The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change

By Dr. Peter H. Howard and Derek Sylvan

November 2015
Working Paper No. 2015/1

The paper's authors can be contacted at HowardP@exchange.law.nyu.edu and derek.sylvan@nyu.edu

The Economic Climate:

Establishing Expert Consensus on the Economics of Climate Change

I. Introduction

Climate change is one of the preeminent policy issues of our day. Given that effective climate policy must balance the costs of action and the likely economic damages from inaction, the views of economists about climate change are particularly important.

After decades of research and debate, the scientific community has developed widespread consensus that action to reduce greenhouse gas emissions (GHGs) is necessary. However, the media and policymakers often portray economists as more conservative than scientists when it comes to climate change policy, possibly due to their focus on market-driven adaptation and the costs of mitigation (Holladay et al., 2009). This paper will help clarify the level of consensus among economists with respect to climate change risks, economic impacts, and policy responses. It will also compare the views of economic experts to the views of the general public, and provide insights about the appropriate assumptions to use in integrated assessment models – the climate-economic models that many policymakers consult.

We attempt to establish expert consensus on the economics of climate change by conducting a survey of all those who have published an article related to climate change in a highly ranked, peer-reviewed economics or environmental economics journal since 1994. We designed a 15-question online survey focused on climate change risks, estimated economic impacts, and policy responses. We then invited the 1,103 experts who met our selection criteria to participate, and we received 365 completed surveys.

This project expands on a 2009 survey conducted by Holladay et al. (2009). That survey, which queried a smaller pool of economic experts, revealed widespread consensus that climate change posed major economic risks and that market-based policies to reduce emissions were desirable, among other findings. This survey samples a larger pool of experts (the pool was expanded because many articles on climate change have been published since 2009, and because we added authors who published in top-ranked environmental economic journals to our sample).

Past attempts to gauge the consensus of economists through surveys on climate change generally suffer from one or more problems: reduced variance due to uniformity or censorship (from using deliberation and consensus building); respondent bias (from using informal, open web surveys); and/or small sample size. This survey attempts to avoid these pitfalls and shed light on the consensus views of economists. In doing so, the paper also highlights topics that elude consensus, where future research should focus.

The findings from this paper could be useful in policy debates about climate change. Policymakers often use the output from integrated assessment models (IAMs), which capture the various steps in the climate and economic processes that translate a marginal unit of carbon dioxide (CO_2) emissions into an economic damage. Economists use these models to analyze climate policies and estimate the social cost of carbon (SCC) – the marginal cost of a unit of CO_2 emissions – an essential number in U.S. government cost-benefit analyses of regulations that affect GHG emissions. However, IAMs and their results, including the SCC, are sensitive to many of the assumptions made by modelers. Therefore, the prevailing views of economists are of major importance for determining the proper assumptions to use in climate-economic models, including IAMs. In particular, given the deep uncertainty faced in climate research, modelers can solicit expert opinion to specify the most likely values and the current level of uncertainty for key unknown parameters. To illustrate this point, we utilize the results from this survey to re-calibrate the DICE-2013R to reflect the current state of expert opinion on expected climate damages, and calculate the result SCC estimates.

The paper is structured as follows: Section II reviews the key literature, focusing on previous surveys of economists and other groups on climate change and related issues (e.g., discount rates, policy preferences, etc.). Section III reviews the methodology for selecting our sample and conducting the survey. Section IV presents our results and discusses the importance of particular findings. Section V uses survey results to project climate damage curves and new social cost of carbon estimates. Finally, Section VI concludes with a discussion of the broader implications of these results and the direction of future work.

II. Literature Review

Researchers have conducted several types of surveys to gauge how both experts and the general public view key issues related to climate change. Other surveys have tracked economists' views on discount rates – an important topic given that discount rates are a key determinant of the social cost of carbon. In addition to summarizing the relevant literature, we briefly discuss the recent debate on whether surveys of "experts" are a more accurate means of estimating the social cost of carbon than integrated assessment models.

Expert Surveys on Climate Change Impacts

The survey conducted by Holladay et al. (2009), upon which this study builds, sampled economists who had published an article related to climate change in a leading economics journal between 1994 and 2009. That survey revealed that 84% of respondents believed climate change posed "significant risks to important sectors of the United States' and global economies," and the experts believed that agriculture was the domestic sector most likely to be negatively affected by climate change (86% of respondents predicted a negative effect). The survey also showed that the vast majority of experts felt that "uncertainty associated with the environmental and economic effects of greenhouse gas emissions increases the value of emission controls, assuming some level of risk-aversion" and that most experts supported market-based mechanisms to reduce GHGs and incentivize energy efficiency and low-carbon energy sources. More than 57% of respondents felt that the U.S. government should commit to greenhouse gas reductions "regardless of the actions of other countries." When asked to estimate the appropriate value for the domestic social cost of carbon, the sample provided a median estimate of $50.

Just over twenty years ago, William Nordhaus published the results of what is likely the most influential economic survey about the effects of climate change to date (Nordhaus, 1994). In the oft-cited survey, Nordhaus interviewed 19 experts on climate change (10 economists, four other social scientists, and five natural scientists), each of whom had a working knowledge of economic statistics. He asked respondents to answer a series of questions under three scenarios: a 3°C increase by 2090 (Scenario A), a 6°C increase by 2175 (Scenario B), and a 6°C increase by 2090 (Scenario C). He then asked respondents to estimate the 10th, 50th, and 90th percentiles of climate damages to GDP (market impacts only) under each scenario. At the 50th percentile, the median values he found were losses of 1.9%, 4.7%, and 5.5% of GDP under Scenarios A, B, and C, respectively; the mean values were 3.6%, 6.7%, and 10.4%, respectively. For each of these scenarios, he also asked respondents to determine the share of these impacts borne by the market (Scenarios A: the mean and median share of impacts captured by the traditional national accounts were 62.4% and 62.5%,) and to estimate the probability of catastrophic damages equivalent to a 25% decline in GDP (Scenario A: mean and median probabilities were 4.8% and 0.5%). The survey asked other questions as well, and the overall results varied greatly between respondents, disciplines, and scenarios; the results were somewhat skewed because eight mainstream economists gave very conservative estimates, while three natural scientists gave very high estimates.

In current meta-analyses of climate change impact estimates (Tol, 2009; Tol, 2013a; Tol, 2014), Nordhaus' 1994 survey stands as the sole climate damage estimate derived by surveying experts. Furthermore, that survey includes one of the few estimates of the impacts of extreme climate change.

Nordhaus' 1994 survey is still heavily relied upon today, though it is two decades old and uses a small sample size.

Howard (2015) – a recent meta-analysis of climate change impacts – identifies an additional survey of experts on the external costs of CO_2 emissions: Schauer (1995). Using a survey of 14 experts (of which 10 report climate impacts), Schauer (1995) estimated mean and median declines in global GDP of 5.2% and 2.6%, respectively, with a variance of 71.3% for a doubling of CO_2; this is equivalent to the impact of a 2.5 degree Celsius increase relative to pre-industrial temperature.

These previous expert surveys focused on handpicked experts – including scientists – rather than a large sample of economists (as in our study). Information about the science and economics of climate change has greatly improved over the past 20 years, and our survey attempts to provide a current understanding of experts' views on some of the same economic damage estimates Nordhaus explored.

Surveys of the General Public on Climate Change

Dozens of researchers around the world have conducted surveys of the general public to gather views on climate change issues (Capstick et al., 2015). Ansolabehere and Konisky (2014) compile the results of numerous American public opinion surveys conducted by Gallup, MIT, and other organizations over the past decade. They find that concern about climate change fluctuates considerably, and that practical concerns about energy costs and local environmental issues often shape public opinion significantly. They provide findings from an MIT/Harvard survey on energy issues, conducted annually from 2006-2011 (and in other years before and after that period), in which respondents are asked what level of action should be taken to address climate change. In most years, a plurality (27% to 43%) of respondents say "some action should be taken." Typically, a smaller percentage (19% to 35%) says "immediate and drastic action is necessary," while roughly 20% to 28% say "more research is needed before action is taken." Between 10% and 25% typically say that climate change "is not a serious problem." We ask this question in our survey in order to compare the consensus view of economic experts to the views of the general public.

A 2015 survey of the American public conducted by researchers at Resources for the Future, Stanford University, and the New York Times showed that 44% of respondents felt that global warming would be a "very serious" problem for the United States if nothing is done to address the issue; 34% felt it would be a "somewhat serious" problem (RFF, 2015). The survey found that an overwhelming majority of the American public, including nearly half of respondents who identified as Republicans, support government action to curb global warming.

Leiserowitz et al. (2015) conducted a nationally representative survey of the American public on climate change, which has been updated twice annually since 2010.[1] Their most recent survey finds that 63% of the American public believes that climate change is happening, though only 52% think it is caused by human activity. Only 9% of the American public understands the extent of expert consensus on the issue – namely that 90% of climate scientists have concluded that man-made warming is happening.

Expert Surveys on Discount Rates

Weitzman (2001) conducted an e-mail survey of 2,800 Ph.D. economists on the social discount rate. Using "unscreened sampling" of economists of varying backgrounds and fields to ensure balance, Weitzman asked respondents to provide the appropriate discount rate to utilize in climate change cost-benefit analyses.[2] He obtained approximately 2,160 responses (a 77% response rate), of which 12% were given with objections to the question.[3] His mean and median responses were approximately 4% and 3%, respectively; he had a standard deviation of approximately 3%. Similarly, in a sub-sample of 50

[1] An initial survey was conducted in 2008 before the biannual surveys began in 2010.
[2] Specifically, Weitzman (2001) asked: "Taking all relevant considerations into account, what real interest rate do you think should be used to discount over time the (expected) benefits and (expected) costs of projects being proposed to mitigate the possible effects of global climate change?"
[3] In addition to non-respondents, Weitzman (2001) also struck from the record any extreme responses, i.e., below 0.5% or above 12%, for which a reasonable justification was not supplied upon follow up.

"blue ribbon" economists, Weitzman again found a mean response of approximately 4% and a standard deviation of 3%. Essentially, results from Weitzman (2001) support the argument that the choice of expert group does not matter if an effort to achieve of a balance of views is made.

These results are similar to Schauer (1995) – a previously discussed small-sample survey of economists. As part of the Schauer (1995) survey, 14 experts were asked to also estimate "the long-term average real discount rate for greenhouse damages (%/year)." From the 10 responses to this question, the study found a mean and median of 4.9% and 2.5% with a standard deviation of 5.5%.

In a more recent survey, Drupp et al. (2015) surveyed 627 "experts" – as determined by publication in leading economic journals – on social discount rates. The authors asked respondents to provide their opinion on the value of: (1) the real risk-free interest rate, (2) the components of the prescriptive interest rate, (3) the acceptable range for the social discount rate, and (4) the relative weight that policymakers should place on the descriptive and prescriptive approaches. In total, 197 economists responded (a 31% response rate), of which 185 provided quantitative responses. Unlike Weitzman and Schauer (1995), the authors found that the mean and median of the constant discount rate are 2.25% and 2%, respectively – providing evidence that the group of experts polled does matter. The authors found a general consensus that the social discount rate was between 1% and 3%, and found that both prescriptive and descriptive approaches matter. Specifically, Drupp et al. (2015) found that, on average, economists place more weight on normative determination of discount rates (61.5%) than positive/ethical determinants (38.5%).

Calls for Expert Consensus/Critiques of IAMs

Pindyck (2015) argues that integrated assessment models (IAMs) are over-reliant on the opinion of the modeler,[4] and as a consequence, IAMs essentially represent the modeler's informed opinion rather

[4] Specifically, Pindyck (2015) states that "the ad hoc equations that go into most IAMs are no more than reflections of the modeler's own 'expert' opinion…determining plausible outcomes and probabilities, and the emission reductions needed to avert these outcomes, would mean relying on 'expert' opinion. For an economist, this is not

than the scientific consensus. He argues that by presenting these opinions in the form of a "sophisticated" model, modelers dishonestly represent IAMs as current scientific consensus, instead of as a black box that transforms the modeler's assumptions into policy recommendations and SCC estimates. To avoid the current situation in which IAM modelers are free to choose ambiguous parameter values (such as the probability of catastrophic outcomes, the discount rate, etc.) based on their own opinions, Pindyck (2015) proposes using a simple model with inputs determined by expert opinion from "a range of economists and climate scientists." Given a specific GHG scenario, experts would be asked about their assumptions for key values in determining the social cost of carbon: (1) the discount rate, (2) the probability of catastrophic outcomes (e.g., 10%, 30%, and 50% losses in GDP from climate change occurring in the next 50 years), and (3) the CO_2 emission reduction necessary to avoid these catastrophic outcomes. The initial two questions are essential in calculating the bulk of the net present value of benefits from avoiding emissions, which when divided by the emission reduction roughly approximates the SCC.[5]

There are many issues that can be raised with respect to Pindyck's simple model approach. A key concern is how to define a representative range of experts. In particular, "expert" opinion may depend on the chosen definition of expertise. Our survey seeks the opinion of a wide range of economists about the economics of climate change, similar to what Pindyck (2015) suggests. Additionally, we ask experts about catastrophic impacts and the appropriate discount rate – two of the three essential questions according to Pindyck – in addition to several other questions. Our dataset also allows us to compare the results of questions across various definitions of expertise: economists versus environmental economists; those who have published multiple articles on relevant topics versus those with a single

---

very satisfying…But remember that the inputs to IAMs (equations and parameter values) are already the result of 'expert' opinion; in this case the modeler is the 'expert'…If effect, we would use expert opinion to determine the inputs to a simple, transparent and easy-to-understand model."

[5] This is not really a calculation of the SCC. Instead, it should be interpreted as the average benefit of avoiding catastrophic impacts of climate change.

publication; and expertise in a certain sub-discipline versus general expertise. In doing so, we are able to test whether the specific definition of expertise affects the results.

III. Methodology

In an attempt to gauge expert consensus on key economic issues related to climate change, we surveyed more than 1,000 of the world's leading experts on climate economics. We sent each respondent a link to a 15-question online survey, with questions focused on climate change risks, economic damage estimates, and policy responses. In total, 1,187 experts met our selection criteria, and we could successfully locate 1,103 (the intended recipients of the survey). We received 365 completed surveys – a response rate of 31.1% (as defined by R6 on page 45 of the 2011 AAPOR's *Standard Definitions*).

Survey Design

Our survey was designed to accomplish four objectives: (1) to establish expert consensus on critical economic questions related to climate change policy; (2) to compare experts' views of climate change risks to the views of the general public; (3) to compare experts' views to those expressed in a similar expert survey from 2009 by Holladay et al.; and (4) to solicit specific estimates of the economic impacts of climate change and the likelihood of catastrophic outcomes. We surveyed respondents on the following topics:

- The specific subjects on which they have published, with respect to the economics of climate change (Question 1) – this information was collected in order to understand the effect of expertise in more specific issue areas.
- The level of risk climate change poses to the domestic and global economies, and the domestic economic sectors most likely to be affected (Questions 2-6);

- The design of GHG control mechanisms that would be most desirable under the U.S. Environmental Protection Agency's "Clean Power Plan" – a new climate regulation (Question 7);
- The optimal strategy that the United States should employ in international climate negotiations (Questions 8-9);
- The appropriateness of the United States government's "social cost of carbon" valuation, and the discount rate that should be used in related calculations (Questions 10-12);
- Estimates for the economic impact of a 3°C increase in global mean temperature, including "catastrophic" impacts (Questions 13-15).

Because we sought to compare our respondents' views to the opinions expressed in other surveys, some of our questions used wording from Holladay et al. (2009), while questions 2 and 3 used wording from surveys of the general public – RFF (2015) and MIT (2008), respectively. The full text of our survey is included as Appendix B.

At the end of the survey, we included an optional space for respondents to leave comments about survey content, question wording, and/or the approaches/assumptions they used to answer questions. Some of the comments helped shed light on our findings and suggested improvements that could be made in future survey projects of this type.

Before distributing the survey, we conducted a series of internal and external tests to help ensure that the questions were unambiguous, and we made several changes to improve question clarity.[6]

Selection of Respondents

We sought to identify a pool of respondents with demonstrated expertise in the economics of climate change. Building on the approach used in a prior survey (Holladay et al., 2009), we compiled a list of all authors who had published an article related to climate change in a leading economics or

[6] Even so, responses to question 14 seemed to show ambiguous interpretation by respondents, so we chose to drop this question from our analysis. This ambiguity was not flagged during pre-testing.

environmental economics journal since 1994.[7] We included all papers that referenced climate change and had implications for the climate change debate, even if that was not their main focus.[8] We defined leading journals as those ranked in the top 25 economics journals or top five environmental economics journals, according to two peer-reviewed rankings. Given that economic journal rankings have changed over our time frame, we use rankings from two time periods (Kalaitzidakis et al. (2003) and Kalaitzidakis et al. (2011)) and include any journal listed as a top-25 economics journal in either ranking. In total, we included 32 economic journals. Our environmental economics journal rankings came from Rousseau (2008) and Rousseau et al. (2009), which together revealed five journals with the highest ratings. One journal, the *Journal of Environmental Economics and Management (JEEM)*, appeared in both the economics and environmental economics rankings.

We conducted a thorough search of each journal for articles that mentioned "climate change" or "global warming" and significantly discussed the benefits, costs, or uncertainties of climate policies; applied or criticized a climate model; or explored the costs of climate change.[9] The articles published by the economic experts in our sample tended to have an academic focus on economic theory or statistical models; they were not political pieces, and most cannot be easily classified as advocating either for or against climate change policies.

After removing experts who died or individuals we could not locate, our review revealed 1,187 authors who fit our selection criteria. We then excluded respondents who stated that they no longer worked in this field and those who we were unable to contact based on an expired or no longer

---

[7] The 1994 date was chosen because it was 20 years before the beginning of this project, and because this cutoff includes the vast majority of papers on climate change.

[8] This broad definition of "climate change" is consistent with the approach used in Holladay et al, 2009.

[9] A small portion of the respondents in our sample are not Ph.D. economists. We chose to include all those who have authored a publication in a leading economics or environmental economics journal, even if their credentials are in another discipline, or they have not received a Ph.D. We believe this criterion was appropriate for demonstrating expertise in the economics of climate change, even if a small number of respondents are not professional economists.

functioning e-mail address (i.e., for whom the e-mail bounced back). With these authors removed, the total pool of experts was 1,103.

We sampled a larger group of economic experts than Holladay et al. (2009) because we chose to add the top environmental economics journals to our list (their sample focused only on the top 25 "standard" economics journals), and because a large number of articles related to climate change have been published in top journals since 2009. We also included publications from seven additional economic journals that were ranked in the top 25 of a more recent peer-reviewed ranking. That survey was sent to 289 experts, receiving 144 responses. Our pool consisted of 1,103 experts, and we received 365 responses – a response rate of 33.1%.

Our methodology for choosing respondents could suffer from selection bias, given that highly ranked academic journals might not publish articles encompassing the entire spectrum of thought on climate change economics. But we believe our approach adequately identified a large sample with demonstrated expertise in the economics of climate change. And our respondents were representative of a wide range of opinions, based on the diverse and often conflicting arguments made in their published articles.

Respondent Subsets

In addition to analyzing responses from the full sample, we disaggregated our respondent pool into four groups, in order to elucidate possible differences in the views of various subsets:[10]

- Group 1: Those who have published one article in a leading economics journal
    - Sample: 213; Responses: 66
- Group 2: Those who have published multiple articles in a leading economics journal[11]

[10] Respondents who had published in both economic and environmental journals were classified as having published in an economics journal.
[11] Those who had published in JEEM, which was included in both the economics and environmental economics journal ranking, were included in the environmental economics journal subset. However, we did separate JEEM authors into their own subset so we could study any differences in their views in the future.

  - Sample: 94; Responses: 32

- Group 3: Those who have published one article in a leading environmental-economics journal
  - Sample: 727; Responses: 200
- Group 4: Those who have published multiple articles in a leading environmental-economics journal
  - Sample: 153; Responses: 67

We also sought to disaggregate the pool based on specific area of expertise. The first survey question asked respondents which topic(s) they have published on, from the following list:

- Climate Change Risks
- Estimated Damages from Climate Change
- Global Climate Strategies
- International Agreements/Game Theory
- Greenhouse Gas Control Mechanisms
- Integrated Assessment Models/Social Cost of Carbon
- Climate Change Adaptation
- Other Climate-Related Topics
- None

Using this data on specific topic expertise and the subset groups above, we were able to disaggregate responses by group. For instance, we could see if additional markers of expertise, such as multiple publications or publications in the topic area of a specific survey question, were linked to distinctive views. Noteworthy findings related to subset differences are discussed in the "Results and Discussion" section of this paper.

Survey Administration

We administered the survey online through SurveyMonkey.com, creating separate but identical surveys for each survey group so that data could be segregated. The first page of the online survey had nine multiple-choice questions, and the second page had two multiple-choice questions and four open-ended questions asking for a numerical response in a text box.[12]

Each respondent was sent an email message that described the nature of the project, informed them of the reason for their selection, and requested their participation through an embedded hyperlink to the survey. Respondents were told that the survey would take less than 15 minutes to complete, and that individual responses would be anonymous (the survey did not ask for any identifying information or track individual responses). The survey remained open for 18 days, and respondents were sent two reminder emails that included deadline details. These emails were sent to the entire pool since we could not determine who had already completed the survey.

Response Rate

Excluding those who did not receive our e-mail, our overall response rate (as defined by R5 in AAORP (2011)) was 33.1%, and a similar response rate was observed regardless of journal type (31.9% of authors published in economics journals responded, compared to 30.3% of those published in environmental economics journals). The response rate was slightly lower for experts with one climate change publication (30.7%) than for experts with multiple publications (41.8%).

Question-specific response rates were slightly lower than the overall total because not all respondents answered every question. For multiple-choice questions on the first page of the survey, the completion rate was 95.6% to 99.7% – resulting in overall response rates (as defined by R5 in AAORP (2011)) of 31% to 33%. Multiple-choice questions on the second page had a response rate of 31%.

[12] We formatted the survey in this manner so that neither page would have an excessive amount of content, and so that the initial responses would be saved when a respondent clicked onto the second page. This allowed us to record responses from any respondents who chose not to finish all the questions on the second page.

Roughly 7% of those who participated stopped after completing the first page. The four "open-ended" questions asking for numerical estimates (on the second page) were answered by 58% to 65% of participants, leading to an overall response rate (R5) between 20% and 22%.

Though it is unclear from the literature what an "acceptable" response rate entails (Anderson et al., 2011), our general response rate was roughly in line with the average for online surveys in recent periods. Our overall effective response rate (RR6) is slightly lower than the 37% average found across 31 studies summarized in Sheehan (2001). However, there is strong evidence that e-mail survey response rates have been declining over time (Sheehan, 2001; Fan and Yan, 2010). For example, Sheehan's (2001) response rates over the 1998 and 1999 period average to 31%; these numbers are similar to our response rates in this survey. Similarly, Manfreda, Bosnjak, Berzelak, Haas, & Vehovar (2008) find that the average response rate for 45 web survey was 11% (Fan and Yan, 2010). With regards to these studies, our response rates are above or close to average. In a survey on discount rates, Drupp et al. (2015) had an overall response rate – for quantitative answers – of 30%, and a slightly lower response rate of 28% for the value of the "real risk free [interest] rate." This is slightly below our response rate for multiple choice questions and above our response rate for open-ended questions.

Chart 1. Response and Completion Rates of Survey, as defined by AAORP (2011)

Respondent Subset	Responses: Number of Complete and Partial responses	Response Rate (RR1 and RR2) Based on All Experts Who Met Our Selection Criteria (i.e., relative to 1,187)	Response Rate (RR5 and RR6) Excluding Those Who We Were Unable to Contact (i.e., relative to 1,103)	Completion Rate: % of Respondents Who Completed the Question
Total	365	30.7%	33.1%	-
Economics Journals	98	31.9%	33.2%	-
Environmental Journals	267	30.3%	33.0%	-
One publication	266	28.3%	30.7%	-
Multiple Publications	99	40.1%	41.8%	-
Multiple Choice Questions on 1st Page of Survey - All Respondents	349 to 364	29.4% to 30.7%	31.6% to 33%	95.6% to 99.7%
Multiple Choice Questions on 2nd Page of Survey - All Respondents	338 to 339	28.5% to 28.6%	30.6% to 30.7%	92.6% to 92.9%
Open Ended Questions on 2nd Page of Survey - All Respondents	213 to 238	17.9% to 20.1%	20.1% to 21.6%	58.4% to 65.2%

IV. Results and Discussion

Our results reveal several areas where expert consensus exists on the economics of climate change, and others where more research is necessary. Our key findings for each survey question are discussed below, and additional detail on question results can be found in the Appendix.

Respondent Expertise by Issue Area

Our first survey question helped clarify respondents' specific areas of expertise, based on the topics of their climate-related publications. Respondents were asked to check all topic areas on which they had published, from the following list: climate change risks; estimated damages from climate change; global climate strategies; international agreements/game theory; greenhouse gas control mechanisms; integrated assessment models/social cost of carbon; climate change adaptation; other climate-related topics; and none. This list of topics closely resembles the sections of our survey.

In addition to helping us understand our respondent base (given that all responses were anonymous), this question allowed us to disaggregate responses by group—for instance, we could see if those who had published on the economic risks from climate change viewed those risks differently than other respondents.

Of those who responded to our survey, only one respondent did not answer this question, and only nine respondents stated that they had not published on any of the listed topics.[13] Each topic was relatively well represented—the topic with the fewest published respondents was Climate Change Adaptation (22%), while GHG Control Mechanisms had the most with 38%. Of the 153 respondents that had published on "Other Climate-Related Topics" outside of our list, 72.5% had also published a paper on at least one topic covered in our survey. As a consequence, 85.5% of our total respondents published on at least one of the topics covered in our survey. See Table 1 and Figure 1 for a breakdown of responses to this question.

Comparing Experts and the General Public

Two of our survey questions solicited respondents' views on climate change risks, using question language from prominent surveys of the general public. Question 2 asked about the level of action that should be taken to address climate change, using wording from an MIT/Harvard public opinion survey that has been repeated regularly since 2003 (Ansolabehere and Konisky, 2014).

[13] These nine respondents published a paper that met our criteria for contributing to the discussion on climate economics. However, based on their responses to this question, these authors apparently did not view their papers as publications on climate change. Nevertheless, they completed the survey and we chose to include them in our sample, given that they met our definition for subject matter expertise.

Figure 1. Topics of Past Publications on Climate Change (All Respondents)

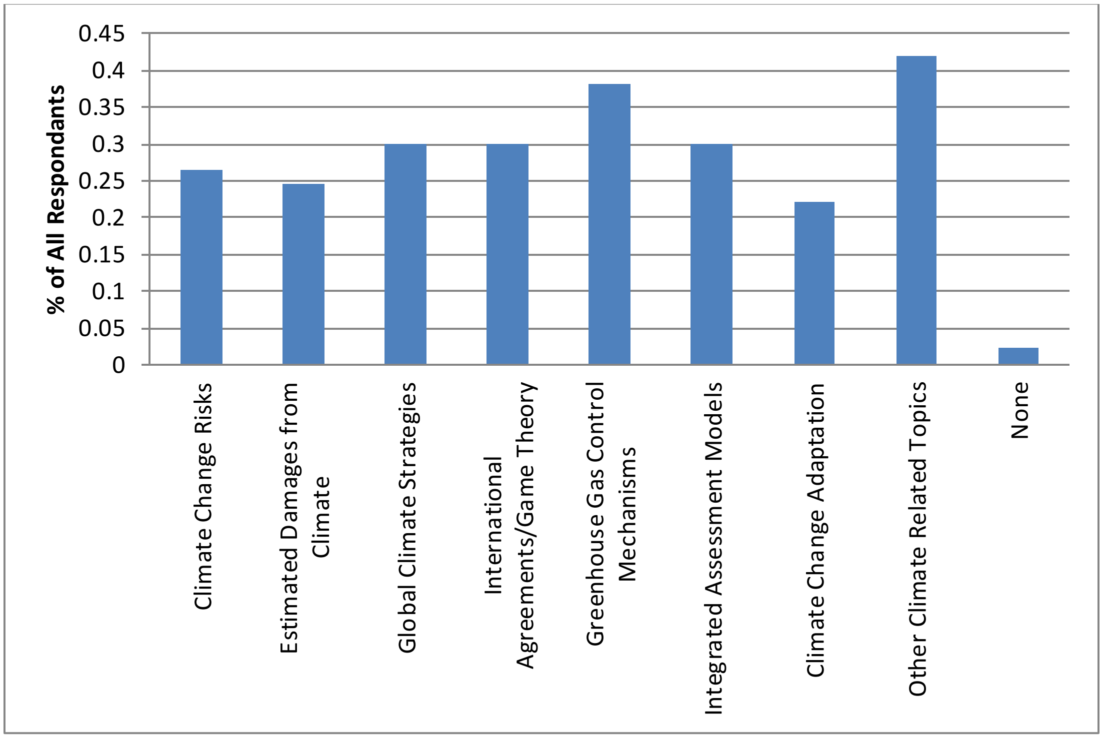
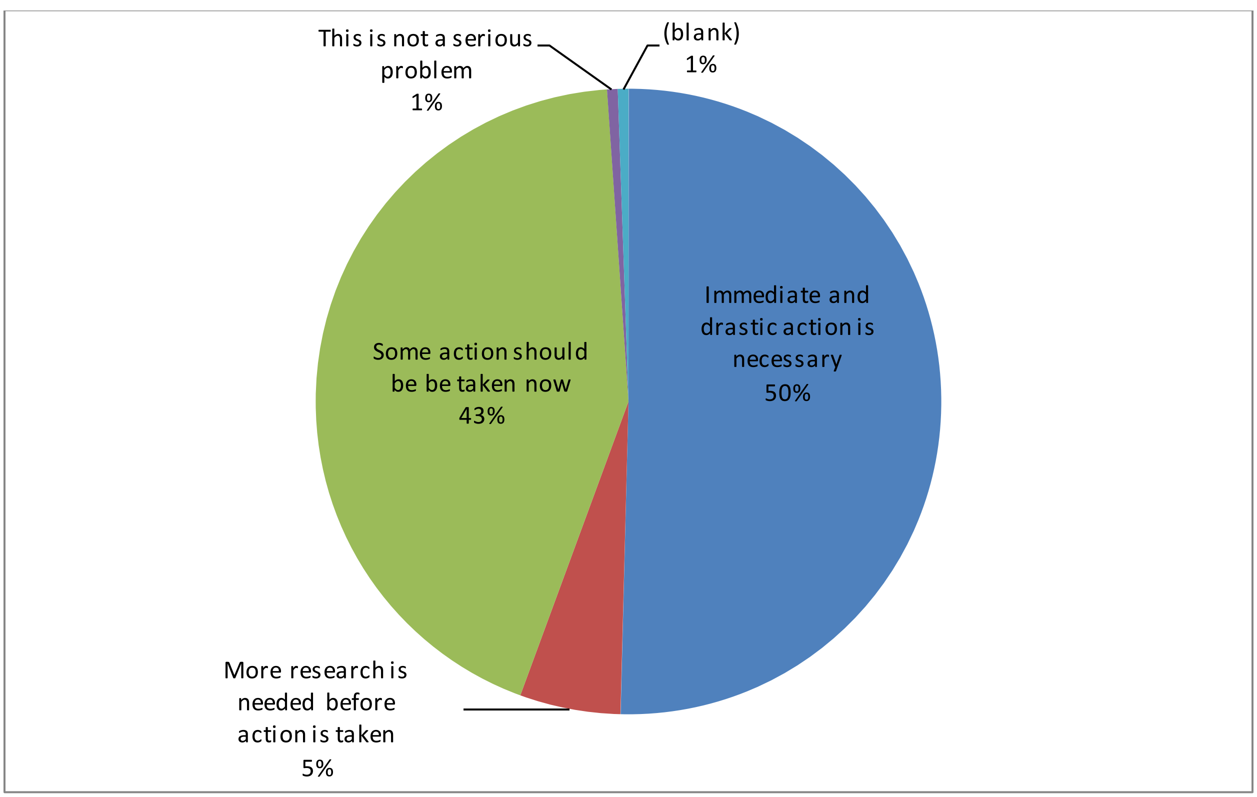


Figure 2. Which of The Following Best Describes Your Views About Climate Change? (All Respondents)

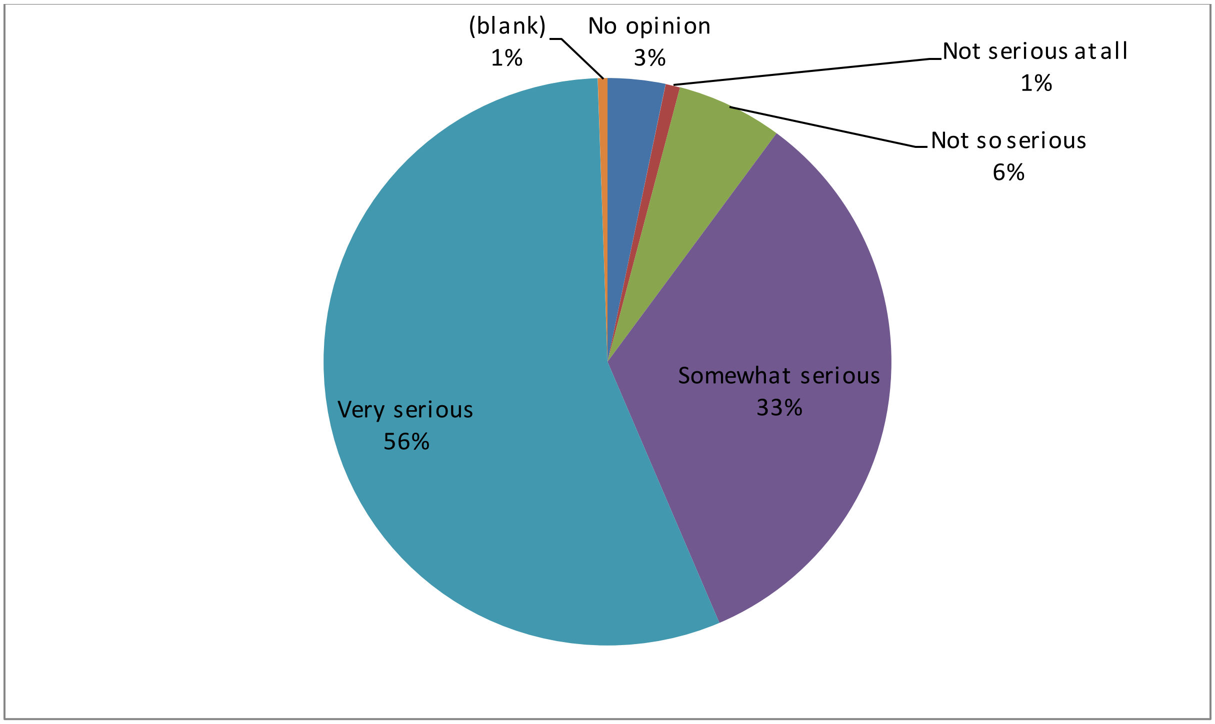


The economic experts in our sample advocated for a far more active response to climate change than did the general public. Half of our expert pool believed "immediate and drastic action is necessary," while the highest percentage of respondents to select this answer in the MIT survey was 35%, in 2006 (the percentage then fell to its all-time low, 19%, in 2007). More than 94% of the experts in our pool believed that either "drastic" or "some" action should be taken now to address climate change. Only 1% of experts believed that climate change "is not a serious problem" – this response has been selected by 10% to 25% of respondents in each iteration of the MIT survey.

