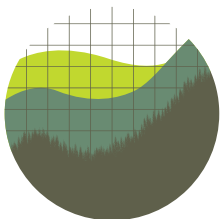




# Expert Consensus on the Economics of Climate Change



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# Executive Summary

Given that effective climate change 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 is necessary. However, policymakers and journalists often portray economists as more conservative than scientists when it comes to climate policy, possibly due to their focus on market-driven adaptation and the costs of mitigation.

In an effort to clarify the level of consensus among economists with respect to climate change risks, economic impacts, and policy responses, we conducted a survey of expert economists. Our survey builds on a similar 2009 survey conducted by other researchers at the Institute for Policy Integrity. We surveyed all those who have published an article related to climate change in a highly ranked, peer-reviewed economics or environmental economics journal since 1994. This survey allowed us to compare the views of economic experts to the views of the general public and help establish expert consensus on the likely economic impacts of climate change and the recommended policy responses. The survey also provides insights about the appropriate assumptions to use in “integrated assessment models” – the climate-economic models that many policymakers consult to inform climate policy decisions.

We designed a 15-question online survey with questions focused on climate change risks, economic damage estimates, and policy responses. We invited the 1,103 experts who met our selection criteria to participate, and we received 365 completed surveys. The survey data revealed several key findings:

- Experts on the economics of climate change expressed higher levels of concern about climate change impacts than the general public, when asked identical survey questions.
- 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 41% saying that climate change is already negatively affecting the economy.
- Respondents believe that numerous sectors of the U.S. economy will be harmed by climate change. A majority predicted negative impacts on agriculture (94%), fishing (78%), utilities (electricity, water, sanitation – 74%), forestry (73%), tourism/outdoor recreation (72%), insurance (66%), and health services (54%).
- More than three-quarters of respondents believe that climate change will have a long-term, negative impact on the *growth rate* of the global economy.
- More than 80% of experts believe that the United States may be able to strategically induce other nations to reduce their greenhouse gas emissions by first adopting policies to reduce U.S. emissions.
- Respondents overwhelmingly support unilateral emissions reduction commitments by the United States, regardless of the actions other nations have taken (77% chose this option over alternatives such as committing only if multilateral agreements are reached).

- The vast majority (75%) of respondents believe that the most economically efficient way for states to comply with the U.S. Environmental Protection Agency’s “Clean Power Plan” carbon regulations is through “market-based mechanisms coordinated at a regional or national level (such as a regional/national trading program or carbon tax).”
- The discounting approach that the U.S. government currently uses to analyze climate 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 in the context of climate policies. Nearly half (46%) of respondents favored an approach that featured declining discount rates, while 44% favored using rates calibrated with ethical parameters.
- On average, economic experts predicted far higher economic impacts from climate change than the estimates found in older surveys of economists and other climate experts. Respondents predicted a global GDP loss of roughly 10% if global mean temperature increases by 3°C relative to the pre-industrial era by 2090 (this increase approximates a “business as usual” emissions scenario).
- Experts believe that there is greater than a 20% likelihood that this same climate scenario would lead to a “catastrophic” economic impact (defined as a global GDP loss of 25% or more).
- Our findings revealed a strong consensus (69%) that the “social cost of carbon” should be greater than or equal to the figure currently used by the U.S. government (only 8% believe the value should be lower).

These findings strongly suggest that policymakers in the United States and elsewhere should be concerned about a lack of action on climate change. In particular, economists seem to believe that the United States would benefit from enacting strong domestic climate policies in the near term regardless of any concerns about “free-riding” by other countries. Our results also suggest that the integrated assessment models used to calculate the social cost of carbon are likely underestimating climate damages. There is clear consensus among economic experts that climate change poses major risks to the economy and that significant policy responses will be needed to avoid large economic damages.

# Why Survey Economists?

Over the past two decades, economic research on climate change has expanded dramatically. Thousands of articles related to climate change have been published in peer-reviewed academic journals, and an entire sub-field of economics has developed, focusing on these issues. Many economists have developed significant expertise on a host of relevant topics, including:

- The speed, severity, and regional distribution of climate change’s potential economic impacts;
- The nature of low-probability climate risks with potentially catastrophic consequences;
- The costs and benefits to both current and future generations of climate policies;
- The dynamics of international cooperation related to climate change;
- The ability of populations to adapt to the impacts of climate change.

Economic experts are uniquely qualified to provide insights on climate change risks and appropriate policy responses. Yet their input is not always taken into account in debates on climate policy, and many of these debates focus only on the costs of policy options rather than on a comprehensive economic analysis of the issues at hand.<sup>1</sup> Furthermore, some have suggested that economists are more conservative than scientists about climate policy, possibly due to their focus on market-driven adaptation and the costs of mitigation policies.<sup>2</sup> This survey clarifies some areas where there is strong expert consensus on key issues.

This project expands on a 2009 survey conducted by other researchers at the Institute for Policy Integrity.<sup>3</sup> 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 our sample included authors who published in top-ranked environmental economics journals as well as mainstream economics journals).

In addition to providing policymakers with data on the opinions of economic experts, this survey has implications for modelers who estimate climate damages. Economists have developed “integrated assessment models” (IAMs), which capture the various steps in the climate and economic processes that translate an additional ton of carbon dioxide emissions into an economic damage. Economists use these models to analyze climate policies and estimate the “social cost of carbon” (SCC) – the marginal damage of a ton of carbon dioxide emissions – an essential number in U.S. government cost-benefit analyses of regulations that affect greenhouse gas emissions. However, IAMs and the results derived from them, including the SCC, are sensitive to many of the assumptions made by modelers. Therefore, the prevailing views of economists are of major importance for improving climate-economic models, including IAMs. Our data can help establish the appropriate assumptions to be used in IAMs, in addition to providing other useful information for policymakers.

## The Value of Expert Consensus

The consensus view of experts can have significant influence on both policymakers and public opinion.<sup>4</sup> In an effort to clarify consensus on climate issues, the United Nations established the Intergovernmental Panel on Climate Change (IPCC) and asked it to provide a clear, consensus-based, scientific view on the current understanding of climate change and its consequences. Through the IPCC's deliberative review process, thousands of climate experts from across the globe assess the most recent scientific, technical, and socio-economic information, and then synthesize their findings. The IPCC's findings have been cited by the U.S. Environmental Protection Agency as justification for regulatory actions to reduce carbon emissions,<sup>5</sup> and some evidence suggests that the work of the IPCC has also influenced public opinion on climate change.<sup>6</sup>

The IPCC does review the research of economists and solicits their expertise to help develop the consensus viewpoint. In particular, economists participate in the Working Group on "Impacts, Adaptation, and Vulnerability," which has explored the consensus view on such economic topics as the social cost of carbon.

However, there are drawbacks to the deliberative process used by the IPCC to identify consensus. Group deliberations can lead to "groupthink," which can cause the results of deliberation to suffer from censorship and uniformity.<sup>7</sup> Indeed, the IPCC has been criticized for moving too slowly and adopting only the "lowest-common denominator" conclusions, leading to overly conservative results that ignore more up-to-date viewpoints.<sup>8</sup> In fact, actual measures of sea-level rise in recent years have tracked the high end of the IPCC's projections, and the IPCC's past temperature predictions were shown to be somewhat low.<sup>9</sup> In other words, the IPCC has tended to underestimate the rate of climate change, and the results of its deliberative process perhaps only indicate the minimal consensus in the scientific community – the *least* we can expect.

Besides deliberation, an alternate method for identifying the consensus opinion of experts is to use surveys and find a group's "statistical" or average answer. Well-developed theories on "the wisdom of crowds" explain why the average answer from a group is likely to be more accurate than most individuals in that group, and why large groups perform better than small groups.<sup>10</sup> For example, statistical groups of experts have been shown to significantly outperform individual experts on predicting such uncertain (and climate change-related) quantities as the annual peak rainfall runoff of various countries or changes in the U.S. economy.<sup>11</sup> By comparison, deliberating groups only tend to do about as well as their average members on making accurate predictions, and not as well as their best members.<sup>12</sup>

Surveys and statistics can often produce a more nuanced understanding of expert consensus, and help reveal the full range of opinions in a group. Deliberation tends to reduce variance, since deliberations can amplify cognitive errors and overemphasize common knowledge, causing a group to converge on a common – though not necessarily accurate – answer. By showing the diversity of opinion, surveys can indicate where debate still exists on an issue and where a consensus might emerge in the future.

### *Calls for Expert Consensus and Critiques of Integrated Assessment Models*

Data from surveys of expert economists can help improve climate-economic models. Noted economist Robert Pindyck has argued that integrated assessment models (IAMs) are over-reliant on the opinion of the modeler,<sup>13</sup> and as a consequence, IAMs essentially represent the modeler's informed opinion rather 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 parameter values (such as the probability of catastrophic outcomes, the discount rate, etc.) based on their own opinions, Pindyck proposes using a simple model with inputs determined by expert opinion from “a range of economists and climate scientists.” Given a specific climate scenario, experts would be asked about their assumptions for key values in determining the SCC: (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 carbon dioxide emissions 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 emissions reduction roughly approximates the SCC.<sup>14</sup>

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 opinions of a wide range of economists about the economics of climate change, similar to what Pindyck 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.<sup>15</sup>

## Past Surveys

Researchers have conducted several types of surveys to gauge how both experts and the general public view key issues related to climate change. Many past attempts to clarify the consensus views of economists on these issues 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 current consensus views of economists and the topics that elude consensus.

