# The Social Cost of Carbon in Federal Rulemaking

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# Outline

- Background
- Overview of U.S Government's SCC Estimates
  - 2009-2010 Process
  - 2013 Update
- Discussion

# What is the Social Cost of Carbon (SCC)?

- The SCC provides a measure of the marginal damage from $CO_2$ emissions – and thus the *marginal benefit of abatement*
  - The SCC is the theoretically consistent value to compare with the marginal cost of abatement in benefit cost analysis
- Specifically, the SCC is the monetized value of future worldwide economic damages associated with a one-ton increase in $CO_2$ emissions in a particular year discounted to the present.
  - This is identical to the avoided damages associated with a one-ton decrease.
- It is intended to be a comprehensive measure of climate change damages, including (but not limited to):
  - changes in net agricultural productivity
  - net energy demand
  - human health
  - property damages from increased flood risk
  - the value of ecosystem services

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# Why do we need an estimate of SCC?

- Setting the stringency of regulations requires a framework for comparing benefits and costs
  - Benefit-cost analysis (BCA) provides a consistent framework for comparing regulatory designs that have both different costs and emission reductions of multiple pollutants
- The SCC is an estimate of the benefits of reducing emissions of $CO_2$, which allows those benefits to be considered in BCA
  - Without a SCC, the benefit to society of reducing $CO_2$ emissions are treated as zero – effectively ignoring climate change damages
- Moreover, since 1981, BCA must be conducted for all significant U.S. Federal regulations
  - Executive Order 12866 directs federal agencies "to assess both the costs and benefits of the intended regulation…."

# Overview of 2009-2010 Interagency SCC Process

# SCC Interagency Working Group

- In 2009, the Obama Administration launched an interagency process to promote consistency in the SCC values used by agencies
  - Prior to 2008, reductions $CO_2$ emissions impacts were not valued
  - From 2008 to 2009, SCC estimates varied substantially among agencies
  - In 2009, "interim" USG SCC estimates were issued based on literature review
  - The 2010 USG SCC estimates have been used in 30+ regulations to date (EPA, DOT, DOE)
- Workgroup members
  - Leads: CEA and OMB
  - Actively participating offices/agencies: CEQ, NEC, OECC, OSTP, EPA, DOT, DOE, Treasury, USDA, Commerce
  - Others also invited, but did not attend many meetings, if any (e.g., DOI, NOAA)

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# Overview of USG SCC Analytic Process

