *available at* http://foreign.senate.gov/testimony/2009/McGinnTestimony090721p.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, KEY CHALLENGES REMAIN FOR DEVELOPING AND DEPLOYING ADVANCED ENERGY TECHNOLOGIES TO MEET FUTURE NEEDS (2006), *available at* http://www.gao.gov/new.items/d07106.pdf; GEN. CHARLES F. "CHUCK" WALD ET AL., CNA MILITARY ADVISORY BOARD, POWERING AMERICA'S DEFENSE: ENERGY AND THE RISKS TO NATIONAL SECURITY, at i, vii, x (2009), *available at* http://www.cna.org/documents/PoweringAmericasDefense.pdf; PETER SCHWARTZ & DOUG RANDALL, AN ABRUPT CLIMATE CHANGE SCENARIO AND ITS IMPLICATIONS FOR UNITED STATES NATIONAL SECURITY (2003).

[128] *See* J. Alan Pounds et al., *Widespread Amphibian Extinctions from Epidemic Disease Driven by Global Warming*, 439 NATURE 161, 163 (2006); Chris D. Thomas et al., *Extinction Risk from Climate Change*, 427 NATURE 145 (2004); Camille Parmesan & Gary Yohe, *A Globally Coherent Fingerprint of Climate Change Impacts Across Natural Systems*, 421 NATURE 37 (2003); Terry L. Root et al., *Fingerprints of Global Warming on Wild Animals and Plants*, 421 NATURE 57 (2003).

[129] Adam Felton et al., *Climate Change, Conservation and Management: An Assessment of the Peer-Reviewed Scientific Journal Literature*, 18 BIODIVERSITY & CONSERVATION 2243, 2243-44 (2009) (surveying over 240 articles and noting that regions susceptible to climate change impacts and rich in biodiversity are *understudied*, suggesting that there could be a general conservative bias in recent findings); *see also* Jay R. Malcolm et al.,

use values attributable to rich biodiversity, Hsiung and Sunstein (2007) identify impacts on several economic sectors—notably pharmaceuticals—as a result of declining biodiversity.[130]

IAMs are ill suited to identify and capture these spillover effects.[131] Divvying up IAM outputs by sector or region is certain to result in a loss of information, and likely also to substantially underestimate the true regional or sectoral SCC—for example if a model ignores how energy prices or water resources availability are likely to affect agricultural output,[132] or fails to capture how climate change might reduce saving or investment in capital stock.[133]

Some analysts estimate that the United States's share of direct climate effects will be comparatively small.[134] However, given its unique place in the world—both as the largest global economy with trade- and investment-dependent links throughout the world, and as the only military superpower—the United States is especially vulnerable to spillover effects. Given the disconnect between its share of global direct effects, which IAMs are designed to measure, and its share of global spillover effects, which IAM are not designed to measure, reporting a domestic percentage of the SCC without accounting for spillovers is likely to be particularly misleading.

We recommend that, if a domestic percentage of the SCC is reported, spillover effects must be incorporated to reflect the United States's unique economic, trade, diplomatic, and military position in the world.

Section 4: Uses of the Social Cost of Carbon

Because many different kinds of actions of the federal government, from environmental rules targeted at conventional pollutants, to transportation rules with implications for land use, can have implications for greenhouse gas emissions, the SCC is likely to arise repeatedly in a variety of regulatory contexts. Because of long-standing requirements that rules be subject to cost-benefit analysis,[135] the value given to the SCC is likely to have an extremely broad impact across the federal administrative system.

Global Warming and Extinctions of Endemic Species from Biodiversity Hotspots, 20 CONSERVATION BIO. 538, 539-50 (2006).

[130] Wayne Hsiung & Cass Sunstein, *Climate Change and Animals*, 155 U. PA. L. REV. 1695 (2007).

[131] *See, e.g.*, DALE W. JORGENSON ET AL., PEW CTR. ON GLOBAL CLIMATE CHANGE, U.S. MARKET CONSEQUENCES OF GLOBAL CLIMATE CHANGE iv (2004) (describing various intersectoral spillovers and other factors omitted from consideration). *See* Richard S.J. Tol et al., *How Much Damage Will Climate Change Do? Recent Estimates*, 1 J. WORLD ECON. 179, 182-83 (2000) (noting gaps left when IAM is insensitive to significant spillover effects).