### *Expert Surveys on Climate Change Economics*

The 2009 Institute for Policy Integrity survey, 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.<sup>16</sup> 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 greenhouse gasses and incentivize energy efficiency and low-carbon energy production. 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. The 2009 survey did not ask for other economic damage estimates – our study adds new survey questions on this and other topics.

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.<sup>17</sup> 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 based on three climate 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 (including market and non-market impacts) 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 damages (as measured in percentage of GDP loss) borne by the market – defined as what is traditionally included in the national accounts. For Scenario A, the mean and median share of impacts captured by the traditional national accounts were 62.4% and 62.5%). Additionally, respondents were asked to estimate the probability of catastrophic damages equivalent to a 25% decline in GDP (for 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,<sup>18</sup> Nordhaus's 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. The survey is still heavily relied upon in research today, though it is two decades old and uses a small sample size.

Another 1995 survey by M.J. Schauer queried 14 experts on the external costs of carbon emissions (10 of the experts reported on climate impacts).<sup>19</sup> For a climate scenario in which atmospheric carbon dioxide concentrations doubled (this is equivalent to a 2.5°C increase relative to pre-industrial temperature), the group estimated mean and median declines in global GDP of 5.2% and 2.6%, respectively, with a variance of 71.3.

The U.S. Government Accountability Office conducted a survey of economists on climate change in 2008.<sup>20</sup> Eighteen experts submitted questionnaires for this survey panel, which focused on actions that U.S. Congress might take to address climate change and the key strengths and limitations of these policies. All of the panelists agreed that Congress should consider using a market-based mechanism to establish a price on greenhouse gas emissions, and 14 of the 18 panelists recommended additional actions to address climate change, such as investment in research and development of low-emissions technologies.

With the exception of the prior Institute for Policy Integrity survey, these expert surveys focused on handpicked respondents – often including scientists – rather than a large sample of economists. Our survey uses a large sample of economic experts and attempts to provide a current understanding of experts' views on some of the same policy issues and economic damage estimates previously 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.<sup>21</sup> In a 2014 analysis of numerous American public opinion surveys conducted by Gallup, MIT, and other organizations over the past decade, researchers found that concern about climate change has fluctuated considerably, and that practical concerns about energy costs and local environmental issues often shape public opinion significantly.<sup>22</sup> Of particular note is an MIT/Harvard survey on energy issues, conducted annually from 2006-2011 (and in other years before and after that period), in which respondents were asked what level of action should be taken to address climate change. In most years, a plurality (27% to 43%) of respondents said “some action should be taken.” Typically, a smaller percent-



age (19% to 35%) said that “immediate and drastic action is necessary,” while roughly 20% to 28% said “more research is needed before action is taken.” Between 10% and 25% typically said that climate change “is not a serious problem.” We asked 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.<sup>23</sup> The survey found that a large majority of the American public, including nearly half of respondents who identified as Republicans, supported government action to curb global warming. We asked our pool of experts a question from this survey in order to provide another point of comparison between experts and the general public.

Researchers at Yale and George Mason University have conducted a nationally representative survey of the American public on climate change twice annually since 2010.<sup>24</sup> Their most recent survey found 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.

# 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%.<sup>25</sup>

## Survey Design

Our survey was designed to accomplish four objectives: (1) to determine the extent of 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 the Institute for Policy Integrity; 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 better understand our respondent pool and gauge the effect of expertise in more specific issue areas;
- The level of risk that 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 greenhouse gas 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 with respect to climate policy and 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 a 2009 Institute for Policy Integrity survey, while two other questions used wording from surveys of the general public.<sup>26</sup> 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 the approaches and 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.<sup>27</sup>

## 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 by the Institute for Policy Integrity, we compiled a list of all authors who had published an article related to climate change in a leading economics or environmental economics journal since 1994.<sup>28</sup> We included all papers that referenced climate change and had implications for the climate change debate, even if that was not their main focus.<sup>29</sup> We defined leading journals as those ranked in the top 25 economics journals or top five environmental economics journals, according to two rankings published in peer-reviewed publications. Given that the rankings of various journals have changed during this time frame, we used rankings from two time periods<sup>30</sup> and included any publication listed as a top-25 economics journal in either ranking. In total, our final list included 32 economic journals.<sup>31</sup>

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. 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 had died or individuals we could not locate, our review revealed 1,187 authors who fit our selection criteria.<sup>32</sup> We then excluded respondents who stated that they no longer worked in this field and those for whom we could not find a working email address. With these authors removed, the total pool of experts was 1,103.<sup>33</sup>

Our methodology for choosing respondents could potentially suffer from selection bias, given that highly ranked academic journals might not publish articles encompassing the entire spectrum of thought on climate change economics. However, we believe our approach adequately identified a large sample with demonstrated expertise in the economics of climate change. Furthermore, our respondents were representative of a wide range of opinions, based on the diverse and often conflicting arguments made in their published articles.<sup>34</sup>

We disaggregated our respondent pool into various subsets based on the type of journal publications (economics versus environmental economics); the number of relevant articles a respondent had published; and the areas of expertise a respondent identified in the survey. This allowed us to analyze any differences in the views of various subsets. Information about the response patterns of various respondent subsets is available in a working paper that offers expanded analysis of our survey data.<sup>35</sup>

## Survey Administration and Response Rate

We sent each respondent an email message that described the nature of this project, informed them of the reason for their selection, and requested their participation through an embedded hyperlink to the survey.<sup>36</sup> We administered the survey online through SurveyMonkey.com, creating separate but identical surveys for each respondent subset 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 that asked for a numerical response in a text

box. 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.

Excluding those who did not receive our e-mail, our overall response rate was 33.1%. Not all respondents answered every question.<sup>37</sup> This rate is roughly consistent with the average response rate for online surveys of this type.<sup>38</sup>

# Survey 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 a related working paper.<sup>39</sup>

## Respondent Expertise by Issue Area

Our first survey question sought to 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.<sup>40</sup> 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.<sup>41</sup>

Each topic was relatively well represented. The topic with the fewest published respondents was Climate Change Adaptation (22%), while Greenhouse Gas 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 such, 85.5% of our total respondents published on at least one of the topics covered in our survey.

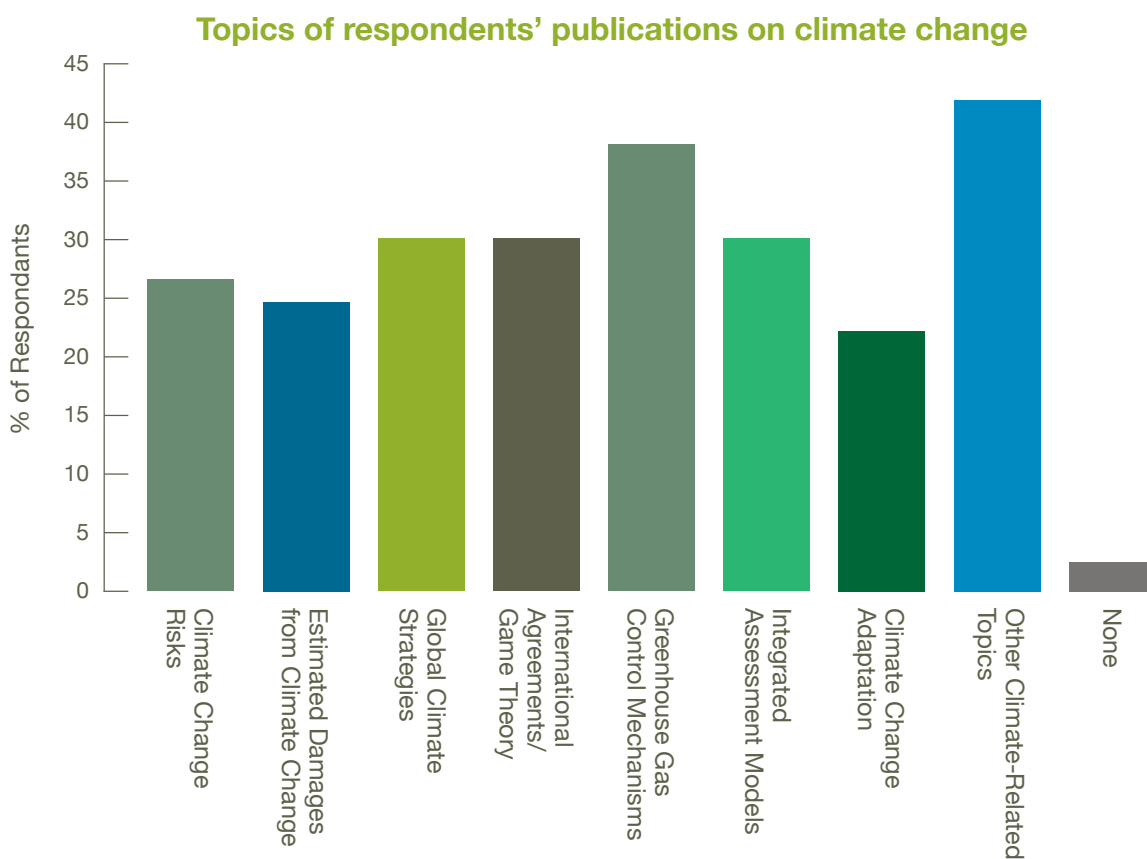


Figure 1.