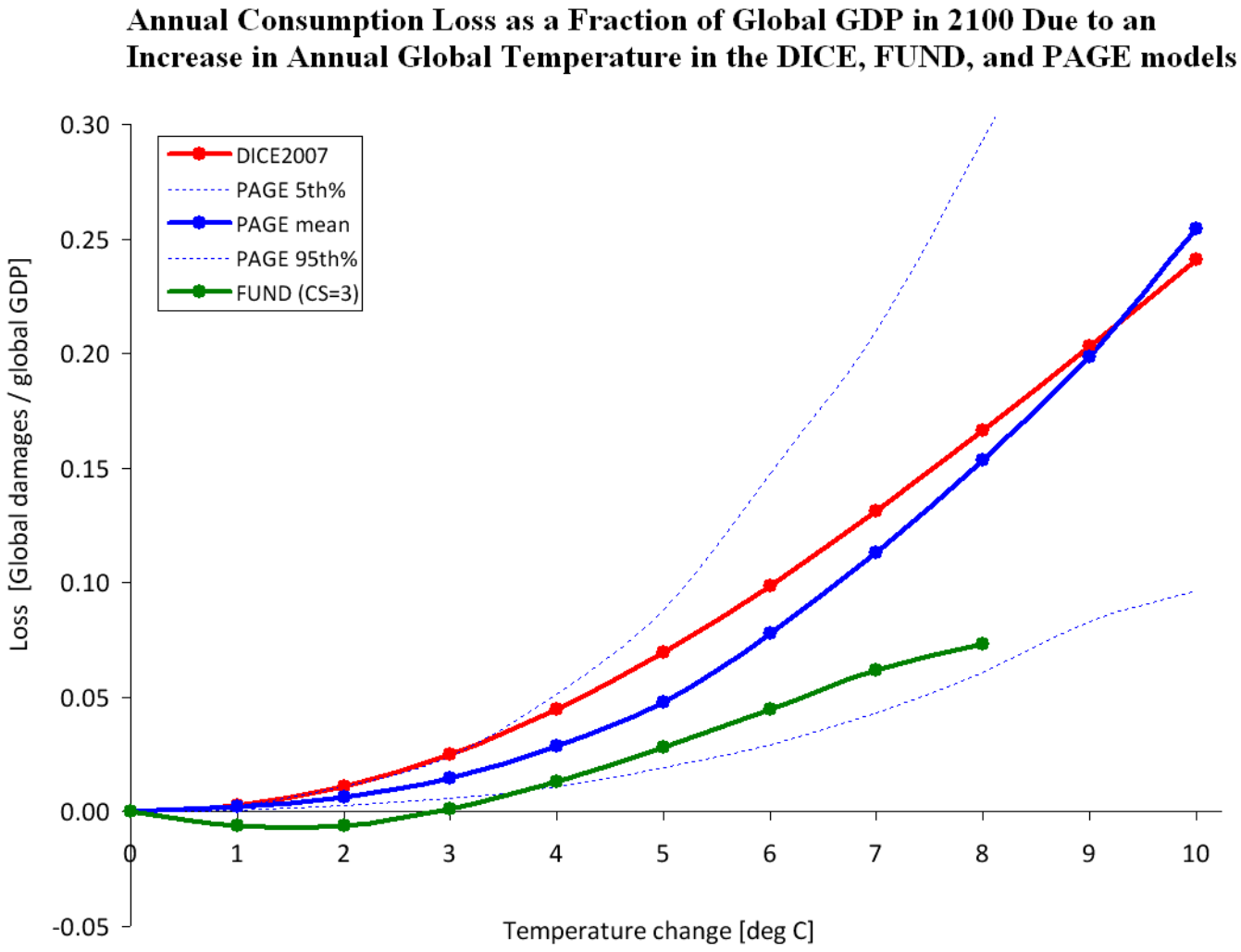
- Used 3 “integrated assessment models” (IAMs) - PAGE, DICE, and FUND models - each given equal weight
- Applied a common set of assumptions in each model for: reference socioeconomic and emissions trajectories, climate sensitivity, and discount rates
- All other features of the IAMs were left unchanged
- It was decided the SCC used for Federal rulemaking should reflect global damages from $CO_2$ emissions, not just those that would occur in the U.S.

# Integrated Assessment Models (IAMs)

- IAMs combine climate processes, economic growth, and feedbacks between the two in a single modeling framework
  - IAMs are highly simplified representations of the potential economic damages from climate change and limited by the current state of research
  - Despite their inherent uncertainties and limitations, they are the best tools currently available for estimating the SCC

- DICE, FUND, and PAGE are by far the most widely used and widely cited IAMs that can link physical impacts to economic damages for the purposes of estimating SCC (NAS 2010, Tol 2008)
  - Other IAMs generally do not include damage functions (e.g., MIT's IGSM and PNNL's GCAM used primarily for cost-effectiveness analysis)

# Illustrative Climate Damages in 2100*




*Based on modelers default inputs. For general illustrative purposes only. Values are model run specific. See 2010 TSD for discussion.

# Key Modeling Assumptions

- Socio-Economic & Emissions Trajectories:
  - Selected 5 reference paths for emissions, GDP, and population based on modeling runs performed for Stanford Energy Modeling Forum (EMF) 22
  - Each scenario given equal weight
- Climate Sensitivity:
  - Probability distribution calibrated closely to IPCC AR4 consensus statement.
  - The Roe and Baker (2007) distribution was selected (out of 4 distributions considered) because it was most consistent with the theoretical understanding of climate system response to increased GHG concentrations, and with IPCC judgments regarding the tails of the distribution

# Key Modeling Assumptions (cont'd.)

- Discount Rate:
  - Federal regulatory analyses typically employ constant discount rates of both 3% and 7% per OMB Circular A-4 guidance
  - No consensus on what to use in inter-generational context
  - In light of disagreement in the literature, the interagency group used 3 constant discount rates to span a plausible range
    - 2.5%: incorporates concern that interest rates are highly uncertain over time
    - 3% : consistent with economics literature and OMB Circular A-4 guidance for the consumption rate of interest
    - 5%: represents the possibility climate damages are positively correlated with market returns