[132] *See* Jody Freeman & Andrew Guzman, *Seawalls Are Not Enough: Climate Change & U.S. Interests* 31 (U.C. Berkeley Public Law Research Paper No. 1357690, 2009) (criticizing Robert Mendelsohn et al., *The Distributional Impact of Climate Change on Rich and Poor Countries*, 11 ENV'T & DEV'T ECON. 159 (2006)).

[133] Samuel Fankhauser & Richard S.J. Tol, *On Climate Change and Economic Growth*, 27 RESOURCE & ENERGY ECON. 1, 3-6 (2005).

[134] WILLIAM NORDHAUS & JOSEPH BOYER, WARMING THE WORLD 96-97 (2000) (noting the country's "relatively temperate climate, [the] small dependence of its economy on climate, the positive amenity value of a warmer climate in many parts of the United States, its advanced health system, and [its] low vulnerability to catastrophic climate change").

[135] Exec. Order No. 12,866 § 6(3)(C), 58 Fed. Reg. 51,735, 51,741 (Oct. 4, 1993) (codified at 45 C.F.R. pt. 88).

The Proposed Rule notes several past contexts where some characterization of the SCC has been necessary for complete regulatory impact analysis.[136] Proposed Rule also notes the widely divergent SCC values that have been used in the past rules.

The current attempt by the Administration to "develop a transparent methodology"[137] to estimate the SCC and apply a consistent value across current and future rulemakings is extremely important. A consistent and rigorously supported SCC helps rationalize the system of regulation by avoiding widely divergent values among agencies or for different rules. Further a well-supported SCC developed at the interagency level can avoid duplication and wasted effort by agencies, and ensure that future rules will be better able to withstand litigation challenges. An interagency process—updated on a regular basis to reflect the latest scientific and economic information—is far preferred to the ad hoc agency processes that have been used to date.

However, because the SCC will be used in a number of different regulatory context in the future, it is important for the interagency group not only to develop a rigorous assessment of appropriate SCC values, but also to clarify how the SCC should be used in regulatory impact analysis and agency rulemaking. A well-justified SCC estimate can still be misused, leading to sub-optimal results. The interagency group should make several clarifications about the appropriate use of the SCC.

4.1 Setting Optimal Regulatory Levels

As the Proposed Rule states, "[t]he marginal and total benefit estimates [in the SCC] are limited to the impacts that can be monetized"[138] and for this reason, the "dollar estimates of the SCC represent a partial accounting of climate change impacts."[139] Because of the large number of un-quantified or non-monetized damages associated with climate change, there is good reason to believe that the SCC systematically undervalues the true harm associated with the emission of a ton of greenhouse gases.

If we can predict that the SCC is a lower bound of damages associated with climate change, use of the SCC in an optimization model will lead to sub-optimal levels of regulation.[140] For example, if the SCC is calculated to be $20 and stringency was set such that the marginal costs imposed by the rule were equal to the SCC per ton of GHG reductions, net benefits could be increased by increasing the stringency of the rule because the SCC is only picking up a portion of the total benefits. Net benefits are maximize when marginal costs equal "true" marginal benefits, which we have good reason to believe are greater than the SCC. While it is less clear by *how much* stringency can be increased, if marginal costs are set at the SCC, the existence of un-quantified and non-monetized effects of climate change ensure under-regulation.

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[136] Proposed Rule at 49,611 and 49,676 (citing DOT, DOE, and EPA rules).

[137] *Id*. at 49,612 and 49,676.

[138] *Id*. at 49,611 note 358.

[139] *Id.* at 49,611.

[140] There is an additional complication because the SCC calculated in the Proposed Rule uses a business-as-usual baseline, meaning that it is higher than the efficient carbon price, which would be calculated on the optimal pathway. Use of the SCC in an optimization model, if the SCC were an accurate representation of marginal damages under business-as-usual, would tend to result in super-optimal regulatory levels. However, non-monetized damages and multiple sources of upward skewed uncertainty very well may be sufficient to overcome this effect, so that treating the SCC as a lower-bound is reasonable.

For this reason, the interagency group should make clear that in rulemaking and regulatory impact analysis, *the SCC should be treated as a floor* for the value of GHG reductions brought about by a proposed rule. Supplemental methodologies that also account for the un-quantified and non-monetized benefits may be necessary to capture the full range of effects associated with GHG reductions. For example, a rule with marginal costs of $25 (if the SCC is $20 and *ceteris paribus*) implies a social willingness to pay of $5 per ton to avoid the non-quantified and non-monetized effects of a ton of GHG reduction. The interagency group should clarify that a positive willingness to pay to avoid impacts not captured by the SCC should be expected in the rulemaking process. An interim value associated with the un-quantified and non-monetized impacts may also be advisable, both for the sake of consistency and to ensure that agencies do not ignore this value in the rulemaking process.