## 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.<sup>42</sup>

Figure 2.

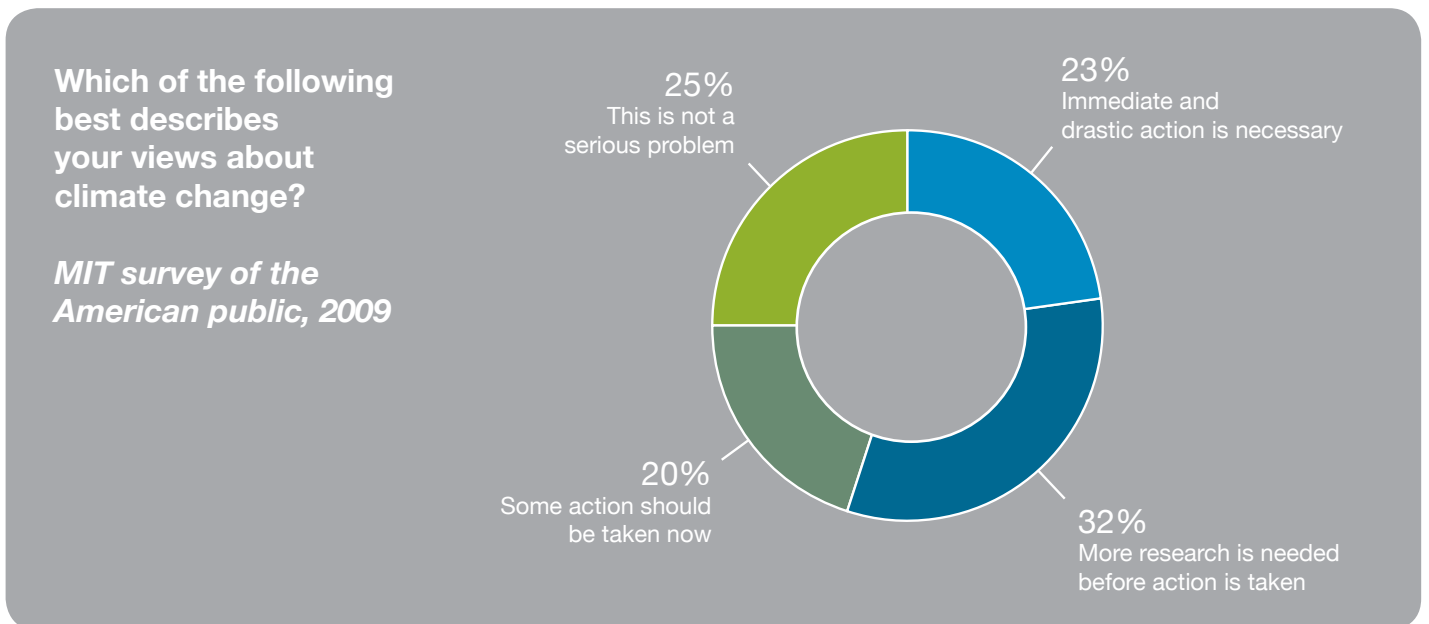
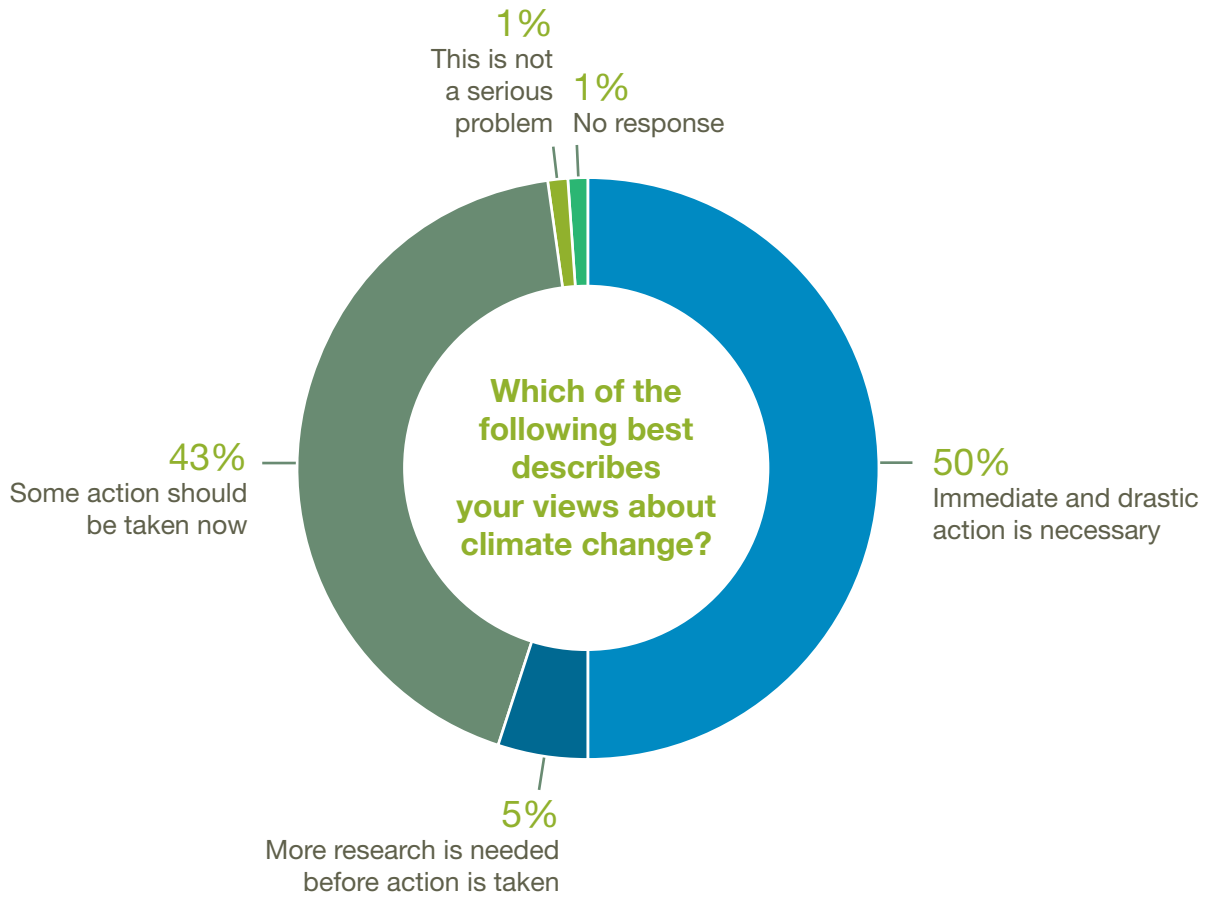


Figure 2a.

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.

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

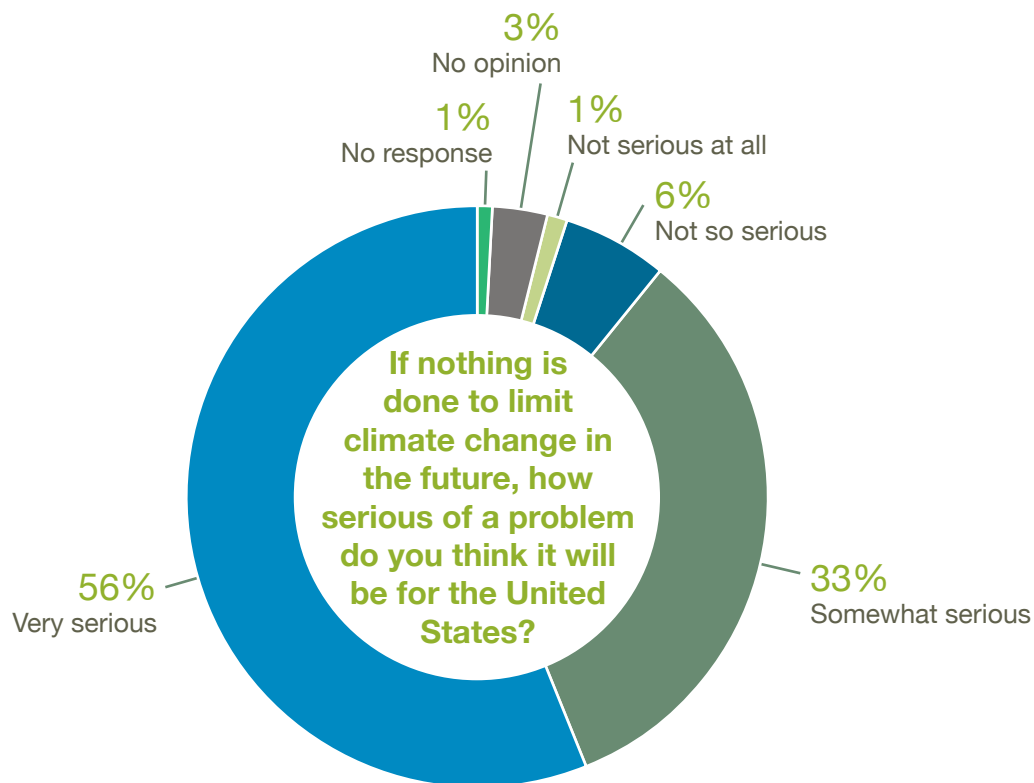


Figure 3.