Nearly all subsets of our pool overwhelmingly supported either "drastic" or "some" action. Those who have published an article that specifically addresses climate change risks were even more likely to support "drastic" action (55%). Authors who were selected based on publications in mainstream economics journals (rather than environmental economics journals) and those who were selected based on multiple publications were slightly more likely to support "some" action than "drastic" action, suggesting that these subsets are slightly more conservative in their views of climate risks. (For purposes of brevity we will refer to these groups as having published in economics journals or publishing multiple times from this point forward.) See Tables 2a and 2b and Figure 2 for responses.

A 2015 survey of the American public conducted by researchers at Resources for the Future, Stanford University, and the New York Times showed that 44% of respondents felt that global warming would be a "very serious" problem for the United States if nothing is done to address the issue (RFF, 2015). We asked the same question to our sample, and 56% said the problem would be "very serious." Leiserowitz et al. (2015) found that 52% of Americans are at least "somewhat worried" about global warming, but only 11% say they are "very worried" about it. Again, our sample showed higher levels of concern than the general public. We found that economic experts who have published on climate change risks were much more likely than other experts to believe that climate change would be a "very serious" problem (62%). See Tables 3a and 3b and Figure 3 for responses.

Figure 3. If Nothing Is Done to Limit Climate Change in the Future, How Serious of a Problem Do You Think it Will Be for the United States?



The economic experts in our pool clearly believe that climate change presents major risks, and that significant action should be taken to address climate change in the near term. On both counts, experts seem to show more concern about climate change than the general public.

Impact on Domestic Economic Sectors

We asked respondents to identify which major sectors of the United States' economy will be negatively affected by climate change, and the vast majority predicted negative impacts on agriculture (94%), fishing (78%), utilities (electricity, water, sanitation) (74%), forestry (73%), tourism/outdoor recreation (72%), and insurance (66%).

The almost universal agreement that agricultural will be negatively affected is somewhat surprising given the ongoing debate within the literature on whether moderate warming will boost or damage northern agricultural yields. It is possible that this finding is the result of the question's open-ended time frame – experts seem to believe that U.S. agriculture will be negatively affected over time, though they may or may not differ in their estimates of near-term changes.

Figure 4a. Domestic Economic Sectors Likely To Be Negatively Affected By Climate Change (All Respondents)

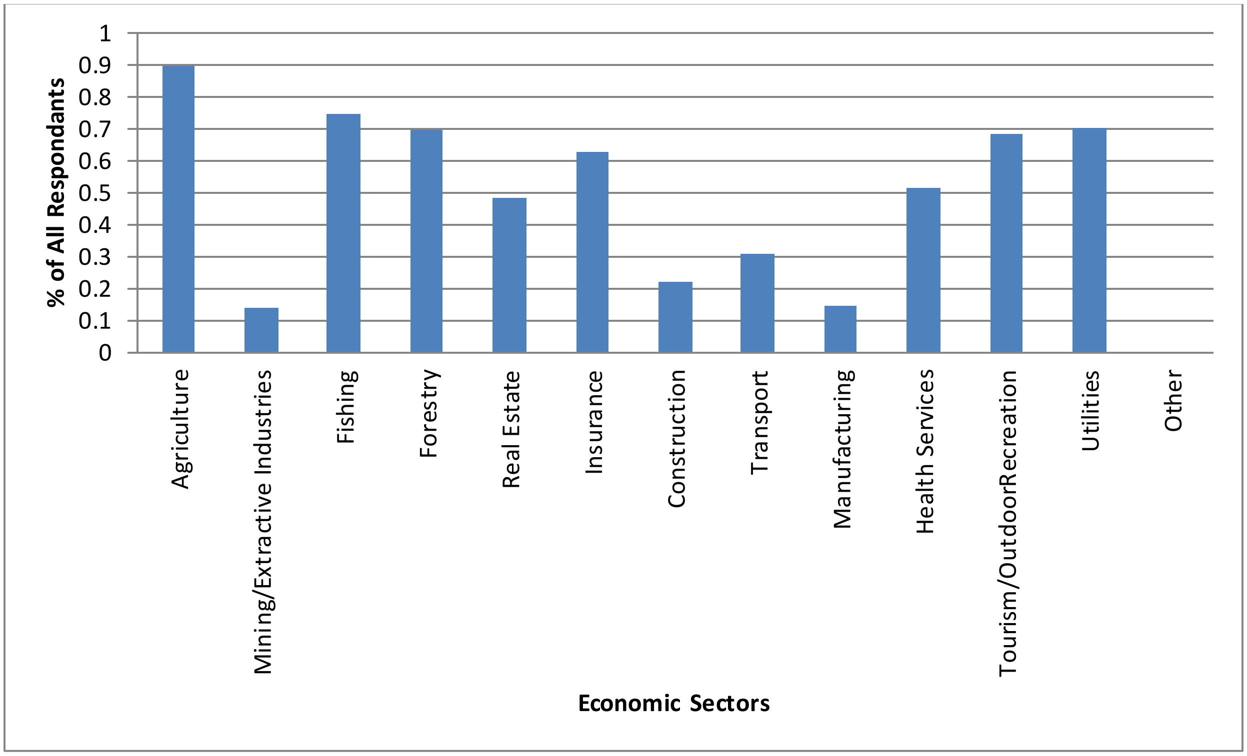
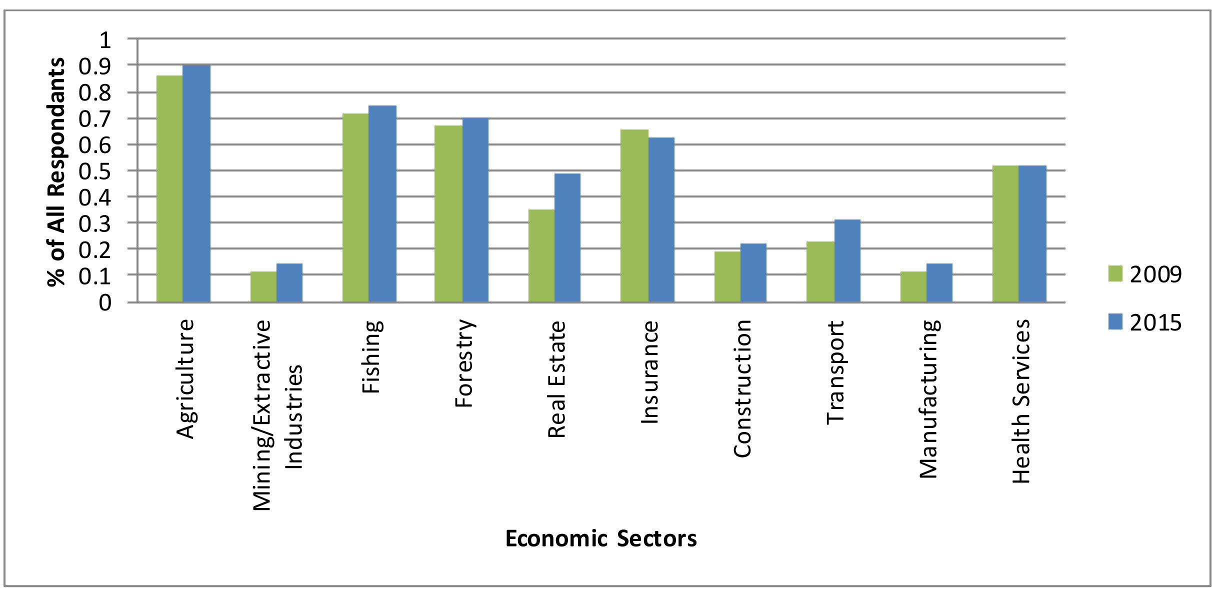


Figure 4b. Domestic Economic Sectors Likely To Be Negatively Affected By Climate Change (All Respondents), Compared to Results from Holladay et al. (2009)



More than half of respondents also predicted negative impacts on health services (54%) and real estate (51%). However, most experts believed that mining (15%), construction (24%), and transportation (32%) will be more resistant to negative impacts from climate change.

Holladay et al. (2009) asked this exact question to a smaller pool of similarly defined economic experts and their findings were remarkably consistent with these results (we added three sectors to the list in our survey: Tourism/Outdoor Recreation, Utilities, and Other). A comparison is shown in Figure 4b. The relative vulnerability of sectors remained consistent across the two surveys, though the results suggest that some perceptions have changed over time. Notably, the percentage of experts who believe real estate will be negatively affected grew from 35% to 49%. This finding suggests that economic experts have grown more confident that climate change will significantly damage the U.S. real estate sector; the difference does not seem to stem from our inclusion of environmental economics publications, given that nearly 50% of each subset of our sample predicted a negative effect on real estate.

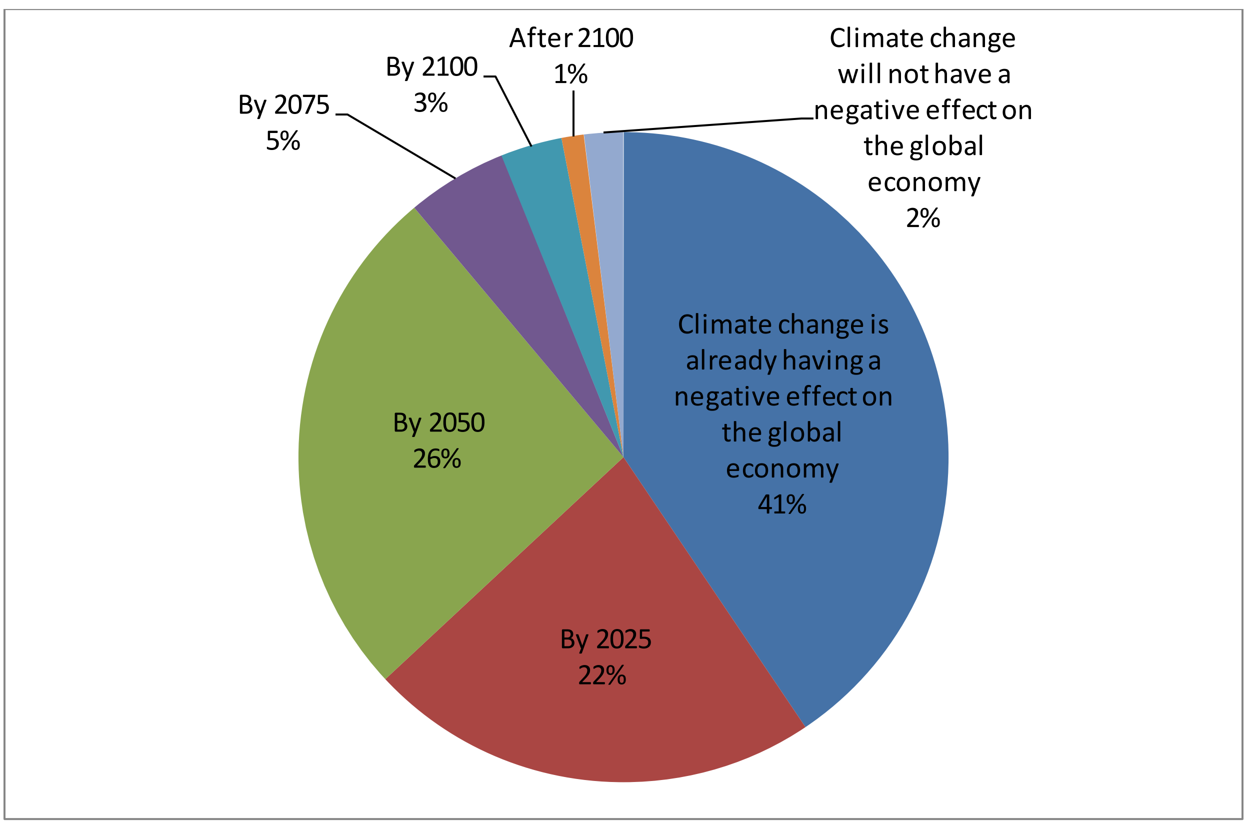
A few small but significant differences emerged when disaggregating responses to our survey by subset. Experts who had published in economics journals (rather than environmental economics journals) agreed strongly that the sectors generally seen as the most climate-sensitive—agriculture, fishing, and forestry—were highly susceptible to damages. However, they were less likely than other respondents to predict damages to other sectors, including transportation (25%), mining (12%), manufacturing (12%), health services (47%), tourism/outdoor recreation (65%), and utilities (68%). Those who had published more than one article were also approximately 10% more likely to predict negative effects on the U.S. mining industry. See Tables 4a and 4b and Figure 4 for responses.

When will climate change have a net negative affect on the global economy?

One of our most noteworthy findings emerged from our question about when the net effects of climate change will first have a negative impact on the global economy. (Respondents were told to assume a business-as-usual path for emissions, with no major new climate policies implemented.)

Policymakers and journalists often discuss damages from climate change as a problem for the distant future, but 40.6% of our respondents believed that "climate change is already having a negative effect on the global economy." Many others believed the net impact would be negative by 2025 or 2050; approximately 90% of total respondents believed that climate change will damage the global economy by mid-century. There was almost universal agreement that there will be a negative effect by the end of the century (97%).

Figure 5. During what time period do you believe the net effects of climate change will first have a negative impact on the global economy? (All Respondents)



The median estimate for when the net effects of climate change will become negative was "by 2025." This result differs greatly from the output of the FUND model, a climate-economic model used by many policymakers. FUND predicts that the net effects of climate change will begin to negatively affect the global economy around 2080 (Tol, 2013b). As a point of reference, Leiserowitz et al. (2015) found that 32% of Americans think people in the U.S. are being harmed "right now" by global warming.

Those who published in economics journals were slightly more conservative with respect to impacts in the next 10 years; 29% believed that negative impacts are already occurring and 54% believed that impacts will occur by 2025. Almost 85% believed that negative impacts will occur by 2050. Approximately 97% of experts publishing in economic journals believe that negative impacts will occur by the end of the century. Again, this subset had a median estimate of "by 2025."

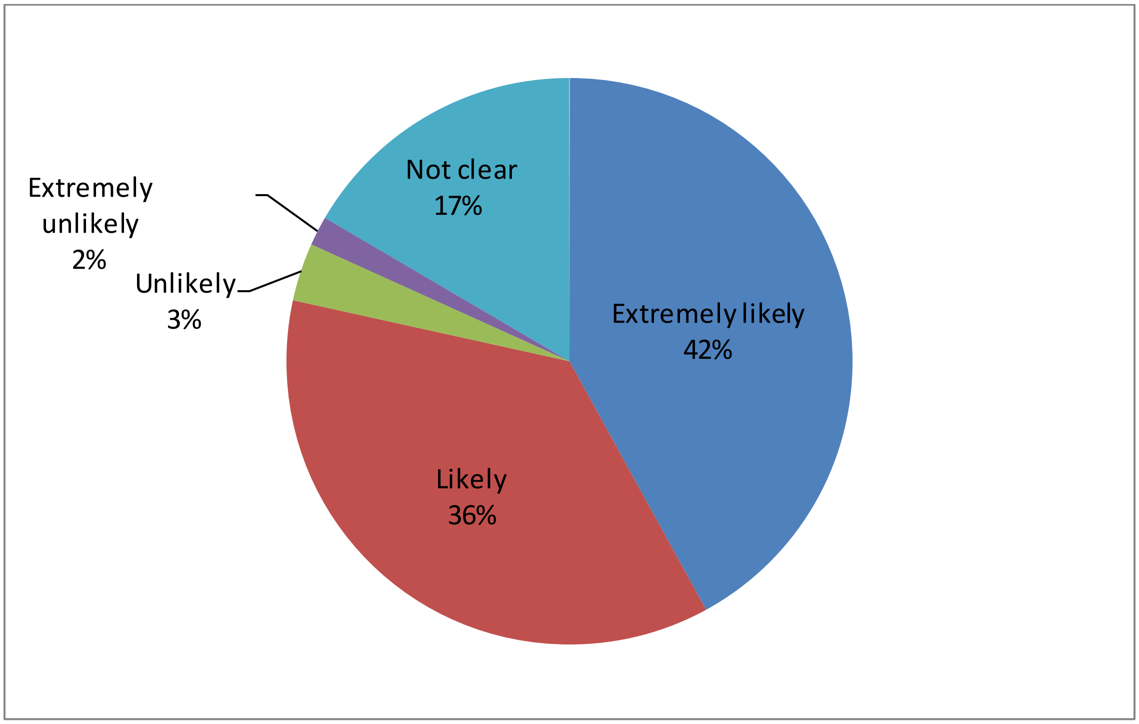
Additional markers of expertise, such as multiple publications or publications on climate damages or IAMs, did not have a large effect on respondents' views. Compared to the full sample, experts with multiple publications believed that there is a slightly higher probability of negative impacts in each of the time periods, while those with relevant publications believed that there are slightly lower probabilities in each period. Each group had a median estimate of "by 2025." See Tables 5a-d and Figure 5 for responses.

Growth Rates and Climate Change

In our sixth question, we asked respondents whether climate change will have a long-term, negative impact on the growth rate of the global economy. Approximately three-quarters believed that climate change will negatively affect economic growth. In particular, more than 40% believed that such effects are extremely likely. Only 5% of respondents thought that negative growth impacts were unlikely or extremely unlikely (approximately 15% of respondents believed that the evidence is unclear).

Those who had published in economics journals were marginally more conservative than the overall sample, with slightly more of these respondents viewing growth rate declines as "likely" (40%) than "extremely likely" (38%). Of those who had published an article on damages from climate change, 47% saw negative growth rate impacts as "extremely likely." See Tables 6a and 6b and Figure 6 responses.

Figure 6. What Is The Likelihood That Climate Change Will Have A Long-Term, Negative Impact On The Growth Rate Of The Global Economy? (All Respondents)

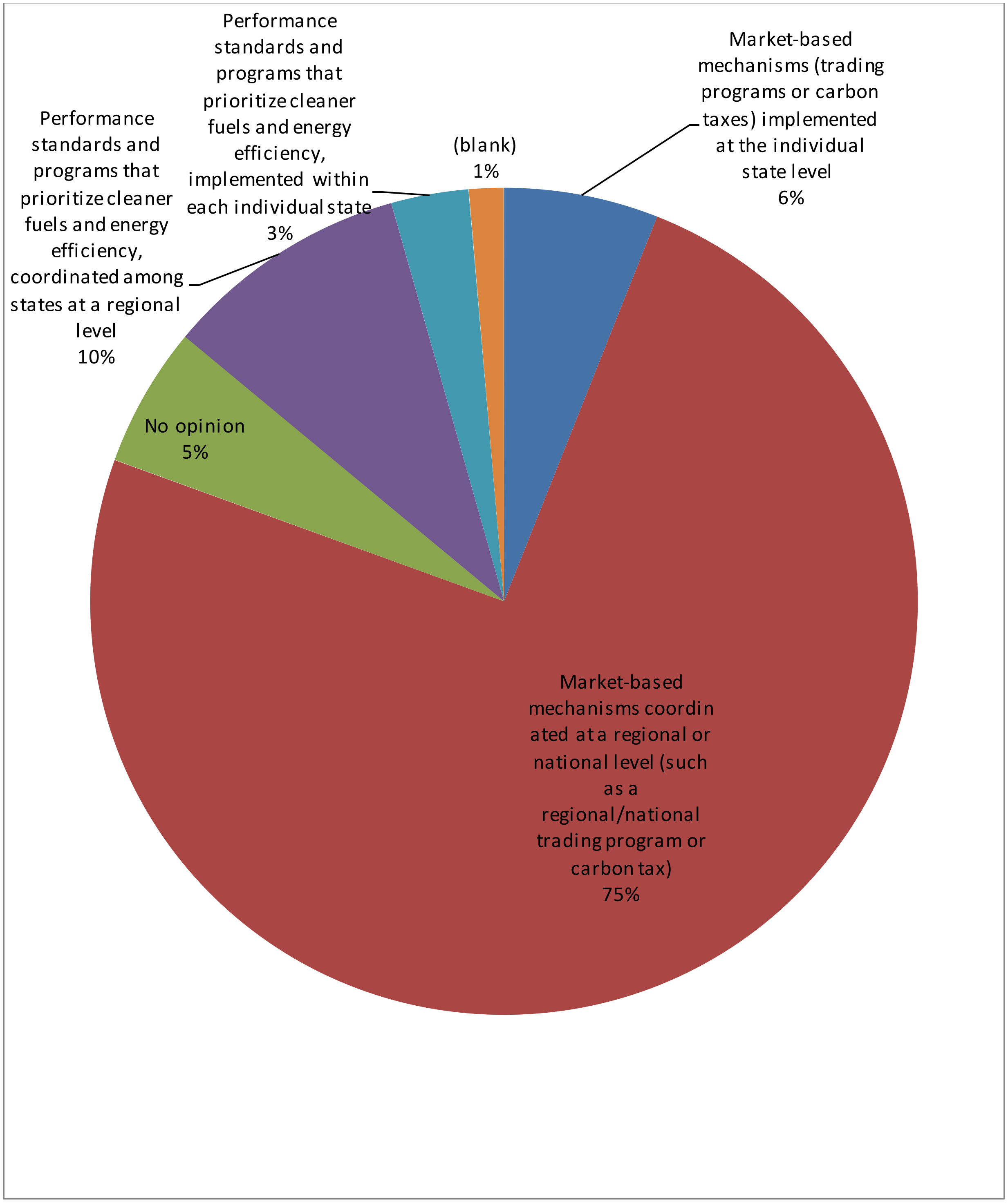


Greenhouse Gas Control Mechanisms under the Environmental Protection Agency's "Clean Power Plan"

We asked our pool of experts to weigh in on a current climate policy question facing many policymakers in the United States. Question 7 asked about the most desirable GHG control mechanisms to use for implementation of the Clean Power Plan – a soon-to-be-finalized regulation that will set GHG emission reduction targets for each state's electricity sector.

The vast majority of respondents (76%) believed that the most efficient option was "market-based mechanisms coordinated at a regional or national level (such as a regional/national trading program or carbon tax)."

Figure 7. The U.S. Environmental Protection Agency's "Clean Power Plan" Will Set Carbon Dioxide Emission Targets for Each Individual State's Electricity Sector. What Would Be the Most Efficient Way to Implement These Targets? (All Respondents)



The experts clearly believed that interstate trading would maximize efficiency, as the next most popular response also involved regional coordination – nearly 10% chose performance standards or similar programs coordinated regionally. In total, 85% of respondents supported mechanisms that allow for interstate trade.

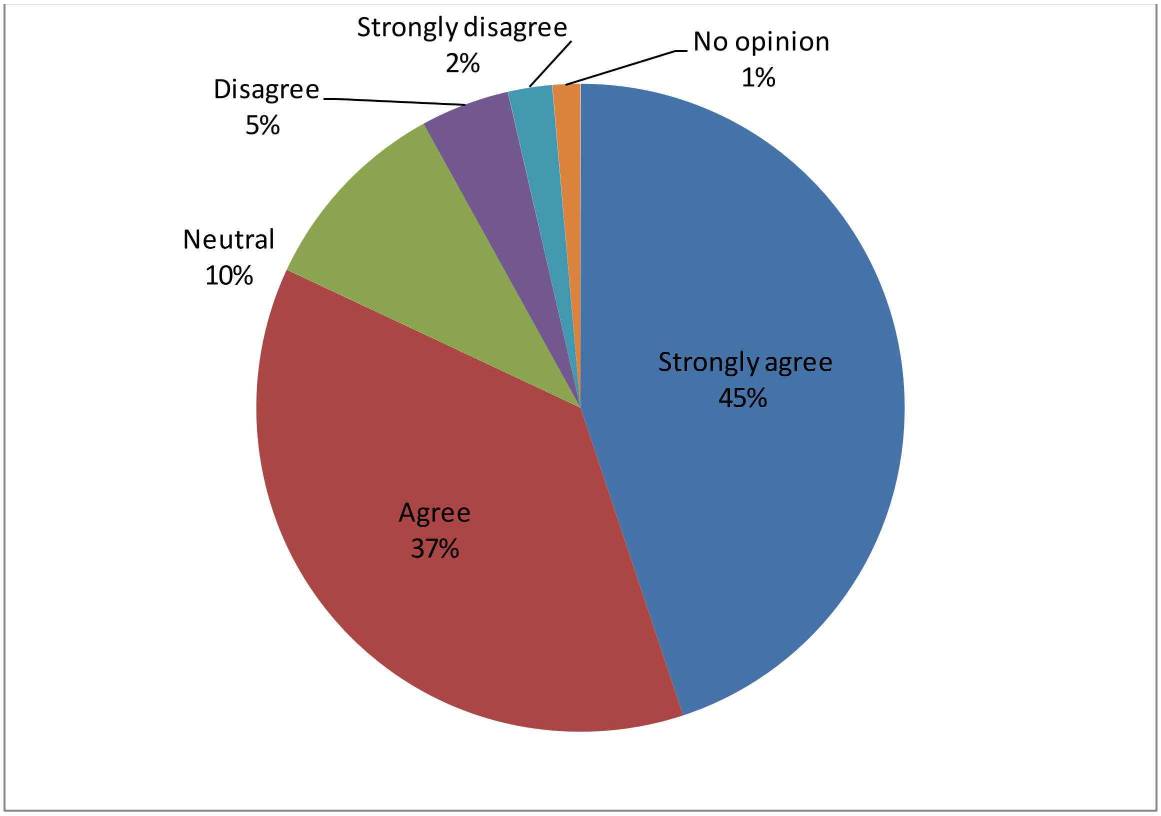
The preference for market-based mechanisms with interstate coordination was even stronger among experts who had published about GHG control mechanisms or published in mainstream economics journals (84% and 89%, respectively). Very few experts who had published in economic journals preferred performance standards; 1% supported state standards while none supported regional standards. See Tables 7a and 7b and Figure 7 for responses.

The United States Could Induce Other Countries to Reduce Emissions by Reducing U.S. Emissions

We asked our sample whether the United States may be able to strategically induce other countries to reduce their GHG emissions (or enter into an emissions reduction agreement) by adopting policies to reduce U.S. emissions. We found that 82% of the experts either "agreed" (37%) or "strongly agreed" (45%) that this may be possible. The findings were generally consistent across subsets of our sample, though experts who had published in economics journals or written about international agreements were slightly more likely than average to disagree (they disagreed/strongly disagreed at rates of 8% and 6%, respectively). Experts who had published on global climate strategy chose "strongly agree" at a very high rate of 55%. See Tables 8a and 8b and Figure 8 for responses.

This finding could be relevant to policymakers, as it suggests that more aggressive domestic climate policies could induce international action, potentially overcoming the free-rider problem that some cite as a reason to avoid unilateral emissions reductions.