The complexities of regulatory impact analysis, including uncertainty over costs or discontinuities in marginal costs among regulatory alternatives, also imply that the SCC should be understood as a floor rather than an optimal estimate of benefits. Discontinuous marginal costs between alternatives may give rise to the situation where the SCC is "between" the marginal costs of two alternatives—in that situation, the more stringent alternative should generally be favored, unless the difference between the higher cost alternative and the SCC is significantly larger than the difference between the lower cost alternative and the SCC. While consistency is an important value that should be promoted throughout the regulatory process, some important measure of discretion will be needed by agencies in these contexts.

Where there are wide ranges of possible costs, a central estimate of costs should not be compared to the SCC (which is not a central estimate of benefits). An accurate central estimate of costs will include an error term in either direction, while the error in the SCC is much more likely to be positive than negative because of non-quantified benefits. In rulemaking, marginal costs as expressed by a central estimate should be higher than the SCC in order to account for the unidirectional nature of the error in the SCC.

We recommend that the interagency group explicitly state that the SCC is not meant to replace traditional regulatory impact analysis and should not be used in an optimization model. To the extent that the SCC must be used in such a model, higher SCC values should be used to account for non-monetized or un-quantified benefits.

4.2 Ancillary Benefits

There is a significant literature showing the relationship between greenhouse gas reductions and a host of ancillary benefits or "co-benefits." Because rules that control greenhouse gas emissions will often end up reducing fossil fuel combustion, emission of a range of conventional pollutants associated with fossil fuels can be expected to decline in the face of GHG regulation. Reductions in particulate matter, nitrogen oxides, sulfur dioxides, volatile organic compounds, and other pollutants can be anticipated to accompany GHG controls.

For example, measures that increase energy efficiency or encourage clean energy generation will also lead to reductions in local air pollutants, with attendant benefits for human health and ecosystems. Other ancillary benefits include reduced ocean acidification and increased forest preservation.[141]

[141] For a more complete discussion of possible ancillary benefits, see ENV'T POL'Y COMM., ORG. FOR ECON. COOPERATION & DEV. (OECD), ENV/EPOC/GSP(2001)13/Final, ANCILLARY BENEFITS AND COSTS OF GHG MITIGATION:

The magnitude of such ancillary benefits may be significant. For example, a forthcoming working paper estimates that representative federal climate legislation would result in health-related co-benefits of $3 to $9 per ton of carbon dioxide avoided (due to reductions in conventional air pollutants).[142] Other studies, using different methodologies, have found similarly large benefits.[143] Because the ancillary benefits of greenhouse gas reductions could represent an important component of total benefits, it is essential for rulemakings that use the interagency SCC estimates not to omit significant ancillary benefits.

One mechanism to take ancillary benefits into account would be to imbed a default estimate of ancillary benefits within the SCC. An estimate of $5-$10 for ancillary benefits could be added directly to the SCC. Incorporating these ancillary benefits directly into the SCC would ensure that they were accounted for in regulatory analysis.

However, because different rules will have different effects on ancillary pollutants, directly incorporating a default ancillary benefit estimate into the SCC is a second-best approach. Transportation rules may have different ancillary effects than rules governing power plants. Some rules may be directly targeted at reducing a conventional pollutant, so incorporating an "ancillary" effect in the SCC could result in double counting. For these reason, simply including a default assumption concerning ancillary benefits will skew the analysis in some cases.

If such a default assumption is not included, it is important for the interagency group to clarify that GHG reductions are often accompanied by ancillary benefits, and also to provide some guidance for agencies to ensure that they identify and take account of relevant ancillary effects. Citation to the literature on ancillary benefits associated with GHG reductions, as well as a default list of likely ancillary effects of GHG reductions, and perhaps a default value in a "typical rule," could also be provided by the interagency group to give guidance for future rulemakings.

We recommend that the interagency group give explicit direction to agencies on how to account for ancillary benefits associated with GHG reductions.