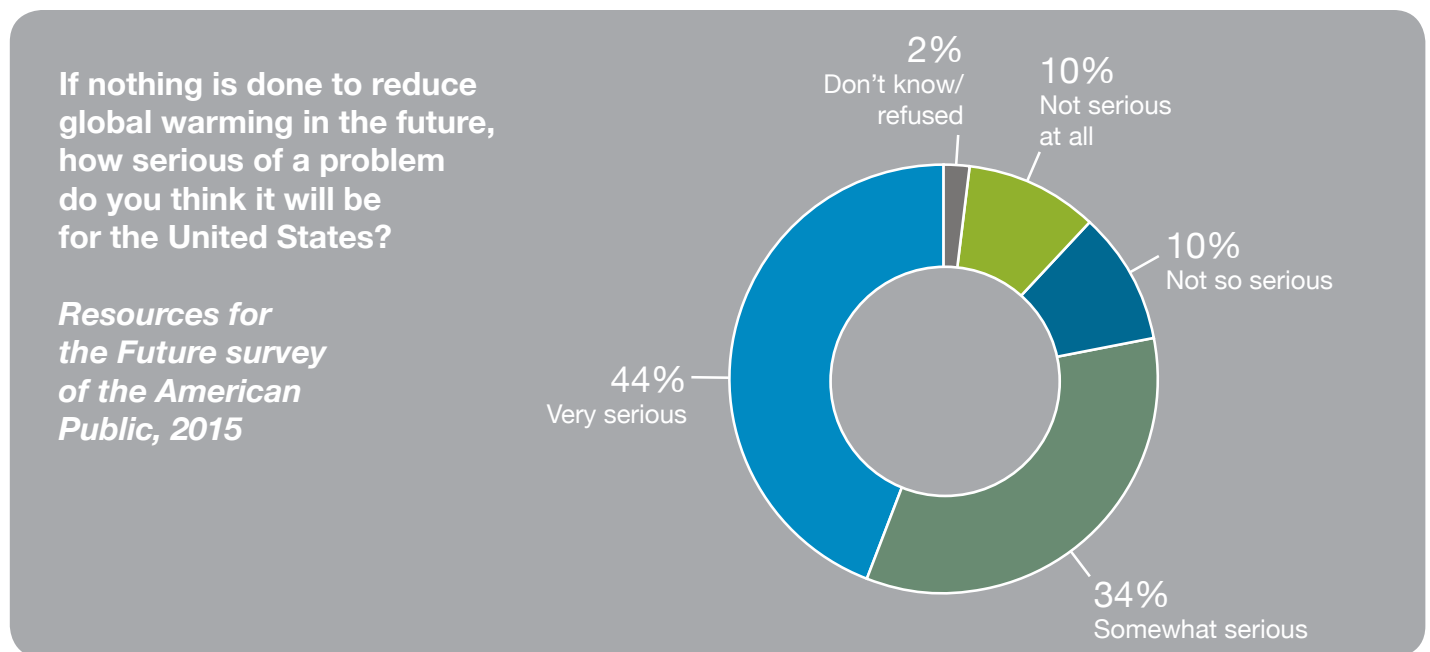


Figure 3a.

United States if nothing is done to address the issue.<sup>43</sup> We asked a nearly identical question to our sample, and 56% said the problem would be “very serious.” Another 2015 survey of the American public from researchers at Yale and George Mason University found that 52% of Americans are at least “somewhat worried” about global warming, but only 11% say they are “very worried” about it.<sup>44</sup> Again, our sample showed higher levels of concern.

The economic experts in our pool clearly believe that climate change presents major risks, and that significant action should be taken to address these risks 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 U.S. 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 agriculture will be negatively affected is somewhat surprising given the ongoing debate within the academic 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.

**Domestic economic sectors likely to be negatively affected by climate change**

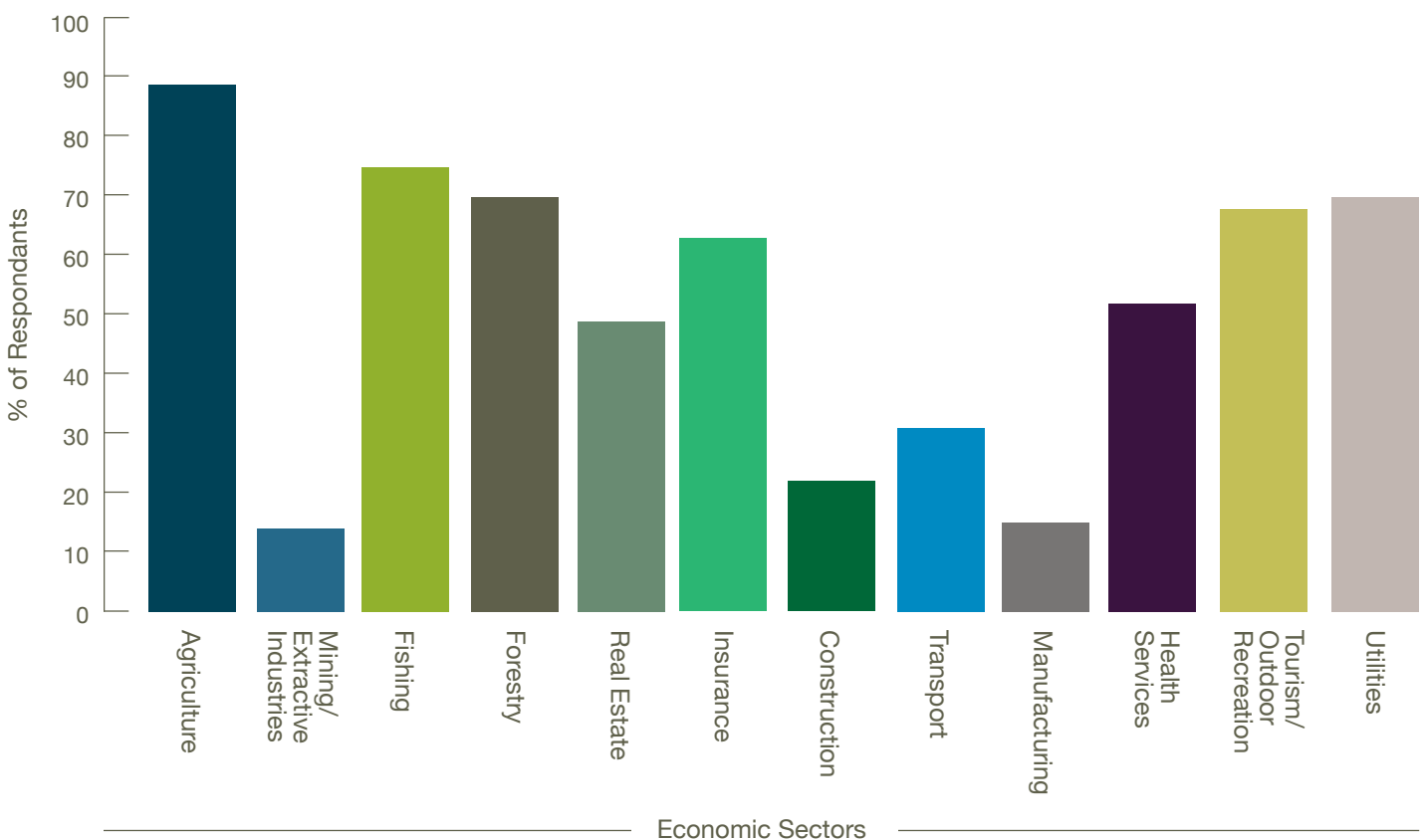


Figure 4a.