# Key Modeling Assumptions (cont'd.)

- Global vs. domestic:
  - Circular A-4: domestic analysis is required; international is optional.
  - Emphasizing need for a global solution to a global problem, interagency group concluded that a global measure is preferable.
  - Also, IAMs are best suited for developing global estimates of SCC. There are relatively few region-or country-specific estimates of SCC in the literature.
  - Interagency group presented limited information available on domestic SCC and determined a range of values from 7 to 23 % to be used to adjust global SCC to calculate domestic effects of rulemakings.
    - FUND model: with a 2.5 or 3 % discount rate, U.S. benefit is about 10% of global benefit, on average, across the scenarios analyzed.
    - If fraction of GDP lost due to climate change is similar across countries, domestic benefit would be proportional to U.S. share of global GDP, about 23%.

# Putting It All Together

- The model runs produced 45 separate SCC distributions for a given year

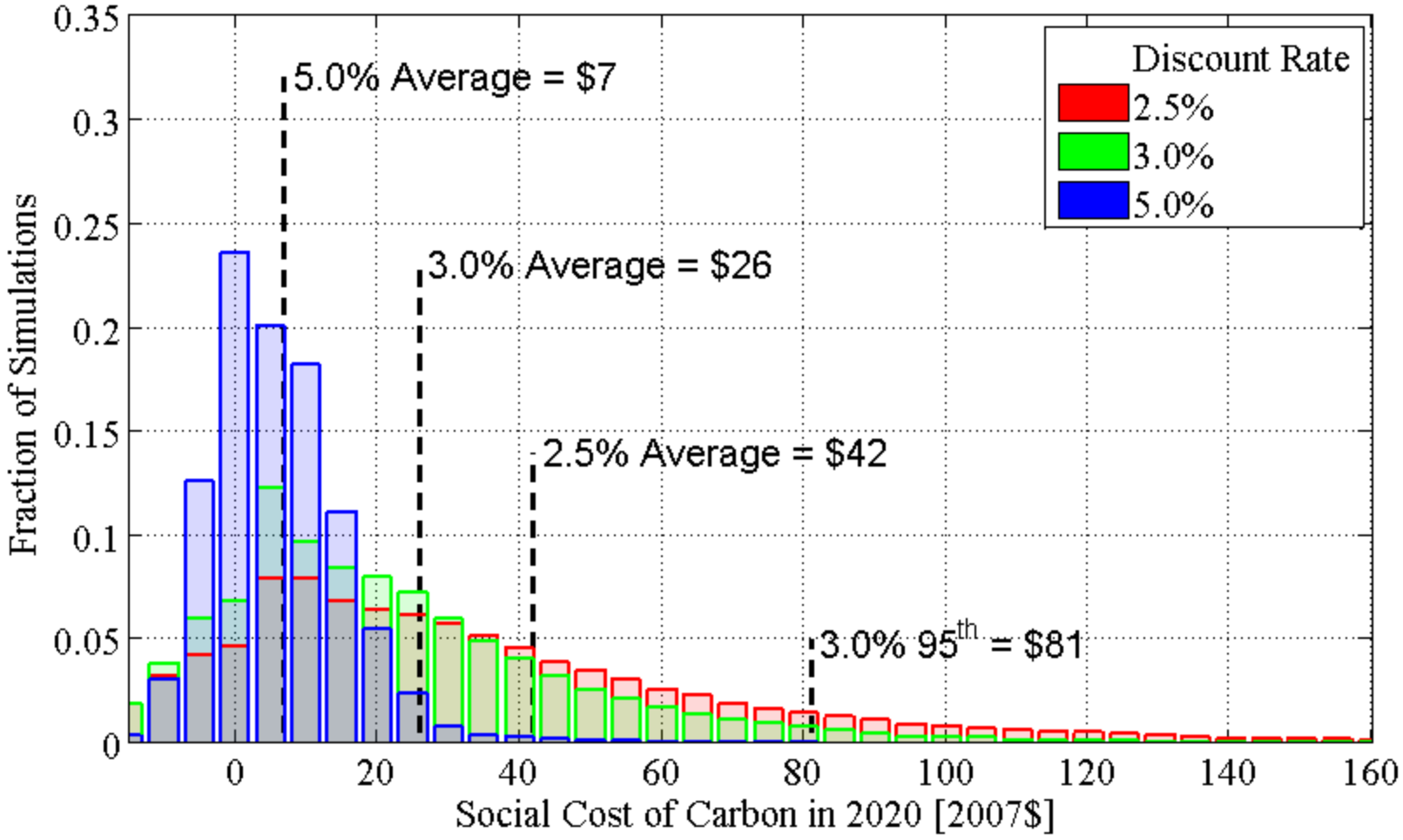
  (3 models) x (5 socioeconomic scenarios) x (1 climate sensitivity distribution) x (3 discount rates)