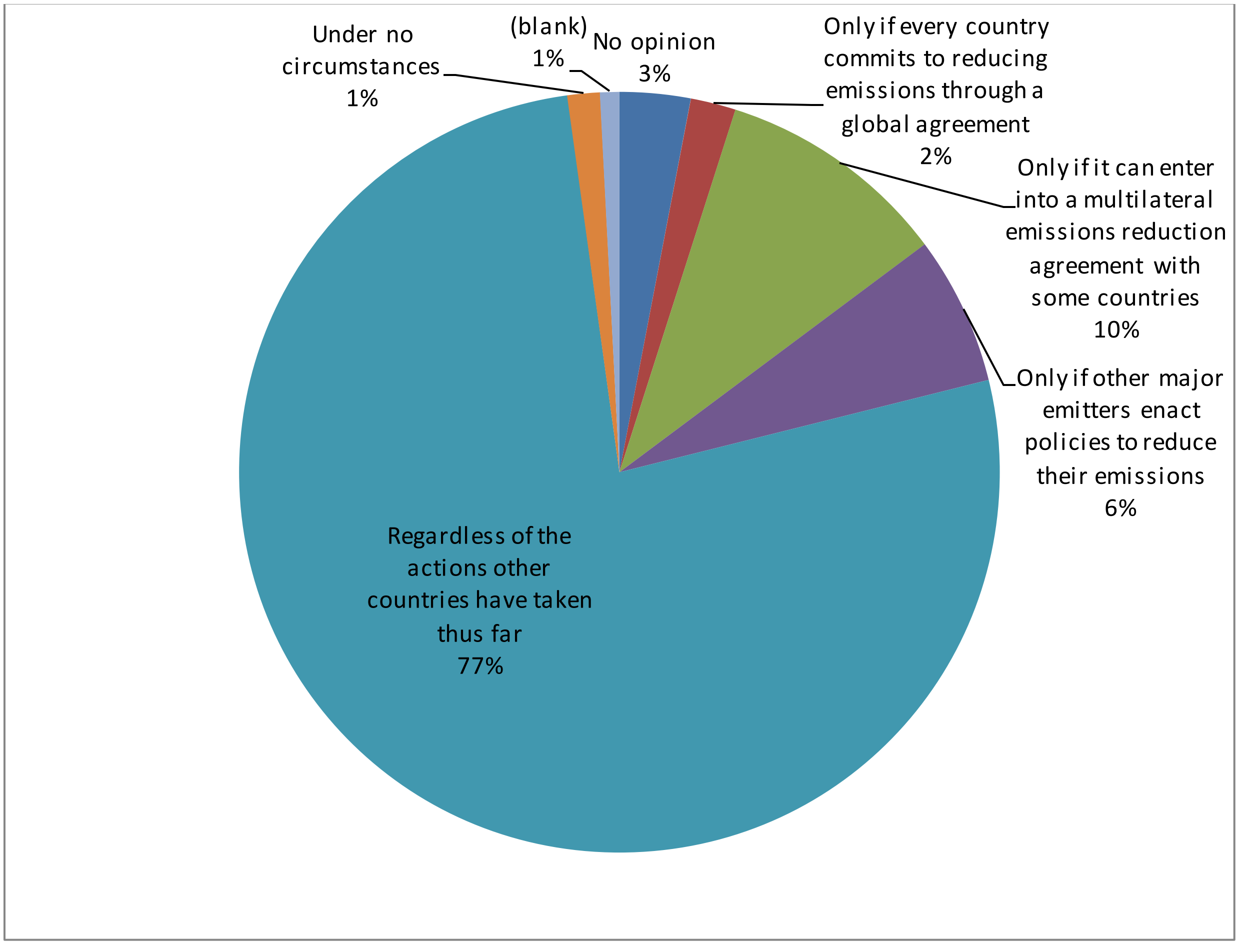
Figure 8. The United States May Be Able To Strategically Induce Other Countries to Reduce Their Greenhouse Gas Emissions (Or Enter Into an Emissions Reduction Agreement) By Adopting Policies to Reduce U.S. Emissions (All Respondents)



Support for Unilateral Emissions Reductions

Experts in our sample overwhelmingly supported unilateral GHG reduction commitments by the United States, regardless of the actions other countries have taken. Some subsets, such as those who have published in economics journals, published multiple articles, or written on international agreements, were a bit more likely to support reduction commitments only if other countries took some form of action. However, at least 72% of every subset supported unilateral action. Nearly 81% of experts who have published on the topic of global climate strategies supported unilateral reduction commitments by the United States. See Tables 9a and 9b and Figure 9 for responses.

Figure 9. The U.S. Government Should Commit To Reducing Greenhouse Gas Emissions: (All Respondents)

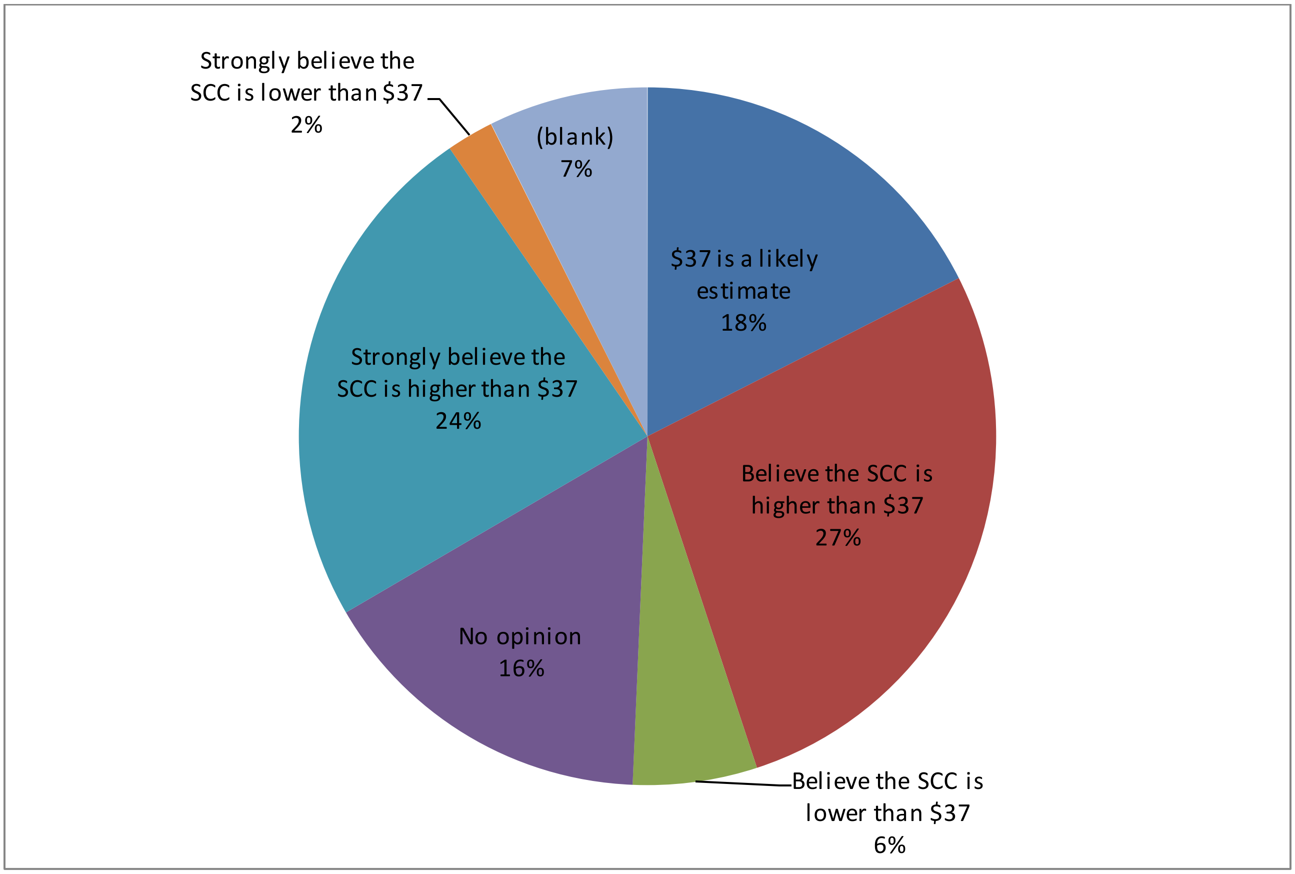


The Appropriateness of the U.S. Government's Social Cost of Carbon Valuation

Economists have long debated the appropriate value for the social cost of carbon (SCC). We asked respondents whether they believed that the official U.S. estimate of the SCC was appropriate, and our findings revealed a strong consensus that the SCC should be greater than or equal to the current $37 estimate.

Our question provided the following background: "The global 'social cost of carbon' (SCC) is the marginal cost to society of carbon dioxide emissions. Specifically, it is the present value of all future damages to the global society of one additional metric ton of carbon dioxide-equivalent greenhouse gasses emitted today. In 2013, a U.S. government Interagency Working Group adopted $37 (in 2007 USD) as its central estimate for the SCC (this figure estimates the economic damages of a unit of 2015 emissions, with a 3% discount rate)." We then asked respondents for their opinion of the estimate.

Figure 10. Opinions of the U.S. Government's SCC Valuation (All Respondents)



This was the initial question on the survey's second and final page, and the completion rate dropped from roughly 99% (for questions on the first page) to just above 90% (338 responses).[14]

More than half of respondents believed that $37 is too low of a value for the SCC, and more than two-thirds believed that that actual SCC was equal or greater than $37. Twice as many experts had no opinion (16%) as believed that the SCC is too low (8 %). If we exclude individuals that did not answer this question, three-quarters of respondents believed that the actual SCC is equal or greater than $37, as

[14] Given that the experts who did not fill out question 10 also did not fill out questions 11-15 (with the exception of one respondent), it is likely that this drop in the response rate to question 10 is result of it being the first question on the second page of the survey.

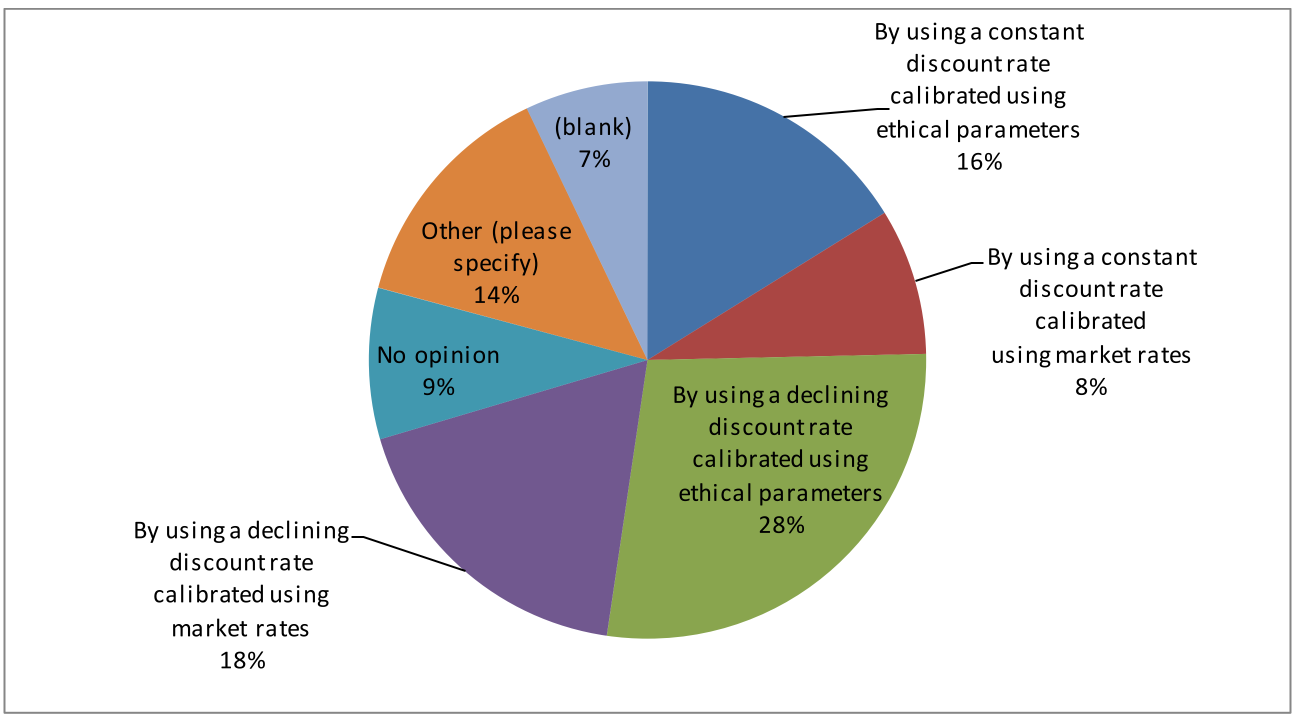
compared to the 9% that believe that $37 is too high. Results were consistent across most subsets, though experts who published in economics journals were far more likely to believe that the official SCC estimate is too high (13.6%).

Respondents who have published on IAMs and/or the SCC were far more likely than the general sample to believe that the official SCC is too low: approximately one third of this group "strongly believed" that the SCC is higher than $37, and approximately two thirds believed that it is higher. Only 12% believed or strongly believed it was lower. See Tables 10a-d and Figure 10 for responses.

Discounting Benefits to Future Generations

We asked respondents about the appropriate method for discounting the benefits and costs of climate change and climate change action (such as adaptation and mitigation) to future generations. Specifically, we sought their views on (1) constant vs. declining rates, and (2) market-calibrated rates vs. rates calibrated using ethical parameters.

Figure 11. How Should the Benefits to Future Generations of Climate Change Mitigation Be Evaluated/Discounted? (All Respondents)



No consensus emerged around a single methodology, though nearly half (46%) of respondents favored one of the two approaches that featured declining discount rates. The two approaches using rates calibrated with ethical parameters also received support from nearly half of the group (44%) when summed. The most common response (28%) combined these two attributes.

It is noteworthy that the least popular approach (8%) was a constant discount rate calibrated to market rates – this is the approach currently used by the U.S. government to analyze regulations and other policies.

Respondents who published in economics journals were much more likely to favor a declining discount rate (58%) and calibration based on ethical parameters (52%). Similarly, those with additional expertise – as defined by multiple publications or publications on IAMs/ SCC – were also much more likely to support declining discount rates and/or ethical based calibration. In fact, close to two thirds of authors who published on IAMs or the SCC favored declining discount rates, and approximately half favored calibration based on ethical parameters. See Tables 11a-d and Figure 11 for responses.

Choosing an Appropriate (Constant) Discount Rate

Our first open-ended question asked respondents to provide the appropriate constant discount rate for calculating the social cost of carbon. Currently, the U.S. government uses rates of 2.5%, 3%, and 5% in this calculation. Our pool of experts believed that the appropriate constant discount rate should be equal to or less than the 3% central discount rate used by the government.

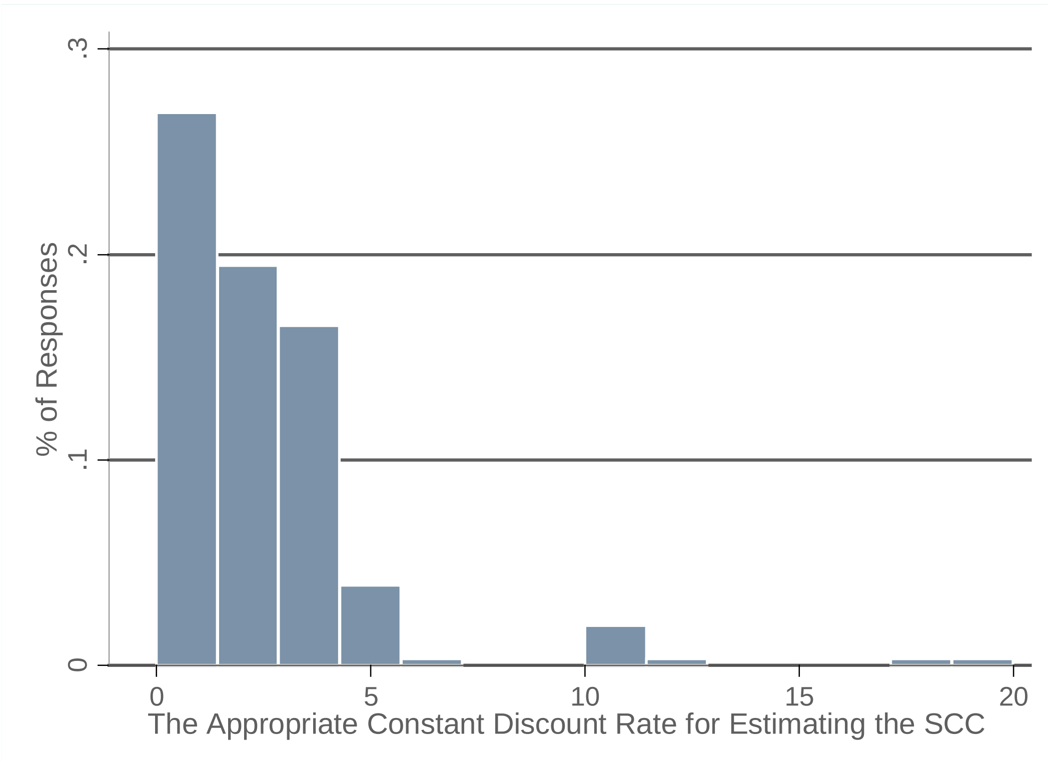
Roughly 60% of completed surveys included an answer to this question (completion rates for all open-ended questions were lower than for multiple-choice questions).[15]

For those that responded to this question, the mean and median estimates were approximately 3% and 2%, respectively. Similar results were found for all subsets. Interestingly, 2% was the mean and

[15] The response rate increases to greater than two-thirds for "experts" as defined as authors selected for the survey based on multiple publications or respondents who identified themselves as publishing on the topics of integrated assessment models or the social cost of carbon.

median constant discount rate selected by experts who published in economics journals; this is below the lowest discount rate (2.5%) used by the U.S. government in the calculation of the official social cost of carbon.

Figure 12. Histogram: "If Benefits To Future Generations Are To Be Discounted Using A Constant Discount Rate, The Appropriate Discount Rate To Use When Calculating The Social Cost Of Carbon Is:" (Trimmed bottom 1% and top 99%)



If we trim the full data set to eliminate outliers, the consensus estimate gets even lower. When excluding the 1st percentile and 99th percentile estimates, we find that the mean and median are 2.3% and 2%, respectively. If we further restrict our attention to estimates between the 5th and 95th percentile, we find mean and median estimates of 1.87% and 2%. (These estimates are similar to those of experts who were selected based on publications in economic journals.). Following Wietzman (2001), we trim estimates below 0.5% and above 12%, and find a mean and median of 2.6% and 2%.

Additionally, we find that responses in the 90th percentile vary from 3% to 5% across all subsets. This strongly suggests that experts believe that the 5% discount rate – the maximum rate used by the U.S.

government – is on the high end of what economists recommend. A 7% discount rate – suggested by some – is clearly inappropriate.

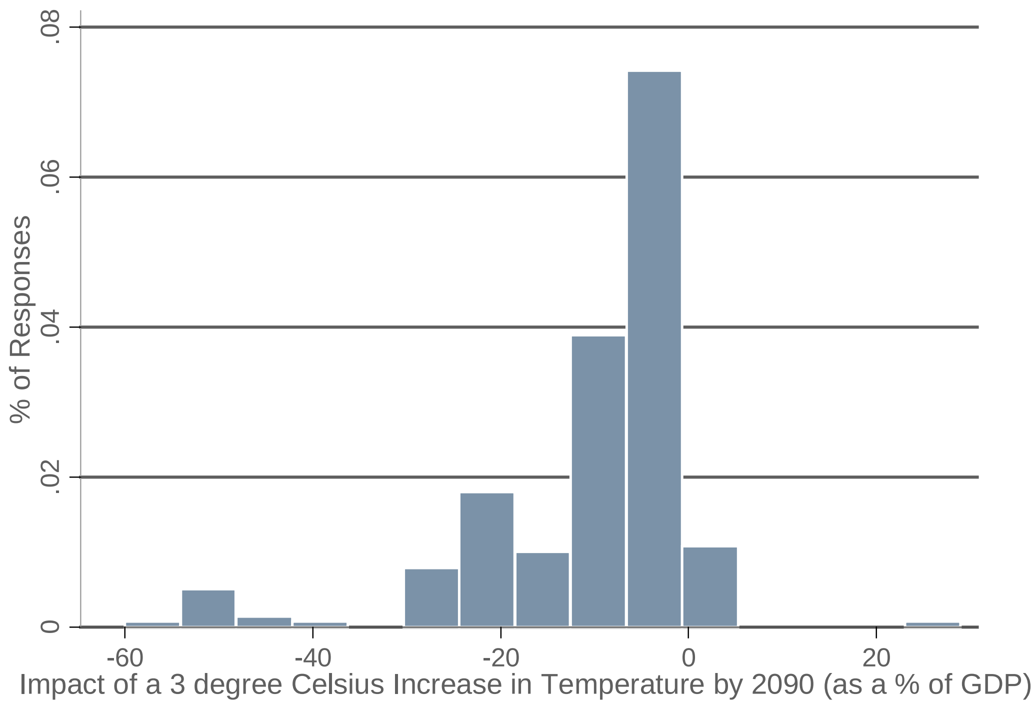
Our results are similar to Drupp et al. (2015) who find that the mean and median of the constant discount rate are 2.25% and 2%, respectively. (Our findings match these results especially closely when we exclude outliers.) Like Drupp et al. (2015), our results are slightly below the mean and median found by Weitzman (2001) of 4% and 3%, respectively. See Table 12 and Figure 12 for results.

Estimating Climate Impacts

We asked respondents to provide their best estimate of the impact on market and non-market goods as a percentage of GDP, based on the following climate change scenario: global mean temperature increases by 3°C relative to the pre-industrial era (i.e., a 2.1°C increase from the current period) by approximately 2090.

We find that on average, experts' best estimate of the economic impacts from 3°C of warming by 2090 is between -5% and -10% of GDP (including market and non-market impacts), with considerable variation. For experts that responded to this question, the mean and median estimates for impacts were -10.2% and -5.5%, respectively, with a variance of 133%.

Figure 13. Histogram: What Is Your Best Guess (Median/50th Percentile Estimate) of the Impact on Global Output, as a Percentage of GDP? Please Include Non-Market and Market Impacts, and Factor In Adaptation To Climate Change. (All Respondents)



Similar results were found for all subsets, with some minor exceptions: the mean impact for those publishing in economics journals was slightly more conservative at -7.1%, while the median impact for those who published in environmental journals was higher at -10%. Experts with multiple publications had a mean of -9.1%, while those who had published on IAMs had a mean of -8.5%.

The 90th percentile estimate was between -2% and 0% for all groups. If we trim the data to eliminate outliers, we get slightly lower damage estimates. If we restrict our attention to estimates between the 1st and 99th percentiles, we find that the mean and median are -10.2% and -6%, respectively, for the overall sample. If we further restrict our attention to estimates between the 5th and 95th percentile, we find mean and median estimates of -8.7% and -5%, respectively.

These average impact estimates are slightly higher than the estimates from a previous survey on non-catastrophic impacts, though the range of the magnitude and variance are similar. Nordhaus (1994) found mean and median estimates of -3.6% and -1.9% for an identical scenario. Schauer (1995) estimated mean and median impacts of -5.2% and -2.6% with a variance of 71.3% for a doubling of CO_2 (a 2.5 degree Celsius increase relative to pre-industrial temperature). These previous estimates relied on the results of handpicked experts – including scientists – instead of a large sample of economists. The estimates are also higher than the three IAMs used by the US government to calculate the official SCC: DICE-2010 has an estimate of slightly below -2.4% for a 3°C increase relative to the pre-industrial temperature (based on RICE-2010);[16] FUND projects +1.42% for a 1 °C increase; and PAGE09 projects 1.12% for a 3°C increase (Howard, 2015). See Table 13 and Figure 13 for response details.

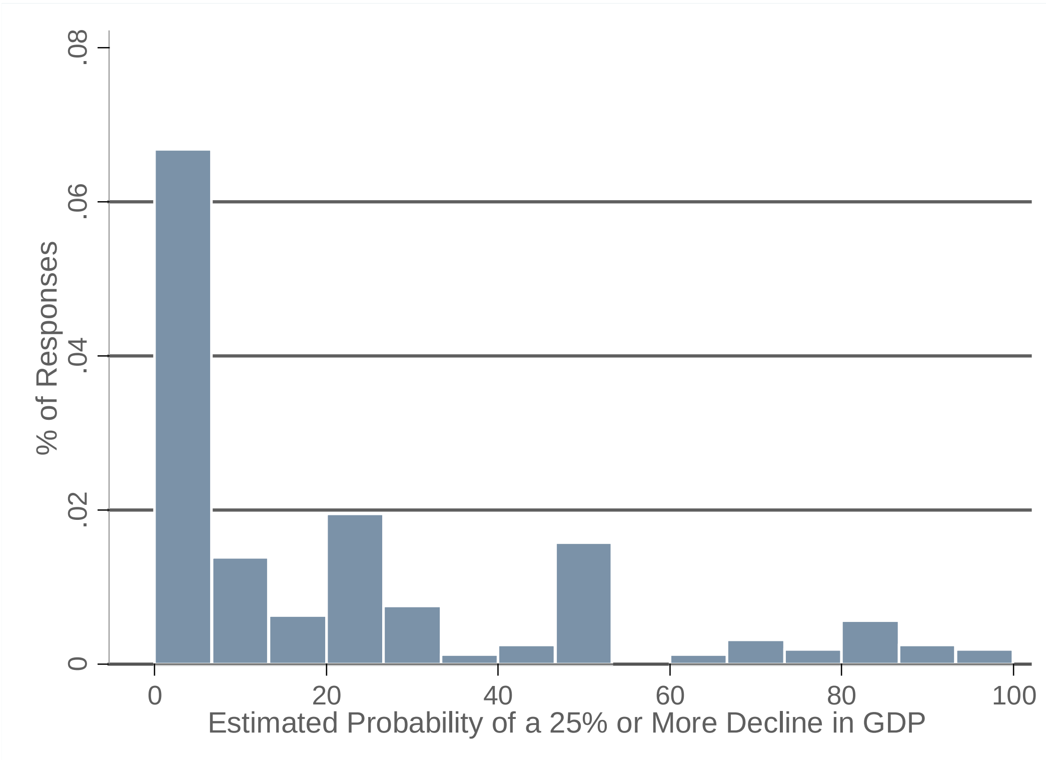
Probability of Catastrophic Impacts from Climate Change

Our final question[17] asked respondents to estimate the probability of catastrophic impacts from a 3°C global temperature increase by 2090. Our question read: "Some people are concerned about a low-probability, high-consequence outcome from climate change, potentially caused by environmental tipping points. Assume by 'high-consequence' we mean a 25% loss or more in global income indefinitely. (Global output dropped by approximately 25% during the Great Depression.) What is your median/50th percentile estimate of the probability of such a high-consequence outcome if global average temperature were to increase 3°C by 2090?"

[16] The most recent version of DICE, i.e., DICE-2013, predicts a decline of 2.4% for a 3 degree increase; this version of DICE is not yet used to calculate the United States' official SCC estimate.

[17] In our penultimate question, we asked respondents to provide their best guess of the breakdown between effects on the market sector (e.g., food and fiber, service sector, and manufacturing) and the non-market sector (e.g., environmental amenities, ecosystems, and human health). Respondents were again asked to assume a 3°C temperature increase by 2090. Our results implied that many respondents misunderstood the question, as some seemed to give percentages of GDP rather than percentages of total impact. Given this uncertainty, we do not present results here (results are available from the authors upon request). We used various methods to clean up the data, and based on those methods, mean market impacts ranged between 30% and 50%. These results differ from Nordhaus (1994), who unexpectedly found that impacts were borne mostly by the market sector. Under an identical warming scenario, Nordhaus (1994) estimated that the market sector would face mean and median impact percentages of 62.4% and 62.5%, respectively.

Figure 15. Histogram: Median/50th Percentile estimates of the Probability that a 3°C Increase by 2090 Will Reduce GDP by 25% or More (All Respondents)



On average, respondents' best estimate of the probability of a "high-consequence" outcome was between 10% and 20%, though the variance in the responses was quite high. For the full sample, the mean and median probabilities were 22% and 10%, respectively. The variance was 665.6%, resulting in a wide 90th percentile of 0.8% and 60%, respectively. These results do not differ between the 95th and 99th percentiles. Respondents who have published in an economics journal differed from the general sample: this subset had mean and median probabilities of 11.3% and 5%, respectively.

Our respondents estimated a higher probability of catastrophic outcomes than Nordhaus (1994) found for an identical warming scenario. He found mean and median probabilities of 0.5% and 4.8% for a 25% drop in GDP. Our results are not directly comparable with Nordhaus because (1) we ask for a probability of a 25% *or greater* loss in GDP instead of a 25% decline specifically, and (2) we analyze a large group of economic experts, while he analyzed a select group of economists, other social scientists, and natural scientists. See Table 15 and Figure 15 for more details.

V. Additional Analysis on Climate Damages

Using our survey results on climate damages (Questions 5, 13, and 15), we are able to construct climate damage curves. Using these damage curves in the DICE model, we estimate the social cost of carbon such that it reflects the current state of expert opinion on expected damages from climate change.

Non-catastrophic Damages

Using our survey results, we can calibrate non-catastrophic climate damage functions to replace the DICE-2013 damage function.[18] Much in the way that Nordhaus and Boyer (1999) and Nordhaus (2008) used the responses in the Nordhaus (1994) survey to calibrate catastrophic damages in the DICE-99 and DICE-2007 models, we utilize responses to our survey to calibrate the DICE damage function – $D = \alpha_1 T + \alpha_2 T^2$ where D is the % decline in GDP from a T °C increase in global average surface temperature above the pre-industrial level – to reflect the current consensus of economic experts on climate change. Following the DICE-2013R assumption, we calibrate α_2 using responses to questions 13 assuming no initial benefits from climate change (i.e., $\alpha_1 = 0$). Making the traditional assumption that damages are equal to zero when the temperature increase equals zero, this parameter equals the mean (or median) damage estimate drawn from responses to question 13 divided by the corresponding temperature increase – a 3°C increase relative to pre-industrial temperatures – squared (i.e., $\alpha_2 = \frac{D}{T^2} = \frac{D}{9}$). We calibrate the parameter α_2 using responses to our survey by the various sub-groups and responses to Nordhaus (1994). See Table 16a and Figures 16a.

[18] The DICE-2013 damage function captures only non-catastrophic climate impacts.