## Domestic economic sectors likely to be negatively affected by climate change

(Compared to results from 2009 Institute for Policy Integrity survey)

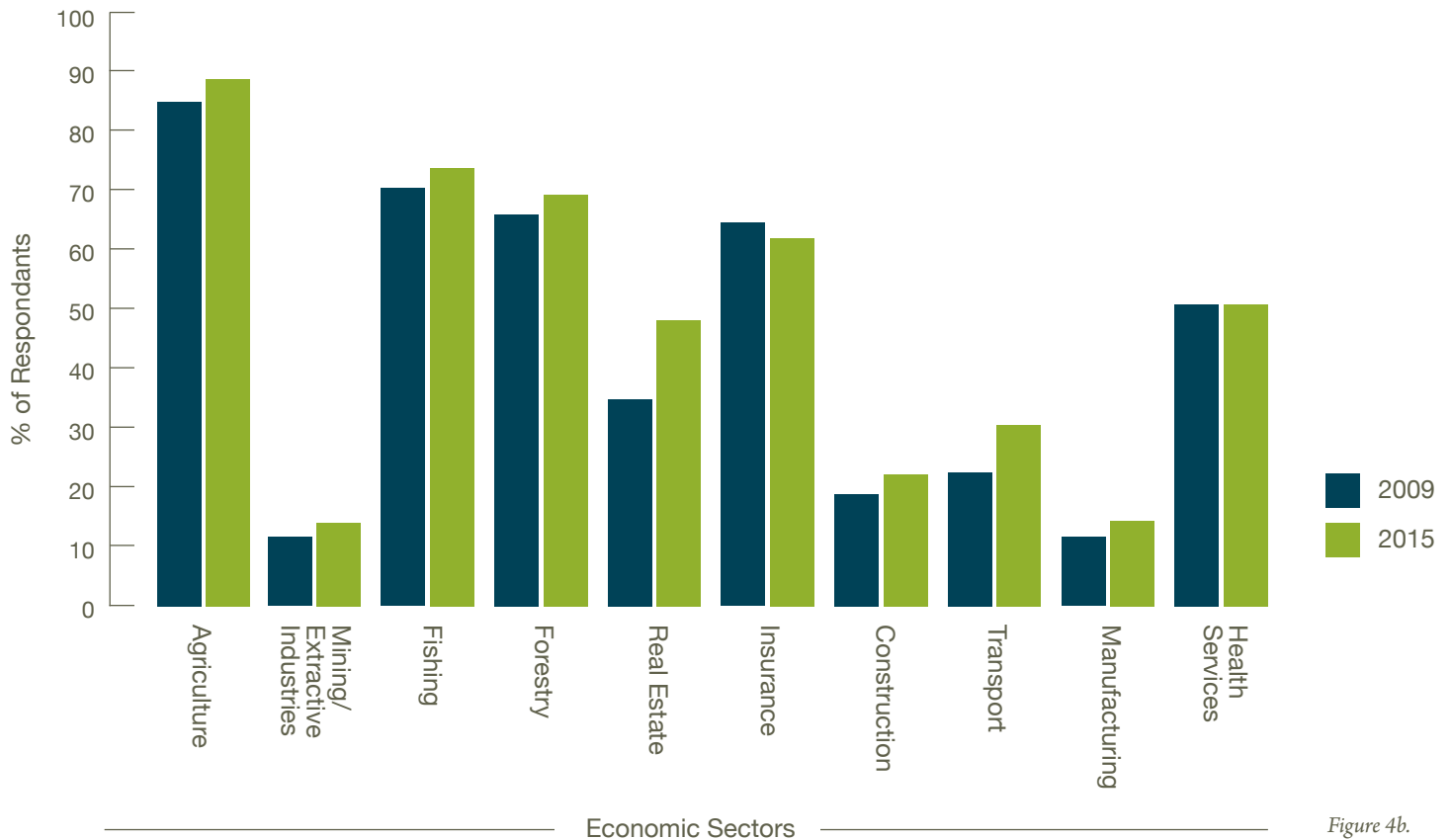


Figure 4b.

More than half of respondents also predicted negative impacts on health services (54%), and 49% selected real estate. However, most experts believed that mining (15%), construction (24%), and transportation (32%) will be more resistant to negative impacts from climate change.

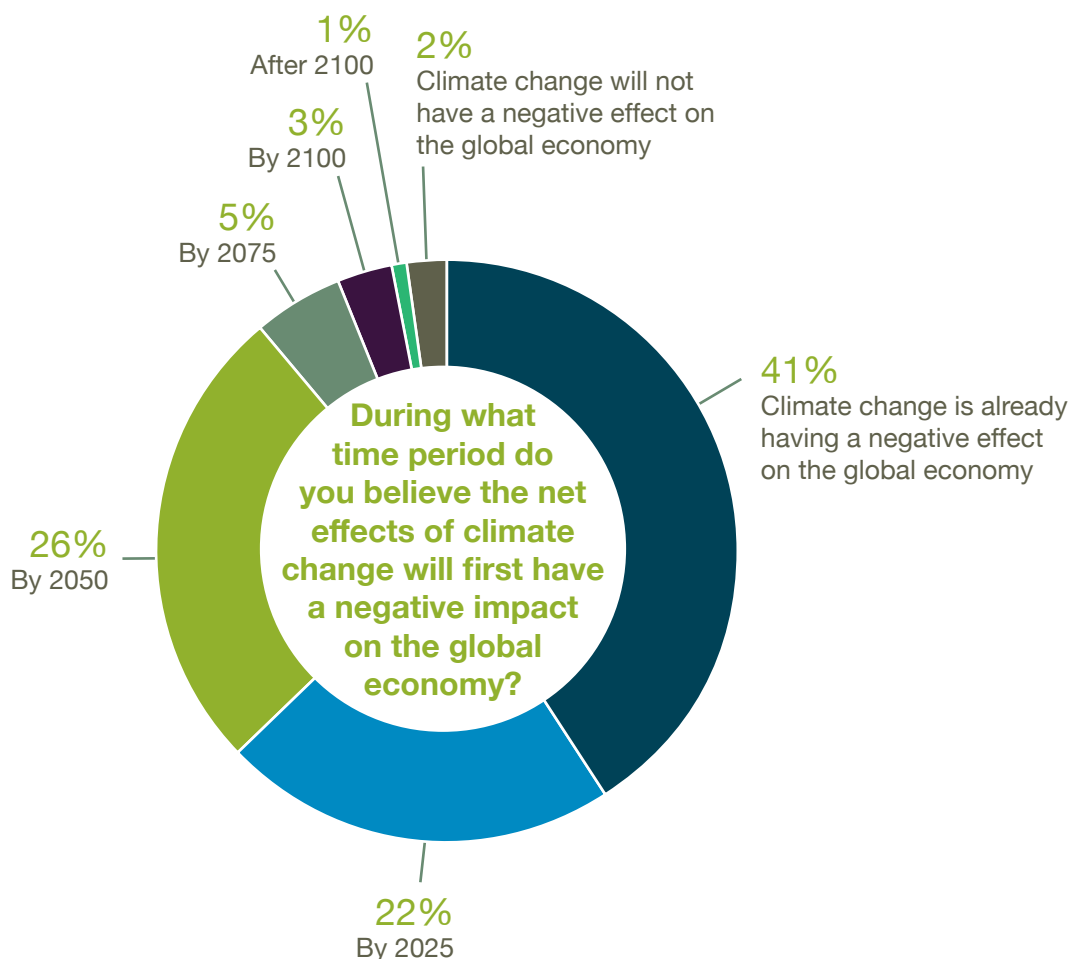
The 2009 Institute for Policy Integrity survey asked a nearly identical question to a smaller pool of similarly defined economic experts, and the findings were remarkably consistent with these results (we added three sectors to the list in our 2015 survey: Tourism/Outdoor Recreation, Utilities, and Other). 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.<sup>45</sup>

## When Will Climate Change Begin to Have a Net Negative Effect on the Global Economy?

One of our most noteworthy findings emerged from a 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,<sup>46</sup> 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.

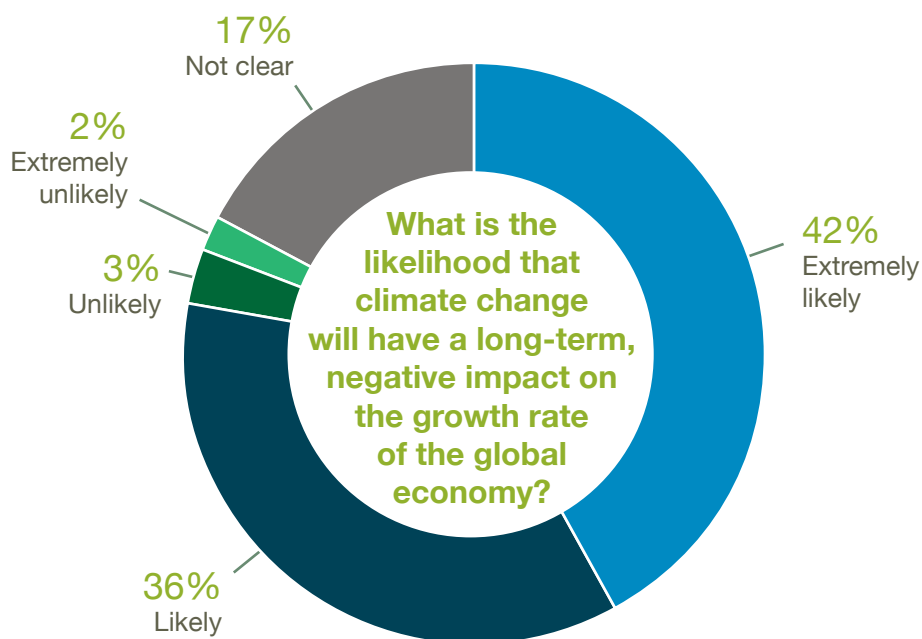


The median estimate for when the net effects of climate change will become negative was “by 2025.” This result differs greatly from the output of the FUND model, one of three main climate-economic models used to calculate the social cost of carbon. FUND predicts that the net effects of climate change will only begin to negatively affect the global economy around 2080.<sup>47</sup>

## Economic Growth Rates and Climate Change

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).