- The distributions from each model and scenario were equally weighted and combined to produce three separate probability distributions for SCC in a given emissions year, one for each of the three discount rates.

- From the 3 distributions, the interagency group selected 4 values:
  - The average SCC at each discount rate: 2.5%, 3%, and 5%
  - The 95$^{th}$ percentile at a 3% discount rate, representing higher than expected economic impacts further out in the tails of the distribution.

# USG SCC Estimates (Feb 2010)

Distribution of 2020 Social Cost of Carbon Values at Each Discount Rate

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# Discussion

- Higher discount rates resulted in lower SCC values, and vice versa
- There were clear differences in the SCC across the 3 models
  - FUND produced the lowest mean estimates
  - PAGE produced the highest mean estimates
- Results were in the range of estimates published in the peer-reviewed literature
- It was understood that any SCC estimate must be taken as provisional and subject to further refinement in accordance with evolving scientific, economic, and ethical understandings.
  - Limitations of the analysis include, e.g., incomplete treatment of non-catastrophic and "catastrophic" damages, uncertainty in extrapolation of damages to high temperatures, incomplete treatment of adaptation, technological change, and inter-sectoral and inter-regional interactions.

# 2013 Update

# Why Were the SCC Values Updated?

- Executive Order 13563 declares that our regulatory system must be based on "the best available science."
  - Most models that EPA and other agencies rely on are updated regularly (often annually) as new information becomes available.
  - 2010 SCC estimates were based on model versions that were developed up to 10 years ago in a rapidly evolving field.
  - Significantly updated models are available that correct some shortcomings in earlier versions, especially in treatment of sea level rise.
- The 2010 interagency report committed to an update "within 2 years" and when "substantially updated models become available."
- A technical update based only on updated versions of the models allows for improvements while science progresses on other aspects of the models.