As expected given the responses to questions 13, our mean and median damage functions are above Nordhaus' (1994) mean and median damage functions for non-catastrophic impacts. Specifically, the damage coefficient calibrated using all responses to question 13 is slightly below a three-fold increase from Nordhaus (1994). Even when α_2 is calibrated using response to question 13 from relatively conservative subgroups – those who published in economic journals or who have expertise in integrated assessment models – the coefficient is two-fold or higher than Nordhaus' (1994).[19]

Interestingly – even with the rather arbitrary quadratic functional form – our resulting damage functions correspond to recent scientific literature cited by Weitzman (2010) in arguing that 99% of GDP will be lost for a 12°C increase. We find that climate change will result in a 100% loss in GDP for 9°C (mean) to 13 °C (median) increases when considering only non-catastrophic impacts. Alternatively, the quadratic damage function calibrated to the mean and median responses of the Nordhaus (1994) study implies threshold temperatures of 16°C and 22°C, respectively, while the recent DICE-2013 damage function implies a 100% decline in GDP for a 19°C increase in temperature above pre-industrial levels.

Given that the consensus damage functions drawn from our survey imply higher impacts than those generated from integrated assessment models, it is unsurprising that they suggest that the social cost of carbon is higher than the estimates from DICE and other models. The base scenario run of DICE-2013R estimates a 2015 social cost of carbon[20] of $23/metric ton in current USD. If we maintain Nordhaus' assumption of no initial benefits from climate change and replace the DICE-2013R damage function with the damage functions estimated above, we find a 3 to 16 fold increase in the 2015 SCC, depending on the expert group of interest. If we utilize the damage function corresponding to the consensus of all

[19] The subgroups of experts who published in environmental journals and/or who have published about climate damages have damage coefficients that are higher than the general population of economic experts.

[20] DICE-2013R assumes that the 2015 social cost of carbon equals the value of consumption necessary to offset the social welfare loss from an additional unit of emissions in 2015. Thus, it is equal to marginal social welfare with respect to emission $\left(\frac{\partial U}{\partial E}\right)$ divided by marginal social welfare with response to consumption $\left(\frac{\partial U}{\partial C}\right)$, such that $SCC = \left(\frac{\partial U}{\partial E} / \frac{\partial U}{\partial C}\right) = \frac{\partial C}{\partial E}|_{U=\bar{U}}$ where U is the social welfare function, E is the amount of carbon emissions, C is per capita consumption in dollar terms, and $\bar{U}$ is the level of social welfare before adding the marginal emission.

responses to question 13, the 2015 SCC increases to $113/metric ton in current USD – almost a five-fold increase with respect to DICE-2013R and a three-fold increase with respect to Nordhaus (1994); see Table 17 and Figures 17 and 18a.

Figure 16a. Non-Catastrophic Damage Functions Calibrated using Responses to our Survey (i.e., questions 13) and Nordhaus' (1994) Survey, assuming no initial benefits from climate change

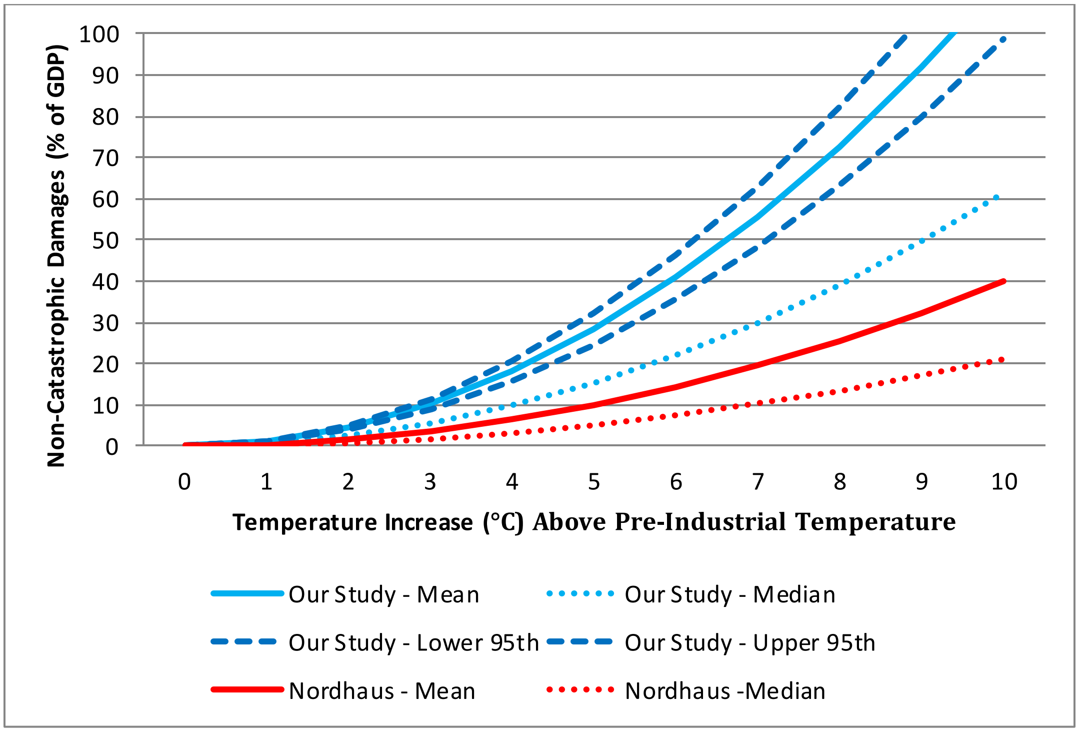


Figure 16b. Damage Functions Calibrated using Responses to Our Survey (i.e., questions 5 and 13) assuming initial benefits and/or a limit on GDP impacts of 100% of GDP

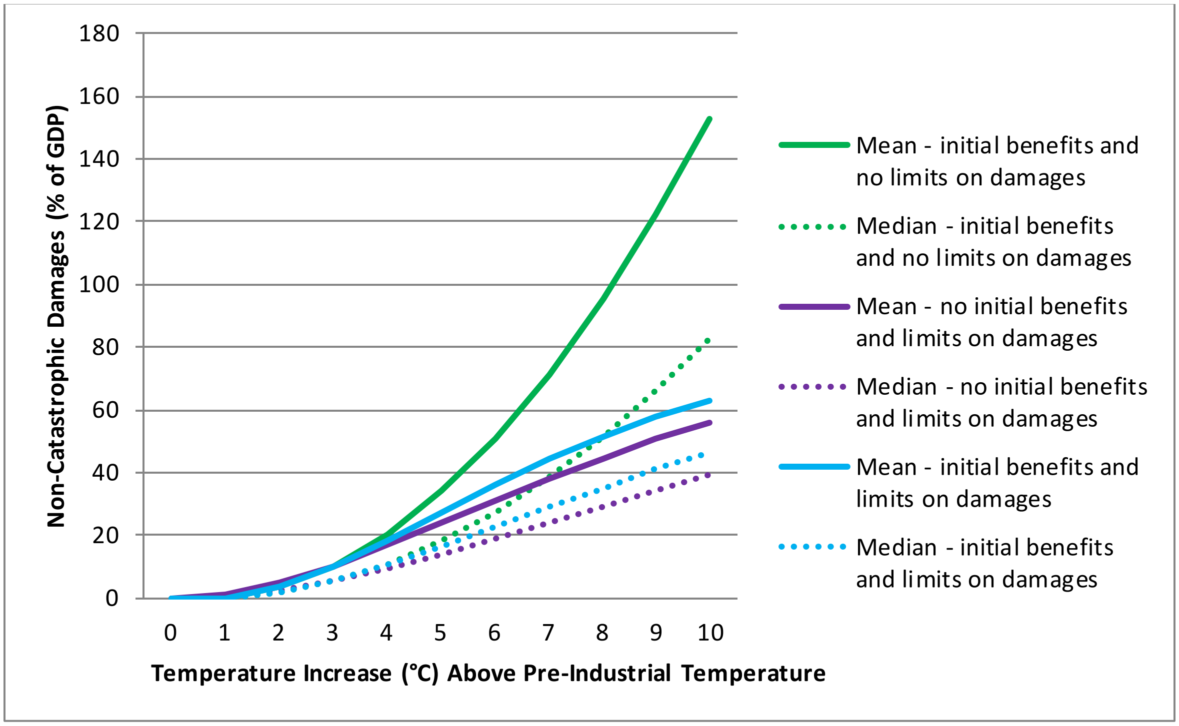
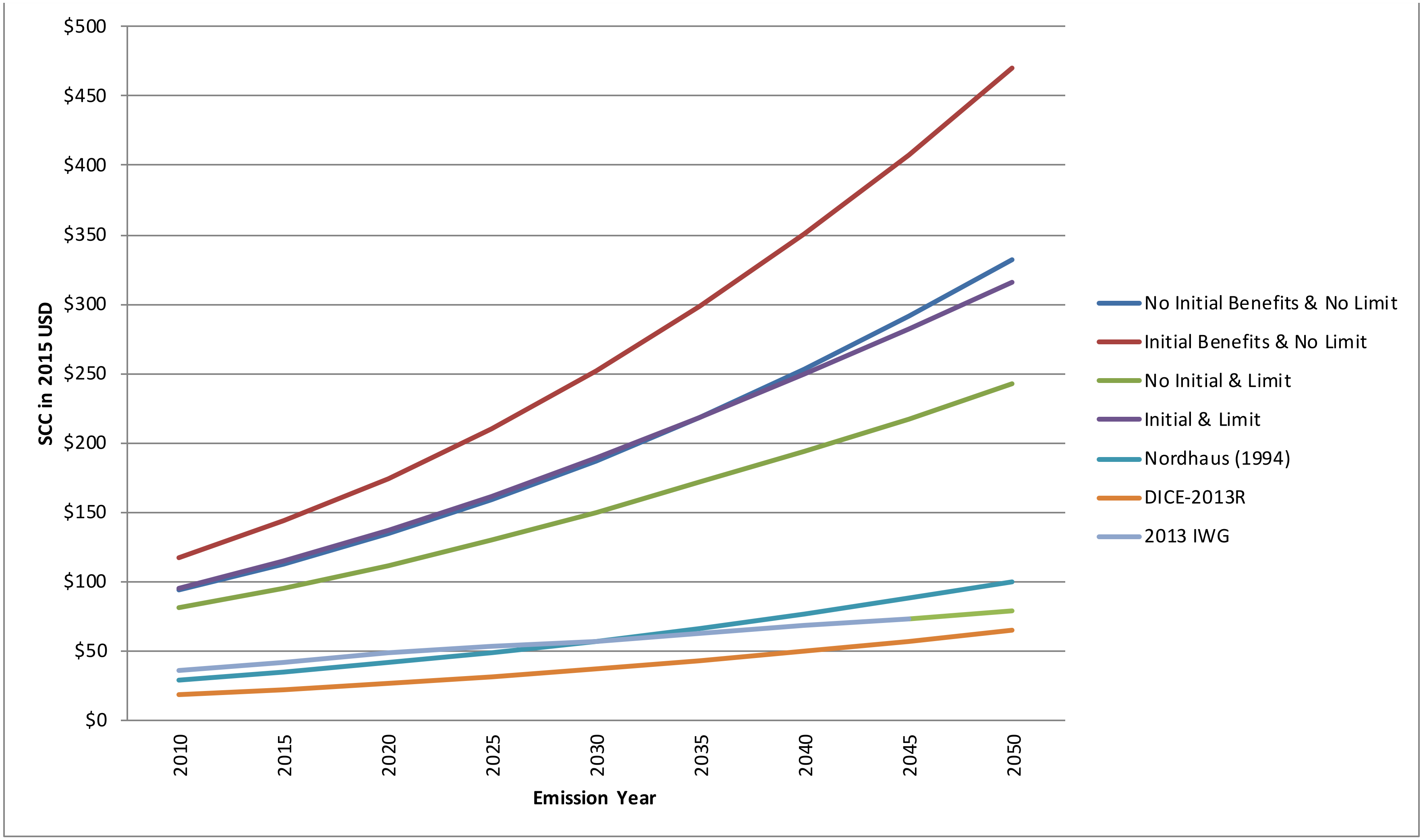


Figure 17. The SCC for Emissions from 2010 to 2050 in 2015 USD using Damage Functions Calibrated using All Responses to Our Survey (i.e., questions 5 and 13)



Allowing Initial Benefits from Climate Change ($\alpha_1 > 0$)

A concern may be that while these damage curves are more accurate for high temperatures, they are too high for low temperature increases. To test the sensitivity of our results, we calibrate α_1 and α_2 allowing for initial benefits from climate change (i.e., $\alpha_1 > 0$). To calibrate the two parameters, we utilize responses to question 5 – in addition to question 13 – as an additional data point for calibrating the damage function. In question 5, we asked respondents when they believed that the net effect of climate change will be become negative. The median response to this question was 2025, regardless of group, and the mean response was between 2019 and 2028.[21] Given that the predicted temperature increase for FUND and DICE are slightly below and above 1°C in 2025, respectively, we assumed that the mean and median respondents believe impacts will become negative (i.e., equal zero) when global average surface temperature rises by one degree Celsius relative to the pre-industrial period. We assume that respondents did not consider catastrophic damages[22] when answering question 5. See Table 16b and Figure 16b.

The damage functions calculated using this second method implie lower impacts for low temperatures increases, relative to the damage function calculated above assuming no initial benefits from climate change. Specifically, the damage functions are lower for temperature increases up to 3°C, and higher thereafter. A 100% decline in GDP results from a 8°C (mean) or 11°C (median) increase depending on whether the mean or median responses were sued to calibrate the damage function, respectively.

[21] Calculating the mean response required additional assumptions. First, we looked only at individuals that believed impacts would occur this century – this was approximately 97% of respondents. Second, we assumed that the net effect occurred in the middle of the time period that they chose (e.g., "by 2050" translated into 2037.5). Third, we assumed that all respondents believed that negative impacts could not occur before 1990, so as to create a midpoint of 2002.5 for those who believe net negative climate impacts have already occurred (i.e., "by 2015").

[22] We solve two simultaneous equations: $0 = \alpha_1 + \alpha_2$ and $D = 3\alpha_1 + 9\alpha_2$ where α_1 and α_2 are the coefficients corresponding to temperature and temperature squared and D is the impact estimates drawn from responses to question 13 of our survey.

Again, our SCC estimates greatly exceed the DICE-2013R SCC estimates. In our results, the 2015 SCC increases 4-fold to 8-fold compared to the $23 per metric ton estimate, depending on the expert group of interest. For example, if we calibrate the damage function using the consensus drawn from all response to questions 5 and 13, the 2015 SCC increases to $144/metric ton. Surprisingly, the social cost of carbon increases when we relax the assumption of no initial benefits from climate change (with respect to our earlier results when we assume away initial benefits), implying that the short-run benefits of climate change are far outweighed by the resulting steeper damage function with respect to temperature. This result is consistent across all expert groups considered. See Table 17 and Figure 18b.

Limiting Damages to 100% of GDP

There may be a concern that these results are due to the quadratic functional form of the DICE-2013R damage function, which technically allows impacts that exceed 100% GDP. While no temperature is observed during the above runs that would produce such an impact, we tested this assumption by replacing the DICE-2013 damage function with the earlier DICE function form $D = \frac{\alpha_1 T + \alpha_2 T^2}{1 + \alpha_1 T + \alpha_2 T^2}$ where $\alpha_1 > 0$ in DICE-1999 and $\alpha_1 = 0$ in DICE-2007 (Nordhaus and Sztorc, 2013); see Tables 16c and 16d and Figure 17.

The resulting SCC estimates exceed DICE-2013R and Nordhaus (1994)-based estimates, though they may be lower or higher than our earlier survey estimates depending on whether initial benefits are allowed (and on the group of experts considered). If no initial benefits from climate change are assumed (i.e., $\alpha_1 = 0$), limiting damages to 100% of GDP results in only a three to five-fold increase in the 2015 SCC (from $23/metric ton) depending on the expert group of interest. For example, if we utilize the damage function corresponding to the consensus of all responses to question 13, the 2015 SCC is $96/metric ton in current USD – a four-fold increase with respect to DICE-2013R. However, the resulting SCC estimates are below our earlier SCC estimates using a quadratic damage function (and no initial benefits from climate change), regardless of the group of experts chosen. If instead initial climate benefits are allowed (i.e., $\alpha_1 > 0$), the 2015 SCC increases by three-fold to nine-fold with respect to the $23 amount depending on the expert group of interest. For example, if we utilize the damage function corresponding to the consensus of all responses to question 13, the 2015 SCC is $115/metric ton in current USD. While this value is above our earlier SCC estimates using a quadratic damage function (and allowing for initial benefits from climate change), this relationship does not hold across all expert groups. See Table 17 and Figures 18c and 18d.

Overall results

Our results imply that calibrating the DICE damage function to reflect consensus views on non-catastrophic damages from climate change significantly increases the SCC with respect to DICE-2013R and Nordhaus (1994). While we find that the views of all respondent subgroups imply an increase in the SCC, there is significant variation by group. Depending on the expert group and functional form for the damage curve used, the 2015 SCC increases range from $66 to $204 per metric ton. Given that all of the expert groups – on average - also selected lower constant discount rates than implied by the DICE model, the consensus view calls for even higher SCC estimates than obtained above.

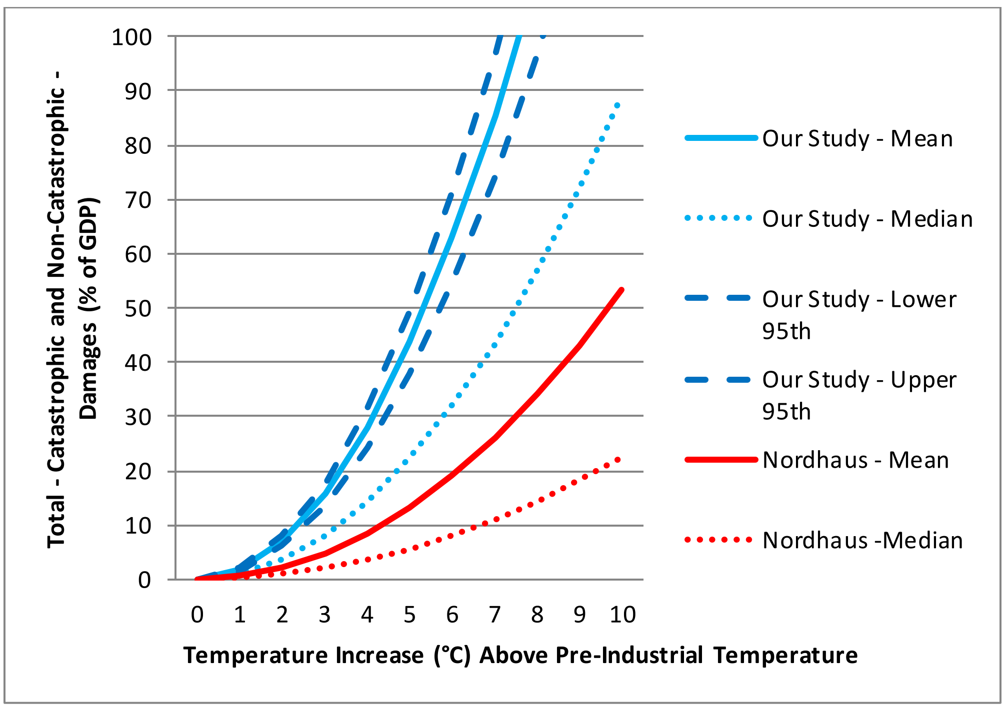
Catastrophic Damages

Like the default version of DICE-2013R, the above damage curves and their corresponding SCC estimates capture only non-catastrophic impacts. However, earlier versions of DICE (DICE-99 and DICE-2007) included an expected value of catastrophic climate change impacts in the DICE damage function. Given that tipping points and catastrophic damages are a major concern for policymakers, capturing the potential for catastrophic impacts within the SCC is critical to making appropriate policy decisions.

Outdated methodology

In earlier versions of DICE, Nordhaus estimated the expected value of catastrophic damages using results from his 1994 survey (a question almost identical to our question 15). In order to match earlier versions of DICE, we calibrate a catastrophic damage coefficient in addition to the non-catastrophic damage coefficient calibrated above. Following Nordhaus (1999), the catastrophic damage coefficient equals the catastrophic impact (a 25% decline in GDP) multiplied by the probability of such an impact occurring (drawn from responses to question 15) divided by the corresponding temperature increase squared (i.e., $\alpha_{cat} = \frac{-0.25*p}{T^2} = \frac{-0.25}{9}p$).[23] If we add the resulting catastrophic damage function to the non-catastrophic damages estimated earlier, the resulting damage functions are much higher than the non-catastrophic impacts alone – see Tables 16a and 16b and Figure 19 – and imply even higher SCC estimates. However, this method for capturing catastrophic impacts does not correspond to economic theory.

Figure 19. Total (Non-Catastrophic plus Catastrophic) Damage Functions Calibrated Using Responses to Our Survey (Questions 13 and 15) and Nordhaus' Survey, Assuming No Initial Benefits From Climate Change



[23] Given that we asked in question 15 for the probability of a 25% or greater GDP decline, a higher impact could have been chosen. However, we chose 25% in order to estimate a lower bound on catastrophic impacts and to correspond to the calibration method used in Nordhaus and Boyer (1999).

Instead, the theoretically correct way to capture catastrophic impacts in the SCC is to calibrate probability distribution functions for the damage function parameters – i.e., α_1 and α_2 – and then run a Monte Carlo simulation using DICE. Assuming that there is no probability of initial benefits from climate change for a 3°C increase in temperature, we use two methods to calibrate five parametric distributions (Weibull, Pareto, Beta, Log-normal, and Triangular)[24] of the economic damages (in terms of % of GDP loss) of a 3°C increase, using responses to questions 13 and 15.

In the first method (which we call the "untrimmed-group" method), we use the mean response to each question to develop two data points for calibration assuming that these values represent the wisdom of the crowd.[25] For each expert group and Nordhaus (1994), we calibrate each of these distributions using their mean responses. See Figures 20a to 20e.

In the second method (which we call the "trimmed-individual" method), we use the responses of each individual (who responded to both questions 13 and 15) to calibrate individual-specific damage distributions (i.e., the probability of a X% decline in GDP for a 3 °C increase in global average surface temperature for all Xs between 0 and 100), and then take the average probability across all individuals for each impact level (from 0% to 100% of GDP) using each of these distributions. Consistent with assuming no initial benefits from climate change, we assume that the handful of individuals who predict climate benefits according to question 13 or question 15 would predict no impact from climate change if provided this restriction.[26] Additionally, we drop individuals who provided inconsistent responses to

---

[24] The first four distributions are chosen because they are characterized by two parameters and allow for a positive skew as observed in the responses to questions 13 and 15; see Figures 13 and 15. The triangular distribution is chosen because it is a popular distribution in the IAM literature, and it both allows initial benefits from climate change and it limits impacts to a maximum amount.

[25] Unlike the other distributions, the triangular distribution has three parameters: the minimum impact *a*, the maximum impact *b*, and the mode of the distribution *c*. Using the average responses to questions 13 and 15, only allows us to calibrate the value of *b* and a relationship between *a* and *c*. We calibrate the remaining two parameters by assuming that the median response to question 13 equals *c*.

[26] Numerically, this is necessary because the domains of these distributions are restricted to greater than zero.

questions 13 and 15 (see Table 19);[27] this results in a drop of approximately 25% for the pool as a whole, with some variation by group.[28] For each expert group and Nordhaus (1994), we calibrate four distributions using their mean responses to questions 13 and 15.[29] See Figures 21a to 21d.

From these results, it is clear that over the last two decades the economic consensus on climate impacts has become more pessimistic. Regardless of the distribution and calibration method chosen, the cumulative distribution for net climate damages (specifically, for a 3°C increase in global average surface temperature by 2090) has shifted to the right over time (with respect to Nordhaus (1994)). In other words, there is a higher probability for any impact level between 0% and 100% of GDP, compared to results from two decades ago. Even so, there is considerable variation between groups, with experts publishing in economic journals and on IAMs being less pessimistic and authors publishing in environmental journals and on climate damages and adaptation being more pessimistic. For most impact levels, the general consensus appears to be less pessimistic when we utilize the second – the "trimmed-individual" – methodology as compared to the first – the "untrimmed-group" approach, with the exception of high impact levels (see Figures 22a to 22e). The "trimmed-individual" methodology assigns significantly higher probabilities to high impact losses.[30] Similarly, various distributions overlap with each other for most impact levels, with the exception being high impact levels. The triangular and

[27] For example, an inconsistent responses would be an individual who states that the most likely outcome for a 3°C by 2090 is a 10% decline in GDP (response to question 13) and who states that there is a 60% change of a 25% or more decline in GDP (response to question 13). The inconsistency arises because both of these responses cannot be simultaneously true.

[28] Inconsistent responses are most common for economic experts publishing in environmental economic journals and those identified using multiple publications. Alternatively, those publishing in economics journals and on integrated assessment models had lower inconsistent response rates.

[29] Because the triangular distribution is characterized by three parameters, it cannot be calibrated for each individual.

[30] In Figures 22a to 22e, we also employed the first methodology using only consistent responses – i.e., a trimmed-group methodology. For all impact levels, the trimmed-group distribution assigns a lower cumulative probability to each impact level; this occurs because experts that provided inconsistent results tended to provide more pessimistic results as well. However, consistent pessimistic survey responses have greater weight when averaging across individuals implying higher probabilities of cataclysmic impacts (i.e., extreme high GDP damages) for distributions corresponding to the "trimmed-individual" methodology.

beta distributions appear to be the most optimistic of distributions, while the Pareto and log-normal distributions are the most pessimistic; see Figures 23a and 23b.

Figure 20a. Cumulative Weibull Distribution Calibrated Using the "Untrimmed-Group" Methodology, by Group

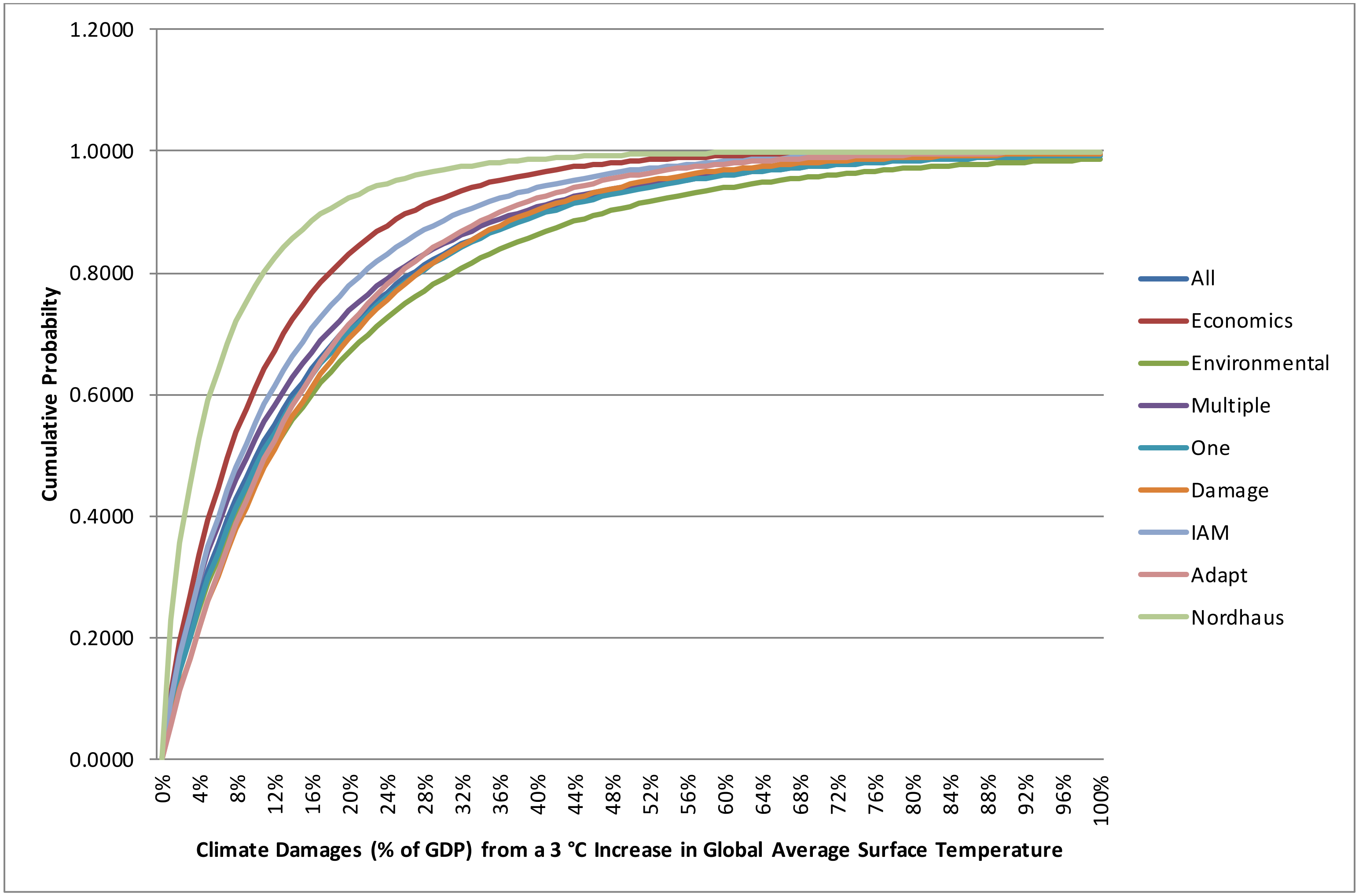


Figure 21a. Cumulative Weibull Distribution Calibrated Using the "Trimmed-individual" Methodology, by Group