Figure 6.



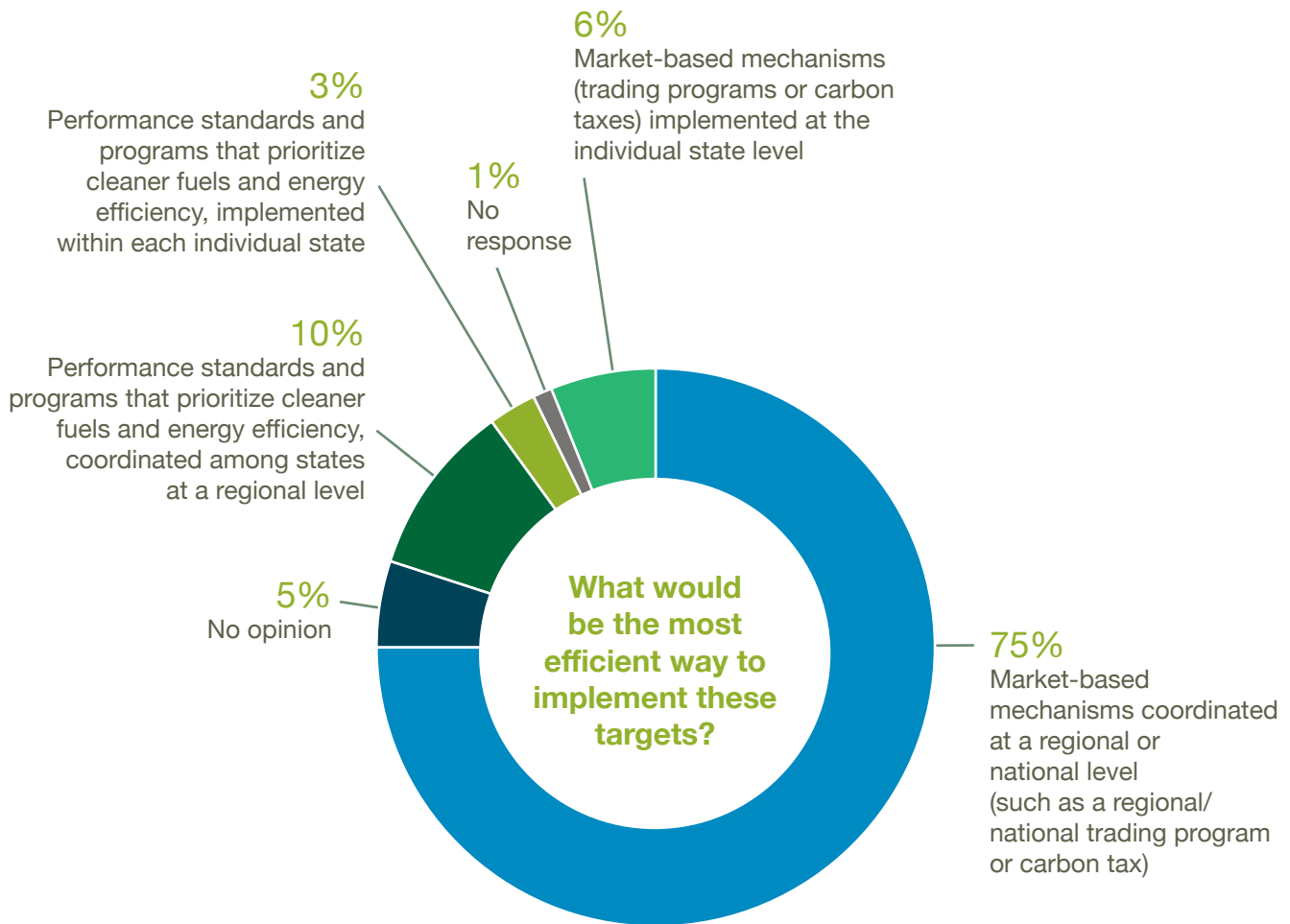
## Greenhouse Gas Control Mechanisms Under the Environmental Protection Agency’s “Clean Power Plan”

We asked our pool of experts to weigh in on a current climate policy question facing many policymakers in the United States. One question focused on the most desirable greenhouse gas control mechanisms to use for implementation of the Clean Power Plan – a new regulation from the U.S. Environmental Protection Agency that will set carbon emission reduction targets for each state’s electricity sector.

The vast majority of respondents (75%) 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).”

The experts clearly believed that interstate coordination and 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 coordination and 81% supported some form of trading.

**The U.S. Environmental Protection Agency’s “Clean Power Plan” will set carbon dioxide emission targets for each individual state’s electricity sector.**



## Reducing U.S. Emissions Could Induce Other Countries to Reduce Their Emissions

We asked our sample whether 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 first 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.

This finding could be especially 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.<sup>48</sup>

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

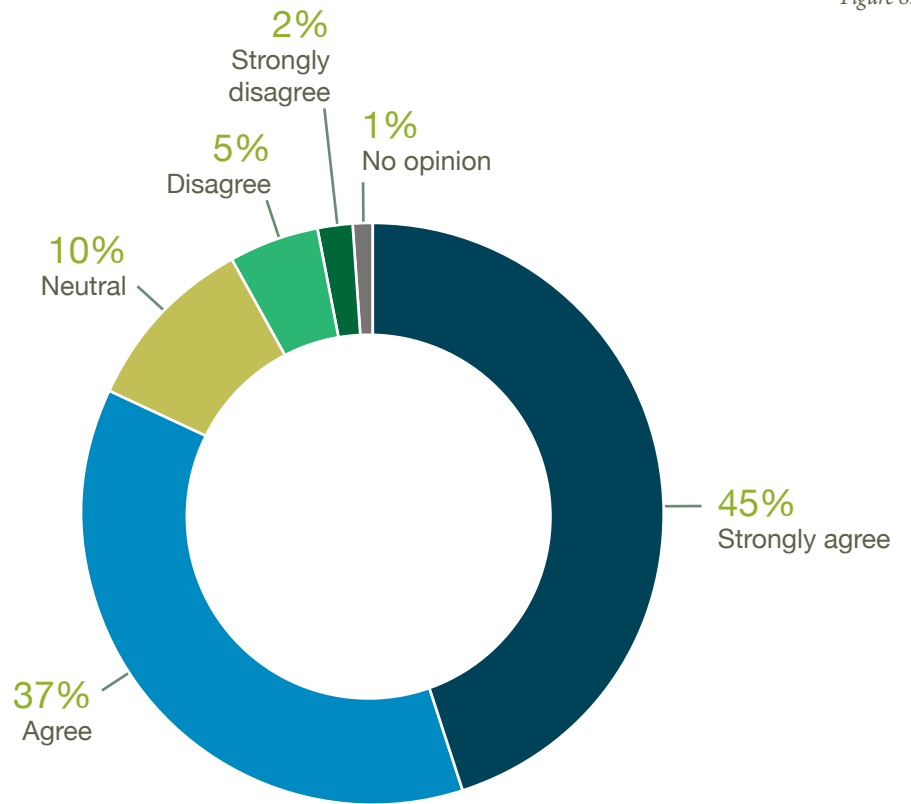
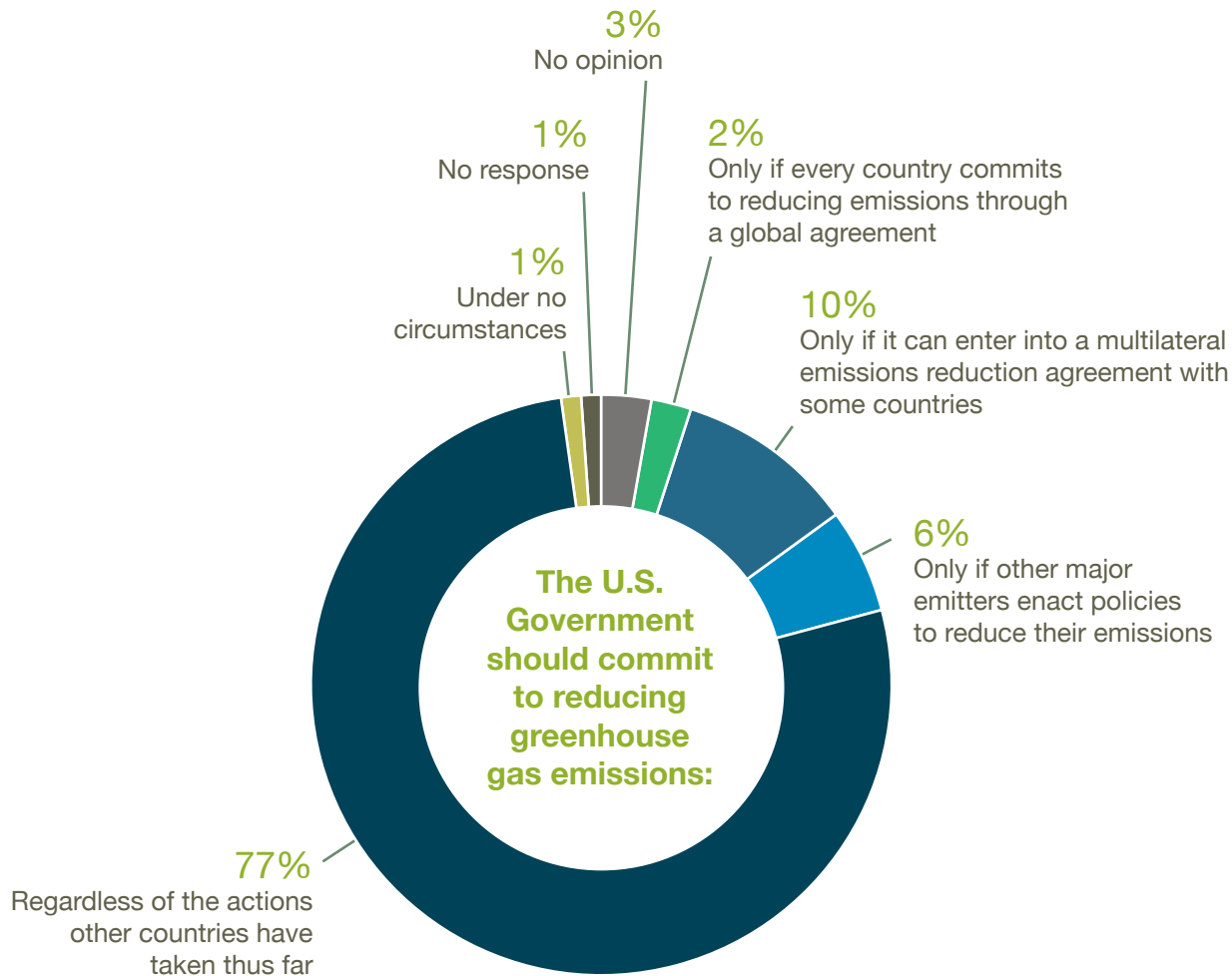