Section 5: Adoption of a Final Value

The Proposed Rule goes to special lengths to "emphasize[]" that "the analysis here is preliminary" and that the SCC estimates in the Proposed Rule "reflect the Administration's current understanding of the relevant literature and will be used for the short-term while an interagency group develops a more comprehensive characterization of the distribution of SCC values for future economic and regulatory analyses."[144] The Proposed Rule makes

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POLICY CONCLUSIONS 6 (2001), *available at* http://www.olis.oecd.org/olis/2001doc.nsf/LinkTo/NT00000ABA/$FILE/JT00124610.pdf

[142] Britt Groosman, Nicholas Z. Muller, & Erin O'Neill, *The Ancillary Benefits from Reductions of Greenhouse Gas Emissions from Mobile and Electric Power Sources in the United States* (Middlebury College Dept. of Economics Working Paper, forthcoming 2009).

[143] John Balbus, Ramya Chari, & Kristie L. Ebi, A Wedge-Based Approach to Estimating Health Co-Benefits of Climate Change Mitigation Activities in the United States: Health Co-Benefits of Specific US Climate Activities, (estimating co-benefits for the year 2020 in the range of $29 and $68 per ton of carbon ($8 to $19 per ton of avoided CO_2-equivalent ton)) (forthcoming paper).

[144] Proposed Rule at 49,612 and 49,676.

clear that the interim value presented is temporary and "should not be viewed as an expectation about the results of the longer-term process."[145]

Before a final set of SCC values can be developed, there are several important steps that must be undertaken. At the most basic level, individual agencies should be given greater opportunity to modify and test the IAMs that were used, at the very least to understand their sensitivity to model specification, inputs, and assumptions. Only after agencies have been given adequate opportunity to "test out" the models will the interagency group have a solid foundation to make final decisions about the SCC.

Once a more complete understanding of how the IAMs respond to exogenous choices is developed, agencies should target the most important specifications, inputs, and assumptions for greater analysis so that the final choices can be based on reasoned analysis and adequate justification. There is a wide range of choices that must be made in the models; at the very least, the most important choices should be subject to significant scrutiny by the agencies that can then inform the interagency group. Reasoned analysis that allows meaningful comment by the public and adequate judicial review should accompany the choices that affect the final SCC values.

After identifying the most important parameters, the agencies should independently make appropriate choices and develop justification for those choices, in light of their effect on the model and based on the most recent literature. For example, the results generated by IAMs are sensitive to the choice of a damage function—once agencies identify the degree of sensitivity, there is a need to specify and justify whatever damage function is chosen. Review of the relevant literature is likely to prove useful, but ultimately the agencies will have to arrive at decisions on the basis of the best available information.

After individual agencies have identified the most important choices and developed appropriate justification for specification, input, and assumption decisions, the interagency group can aggregate all the relevant information in its deliberative process.[146] The views of agencies that have developed special expertise in the models should be given relatively greater weight to ensure that the final choices of the interagency group represent the best information available. On the basis of the expertise and justifications that were developed within the agencies, the interagency taskforce will be in a better position to develop a final set of values that can be used in rulemakings in the future.

The final estimates developed by the SCC should also be periodically reviewed in light of new scientific and economic information. The goal of the current process should be to create estimates that reflect the most up-to-date understanding, and clarify where new information can improve the quality of estimates. As the SCC is revised in the future, the current process should provide a solid foundation so that new information can be incorporated without requiring a "ground up" process that will duplicate the current effort. By clarifying all of the specifications, inputs, and assumptions, stating the basis for all choices, and identifying where data gaps on increases in knowledge could have significant effects on outcomes, the interagency taskforce can ensure that future updates will maximize agency resources.

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[145] *Id.* at 49,612; *id.* at 49,676 ("should not be viewed as a *statement* about the results of the longer-term process) (emphasis added).

[146] There is good reason to believe that the formation of preferences and beliefs *prior* to a deliberative process will generate better results. *See generally,* Cass R. Sunstein, *Group Judgments: Deliberations, Statistical Means, and Information Markets* (John M. Olin Law & Economics Working Paper No. 219, 2004).

We recommend that the interim SCC not be finalized before agencies have had a significant opportunity to further explore the specifications, inputs, and assumptions within the IAMs and develop reasoned conclusions about how the IAMs can be used to generate appropriate SCC values.

Conclusion

Developing a rigorous, defensible, and well-justified SCC is central to coordinating and rationalizing agency actions that have effects on GHG emissions. The interim set of values described in the Proposed Rule are an important start, but many changes are needed to ensure that the Agencies decisions take all significant factors into consideration and are made no the basis of the best scientific, technical, and economic information available.

Respectfully submitted,

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