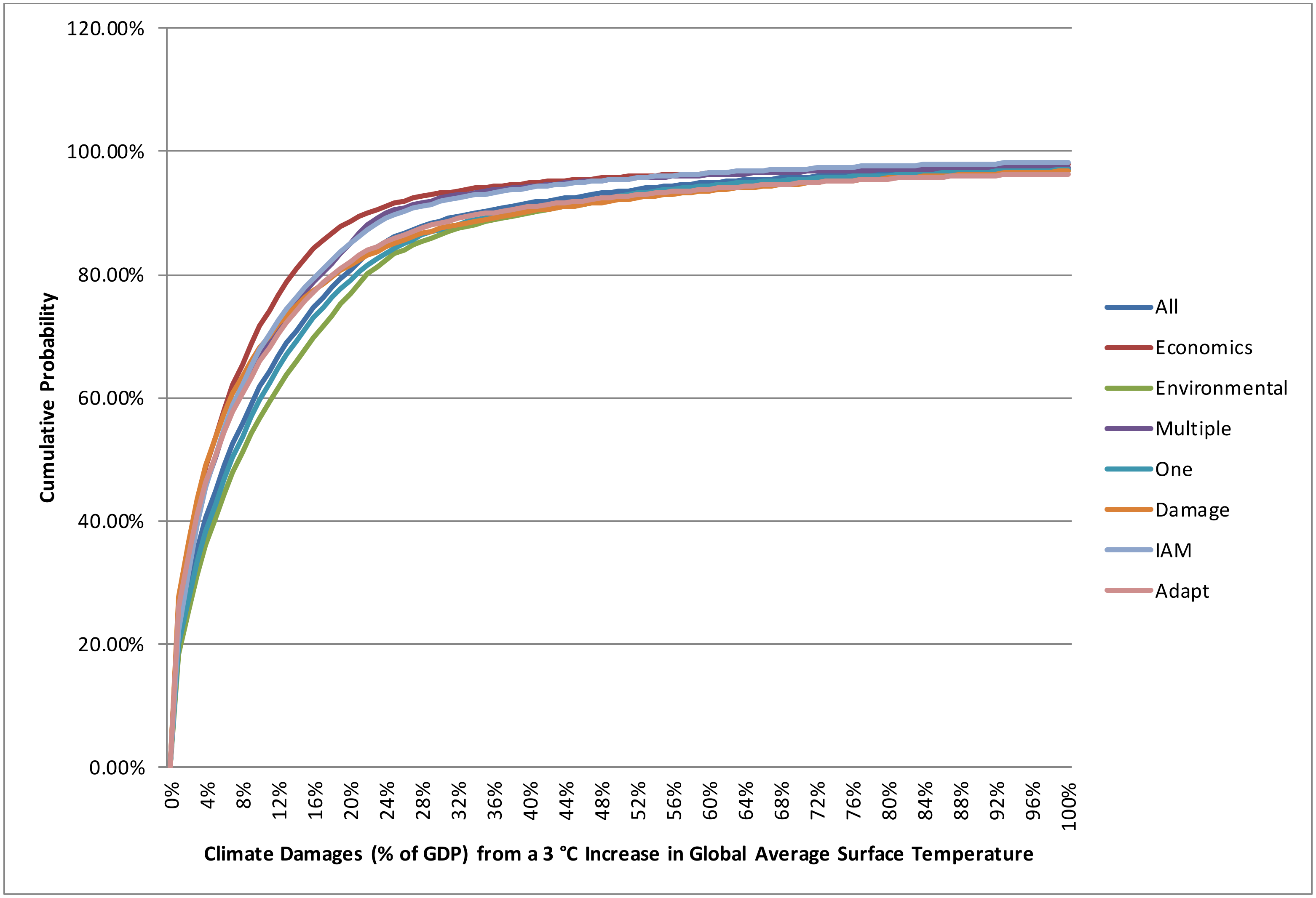


Figure 22a. Cumulative Weibull Distribution Calibrated Using All Observations, by Calibration Method

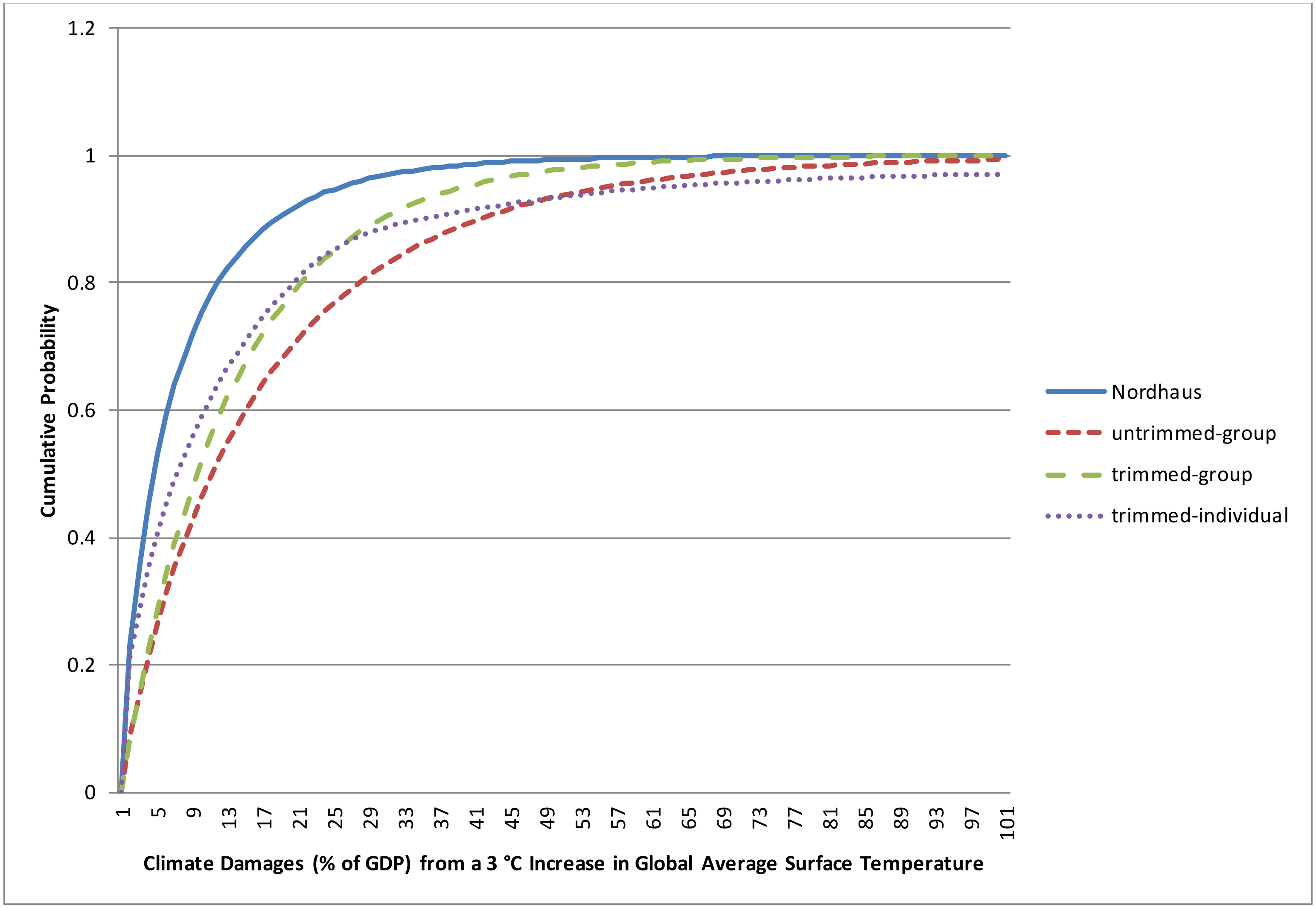


Figure 23a. Cumulative Distribution Calibrated Using the "Untrimmed-Group" Methodology and All Responses, by Distribution

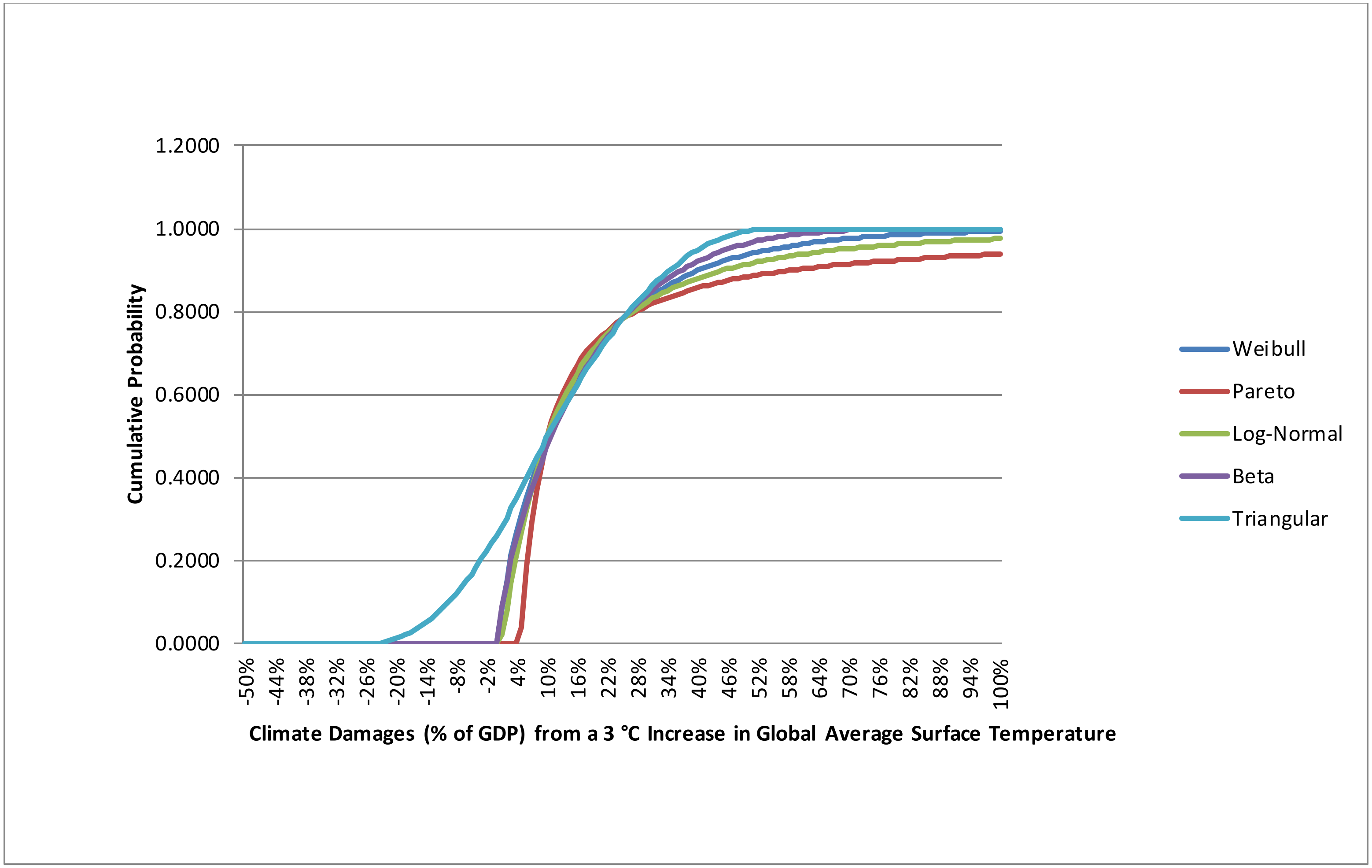
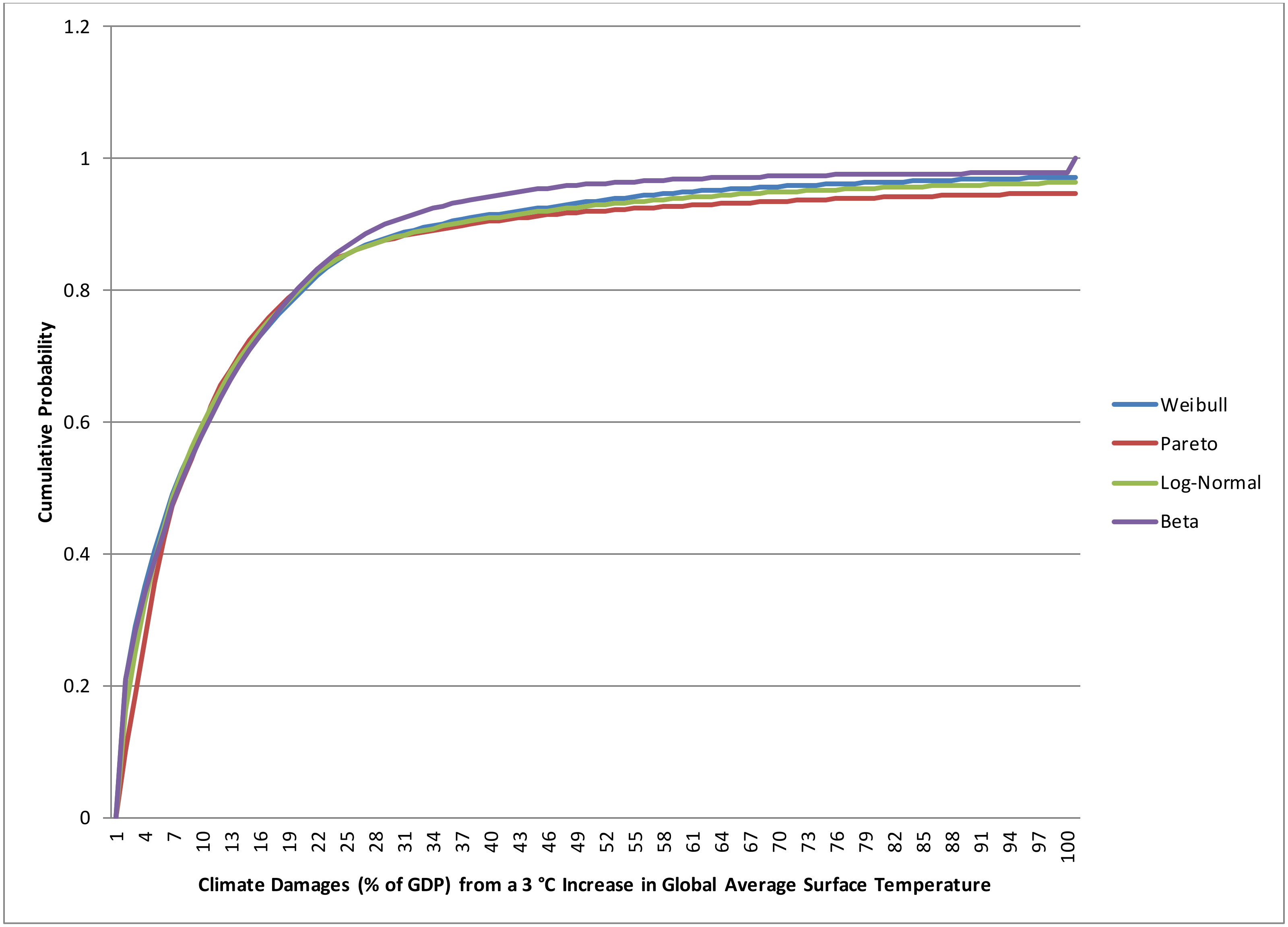


Figure 23b. Cumulative Distribution Calibrated Using the "Trimmed-Individual" Methodology and All Consistent Responses, by Distribution



Using these distributions calibrated to all responses to questions 13 and 15, we run Monte Carlo simulations using the DICE model. Specifically, using the four functional forms for the damage functions discussed in the previous sub-section, we randomly draw 1,000 impact estimates for a three degree °C from each of the five distributions calibrated using the trimmed-group and untrimmed-individual methods. For damage functions with initial benefits (i.e., $\alpha_1 > 0$) from climate change, we assume that impacts equal zero for a 1°C increase regardless of the draw.[31] In general, we find that the DICE-2013R model preforms poorly for higher impact draws – i.e., unrealistic savings rates and interest rates for all damage functional forms and unrealistic climate damage estimates when we limit impacts to 100% of GDP – particularly for impact draws implying GDP losses greater than 80% to 90% for a 3 °C increase.[32] Ideally, we would have asked respondents what the maximum impact was for a 3°C by 2090. Instead, we choose to limit our attention to distributions that are thin-tailed for higher temperatures – the beta, Weibull, and triangle distributions calibrated using the untrimmed-group methodology – to avoid high impact draws that result in unrealistic model solutions.[33,34] Using these distributions, we calculate the mean SCC estimate for each year; see Table 19 and Figure 24a to 24d.

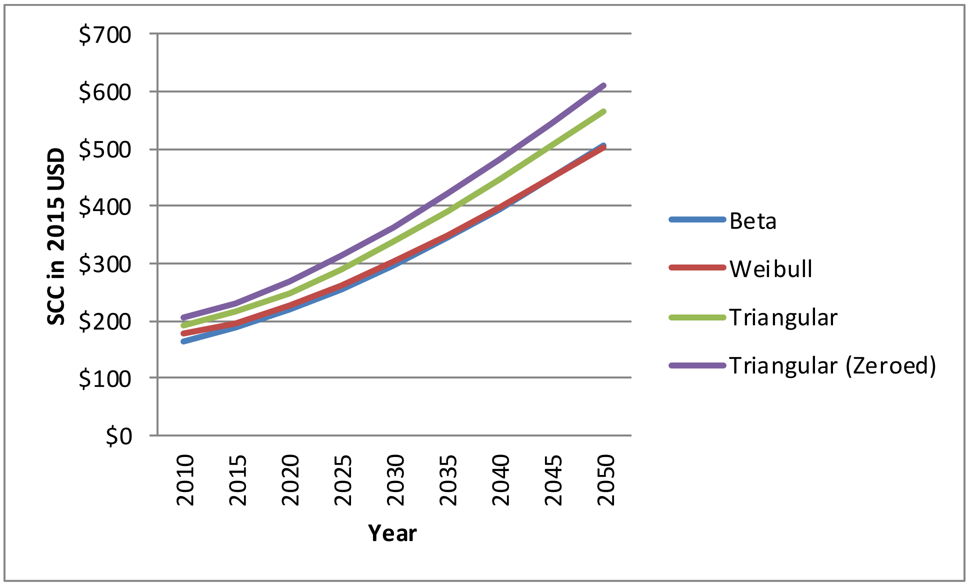
As expected, the mean SCC estimates that capture catastrophic impacts are higher than the corresponding non-catastrophic SCC estimates estimated in the previous sub-section, regardless of the damage function utilized; see Table 20. For the 2015 SCC, we see an average increase across all distributions and damage functions of 63% with a range of 28% to 109% by including catastrophic impacts. For example, the 2015 SCC corresponding to the damage function with only a quadratic

[31] Alternative assumptions are possible, including that the initial benefits match the non-catastrophic impacts estimated in the previous sub-section. We will conduct sensitivity analysis to this assumption in the future.
[32] In cases where we do not limit the damages, the DICE model still never reaches 100% of GDP.
[33] For the Pareto and Log-Normal distributions calibrated using untrimmed data and all distributions calibrated using trimmed data, the social cost of carbon followed a U-shape over time.
[34] For the triangular distribution, we can allow for a quadratic benefit curve where a random draw implies initial benefits from climate change because its domain is not limited like the other distributions. Therefore, we calculate the SCC using the triangular distribution assuming that the climate impacts must be damages – aka "triangular (zeroed)" - and assuming that climate change can have a positive impact for all temperature increases – aka "triangular".

coefficient and with no limit on impacts increased by 75% from $113/metric ton when considering only non-catastrophic impacts to $197/metric ton when modeling total impacts using a Weibull distribution. This implies an average of $85 in catastrophic damages if our modeling assumptions hold. The percentage increases were higher for damage functions that did not limit GDP losses to 100% of GDP or allowed for initial benefits from climate change (i.e., had a steeper damage function). In general, the triangular distribution – regardless of whether we limited impacts to negative for a 3 °C increase – also implied a greater increase. Overall, the responses to our surveys by economic experts potentially imply significant catastrophic impacts, though the results differ widely based on the form of the damage function (i.e., $26 to $157).

The distributions that we dropped due to fat tails imply even larger catastrophic impacts. In fact, catastrophic impacts become so probable at a 3°C increase that the DICE model no longer becomes reliable or even capable of being solved. On the one hand, it is possible that these cataclysmic results would be avoided if we had asked respondents to provide a maximum impact estimate. On the other hand, these results potentially support Weitzman's dismal theorem. Like his results, the significant probability of cataclysmic GDP losses potentially implies a strategy of minimizing the costs of avoiding these risks (e.g., meeting a 2 °C increase limit) over cost-benefit analysis.

Table 24a. The Social Cost of Carbon from 2010 to 2050 Using the Quadratic Damage Function Assuming No Initial Benefits from Climate Change, by Distribution



VI. Conclusions

While the scientific community has established a fairly clear consensus on the threat of climate change, policymakers and journalists often suggest that the economic community lacks a consensus view on climate change risks and appropriate policy responses. We conducted a survey of 1,103 experts on the economics of climate change – all those who have authored an article related to climate change in a highly ranked economics or environmental economics journal since 1994 – and our results reveal several areas where expert consensus exists, and others where more research is necessary. In casting a wider net than many previous surveys of economists on climate change, we avoid many of the pitfalls of previous studies.

Of the 1,103 experts that received the survey, 365 responded – a response rate of approximately 33%. Though the response rate varied from question to question – particularly for open-ended questions – it never dipped below 20%. There are several key takeaways from our results:

- Experts on the economics of climate change express higher levels of concern about climate change impacts than the general public.
- Economic experts believe that climate change will begin to have a net negative impact on the global economy very soon – the median estimate was "by 2025," with many saying that climate change is already negatively affecting the economy.
- Those who have published in economics journals tend to be slightly more conservative in their estimates of climate change damages than those who have published in environmental economics journals. However, this trend is reversed with respect to discount rate preferences.
- Experts believe that the United States may be able to strategically induce other nations to reduce GHG emissions by adopting policies to reduce U.S. emissions. Respondents also support unilateral emission reductions by the United States, regardless of the actions other nations have taken.

- The discounting approach that the U.S. government currently uses to analyze regulations and other policies – a constant discount rate calibrated to market rates – was identified by experts as the least desirable approach for setting discount rates.
- When asked to specify the appropriate constant discount rate for the calculation of the social cost of carbon, economic experts recommended rates lower than (or roughly equal to the lower ranges of) those used by the U.S. government. Experts recommended rates far below the 5% and 7% preferred by some critics of the SCC.
- On average, economic experts predict far higher economic impacts from climate change than the estimates found in landmark surveys from the 1990s (Nordhaus, 1994; Schauer, 1995). However, the variance is significantly high, indicating a need for future research.
- Our findings revealed a strong consensus that the SCC should be greater than or equal to the current $37 estimate. This is consistent with our findings that the SCC is multi-fold higher using damage functions calibrated to the consensus views on impacts taken from our survey.

From a policy perspective, these findings strongly suggest that U.S. policymakers should be concerned about a lack of action on climate change. In particular, economists seem to believe that aggressive domestic climate policies should be enacted immediately.

From a methodological perspective, these results indicate that considerable work is still necessary to improve the values used for discount rates and climate impact assumptions. However, given the deep uncertainty faced in climate change research, future work may never significantly reduce the relevant uncertainties. These uncertainties indicate that relying on a handful of IAMs – which tend to underestimate impacts relative to our findings – may be somewhat problematic. Pindyck (2015) has suggested replacing current IAMs with surveys to help estimate the SCC, but our results suggest that survey responses depend on how the surveyor chooses their pool of experts. Given that even most economic experts have not spent years analyzing each of the steps that translate carbon emissions into welfare impacts and the social cost of carbon, the view of the crowd may potentially correct for the bias of IAM developers, or it may mischaracterize climate risks. Future research is necessary to determine why this difference exists between IAMs and experts on the economics of climate change in general.

One potential path forward could be to solicit expert opinion on which assumptions IAMs should use to calculate the SCC itself. Using this approach, we ran DICE-2013R using a damage function calibrated to reflect the overall consensus of respondents on damages. Accounting for non-catastrophic impacts alone, the SCC increased by three to six-fold relative to the DICE-2013R estimate (using responses from our full pool of survey respondents). Accounting for both non-catastrophic and catastrophic impacts, the SCC increased four- to ten-fold. This approach can be further strengthened by conducting sensitivity analysis to the definition of expertise and including consensus opinion on the appropriate discount rate and other critical parameters.

References

[AAPOR, 2011] The American Association for Public Opinion Research. (2011). *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys*, 7th edition. *AAPOR*. *Available at: http://www.aapor.org/AAPORKentico/AAPOR_Main/media/MainSiteFiles/StandardDefinitions2011_1.pdf.*

Anderson, M., Richardson, J., McKie, J., Iezzi, A., & Khan, M. (2011). The relevance of personal characteristics in health care rationing: what the Australian public thinks and why. *American journal of economics and sociology*, *70*(1), 131-151.

Ansolabehere, S., & Konisky, D. M. (2014). *Cheap and clean: how Americans think about energy in the age of global warming*. MIT Press.

Capstick, S., Whitmarsh, L., Poortinga, W., Pidgeon, N., & Upham, P. (2015). International trends in public perceptions of climate change over the past quarter century. *Wiley Interdisciplinary Reviews: Climate Change*, *6*(1), 35-61.

Drupp, M.A., M.C. Freeman, B. Groom, and F. Nesje. (2015, May). Discounting Disentangled: An Expert Survey on the Determinants of the Long-Term Social Discount Rate. *London School of Economics and Political Science Working Paper.*

Fan, W., & Yan, Z. (2010). Factors affecting response rates of the web survey: A systematic review. *Computers in Human Behavior*, *26*(2), 132-139.

Howard, P., & Sterner, T. (2015). Loaded DICE: Refining the Meta-analysis Approach to Calibrating Climate Damage Functions. *Institute for Policy* Integrity *Working Paper.*

Holladay et al., (2009). Economists and climate change: Consensus and open questions. *Institute for Policy Integrity*. Available at http://policyintegrity.org/files/publications/EconomistsandClimateChange.pdf.

Kalaitzidakis, P., Mamuneas, T. P., & Stengos, T. (2003). Rankings of academic journals and institutions in economics. *Journal of the European Economic Association*, *1*(6), 1346-1366.

Kalaitzidakis, P., Mamuneas, T. P., & Stengos, T. (2011). An updated ranking of academic journals in economics. *Canadian Journal of Economics/Revue canadienne d'économique*, *44*(4), 1525-1538.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Rosenthal, S. (2015). Climate change in the American mind: March, 2015. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication. Available at http://environment.yale.edu/climate-communication/files/Global-Warming-CCAM-March-2015.pdf

[MIT, 2008] Ansolabehere, Stephen (2008). Public Attitudes Toward America's Energy Options - Report of the 2007 MIT Energy Survey. *Center for Energy and Environmental Policy Research.* Available at http://dspace.mit.edu/bitstream/handle/1721.1/45068/2007-002.pdf?sequence=1.

Nordhaus, W. D. (1994). Expert opinion on climatic change. *American Scientist*, 45-51.

Pindyck, R. S. (2015). *The Use and Misuse of Models for Climate Policy* (No. w21097). National Bureau of Economic Research.

[RFF, 2015] Resources for the Future, New York Times, Stanford University (2015). Global Warming National Poll. *RFF.* Available at http://www.rff.org/Documents/RFF-NYTimes-Stanford-global-warming-poll-Jan-2015-topline-part-3.pdf.

Rousseau, S. (2008). Journal evaluation by environmental and resource economists: A survey. *Scientometrics*, *77*(2), 223-233.

Rousseau, S., Verbeke, T., & Rousseau, R. (2009). Evaluating environmental and resource economics journals: A TOP-curve approach. *Review of Environmental Economics and Policy*, rep002.

Schauer, M. J. (1995). Estimation of the greenhouse gas externality with uncertainty. *Environmental and Resource Economics*, *5*(1), 71-82.

Sheehan, K. B. (2001). E-mail survey response rates: A review. *Journal of Computer-Mediated Communication*, *6*(2), 0-0.

Tol, R. S. (2009). The economic effects of climate change. *The Journal of Economic Perspectives*, 29-51.

Tol, R. S. (2013a). Bootstraps for meta-analysis with an application to the impact of climate change. *Computational Economics*, 1-17.

Tol, R. S. (2013b). The economic impact of climate change in the 20th and 21st centuries. *Climatic change*, *117*(4), 795-808.

Tol, R. S. (2014). Correction and Update: The Economic Effects of Climate Change. *The Journal of Economic Perspectives*, 221-225.

Weitzman, M. L. (2001). Gamma discounting. *American Economic Review*, 260-271.