# New Versions of Each Model Are Available

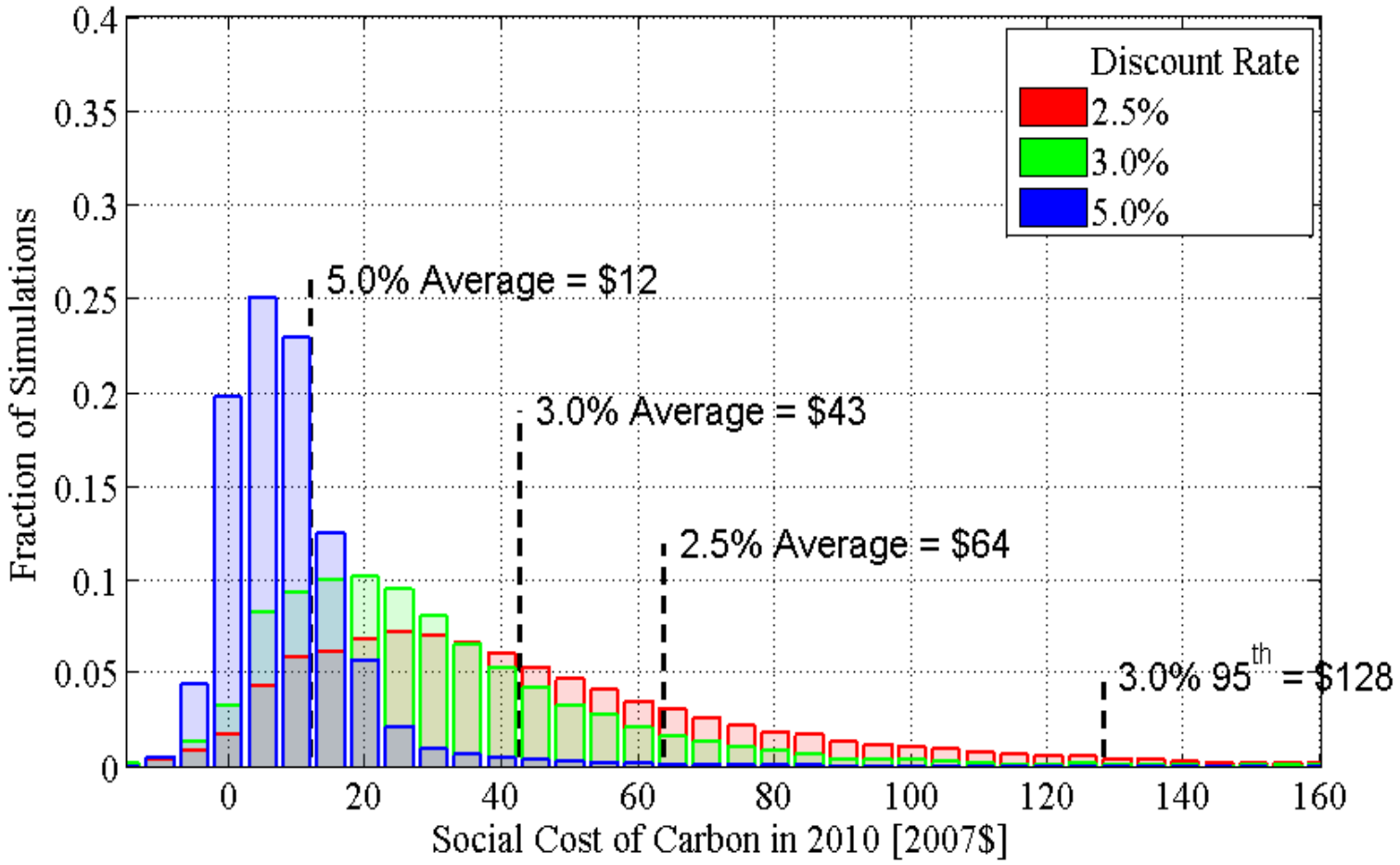
| Model | 2010 TSD Version | New Version | Key changes in new version |
|---|---|---|---|
| DICE | 2007 | 2010 | Updated calibration of the carbon cycle model and explicit representation of sea level rise (SLR) and associated damages. |
| PAGE | 2002 | 2009 | Updated adaptation assumptions, explicit representation of SLR damages, change in regional scaling of damages, revised treatment of potential abrupt damages, revisions to damage function to ensure damages do not exceed 100% of GDP. |
| FUND | 3.5 (2009) | 3.8 (2012) | Updated damage functions for SLR, agricultural impacts, and space heating, inclusion of indirect climate effects of methane, and changes to response of temperature to buildup of GHG concentrations. |

**Other model revisions are superseded by the USG input assumptions.**

# Updated USG SCC Estimates

- For 2020, the revised SCC values are: $12, $43, $64, & $128 (2007$).

**Distribution of SCC Estimates for 2020 (2007$/ton $CO_2$)***




* Includes Nov 2013 technical correction.

# Updated SCC Estimates, 2010-2050

- As before, the values increase over time, as determined within each model, because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change.

**Revised Social Cost of $CO_2$ (2007$/ton),* based on year of emission reductions**

| Discount Rate | 5.0% | 3.0% | 2.5% | 3.0% |
|---|---|---|---|---|
| Year | Avg | Avg | Avg | 95th |
| 2010 | 11 | 32 | 51 | 89 |
| 2015 | 11 | 37 | 57 | 109 |
| 2020 | 12 | 43 | 64 | 128 |
| 2025 | 14 | 47 | 69 | 143 |
| 2030 | 16 | 52 | 75 | 159 |
| 2035 | 19 | 56 | 80 | 175 |
| 2040 | 21 | 61 | 86 | 191 |
| 2045 | 24 | 66 | 92 | 206 |
| 2050 | 26 | 71 | 97 | 220 |

* Includes Nov 2013 technical correction. .