Figure 9.



## Support for Unilateral Emissions Reductions

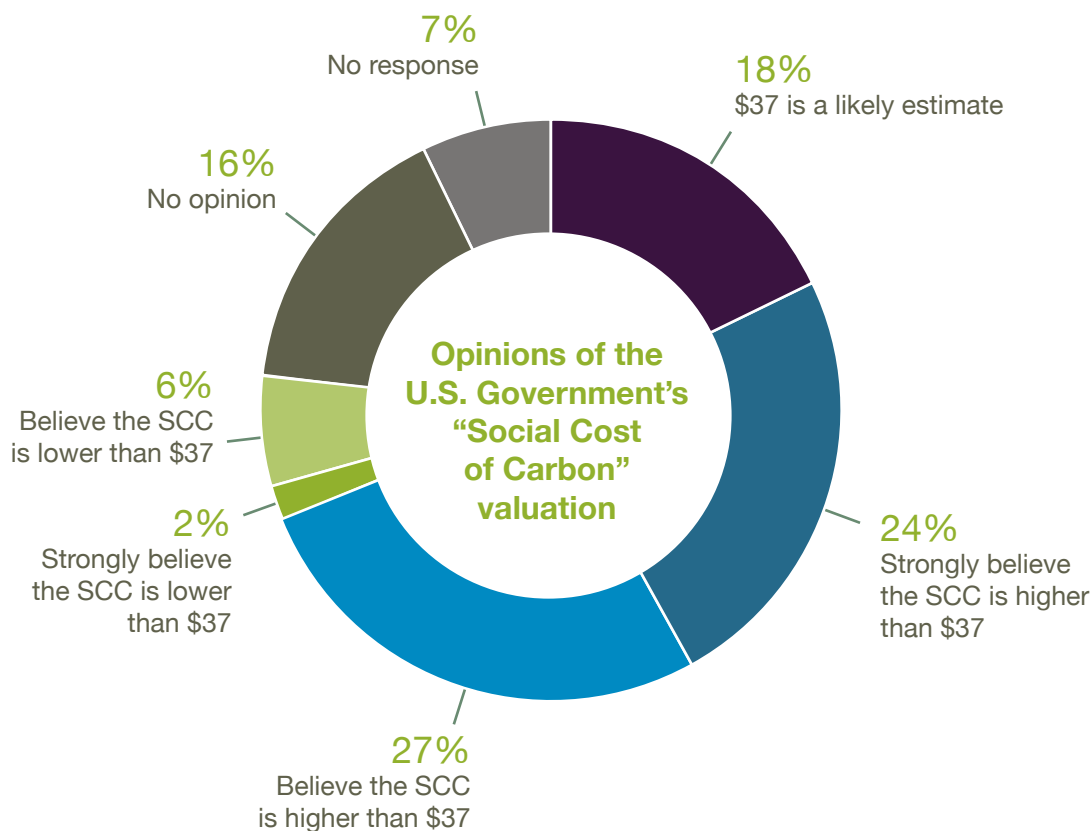
Experts in our sample overwhelmingly supported unilateral greenhouse gas reduction commitments by the United States, regardless of the actions other countries have taken. Critics of domestic climate policies often cite the potential for other countries to free-ride on U.S. reductions as a reason not to act.<sup>49</sup> But economic experts evidently believe that the benefits of unilateral reductions or the potential for these reductions to spur foreign action outweigh the risks of the free-rider problem.

## Assessing the U.S. Government's Social Cost of Carbon Valuation

Economists have long debated the appropriate value for the social cost of carbon (SCC). This metric, which quantifies the estimated economic damages caused by each marginal ton of carbon dioxide emissions, is currently used by the U.S. government to evaluate regulations that impact carbon emissions, and it can be used in numerous other policy contexts. The government derives its estimate based on the output from a set of peer-reviewed integrated assessment models, which capture the various steps in the climate and economic processes that translate a marginal unit of carbon dioxide emissions into economic damages.

Our survey question provided the following background on the topic: “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).”

Figure 10.



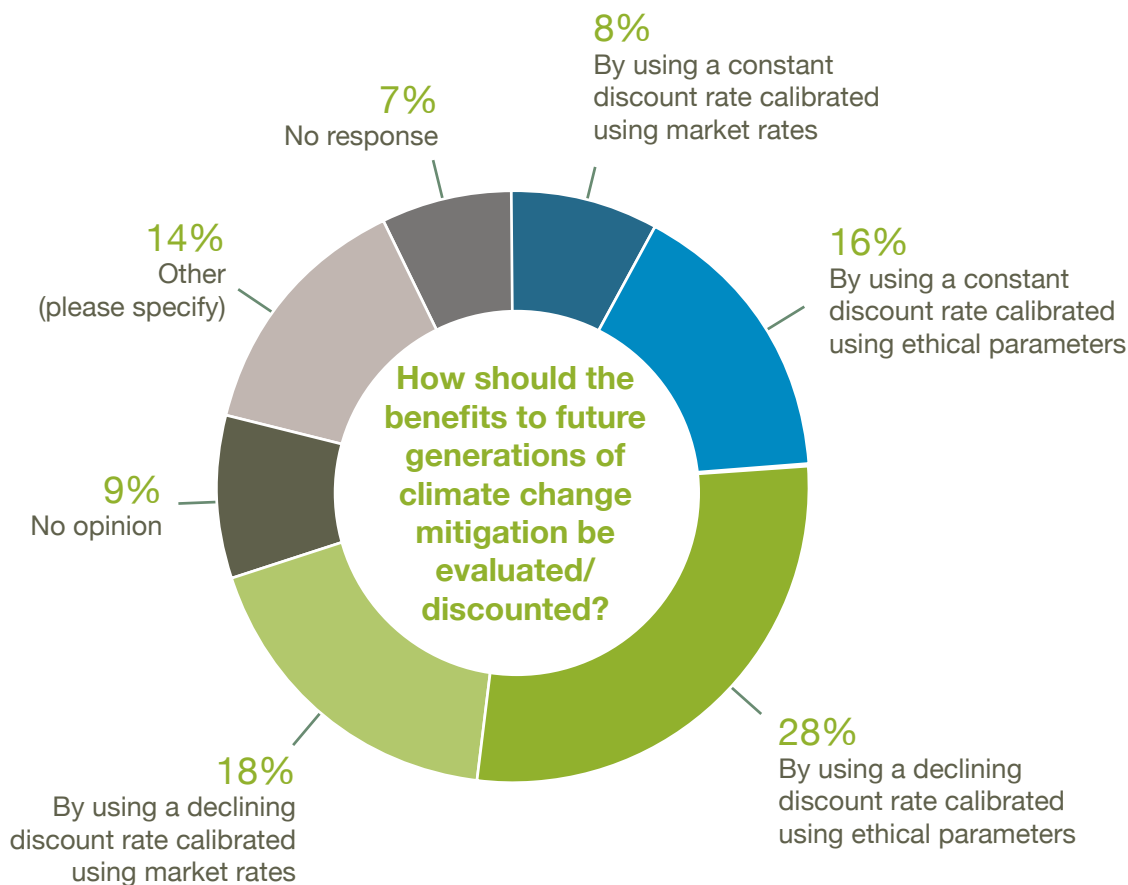
We asked respondents whether they believed that the official U.S. estimate of the SCC was appropriate, and our findings revealed a strong consensus that the SCC should be greater than or equal to the current \$37 estimate.