Tables

Table 1. % of All Respondent to Question 1 by Responses and Group

Groups	Climate Change Risks	Estimated Damages from Climate	Global Climate Strategies	International Agreements/ Game Theory	Greenhouse Gas Control Mechanisms	Integrated Assessment Models	Climate Change Adaptation	Other Climate Related Topics	None	No Response
All	26.6%	24.7%	30.1%	30.1%	38.1%	30.1%	22.2%	41.9%	2.5%	0.3%
Economics	30.6%	22.4%	33.7%	42.9%	38.8%	36.7%	25.5%	35.7%	2.0%	0.0%
Enviornmental	25.1%	25.5%	28.8%	25.5%	37.8%	27.7%	21.0%	44.2%	2.6%	0.3%
Multiple	39.4%	33.3%	47.5%	35.4%	43.4%	42.4%	23.2%	42.4%	1.0%	0.0%
One	21.8%	21.4%	23.7%	28.2%	36.1%	25.6%	21.8%	41.7%	3.0%	0.3%

Table 2a. % of Respondents to Question 2 by Responses and Group, including response rate

Groups	Immediate and drastic action is necessary	More research is needed befo re action is taken	Some action should be taken now	This is not a serious problem	Response rate
All	50.7%	5.2%	43.5%	0.6%	99.5%
Economics	44.3%	4.1%	50.5%	1.0%	99.0%
Environmental	53.0%	5.6%	41.0%	0.4%	99.6%
Multiple	48.5%	1.0%	49.5%	1.0%	100.0%
One	51.5%	6.8%	41.3%	0.4%	99.2%
Climate change	55.2%	5.2%	38.5%	1.0%	99.0%

Table 2b. 95% Confidence Intervals of Responses to Question 2 by Responses and Group

95% Confidence Interval								
Groups	Immediate and drastic action is necessary		More research is needed before action is taken		Some action should be taken now		This is not a serious problem	
All	46.4%	55.0%	3.3%	7.1%	39.3%	47.8%	-0.1%	1.2%
Economics	36.1%	52.5%	0.8%	7.4%	42.3%	58.8%	-0.6%	2.7%
Environmental	48.0%	58.0%	3.3%	8.0%	36.0%	45.9%	-0.2%	1.0%
Multiple	40.8%	56.1%	-0.5%	2.5%	41.9%	57.1%	-0.5%	2.5%
One	46.4%	56.6%	4.2%	9.4%	36.2%	46.3%	-0.2%	1.0%
Climate change risks*	45.3%	65.2%	0.8%	9.7%	28.8%	48.3%	-1.0%	3.1%

**Calculates confidence interval without finite population correction*

Table 3a. % of Respondents to Question 3 by Responses and Group, including response rate

Groups	No opinion	Not serious at all	Not so serious	Somewhat serious	Very serious	Response rate
All	3.3%	0.8%	6.1%	33.6%	56.2%	99.5%
Economics	2.1%	1.0%	9.3%	36.1%	51.5%	99.0%
Environmental	3.8%	0.8%	4.9%	32.7%	57.9%	99.6%
Multiple	5.1%	4.0%	0.0%	38.4%	52.5%	100.0%
One	2.7%	1.1%	6.8%	31.8%	57.6%	99.2%
Climate change risks	2.1%	8.3%	0.0%	27.1%	62.5%	99.0%

Table 3b. 95% Confidence Intervals of Responses to Question 3 by Responses and Group

95% Confidence Interval										
Groups	No opinion		Not serious at all		Not so serious		Somewhat serious		Very serious	
All	1.8%	4.8%	0.1%	1.6%	4.0%	8.1%	29.6%	37.7%	51.9%	60.5%
Economics	-0.3%	4.4%	-0.6%	2.7%	4.5%	14.1%	28.2%	44.0%	43.3%	59.8%
Environmental	1.8%	5.7%	-0.1%	1.6%	2.7%	7.1%	28.0%	37.4%	52.9%	62.9%
Multiple	1.7%	8.4%	1.0%	7.0%	0.0%	0.0%	31.0%	45.8%	44.9%	60.2%
One	1.0%	4.3%	0.1%	2.2%	4.2%	9.4%	27.1%	36.6%	52.5%	62.6%
Climate change risks*	-0.8%	4.9%	2.8%	13.9%	0.0%	0.0%	18.2%	36.0%	52.8%	72.2%

**Calculates confidence interval without finite population correction*

Table 4a. % of All Respondent to Question 4 by Responses and Group, including response rate

Groups	Agriculture	Mining/Extractive Industries	Fishing	Forestry	Real Estate	Insurance	Construction	Transport	Manufacturing	Health Services	Tourism/OutdoorRecreation	Utilities	Other	Response rate
All	94.0%	14.9%	78.2%	73.4%	51.0%	65.6%	23.5%	32.4%	15.2%	53.9%	71.6%	73.6%	0.0%	95.6%
Economics	94.7%	16.0%	79.8%	72.3%	50.0%	66.0%	24.5%	24.5%	11.7%	46.8%	64.9%	68.1%	0.0%	95.9%
Environmental	92.3%	14.3%	76.4%	72.6%	50.6%	64.5%	22.8%	34.7%	16.2%	55.6%	73.0%	74.5%	0.0%	97.0%
Multiple	92.8%	20.6%	74.2%	72.2%	52.6%	66.0%	23.7%	35.1%	13.4%	51.5%	72.2%	71.1%	0.0%	98.0%
One	94.4%	12.7%	79.8%	73.8%	50.4%	65.5%	23.4%	31.3%	15.9%	54.8%	71.4%	74.6%	0.0%	94.7%

Table 4b. 95% Confidence Intervals of Responses to Question 4 by Responses and Group

95% CONFIDENCE INTERNVALS																										
Groups	Agriculture		Mining/Extractive Industries		Fishing		Forestry		Real Estate		Insurance		Construction		Transport		Manufacturing		Health Services		Tourism/OutdoorRecreation		Utilities		Other	
All	91.9%	96.1%	11.8%	18.0%	74.6%	81.9%	69.5%	77.3%	46.6%	55.4%	61.4%	69.8%	19.8%	27.2%	28.3%	36.5%	12.0%	18.4%	49.5%	58.3%	67.7%	75.6%	69.8%	77.5%	0.0%	0.0%
Economics	90.9%	98.5%	9.8%	22.1%	73.0%	86.6%	64.8%	79.9%	41.6%	58.4%	58.0%	73.9%	17.2%	31.7%	17.2%	31.7%	6.3%	17.1%	38.4%	55.2%	56.8%	72.9%	60.2%	75.9%	0.0%	0.0%
Environmental	89.5%	95.0%	10.7%	17.9%	72.1%	80.8%	68.0%	77.2%	45.5%	55.7%	59.6%	69.4%	18.5%	27.1%	29.9%	39.6%	12.4%	20.0%	50.5%	60.7%	68.4%	77.5%	70.1%	79.0%	0.0%	0.0%
Multiple	88.8%	96.8%	14.3%	26.9%	67.4%	81.0%	65.2%	79.1%	44.8%	60.3%	58.6%	73.3%	17.1%	30.3%	27.6%	42.5%	8.1%	18.7%	43.8%	59.3%	65.2%	79.1%	64.1%	78.2%	0.0%	0.0%
One	92.0%	96.9%	9.2%	16.2%	75.5%	84.0%	69.2%	78.5%	45.1%	55.7%	60.5%	70.5%	18.9%	27.9%	26.4%	36.3%	12.0%	19.7%	49.5%	60.0%	66.7%	76.2%	70.0%	79.2%	0.0%	0.0%

Table 5a. % of All Respondent to Question 5 by Responses and Group, including response rate

Groups	Climate change is already having a negative effect on the global economy	By 2025	By 2050	By 2075	By 2100	After 2100	Climate change will not have a negative effect on the global economy	Response rate
All	40.6%	22.5%	25.8%	5.0%	3.1%	1.1%	1.9%	98.6%
Economics	28.9%	24.7%	30.9%	5.2%	7.2%	-	3.1%	99.0%
Environmental	44.9%	21.7%	24.0%	4.9%	1.5%	1.5%	1.5%	98.5%
Multiple	42.4%	25.3%	24.2%	5.1%	2.0%	-	1.0%	100.0%
One	39.8%	21.5%	26.4%	5.0%	3.4%	1.5%	2.3%	98.1%
Estimated Damages from Climate	36.0%	29.2%	23.6%	4.5%	2.2%	1.1%	3.4%	98.9%
Integrated Assessment Models	35.8%	27.5%	22.9%	7.3%	4.6%	1.8%	-	99.1%

Table 5b. 95% Confidence Intervals of Responses to Question 5 by Responses and Group

	95% Confidence Interval													
Groups	Climate change is already having a negative effect on the global economy		By 2025		By 2050		By 2075		By 2100		After 2100		Climate change will not have a negative effect on the global economy	
All	36.3%	44.8%	18.9%	26.1%	22.1%	29.6%	3.1%	6.9%	1.6%	4.5%	0.2%	2.0%	0.8%	3.1%
Economics	21.4%	36.3%	17.6%	31.9%	23.3%	38.5%	1.5%	8.8%	3.0%	11.5%	-	-	0.2%	5.9%
Environmental	39.8%	49.9%	17.5%	25.8%	19.6%	28.3%	2.7%	7.1%	0.3%	2.8%	0.3%	2.8%	0.3%	2.8%
Multiple	34.9%	50.0%	18.6%	31.9%	17.7%	30.8%	1.7%	8.4%	-0.1%	4.2%	-	-	-0.5%	2.5%
One	34.8%	44.9%	17.2%	25.7%	21.9%	31.0%	2.7%	7.2%	1.6%	5.3%	0.3%	2.8%	0.8%	3.8%
Estimated Damages from Climate*	26.0%	45.9%	19.8%	38.7%	14.8%	32.4%	0.2%	8.8%	-0.8%	5.3%	-1.1%	3.3%	-0.4%	7.1%
Integrated Assessment Models*	30.4%	41.2%	3.2%	13.6%	2.8%	13.0%	0.8%	8.9%	0.3%	7.6%	-0.4%	5.5%	-	-

**Calculates confidence interval without finite population correction*

Table 5c. Cumulative % of All Respondent to Question 5 by Responses and Group, including response rate

Groups	By 2015	By 2025	By 2050	By 2075	By 2100	Negative effect at some point in time	No negative effect at any time
All	40.6%	63.1%	88.9%	93.9%	96.9%	98.1%	1.9%
Economics	28.9%	53.6%	84.5%	89.7%	96.9%	96.9%	3.1%
Environmental	44.9%	66.5%	90.5%	95.4%	97.0%	98.5%	1.5%
Multiple	42.4%	67.7%	91.9%	97.0%	99.0%	99.0%	1.0%
One	39.8%	61.3%	87.7%	92.7%	96.2%	97.7%	2.3%
Estimated Damages from Climate	36.0%	65.2%	88.8%	93.3%	95.5%	96.6%	3.4%
Integrated Assessment Models	35.8%	63.3%	86.2%	93.6%	98.2%	100.0%	-

Table 5d. 95% Confidence Intervals of Cumulative Responses to Question 5 by Responses and Group

	95% Confidence Interval													
Groups	By 2015		By 2025		By 2050		By 2075		By 2100		Negative effect at some point in time		No negative effect at any time	
All	36.3%	44.8%	58.9%	67.2%	86.2%	91.6%	91.8%	96.0%	95.5%	98.4%	96.9%	99.2%	0.8%	3.1%
Economics	21.4%	36.3%	45.4%	61.8%	78.6%	90.5%	84.7%	94.7%	94.1%	99.8%	94.1%	99.8%	0.2%	5.9%
Environmental	39.8%	49.9%	61.8%	71.3%	87.5%	93.5%	93.3%	97.6%	95.2%	98.7%	97.2%	99.7%	0.3%	2.8%
Multiple	34.9%	50.0%	60.5%	74.8%	87.8%	96.1%	94.4%	99.6%	97.5%	100.5%	97.5%	100.5%	-0.5%	2.5%
One	34.8%	44.9%	56.3%	66.3%	84.4%	91.1%	90.0%	95.4%	94.2%	98.1%	96.2%	99.2%	0.8%	3.8%
Estimated Damages from Climate*	26.0%	45.9%	55.3%	75.1%	82.2%	95.3%	88.0%	98.5%	91.2%	99.8%	92.9%	100.4%	-0.4%	7.1%
Integrated Assessment Models*	3.6%	14.4%	3.7%	14.4%	1.9%	11.1%	0.7%	8.5%	-0.4%	5.5%	100.0%	100.0%	-	-

**Calculates confidence interval without finite population correction*

Table 6a. % of All Respondent to Question 6 by Responses and Group, including response rate

Groups	Extremely likely	Likely	Unlikely	Extremely unlikely	Not clear	Response
All	42.0%	36.5%	3.3%	1.7%	16.6%	99.2%
Economics	38.1%	40.2%	6.2%	1.0%	14.4%	99.0%
Environmental	43.4%	35.1%	2.3%	1.9%	17.4%	99.3%
Multiple	44.4%	38.4%	2.0%	1.0%	14.1%	100.0%
One	41.1%	35.7%	3.8%	1.9%	17.5%	98.9%
Estimated Damages from Climate	47.2%	31.5%	2.2%	3.4%	15.7%	98.9%
Integrated Assessment Models	43.1%	35.8%	3.7%	2.8%	14.7%	99.1%

Table 6b. 95% Confidence Intervals of Responses to Question 6 by Responses and Group

	95% Confidence Interval									
Groups	Extremely likely		Likely		Unlikely		Extremely unlikely		Not clear	
All	37.7%	46.2%	32.3%	40.6%	1.8%	4.9%	0.6%	2.8%	13.4%	19.8%
Economics	30.1%	46.2%	32.1%	48.3%	2.2%	10.2%	-0.6%	2.7%	8.6%	20.2%
Environmental	38.4%	48.4%	30.3%	39.9%	0.8%	3.8%	0.5%	3.3%	13.5%	21.2%
Multiple	36.9%	52.0%	31.0%	45.8%	-0.1%	4.2%	-0.5%	2.5%	8.8%	19.5%
One	36.0%	46.1%	30.8%	40.7%	1.8%	5.8%	0.5%	3.3%	13.6%	21.4%
Estimated Damages from Climate*	36.8%	57.6%	21.8%	41.1%	-0.8%	5.3%	-0.4%	7.1%	8.2%	23.3%
Integrated Assessment Models*	33.8%	52.4%	26.8%	44.8%	0.1%	7.2%	-0.3%	5.8%	8.0%	21.3%

**Calculates confidence interval without finite population correction*

Table 7a. % of All Respondent to Question 7 by Responses and Group, including response rate

Groups	Market-based mechanisms (trading programs or carbon taxes) implemented at the individual state level	Market-based mechanisms coordinated at a regional or national level (such as a regional/national trading program or carbon tax)	Performance standards and programs that prioritize cleaner fuels and energy efficiency, implemented within each individual state	Performance standards and programs that prioritize cleaner fuels and energy efficiency, coordinated among states at a regional level	No opinion	Response Rate
All	6.1%	75.6%	3.1%	9.7%	5.6%	98.6%
Economics	5.2%	88.7%	1.0%	0.0%	5.2%	99.0%
Environmental	6.5%	70.7%	3.8%	13.3%	5.7%	98.5%
Multiple	5.1%	75.8%	3.0%	11.1%	5.1%	100.0%
One	6.5%	70.7%	3.8%	13.3%	5.7%	98.9%
GHG control Mechanisms	3.6%	84.1%	1.4%	7.2%	3.6%	99.3%

Table 7b. 95% Confidence Intervals of Responses to Question 7 by Responses and Group

	95% Confidence Interval									
Groups	Market-based mechanisms (trading programs or carbon taxes) implemented at the individual state level		Market-based mechanisms coordinated at a regional or national level (such as a regional/national trading program or carbon tax)		Performance standards and programs that prioritize cleaner fuels and energy efficiency, coordinated among states at a regional level		Performance standards and programs that prioritize cleaner fuels and energy efficiency, implemented within each individual state		No opinion	
All	4.0%	8.2%	71.8%	79.3%	7.2%	12.3%	1.6%	4.5%	3.6%	7.5%
Economics	1.5%	8.8%	83.4%	93.9%	0.0%	0.0%	-0.6%	2.7%	1.5%	8.8%
Environmental	4.0%	9.0%	66.1%	75.3%	9.9%	16.7%	1.9%	5.7%	3.4%	8.1%
Multiple	1.7%	8.4%	69.2%	82.3%	6.3%	15.9%	0.4%	5.6%	1.7%	8.4%
One	3.9%	9.0%	66.1%	75.4%	9.8%	16.8%	1.8%	5.8%	3.3%	8.1%
GHG control Mechanisms*	-0.1%	7.4%	76.7%	91.4%	2.1%	12.4%	-0.9%	3.8%	-0.1%	7.4%

**Calculates confidence interval without finite population correction*

Table 8a. % of All Respondent to Question 8 by Responses and Group, including response rate

Groups	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	No opinion	Response
All	44.9%	37.1%	10.0%	4.4%	2.2%	1.4%	98.9%
Economics	40.6%	38.5%	12.5%	7.3%	1.0%	0.0%	98.0%
Environmental	46.4%	36.6%	9.1%	3.4%	2.6%	1.9%	99.3%
Multiple	47.5%	38.4%	8.1%	4.0%	2.0%	0.0%	100.0%
One	43.9%	36.6%	10.7%	4.6%	2.3%	1.9%	98.5%
Global climate strategies	55.0%	31.2%	6.4%	4.6%	1.8%	0.9%	99.1%
International Agreeements / Game Theory	44.0%	38.5%	10.1%	6.4%	0.0%	0.9%	99.1%

Table 8b. 95% Confidence Intervals of Responses to Question 8 by Responses and Group

	95% Confidence Interval											
Groups	Strongly Agree		Agree		Neutral		Disagree		Strongly disagree		No opinion	
All	40.6%	49.2%	33.0%	41.3%	7.4%	12.6%	2.7%	6.2%	0.9%	3.5%	0.4%	2.4%
Economics	32.5%	48.8%	30.5%	46.6%	7.0%	18.0%	3.0%	11.6%	-0.6%	2.7%	0.0%	0.0%
Environmental	41.4%	51.4%	31.8%	41.5%	6.2%	11.9%	1.6%	5.2%	1.0%	4.3%	0.5%	3.3%
Multiple	39.8%	55.1%	31.0%	45.8%	3.9%	12.2%	1.0%	7.0%	-0.1%	4.2%	0.0%	0.0%
One	38.8%	49.0%	31.7%	41.6%	7.5%	13.9%	2.4%	6.7%	0.8%	3.8%	0.5%	3.3%
Global climate strategies*	45.7%	64.4%	22.5%	39.9%	1.8%	11.0%	0.7%	8.5%	-0.7%	4.4%	-0.9%	2.7%
International Agreeements / Game Theory*	34.7%	53.4%	0.0%	18.3%	0.0%	11.3%	0.0%	9.2%	0.0%	0.0%	0.0%	3.6%

**Calculates confidence interval without finite population correction*

Table 9a. % of All Respondent to Question 9 by Responses and Group, including response rate

Groups	Regardless of the actions other countries have taken thus far	Only if it can enter into a multilateral emissions reduction agreement with some countries	Only if other major emitters enact policies to reduce their emissions	Only if every country commits to reducing emissions through a global agreement	Under no circumstances	No opinion	Response
All	77.3%	9.9%	6.4%	1.9%	1.4%	3.0%	99.2%
Economics	72.2%	13.4%	9.3%	1.0%	1.0%	3.1%	99.0%
Environmental	79.2%	8.7%	5.3%	2.3%	1.5%	3.0%	99.3%
Multiple	74.7%	14.1%	7.1%	1.0%	1.0%	2.0%	100.0%
One	78.3%	8.4%	6.1%	2.3%	1.5%	3.4%	98.9%
Global climate strategies	80.9%	7.3%	4.5%	1.8%	0.9%	4.5%	100.0%
International Agreeements / Game Theory	72.7%	15.5%	6.4%	2.7%	0.0%	2.7%	100.0%

Table 9b. 95% Confidence Intervals of Responses to Question 9 by Responses and Group

	95% Confidence Interval											
Groups	Regardless of the actions other countries have taken thus far		Only if it can enter into a multilateral emissions reduction agreement with some countries		Only if other major emitters enact policies to reduce their emissions		Only if every country commits to reducing emissions through a global agreement		Under no circumstances		No opinion	
All	73.8%	80.9%	7.4%	12.5%	4.3%	8.4%	0.8%	3.1%	0.4%	2.4%	1.6%	4.5%
Economics	64.8%	79.6%	7.8%	19.0%	4.5%	14.1%	-0.6%	2.7%	-0.6%	2.7%	0.2%	5.9%
Environmental	75.2%	83.3%	5.8%	11.5%	3.0%	7.5%	0.8%	3.8%	0.3%	2.7%	1.3%	4.7%
Multiple	68.1%	81.4%	8.8%	19.5%	3.2%	11.0%	-0.5%	2.5%	-0.5%	2.5%	-0.1%	4.2%
One	74.1%	82.6%	5.5%	11.2%	3.6%	8.5%	0.7%	3.8%	0.3%	2.8%	1.6%	5.3%
Global climate strategies*	73.6%	88.3%	2.4%	12.1%	0.7%	8.4%	-0.7%	4.3%	-0.9%	2.7%	0.7%	8.4%
International Agreeements / Game Theory*	64.4%	81.1%	0.0%	13.5%	0.0%	9.1%	0.0%	6.1%	0.0%	0.0%	0.0%	6.1%

**Calculates confidence interval without finite population correction*

Table 10a. % of All Respondent to Question 10 by Responses and Group, including response rate

Groups	Strongly believe the SCC is higher than $37	Believe the SCC is higher than $37	$37 is a likely estimate	Believe the SCC is lower than $37	Strongly believe the SCC is lower than $37	No opinion	Response
All	25.7%	29.6%	18.9%	6.2%	2.4%	17.2%	92.6%
Economics	21.6%	31.8%	23.9%	10.2%	3.4%	9.1%	89.8%
Environmental	27.2%	28.8%	17.2%	4.8%	2.0%	20.0%	93.6%
Multiple	28.4%	30.5%	21.1%	10.5%	1.1%	8.4%	96.0%
One	24.7%	29.2%	18.1%	4.5%	2.9%	20.6%	91.4%
Estimated Damages from Climate	30.2%	26.7%	19.8%	8.1%	3.5%	11.6%	95.6%
Integrated Assessment Models	34.0%	31.1%	15.1%	10.4%	1.9%	7.5%	96.4%

Table 10b. 95% Confidence Intervals of Responses to Question 10 by Responses and Group

	95% Confidence Interval											
Groups	Strongly believe the SCC is higher than $37		Believe the SCC is higher than $37		$37 is a likely estimate		Believe the SCC is lower than $37		Strongly believe the SCC is lower than $37		No opinion	
All	21.8%	29.7%	25.5%	33.7%	15.4%	22.5%	4.0%	8.4%	1.0%	3.7%	13.8%	20.6%
Economics	14.3%	28.9%	23.6%	40.1%	16.3%	31.4%	4.9%	15.6%	0.2%	6.6%	4.0%	14.2%
Environmental	22.5%	31.9%	24.0%	33.6%	13.2%	21.2%	2.6%	7.0%	0.5%	3.5%	15.8%	24.2%
Multiple	21.3%	35.6%	23.2%	37.8%	14.6%	27.5%	5.7%	15.4%	-0.6%	2.7%	4.0%	12.8%
One	20.0%	29.4%	24.3%	34.1%	13.9%	22.3%	2.3%	6.8%	1.1%	4.7%	16.2%	25.0%
Estimated Damages from Climate*	20.5%	39.9%	17.4%	36.1%	11.4%	28.2%	2.4%	13.9%	-0.4%	7.4%	4.9%	18.4%
Integrated Assessment Models*	0.0%	18.0%	0.0%	17.6%	0.0%	13.6%	0.0%	11.6%	-0.7%	4.5%	2.5%	12.6%

**Calculates confidence interval without finite population correction*

Table 10c. Cumulative % of All Respondent to Question 10 by Responses and Group, including response rate

Groups	Believe the SCC is higher than $37	Believe the SCC is equal or higher than $37	Believe the SCC is lower than $37	No opinion
All	55.3%	74.3%	8.6%	17.2%
Economics	53.4%	77.3%	13.6%	9.1%
Environmental	56.0%	73.2%	6.8%	20.0%
Multiple	58.9%	80.0%	11.6%	8.4%
One	53.9%	72.0%	7.4%	20.6%
Estimated Damages from Climate	57.0%	76.7%	11.6%	11.6%
Integrated Assessment Models	65.1%	80.2%	12.3%	7.5%

Table 10d. 95% Confidence Intervals of Cumulative Responses to Question 10 by Responses and Group

	95% Confidence Interval							
Groups	Believe the SCC is higher than $37		Believe the SCC is equal or higher than $37		Believe the SCC is lower than $37		No opinion	
All	50.8%	59.8%	70.3%	78.2%	6.1%	11.1%	13.8%	20.6%
Economics	44.6%	62.2%	69.9%	84.7%	7.6%	19.7%	4.0%	14.2%
Environmental	50.8%	61.2%	68.6%	77.8%	4.2%	9.4%	15.8%	24.2%
Multiple	51.2%	66.7%	73.7%	86.3%	6.5%	16.6%	4.0%	12.8%
One	48.5%	59.3%	67.2%	76.9%	4.6%	10.2%	16.2%	25.0%
Estimated Damages from Climate*	46.5%	67.4%	67.8%	85.7%	4.9%	18.4%	4.9%	18.4%
Integrated Assessment Models*	56.0%	74.2%	72.6%	87.8%	6.0%	18.5%	2.5%	12.6%

**Calculates confidence interval without finite population correction*

Table 11a. % of All Respondent to Question 11 by Responses and Group, including response rate

Groups	By using a constant discount rate calibrated using market rates	By using a constant discount rate calibrated using ethical parameters	By using a declining discount rate calibrated using market rates	By using a declining discount rate calibrated using ethical parameters	No opinion	Other (please specify)	Respons e
All	9.1%	17.4%	19.5%	29.8%	9.4%	14.7%	92.9%
Economics	12.4%	19.1%	25.8%	32.6%	5.6%	4.5%	90.8%
Environmental	8.0%	16.8%	17.2%	28.8%	10.8%	18.4%	93.6%
Multiple	2.1%	11.5%	21.9%	36.5%	8.3%	19.8%	97.0%
One	11.9%	19.8%	18.5%	27.2%	9.9%	12.8%	91.4%
Integrated Assessment Models	5.6%	13.1%	26.2%	38.3%	2.8%	14.0%	97.3%

Table 11b. 95% Confidence Intervals of Responses to Question 11 by Responses and Group

	95% Confidence Interval							
Groups	By using a constant discount rate calibrated using market rates		By using a constant discount rate calibrated using ethical parameters		By using a declining discount rate calibrated using market rates		By using a declining discount rate calibrated using ethical parameters	
All	6.5%	11.7%	14.0%	20.8%	15.9%	23.0%	25.7%	33.9%
Economics	6.6%	18.1%	12.2%	26.0%	18.2%	33.5%	24.4%	40.8%
Environmental	5.2%	10.8%	12.9%	20.7%	13.2%	21.2%	24.0%	33.6%
Multiple	-0.2%	4.3%	6.5%	16.5%	15.4%	28.4%	28.9%	44.0%
One	8.4%	15.4%	15.4%	24.1%	14.3%	22.7%	22.3%	32.0%
Integrated Assessment Models*	1.2%	10.0%	6.7%	19.5%	17.8%	34.5%	29.1%	47.5%

**Calculates confidence interval without finite population correction*

Table 11c. Cumulative % of All Respondent to Question 11 by Responses and Group, including response rate

Groups	Constant Rate	Declining Rate	Market Based Rate	Ethical Based Rate	No or other opinion
All	26.5%	49.3%	28.6%	47.2%	24.2%
Economics	31.5%	58.4%	38.2%	51.7%	10.1%
Environmental	24.8%	46.0%	25.2%	45.6%	29.2%
Multiple	13.5%	58.3%	24.0%	47.9%	28.1%
One	31.7%	45.7%	30.5%	46.9%	22.6%
Integrated Assessment Models	18.7%	64.5%	31.8%	51.4%	16.8%

Table 11d. 95% Confidence Intervals of Cumulative Responses to Question 11 by Responses and Group

95% Confidence Interval										
Groups	Constant Rate		Declining Rate		Market Based Rate		Ethical Based Rate		No or other opinion	
All	22.6%	30.5%	44.8%	53.8%	24.5%	32.7%	42.7%	51.7%	20.3%	28.0%
Economics	23.3%	39.6%	49.8%	67.1%	29.7%	46.7%	42.9%	60.4%	4.8%	15.4%
Environmental	20.3%	29.3%	40.8%	51.2%	20.6%	29.8%	40.4%	50.8%	24.4%	34.0%
Multiple	8.2%	18.9%	50.6%	66.1%	17.3%	30.6%	40.1%	55.7%	21.1%	35.2%
One	26.6%	36.7%	40.3%	51.1%	25.5%	35.4%	41.5%	52.3%	18.1%	27.2%
Integrated Assessment Models*	11.3%	26.1%	55.4%	73.6%	23.0%	40.6%	41.9%	60.9%	9.7%	23.9%

**Calculates confidence interval without finite population correction*

Table 12a. Summary of Responses to Question 12 (Original Calculation) by Group, including response rate

Groups	Mean	Std. Dev.	Min	Max	10%	50% (median)	90%	95% Confidence Interval		Response	Response Rate
All	3.1	9.4	-1.5	100	0	2	5	2.0	4.3	220	60.3%
Economics	2.2	1.7	-0.1	10	0.5	2	4	1.8	2.6	63	64.3%
Environmental	3.5	11.1	-1.5	100	0	2	5	1.9	5.1	157	58.8%
Multiple	3.0	11.6	0	95	0	1.5	3	0.6	5.4	66	66.7%
One	3.2	8.4	-1.5	100	0	2	5	2.0	4.4	154	57.9%
Integrated Assessment Models*	3.1	11.0	-0.1	95	0	2	4	0.6	5.6	74	67.3%

Calculates confidence interval without finite population correction

Table 12b. Summary of Responses to Question 12 (Alternative Calculation) by Group, including response rate

Groups	Mean	Std. Dev.	Min	Max	10%	50% (median)	90%	95% Confidence Interval		Response	Response Rate
All	3.1	9.3	-1.5	100	0	2	5	2.0	4.2	225	61.6%
Economics	2.2	1.7	-0.1	10	0.1	2	4	1.8	2.5	64	65.3%
Environmental	3.5	11.0	-1.5	100	0	1.7	5	1.9	5.0	161	60.3%
Multiple	3.0	11.5	0	95	0	1.5	3	0.6	5.3	67	67.7%
One	3.1	8.3	-1.5	100	0	2	5	2.0	4.3	158	59.4%
Integrated Assessment Models*	3.0	10.9	-0.1	95	0	2	4	0.6	5.5	75	68.2%

Calculates confidence interval without finite population correction

Table 13a. Summary of Responses to Question 13 (Original Calculation) by Group, including response rate

Groups	Mean	Std. Dev.	Min	Max	10%	50% (median)	90%	95% Confidence Interval		Response	Response Rate
All	-10.2	11.5	-60	28.968	-20	-5.5	-1	-11.5	-8.9	234	64.1%
Economics	-7.1	9.9	-50	3	-15	-5	-1	-9.2	-5.0	69	70.4%
Environmental	-11.5	11.9	-60	28.968	-25	-10	-1.8	-13.1	-9.9	165	61.8%
Multiple	-9.1	11.3	-60	1	-20	-5	-1.5	-11.4	-6.9	70	70.7%
One	-10.7	11.6	-50	28.968	-25	-8	-1	-12.3	-9.0	164	61.7%
Estimated Damages from Climate*	-11.7	15.3	-60	3	-40	-5	0	-15.4	-7.9	63	70.0%
Integrated Assessment Models*	-8.5	9.9	-50	3	-20	-5	-1	-10.6	-6.3	82	74.5%
Climate-Change Adaptation*	-11.2	14.6	-60	5	-40	-5	-1	-14.9	-7.4	59	72.8%

**Calculates confidence interval without finite population correction*

Table 13b. Summary of Responses to Question 13 (Alternative Calculation) by Group, including response rate

Groups	Mean	Std. Dev.	Min	Max	10%	50% (median)	90%	95% Confidence Interval		Response	Response Rate
All	-10.2	11.5	-60	28.968	-20	-5.5	-1	-11.5	-8.9	234	64.1%
Economics	-7.0	9.9	-50	3	-15	-4.5	-1	-9.0	-4.9	70	71.4%
Environmental	-11.6	11.9	-60	28.968	-25	-10	-2	-13.2	-9.9	164	61.4%
Multiple	-9.1	11.3	-60	2.4	-20	-5	-1.5	-11.4	-6.9	70	70.7%
One	-10.7	11.6	-50	28.968	-25	-8	-1	-12.3	-9.0	164	61.7%
Estimated Damages from Climate*	-11.7	15.3	-60	3	-40	-5	0	-15.4	-7.9	63	70.0%
Integrated Assessment Models*	-8.3	9.9	-50	3	-20	-5	-1	-10.5	-6.2	83	75.5%
Climate-Change Adaptation*	-11.2	14.6	-60	5	-40	-5	-1	-14.9	-7.4	59	72.8%

**Calculates confidence interval without finite population correction*

Table 15a. Summary of Responses to Question 15 (Original Calculation) by Group, including response rate

Groups	Mean	Std. Dev.	Min	Max	10%	50% (median)	90%	95% Confidence Interval		Response	Response Rate
All	22.0	25.8	0	100	0.08	10	70	19.0	24.9	238	65.2%
Economics	11.3	18.5	0	90	0.01	5	30	7.4	15.1	68	69.4%
Environmental	26.2	27.0	0	100	0.15	20	72.5	22.6	29.9	170	63.7%
Multiple	20.0	25.8	0	99	0.01	5	70	14.8	25.1	69	69.7%
One	22.8	25.8	0	100	0.1	10	70	19.3	26.3	169	63.5%
Estimated Damages from Climate*	23.0	27.1	0	90	0.05	10	70	16.2	29.8	61	67.8%
Integrated Assessment Models*	15.9	21.6	0	90	0.01	5	50	11.2	20.5	83	75.5%
Climate-Change Adaptation*	20.6	24.3	0	90	0.05	10	60	14.5	26.7	61	75.3%

**Calculates confidence interval without finite population correction*

Table 15b. Summary of Responses to Question 15 (Alternative Calculation) by Group, including response rate

Groups	Mean	Std. Dev.	Min	Max	10%	50% (median)	90%	95% Confidence Interval		Response	Response Rate
All	21.8	25.7	0	100	0.09	10	65	18.9	24.7	240	65.8%
Economics	11.2	18.3	0	90	0.01	5	30	7.4	15.0	69	70.4%
Environmental	26.1	27.0	0	100	0.2	20	70	22.4	29.7	171	64.0%
Multiple	19.7	25.7	0	99	0.03	5	60	14.6	24.8	70	70.7%
One	22.6	25.8	0	100	0.1	10	65	19.1	26.2	170	63.9%
Estimated Damages from Climate*	22.7	27.0	0	90	0.05	10	70	16.0	29.4	62	68.9%
Integrated Assessment Models*	15.7	21.5	0	90	0.01	5	50	11.1	20.3	84	76.4%
Climate-Change Adaptation*	20.6	24.3	0	90	0.05	10	60	14.5	26.7	61	75.3%