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# Comparison to Latest SCC Estimates from the Model Developers

**U.S. Interagency SCC Estimates – 2013 Update* [2007$/ton CO2]**

| Emission Year | Discount Rate | | | |
|---|---|---|---|---|
| | 5.0% Mean | 3.0% Mean | 2.5% Mean | 3.0% 95th |
| 2010 | $11 | $33 | $52 | $90 |
| 2020 | $12 | $43 | $64 | $128 |

* Includes Nov 2013 technical correction.

**Latest SCC Estimates from the Model Developers [2007$/ton CO2]**

| | Emission Year | SCC | Citation |
|---|---|---|---|
| RICE 2010 | 2010 | $31* | Nordhaus (2010) |
| RICE 2010 | 2020 | $53* | Nordhaus (2010) |
| FUND 3.8 | 2010 | $1-$487 | Anthoff and Tol (2013) |
| PAGE 2009 | 2010 | $113 | Hope (2013) |

* Based on the regionalized version of DICE along the optimal path. Reference path estimates not reported.

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# SCC Estimates Remain Conservative in a Number of Regards

For example,

- SCC estimates do not include damages from ocean acidification
- Damages from most large scale earth system feedback effects (e.g., Arctic sea ice loss, melting permafrost, large scale forest dieback, changing ocean circulation patterns) are not included at all in one model, and at best imperfectly captured in others.
- Many categories of direct impacts remain incomplete and rely on science lagging behind the most recent research (e.g., agriculture).
- A number of potentially significant damage categories remain exceedingly difficult to monetize (e.g., species and wildlife loss).
- Is a partial equilibrium measure of mitigation benefits

# Discussion

# Intergenerational Discounting

- For calculating the SCC, the USG used 3 constant discount rates
- Leads to potential inconsistencies:
  - benefits occurring in the same year being discounted at different rates
  - potential inconsistency with constant discount rates over long time horizons and non-constant consumption per capita growth forecasts
    - Might not matter that much for these deterministic scenarios (Marten et al., forthcoming), but may matter more with formal modeling of scenario uncertainty (Marten 2014)
- USG continues to examine questions related to discounting impacts in the distant future and supports research in this field
  - EPA sponsored a small workshop at RFF in which 13 prominent economists discussed a series of charge questions on intergenerational discounting
  - One output of this workshop, a paper authored by all 13 experts was recently published in *Science*, which argues that a declining discount rate would be appropriate to analyze impacts that occur far into the future (Arrow et al. 2013)

# Representation of "Catastrophic" Impacts

- Analyses of GHG mitigation benefits are often criticized for failing to adequately capture possible "catastrophic" impacts (e.g., Tol 2009, NAS 2009, SCC TSD 2010)
- 2 of the 3 IAMs used for the USG SCC do make some attempt to capture these types of impacts, albeit in a very ad hoc and imperfect manner
- One obstacle that has impeded progress is the inconsistent and sometimes nebulous use of "catastrophic" impacts
- Need to move beyond experiments which are abstracted from important details of the climate problem to substantively inform the policy debate and improve analyses of greenhouse gas mitigation benefits (e.g., SCC) (Kopits et al., 2013)

# A Note on Non-$CO_2$ GHGs

- Published estimates of the social cost of other GHGs are fewer than for SCC, and most estimates are not comparable to USG SCC.
- One crude approach to proxying the social cost of other GHGs is to convert non-$CO_2$ emissions to $CO_2$ equivalent terms using global warming potentials (GWP) and then apply the SCC.
- This approach may produce large errors, because
  - It ignores important nonlinear relationships and the interaction between the gases' relative lifetimes, state variable scenarios, discounting, etc.
  - Not all impacts are due to temperature change (e.g., carbon fertilization & ocean acidification linked to $CO_2$; ozone linked to $CH_4$)
- Recent research finds GWP approach will likely understate benefits (Marten & Newbold 2012, Marten et al. forthcoming)
  - Especially at higher discount rates (e.g., 5%), emission years further out in time

# References


- Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. (February 2010). http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.
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