**Calculates confidence interval without finite population correction*

Table 16a. Coefficients of Quadratic Damages Estimating Using Our Survey (i.e., questions 13 and 15) and Nordhaus' Survey, assuming no initial benefits from climate change

Study	Groups	Non-catastrophic				Catastrophic				Total			
		Mean	Median	95% - Low	95% - High	Mean	Median	95% - Low	95% - High	Mean	Median	95% - Low	95% - High
Our Study	All	-1.13	-0.61	-0.99	-1.28	-0.61	-0.28	-0.53	-0.69	-1.74	-0.89	-1.52	-1.97
	Economics	-0.79	-0.56	-0.56	-1.02	-0.31	-0.14	-0.21	-0.42	-1.10	-0.69	-0.77	-1.44
	Environmental	-1.28	-1.11	-1.09	-1.46	-0.73	-0.56	-0.63	-0.83	-2.01	-1.67	-1.72	-2.29
	Multiple	-1.02	-0.56	-0.77	-1.27	-0.55	-0.14	-0.41	-0.70	-1.57	-0.69	-1.18	-1.96
	One	-1.18	-0.89	-1.00	-1.36	-0.63	-0.28	-0.53	-0.73	-1.82	-1.17	-1.54	-2.09
	Estimated Damages from Climate*	-1.30	-0.56	-0.88	-1.72	-0.64	-0.28	-0.45	-0.83	-1.94	-0.83	-1.33	-2.54
	Integrated Assessment Models*	-0.94	-0.56	-0.70	-1.18	-0.44	-0.14	-0.31	-0.57	-1.38	-0.69	-1.02	-1.75
Nordhaus (1994)	All	-0.40	-0.21	-	-	-0.13	-0.01	-	-	-0.53	-0.23	-	-

Table 16b. Coefficients of Quadratic Damages Estimating Using Our Survey (i.e., questions 5, 13 and 15), allowing for initial benefits from climate change

Groups	Mean			Median (50th Percentile)		
	Non-catastrophic		catastrophic	Non-catastrophic		catastrophic
	Linear	Quadratic	Quadratic	Linear	Quadratic	Quadratic
All	1.70	-1.70	-0.61	0.92	-0.92	-0.28
Economic	1.19	-1.19	-0.31	0.83	-0.83	-0.14
Environm	1.92	-1.92	-0.73	1.67	-1.67	-0.56
Multiple	1.52	-1.52	-0.55	0.83	-0.83	-0.14
One	1.78	-1.78	-0.63	1.33	-1.33	-0.28
Damage*	1.94	-1.94	-0.64	0.83	-0.83	-0.28
IAM*	1.41	-1.41	-0.44	0.83	-0.83	-0.14

Table 16c. Coefficients of Non-Catastrophic, Quadratic Damages Estimating Using Our Survey (i.e., question 13) and Nordhaus' Survey, assuming no initial benefits from climate change and a limit to climate impacts of GDP of 100%

Study	Groups	Non-Catastrophic			
		Mean	Median	95% - Low	95% - High
Our Study	All	-1.26	-0.65	-1.08	-1.45
	Economics	-0.85	-0.58	-0.59	-1.12
	Environmental	-1.44	-1.23	-1.21	-1.68
	Multiple	-1.12	-0.58	-0.82	-1.43
	One	-1.33	-0.97	-1.10	-1.56
	Damage*	-1.47	-0.58	-0.95	-2.03
	IAM*	-1.03	-0.58	-0.75	-1.32
Nordhaus (1994)	All	-0.41	-0.22	-	-

Table 16d. Coefficients of Non-Catastrophic, Quadratic Damages Estimating Using Our Survey (i.e., questions 5 and 13) and Nordhaus' Survey, allowing for initial benefits from climate change and assuming limit to climate impacts of GDP of 100%

Study	Groups	Mean		Median		95% - Low		95% - High	
		Linear	Quadratic	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic
Our Study	All	1.8941	-1.8941	0.9700	-0.9700	1.6242	-1.6242	2.1720	-2.1720
	Economics	1.2771	-1.2771	0.8772	-0.8772	0.8864	-0.8864	1.6856	-1.6856
	Environmental	2.1649	-2.1649	1.8519	-1.8519	1.8218	-1.8218	2.5209	-2.5209
	Multiple	1.6766	-1.6766	0.8772	-0.8772	1.2341	-1.2341	2.1414	-2.1414
	One	1.9885	-1.9885	1.4493	-1.4493	1.6564	-1.6564	2.3328	-2.3328
	Damage*	2.2006	-2.2006	0.8772	-0.8772	1.4276	-1.4276	3.0425	-3.0425
	IAM*	1.5434	-1.5434	0.8772	-0.8772	1.1277	-1.1277	1.9790	-1.9790

Table 17. 2015 SCC (2015 USD per metric ton of CO2) Damage Functions Calibrated to Our Survey (Questions 5 and 13)

Study	Groups	No Limit on Damages		Limit of 100% of GDP on Damages	
		Quadratic only	Linear and Quadratic	Quadratic only	Linear and Quadratic
Our Study	All	$113	$144	$96	$115
	Economics	$74	$92	$66	$79
	Environmental	$132	$169	$108	$130
	Multiple	$99	$124	$85	$103
	One	$119	$153	$100	$121
	Damage*	$134	$171	$110	$204
	IAM*	$90	$113	$79	$126
	Adapt*	$126	$162	$105	$191
Nordhaus (1994)	All	$35	-	$33	-
DICE-2013R	All	$23	-	-	-

Table 18. The Number and Percentage of Inconsistent Responses, by Group

Group	All Responses	Consistent Responses	% of Inconstent Responses
All	238	174	-27%
Economics	68	58	-15%
Environmental	170	116	-32%
Multiple	69	49	-29%
One	169	125	-26%
Damages	61	45	-26%
IAMs	83	66	-20%
Adaptation	61	44	-28%

Table 19. 2015 SCC for total (non-catastrophic and catastrophic) damages, by damage function and distribution (2015 USD)

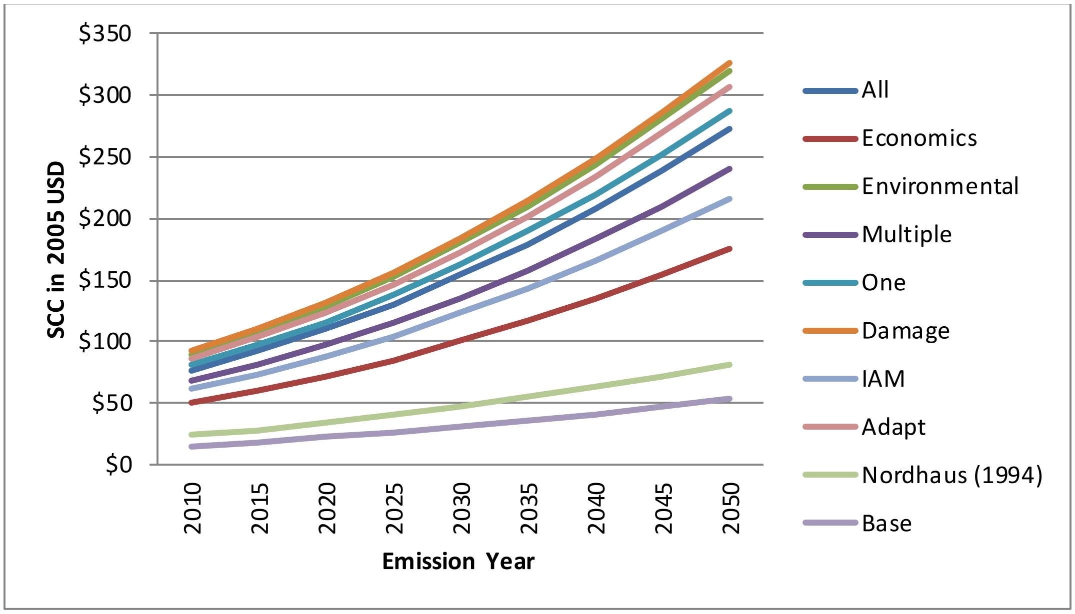
	No Limit on Damages								No Initial ben							
	Quadratic Only				Linear and Quadratic				Quadratic Only							
Year/Distribution	Beta	Weibull	Triangular	Triangular (Zeroed)	Beta	Weibull	Triangula *r	Triangular (Zeroed)	Beta	Weibull	Triangular	Triangular (zeroed)	Beta	Weibull	Triangular	Triangular ((zeroed)
2010	$165	$178	$191	$205	$213	$226	$250	$266	$109	$114	$109	$125	$133	$149	$147	$154
2015	$188	$197	$215	$232	$243	$252	$281	$300	$124	$127	$122	$141	$155	$163	$169	$178
2020	$219	$225	$249	$268	$285	$291	$327	$350	$141	$143	$137	$160	$180	$186	$195	$206
2025	$256	$261	$290	$313	$337	$340	$384	$411	$161	$162	$152	$181	$207	$212	$222	$236
2030	$298	$302	$337	$364	$396	$397	$448	$481	$181	$181	$169	$202	$236	$240	$250	$267
2035	$345	$348	$389	$421	$461	$460	$520	$557	$202	$202	$185	$225	$267	$268	$278	$299
2040	$396	$397	$445	$481	$531	$528	$595	$638	$224	$223	$200	$247	$297	$298	$305	$330
2045	$450	$449	$504	$545	$606	$600	$673	$722	$246	$244	$214	$269	$327	$326	$330	$360
2050	$507	$504	$565	$611	$683	$674	$752	$807	$268	$265	$226	$290	$356	$354	$352	$388

2010 2015 2020 2025 2030 2035 2040
Year

Table 20. % of 2015 SCC for damages due to catastrophic impacts, by damage function and distribution

	No Limit on Damages								No Initial benfits							
	Quadratic Only				Linear and Quadratic				Quadratic Only				Linear and Quadratic			
Year/Distribution	Beta	Weibull	Triangular	Triangular (Zeroed)	Beta	Weibull	Triangular	Triangular (Zeroed)	Beta	Weibull	Triangular	Triangular (zeroed)	Beta	Weibull	Triangular	Triangular (zeroed)
2015	67%	75%	91%	106%	69%	75%	96%	109%	30%	33%	28%	48%	35%	42%	47%	55%

Figures 18a. The SCC for Emissions from 2010 to 2050 in 2015 USD using a Quadratic Damage Functions Assuming No Initial Climate Benefits (i.e., questions 5 and 13), by group



Figures 18b. The SCC for Emissions from 2010 to 2050 in 2015 USD using a Quadratic Damage Functions Allowing for Initial Climate Benefits (i.e., questions 5 and 13), by group

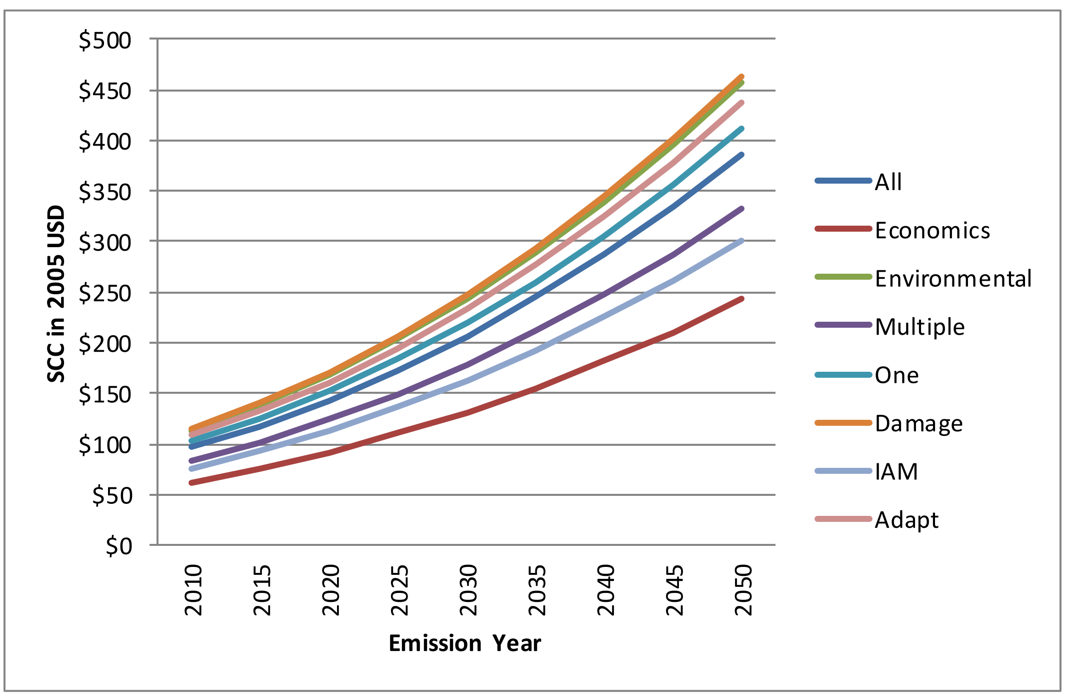


Figure 18c. The SCC for Emissions from 2010 to 2050 in 2015 USD using the DICE-2007 Damage Function (i.e., question 13), by group

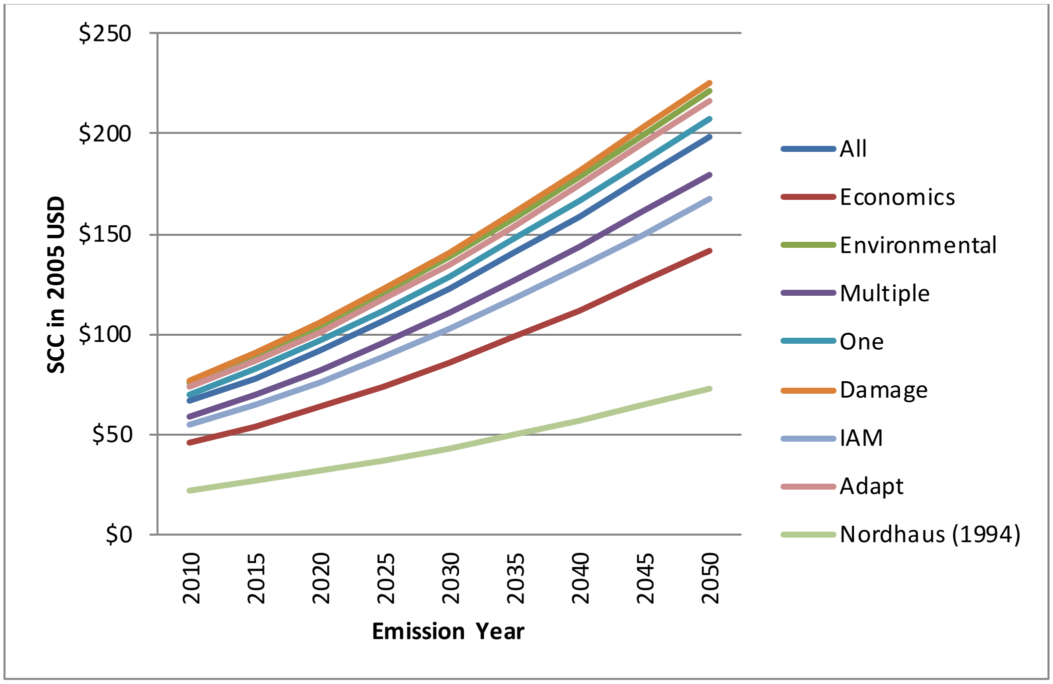


Figure 18d. The SCC for Emissions from 2010 to 2050 in 2015 USD using the DICE-1999 Damage Function (i.e., questions 5 and 13), by group

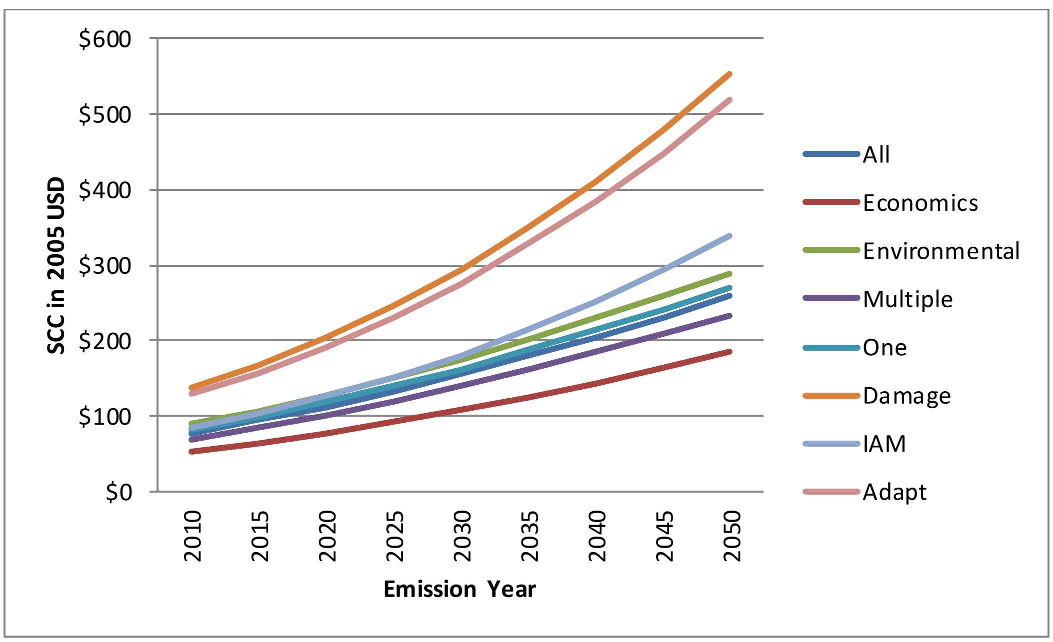


Figure 20b. The Cumulative Pareto Distribution Calibrated Using the "Untrimmed-Group" Methodology, by Group

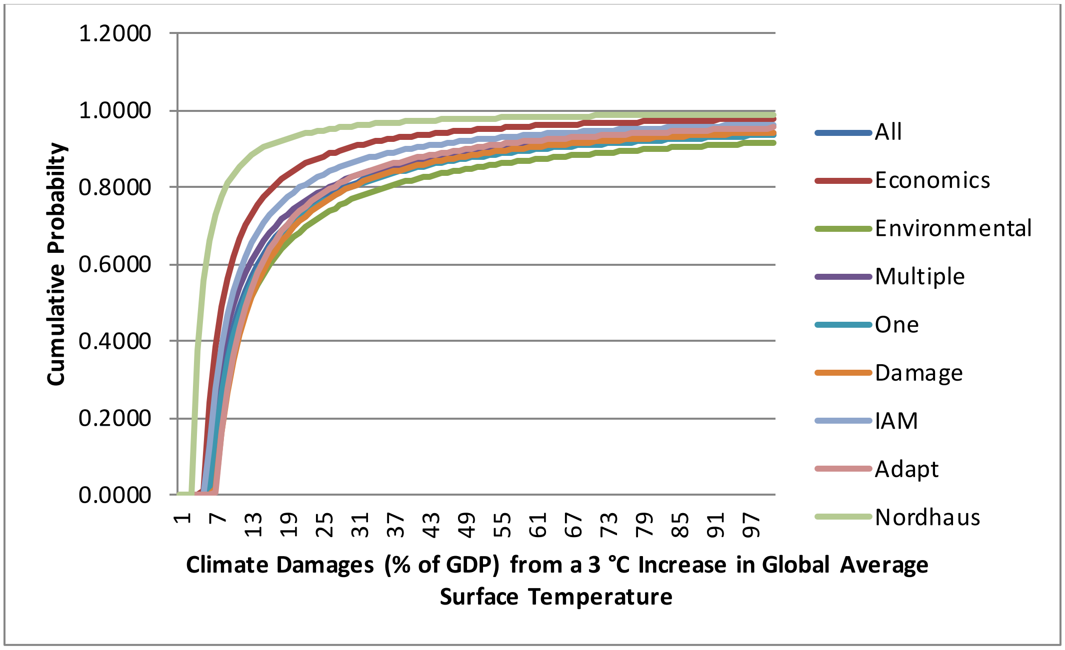


Figure 20c. The Cumulative Log-Normal Distribution Calibrated Using the "Untrimmed-Group" Methodology, by Group

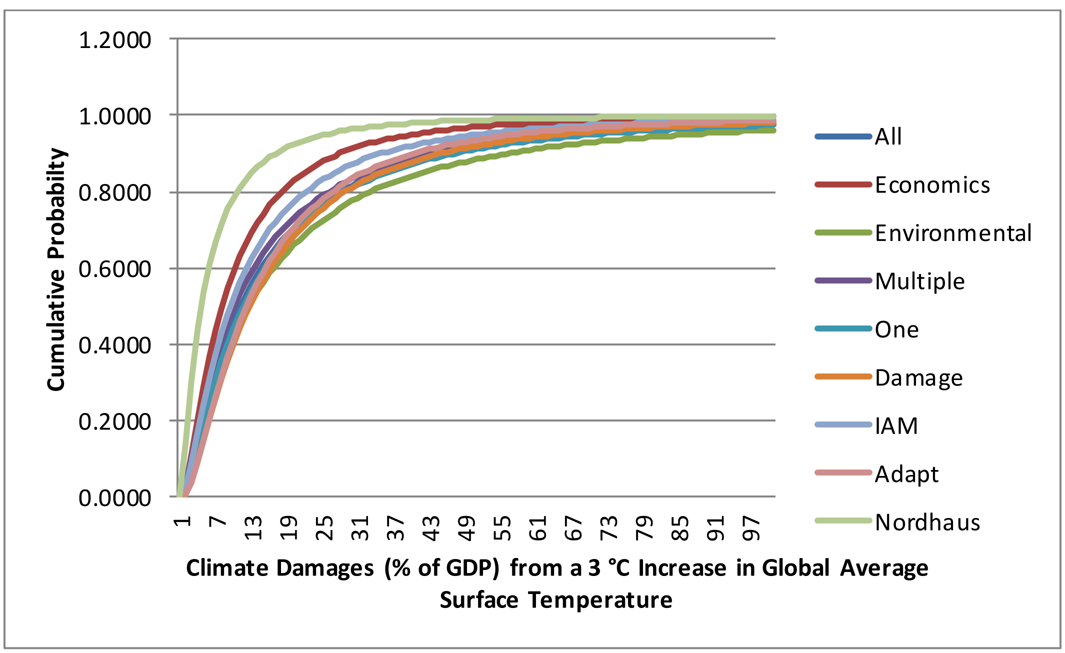


Figure 20d. The Cumulative Beta Distribution Calibrated Using the "Untrimmed-Group" Methodology, by Group

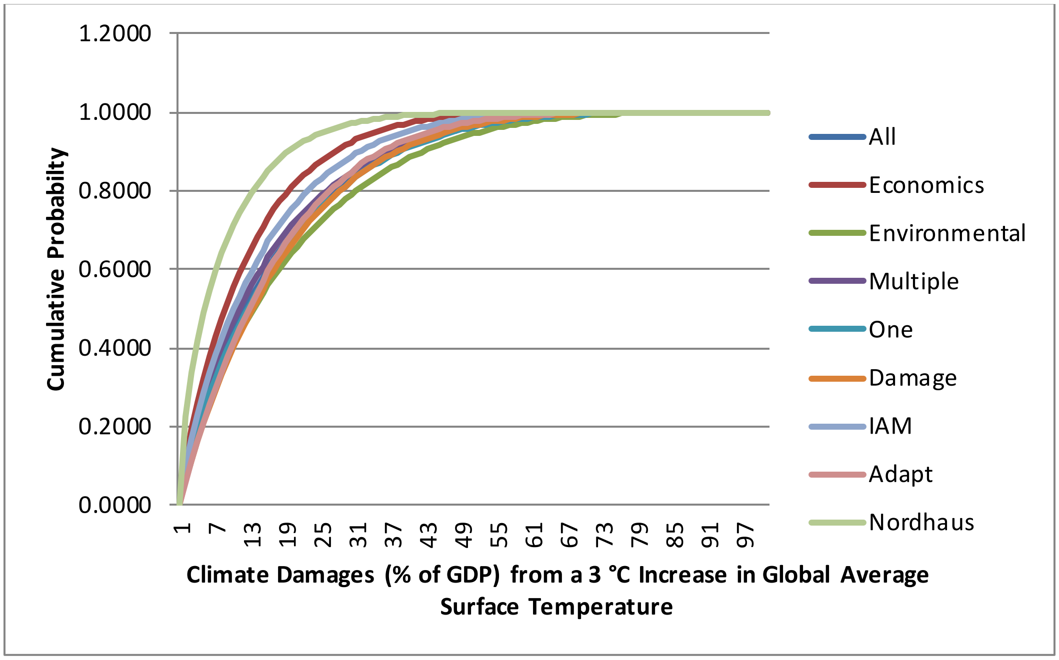


Figure 20e. The Cumulative Triangular Distribution Calibrated Using the "Untrimmed-Group" Methodology, by Group

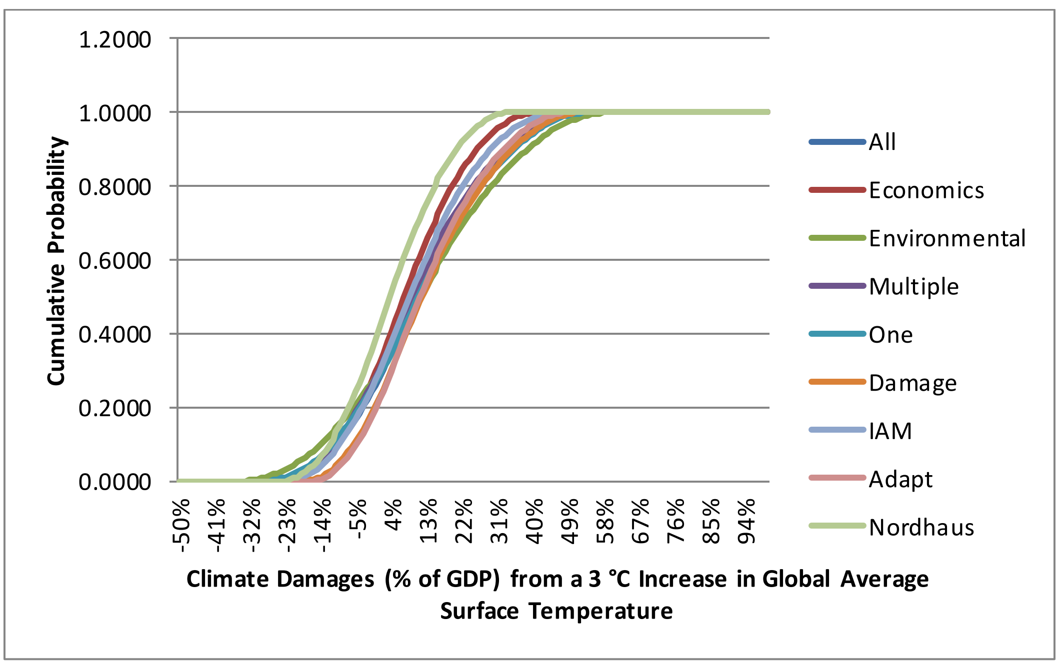


Figure 21b. The Cumulative Pareto Distribution Calibrated Using the "Trimmed-individual" Methodology, by Group

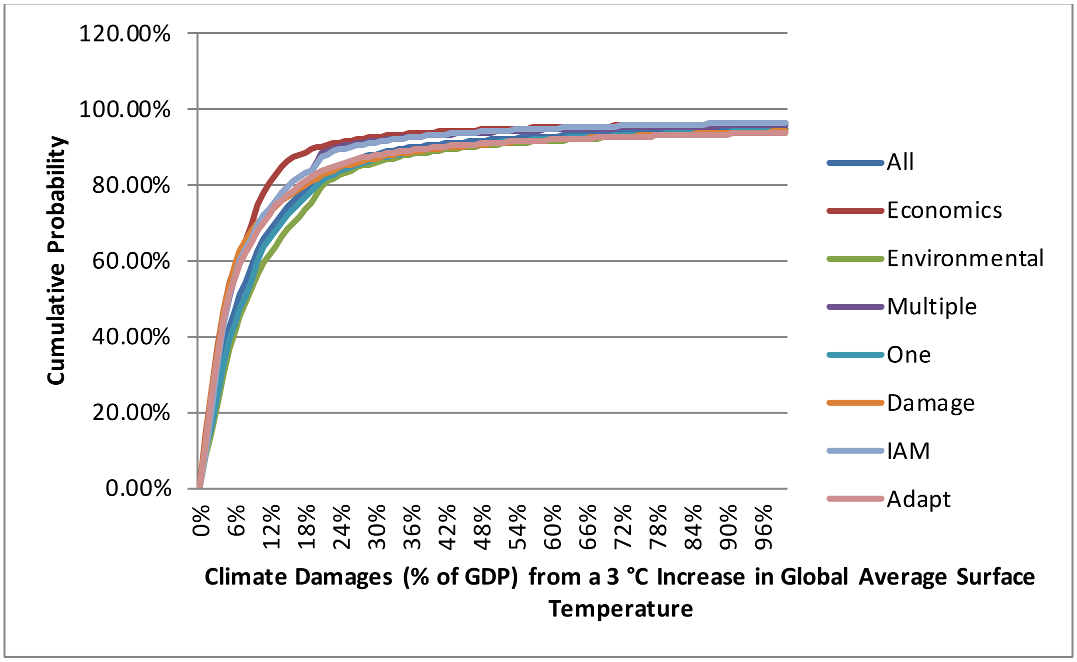


Figure 21c. The Cumulative Log-Normal Distribution Calibrated Using the "Trimmed-individual" Methodology, by Group

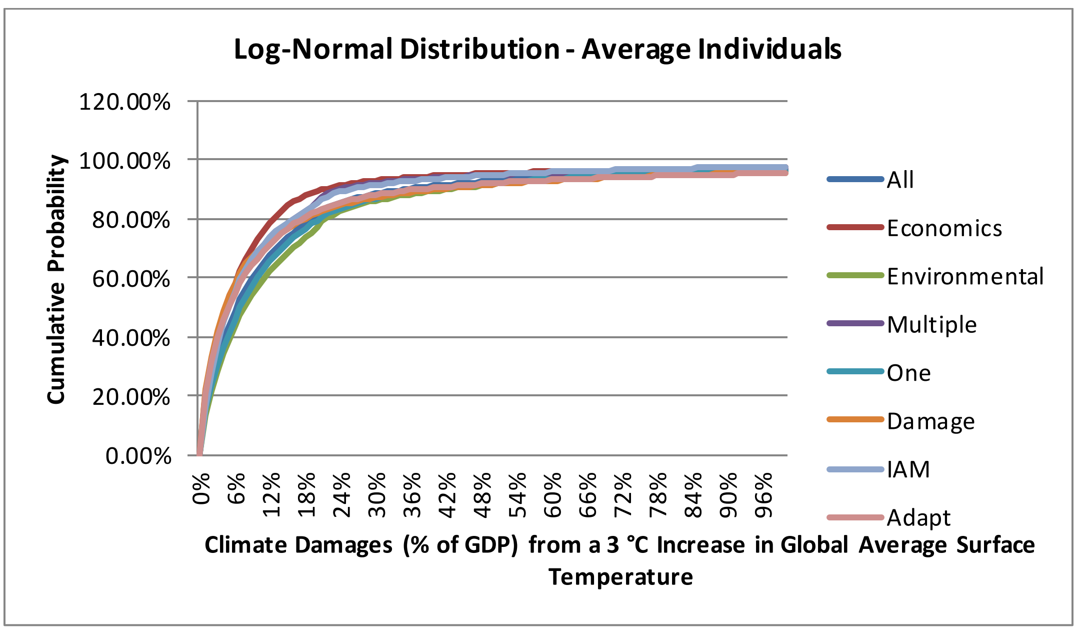


Figure 21d. The Cumulative Beta Distribution Calibrated Using the "Trimmed-individual" Methodology, by Group

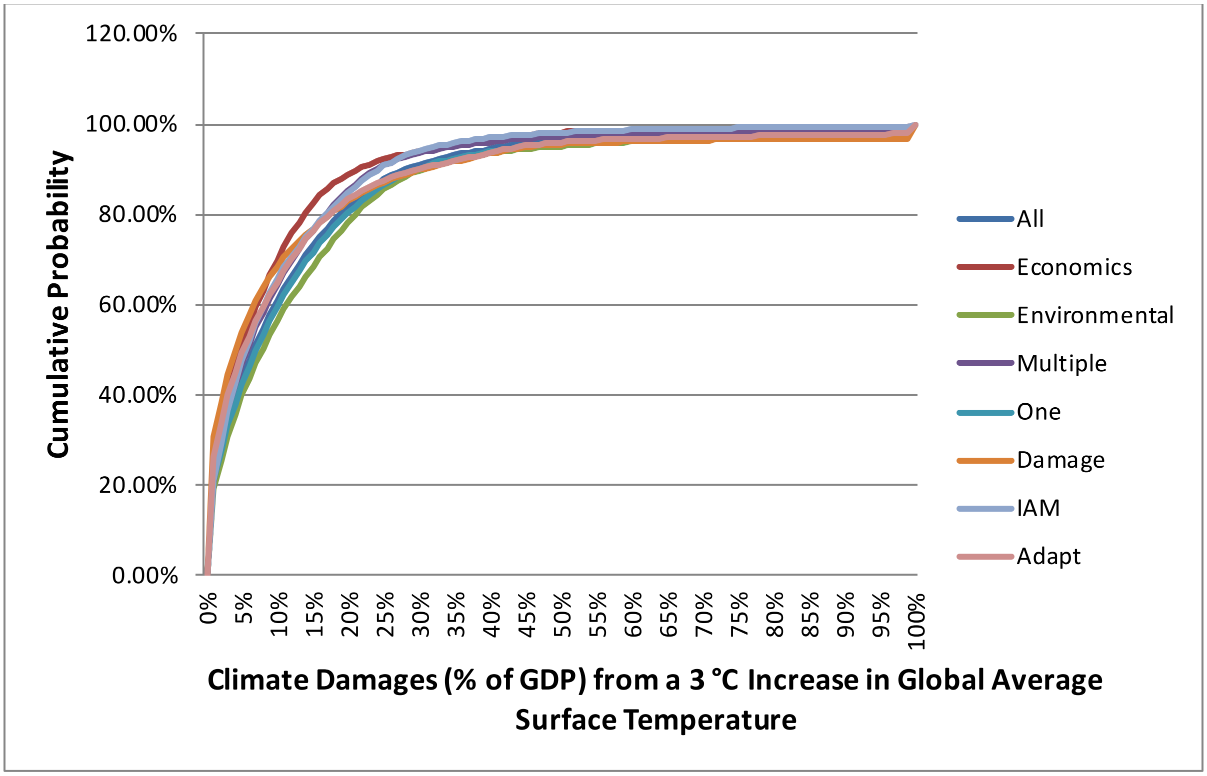


Figure 22b. The Cumulative Pareto Distribution Calibrated Using All Observations, by Calibration Method

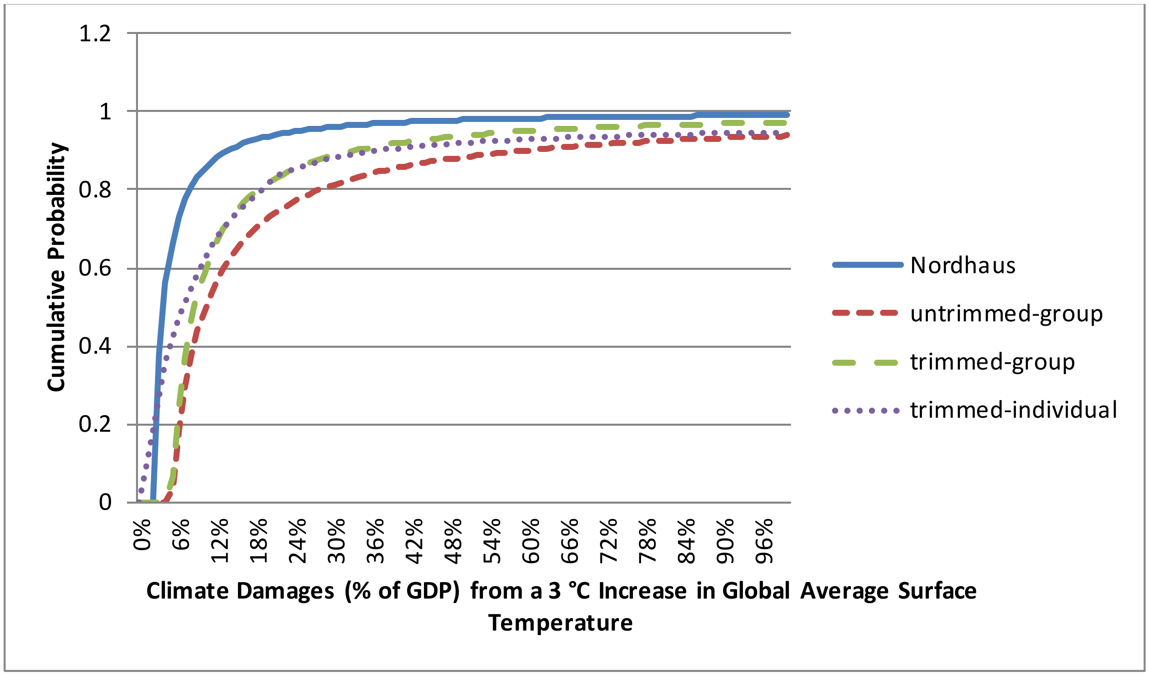


Figure 22c. The Cumulative Log-Normal Distribution Calibrated Using All Observations, by Calibration Method

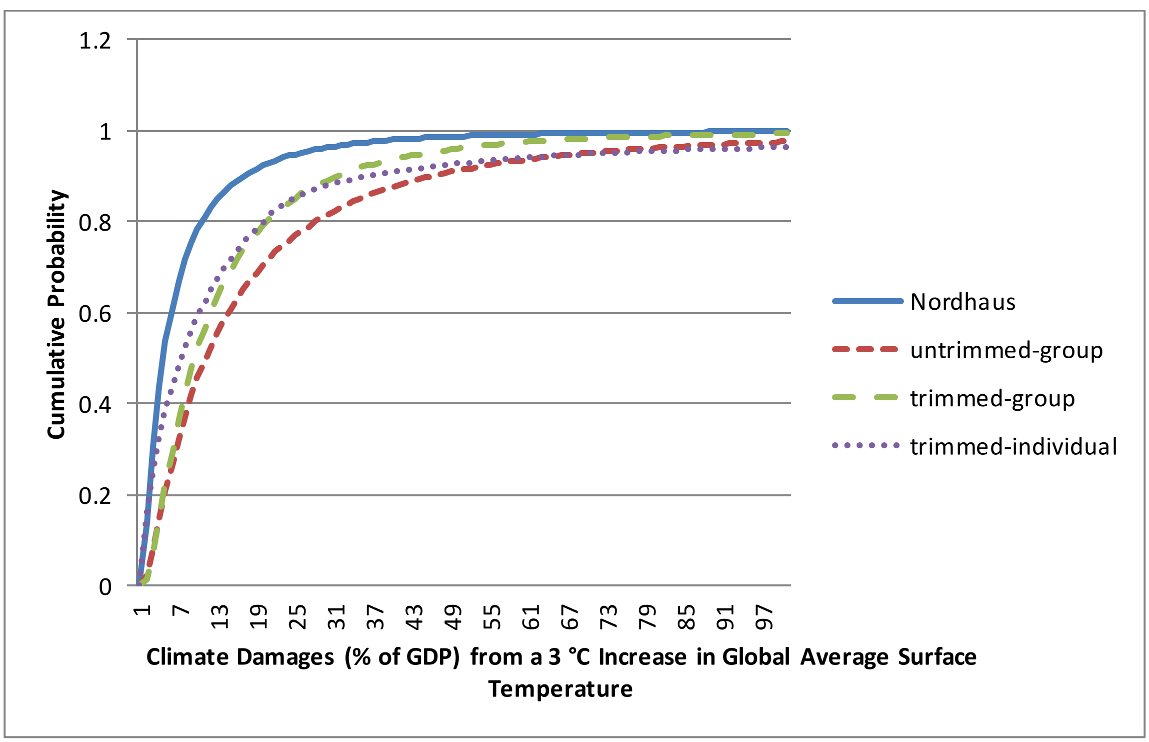


Figure 22d. The Cumulative Beta Distribution Calibrated Using All Observations, by Calibration Method

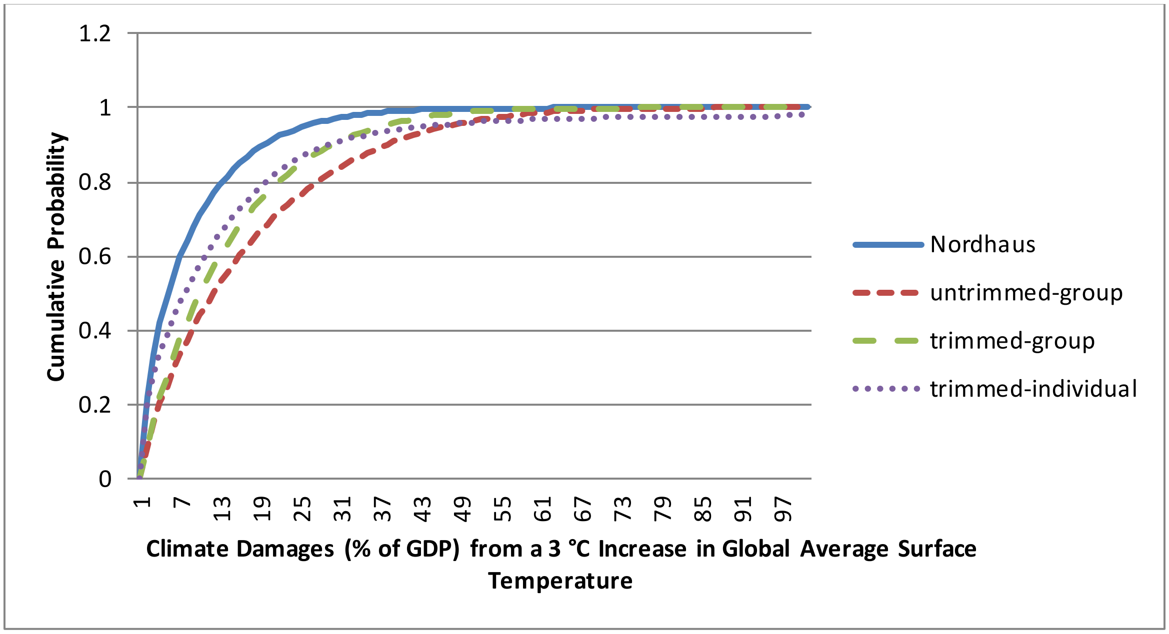


Figure 22e. The Cumulative Triangular Distribution Calibrated Using All Observations, by Calibration Method

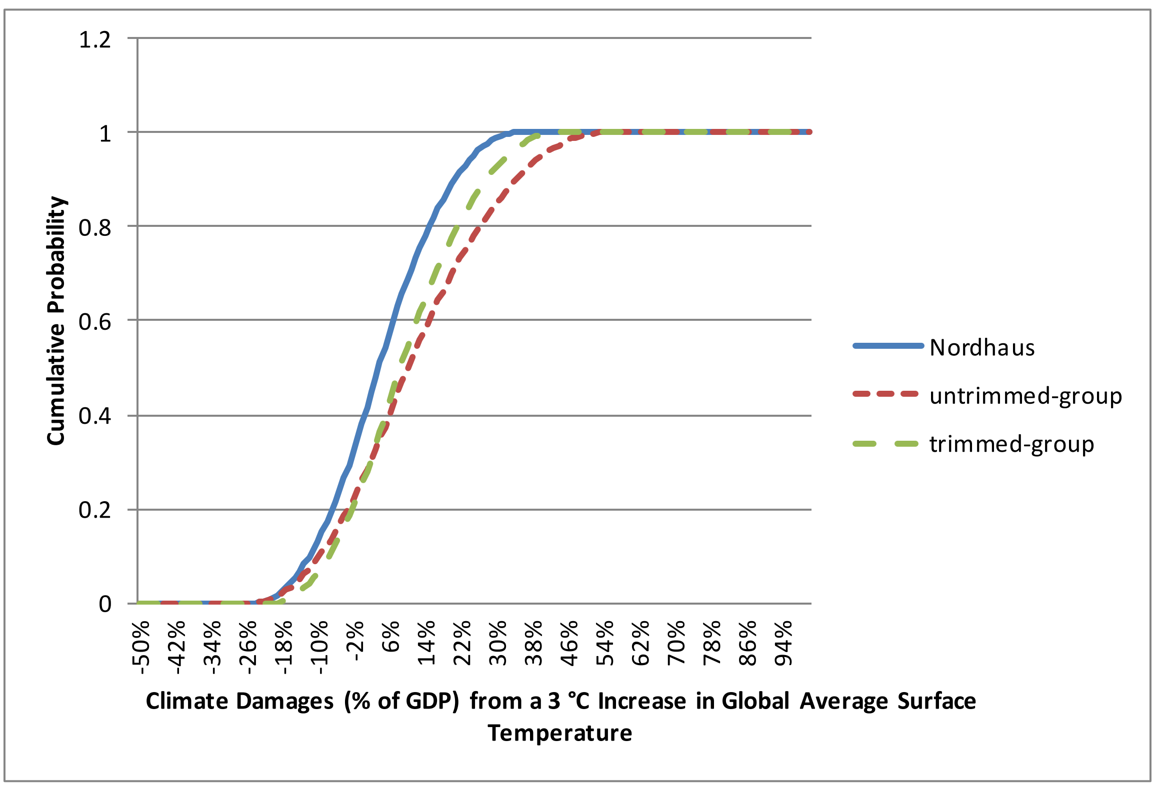


Figure 23b. The Social Cost of Carbon from 2010 to 2050 Using the Quadratic Damage Function Allowing for an Initial Benefits from Climate Change, by Distribution

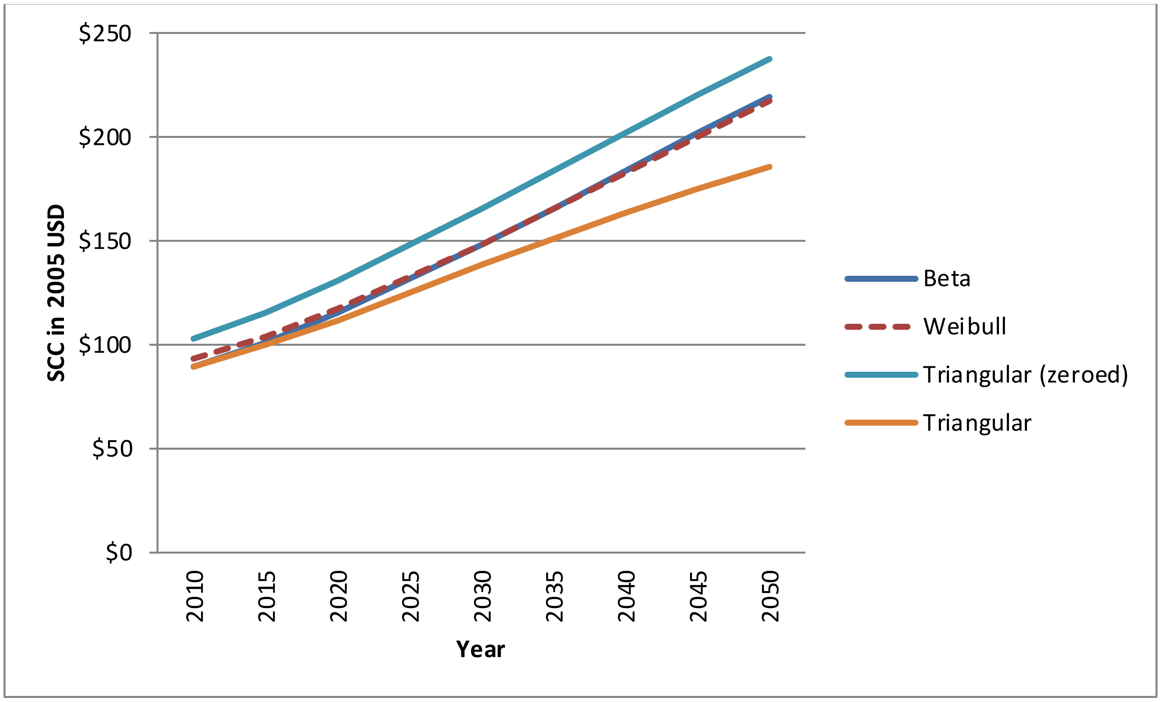


Figure 23c. The Social Cost of Carbon from 2010 to 2050 Using the DICE-2007 Damage Functional Form, by Distribution

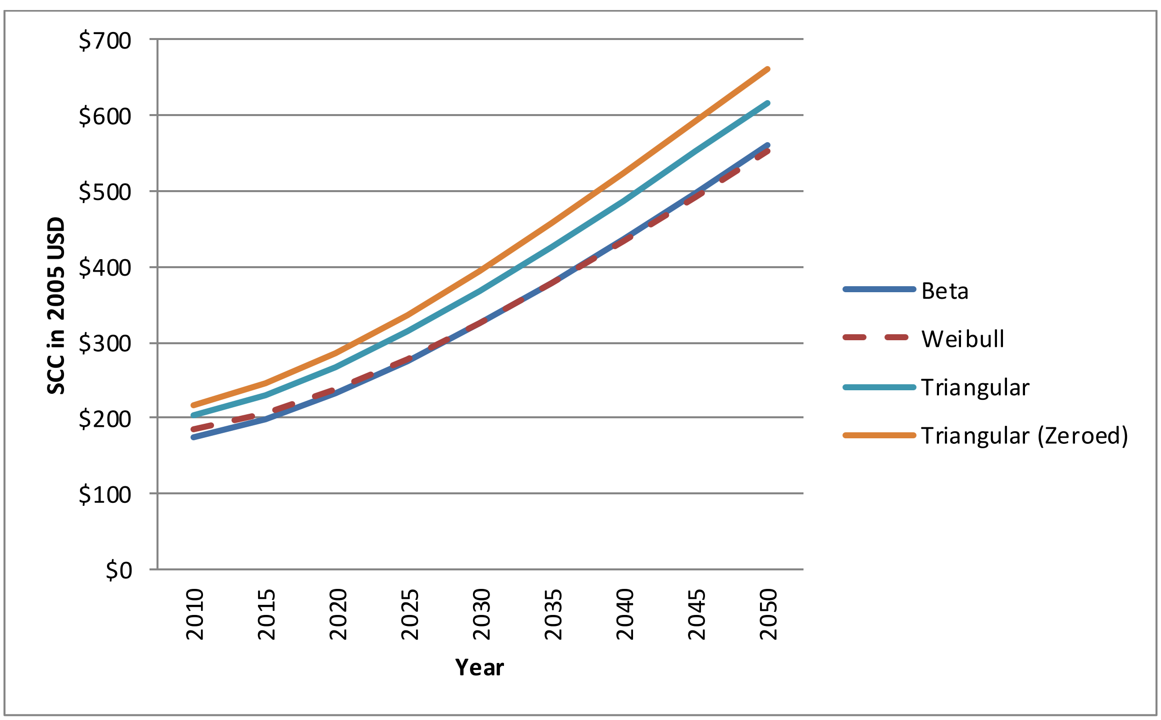
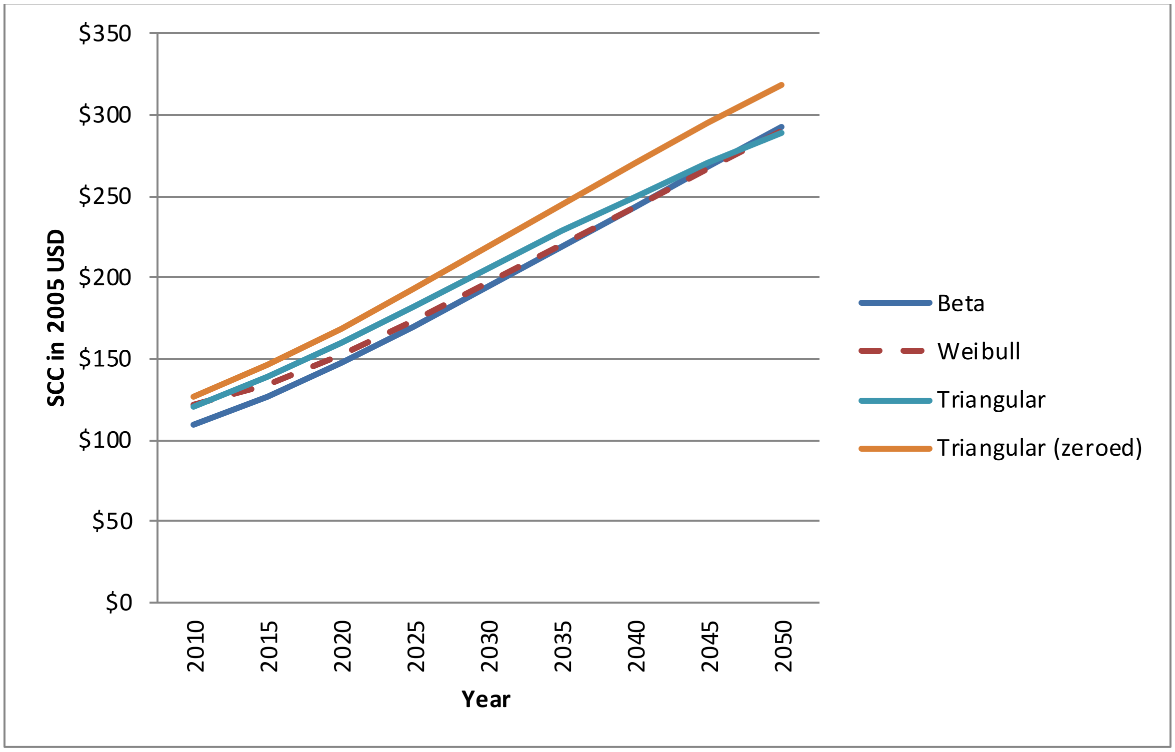


Figure 23d. The Social Cost of Carbon from 2010 to 2050 Using the DICE-1999 Damage Functional Form, by Distribution



Appendix A. List of Journals Used in Survey

Economics Journals
American Economic Review
Econometric Theory
Econometrica
Economic Journal
Economic Theory
Economics Letters
European Economic Review
Games and Economic Behavior
International Economic Review
Journal of Applied Econometrics
Journal of Business and Economic Statistics
Journal of Development Economics
Journal of Econometrics
Journal of Economic Dynamics and Control
Journal of Economic Literature
Journal of Economic Theory
Journal of Financial Economics
Journal of Human Resources
Journal of International Economics
Journal of Labor Economics
Journal of Labor Economics
Journal of Monetary Economics
Journal of Money, Credit, and Banking
Journal of Political Economy
Journal of Public Economics
Journal of the European Economic Association
NBER Macroeconomics Annual
Quarterly Journal of Economics
Rand Journal of Economics
Resource and Energy Economics
The Journal of Economic Perspectives
The Review of Economic Studies
Environmental Economics Journals
American Journal of Agricultural Economics
Ecological Economics
Environment and Resource Economics
Journal of Environmental Economic Management
Land Economics

Appendix B. Survey Questions

Institute for Policy Integrity
new york university school of law

Survey on Economics and Climate Change (2015)

The Institute for Policy Integrity at New York University School of Law is conducting a survey to examine the opinions of expert economists on climate change policy and uncertainty. This survey is only being sent to economists who have published a climate change-related article in a top economic journal.

The survey should take less than 15 minutes to complete. The aggregate results of this survey will be used in academic research and potentially distributed to media members, but individual responses will be anonymous and confidential.

RESPONDENT INFORMATION

1. You have published on the following topics (check all that apply):

- ☐ Climate Change Risks
- ☐ Estimated Damages from Climate Change
- ☐ Global Climate Strategies
- ☐ International Agreements/Game Theory
- ☐ Greenhouse Gas Control Mechanisms
- ☐ Integrated Assessment Models / Social Cost of Carbon
- ☐ Climate Change Adaptation
- ☐ Other Climate-Related Topics
- ☐ None

CLIMATE CHANGE RISKS

2. Which of the following best describes your view about climate change?

- ○ Immediate and drastic action is necessary
- ○ Some action should be be taken now
- ○ More research is needed before action is taken
- ○ This is not a serious problem

3. If nothing is done to limit climate change in the future, how serious of a problem do you think it will be for the United States?

- ◯ Very serious
- ◯ Somewhat serious
- ◯ Not so serious
- ◯ Not serious at all
- ◯ No opinion

4. The following domestic economic sectors are likely to be negatively affected by climate change (check all that apply):

- [ ] Agriculture
- [ ] Mining/Extractive Industries
- [ ] Fishing
- [ ] Forestry
- [ ] Real Estate
- [ ] Insurance
- [ ] Construction
- [ ] Transport
- [ ] Manufacturing
- [ ] Health Services
- [ ] Tourism/Outdoor Recreation
- [ ] Utilities (Electricity, Water, Sanitation, etc.)
- [ ] Other (please specify)

5. During what time period do you believe the net effects of climate change will first have a negative impact on the global economy?

(Please assume a business-as-usual path for emissions, with no major new climate policies implemented.)

- ◯ Climate change is already having a negative effect on the global economy
- ◯ By 2025
- ◯ By 2050
- ◯ By 2075
- ◯ By 2100
- ◯ After 2100
- ◯ Climate change will not have a negative effect on the global economy

6. What is the likelihood that climate change will have a long-term, negative impact on the*growth rate* of the global economy?

(Please assume a business-as-usual path for emissions, with no major new climate policies implemented.)

- Extremely likely
- Likely
- Not clear
- Unlikely
- Extremely unlikely

DOMESTIC GREENHOUSE GAS CONTROL MECHANISMS

7. The U.S. Environmental Protection Agency's "Clean Power Plan" will set carbon dioxide emission targets for each individual state's electricity sector. What would be the most efficient way to implement these targets?

- Performance standards and programs that prioritize cleaner fuels and energy efficiency, *implemented within each individual state*
- Performance standards and programs that prioritize cleaner fuels and energy efficiency, *coordinated among states at a regional level*
- Market-based mechanisms (trading programs or carbon taxes) *implemented at the individual state level*
- Market-based mechanisms *coordinated at a regional or national level* (such as a regional/national trading program or carbon tax)
- No opinion

GLOBAL CLIMATE STRATEGY AND INTERNATIONAL AGREEMENTS

8. The United States may be able to strategically induce other countries to reduce their greenhouse gas emissions (or enter into an emissions reduction agreement) by adopting policies to reduce U.S. emissions.

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree
- No opinion

9. The U.S. government should commit to reducing greenhouse gas emissions:

- ◯ Regardless of the actions other countries have taken thus far
- ◯ Only if it can enter into a multilateral emissions reduction agreement with some countries
- ◯ Only if other major emitters enact policies to reduce their emissions
- ◯ Only if every country commits to reducing emissions through a global agreement
- ◯ Under no circumstances
- ◯ No opinion

Institute *for* Policy Integrity
new york university school of law

Survey on Economics and Climate Change (2015)

SOCIAL COST OF CARBON

(For questions in this section, please assume business-as-usual climate and socioeconomic scenarios.)

10. The global "social cost of carbon" (SCC) is the marginal cost to society of carbon dioxide emissions. Specifically, it is the present value of all future damages to the global society of one additional metric ton of carbon dioxide-equivalent greenhouse gasses emitted today.

In 2013, a U.S. government Interagency Working Group adopted $37 (in 2007 USD) as its central estimate for the SCC (this figure estimates the economic damages of a unit of 2015 emissions, with a 3% discount rate).

What is your opinion of this estimate:

- Strongly believe the SCC is higher than $37
- Believe the SCC is higher than $37
- $37 is a likely estimate
- Believe the SCC is lower than $37
- Strongly believe the SCC is lower than $37
- No opinion

11. How should the benefits to future generations of climate change mitigation be evaluated/discounted?

- By using a constant discount rate calibrated using market rates
- By using a constant discount rate calibrated using ethical parameters
- By using a declining discount rate calibrated using market rates
- By using a declining discount rate calibrated using ethical parameters
- No opinion
- Other (please specify)

12. If benefits to future generations are to be discounted using a constant discount rate, the appropriate discount rate to use when calculating the social cost of carbon is:

(Please enter a percentage)

CLIMATE IMPACT ESTIMATES

13. Imagine this scenario:
Global mean temperature *increases by 3°C* relative to the pre-industrial era (i.e., a 2.1°C increase from the current period) *by approximately 2090*.

What is your best guess (median/50th percentile estimate) of the impact on global output, as a percentage of GDP? Please include non-market and market impacts, and factor in adaptation to climate change.

Please provide your answer as a % of global GDP. If you believe these impacts will increase GDP rather than decrease it, please indicate this with a (+).

14. Climate change is likely to affect both market goods (e.g., food and fiber, service sector, and manufacturing) and non-market goods (e.g., environmental amenities, ecosystems, and human health). Market goods should be thought of as all goods and services traditionally included in national accounts, i.e., GDP.

What is your best guess of the percentage of total impacts (market plus non-market) that will be borne by the market sector?

Please provide the % of impacts in the market sector. (Assume a 3°C rise by 2090.)

15. **Some people are concerned about a low-probability, high-consequence outcome from climate change, potentially caused by environmental tipping points. Assume by "high-consequence" we mean a 25% loss or more in global income indefinitely. (Global output dropped by approximately 25% during the Great Depression.)**

What is your median/50th percentile estimate of the probability of such a high-consequence outcome if global average temperature were to increase 3°C by 2090?

16. ***[Optional]*** Please comment on any of the above questions. We are especially interested in the approach you used for your estimates, any sources you found helpful, your level of confidence in the answers you provided, issues with question clarity, etc.