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 who did not answer this question, three-quarters of respondents believed that the actual SCC is equal or greater than \$37, as compared to the 9% that believe that \$37 is too high. This finding could have significant policy implications, as it suggests that the models underlying the government's SCC valuation are using overly conservative assumptions. Economic experts seem to support an SCC value that would encourage stronger climate policies.

## 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.



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, in the context of future climate costs and benefits, 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 all regulations and policies, including climate policies.

## Choosing an Appropriate (Constant) Discount Rate

Our first open-ended survey question asked respondents to provide the appropriate constant discount rate for calculating the social cost of carbon.<sup>50</sup> 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.

For those who responded to this question, the mean and median estimates were approximately 3% and 2%, respectively. This median response is lower than the lowest discount rate (2.5%) used by the U.S. government in the calculation of the official social cost of carbon. Again, this finding suggests that the federal government is undervaluing strong climate protections by discounting their benefits at a higher rate than experts recommend.

**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:**  
(Histogram with bottom 1% and top 99% trimmed)

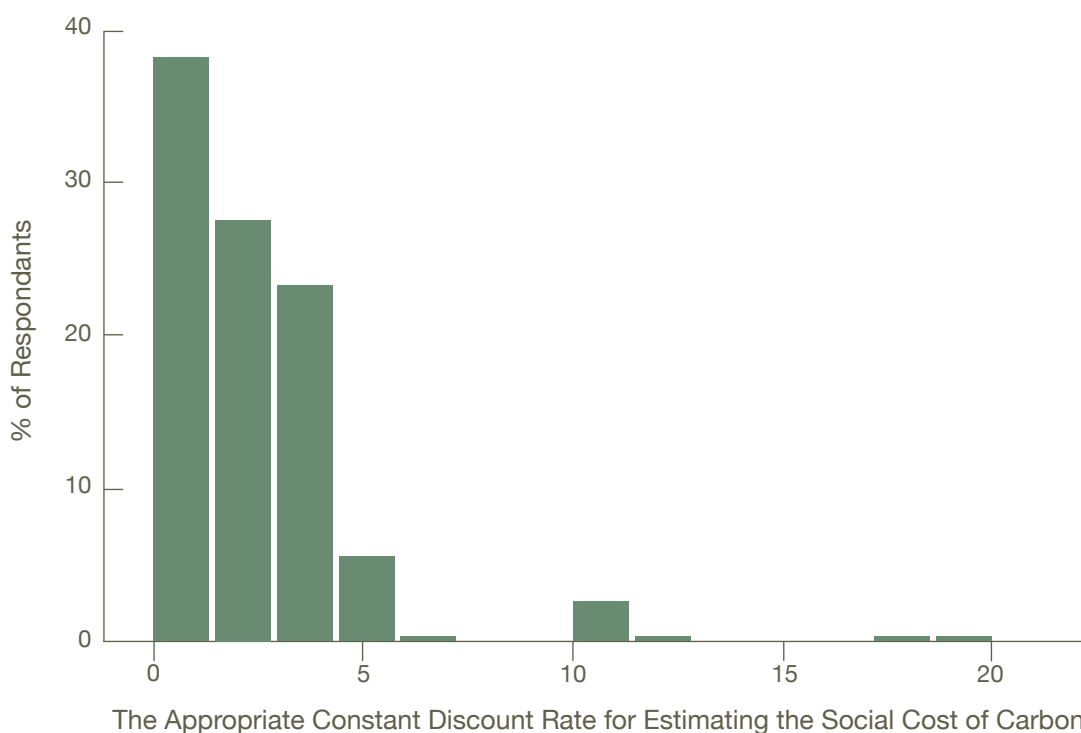


Figure 12.



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%.

Additionally, we find that responses in the 90th percentile vary from 3% to 5%. 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 – which some have advocated using in official calculations – is clearly inappropriate.

## Estimating Climate Impacts

We asked respondents to provide their best estimate of how a specific future climate scenario might affect the global economy. Respondents were asked to consider the following 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. This scenario roughly approximates a “business-as-usual” path for greenhouse gas emissions, though some business-as-usual projections estimate higher temperature increases.<sup>51</sup> We then asked for an estimate of how this temperature increase might affect global GDP, including both market and non-market goods.

On average, these experts predicted losses of between 5% and 10% of GDP, though there was considerable variation. The mean and median estimates were GDP losses of 10.2% and 5.5%, respectively, with a variance of 133%.

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

**What is your best guess (median/50th percentile estimate) of the impact on global output, as a percentage of GDP?**

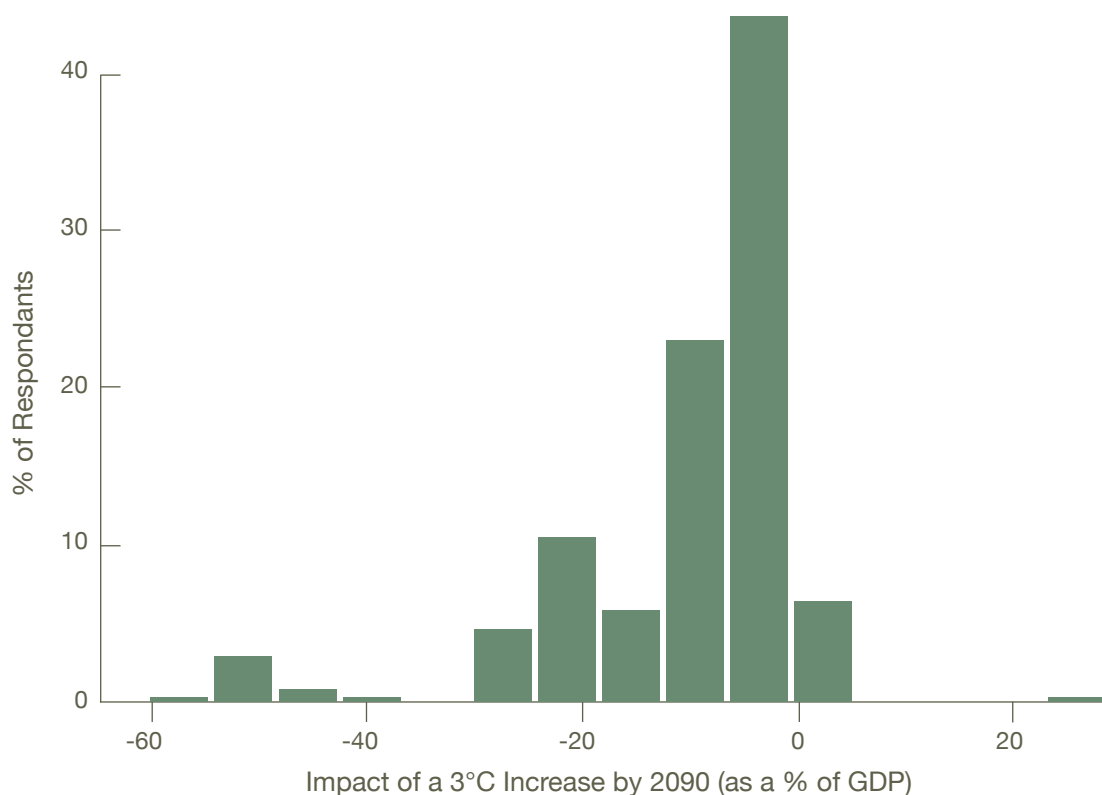


Figure 13.

These average impact estimates are slightly higher than most previous predictions. A past survey by economist William Nordhaus on non-catastrophic impacts found mean and median estimates of -3.6% and -1.9% for an identical scenario.<sup>52</sup> Another study from 1995 estimated mean and median impacts of -5.2% and -2.6% for a very similar scenario.<sup>53</sup> These previous estimates relied on the results of a small number of handpicked experts – including scientists – instead of a large sample of economists. The estimates are also higher than those from the three integrated assessment models used by the U.S. 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); FUND projects +1.42% for a 1°C increase; and PAGE09 projects 1.12% for a 3°C increase.<sup>54</sup>

The implications of this finding could be significant: the damage estimates we are currently using to help evaluate policies may be more conservative than those predicted by a large sample of expert economists.

## Probability of Catastrophic Impacts from Climate Change

Our final question asked respondents to estimate the probability of catastrophic impacts from a 3°C global temperature increase by 2090.<sup>55</sup> 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?”

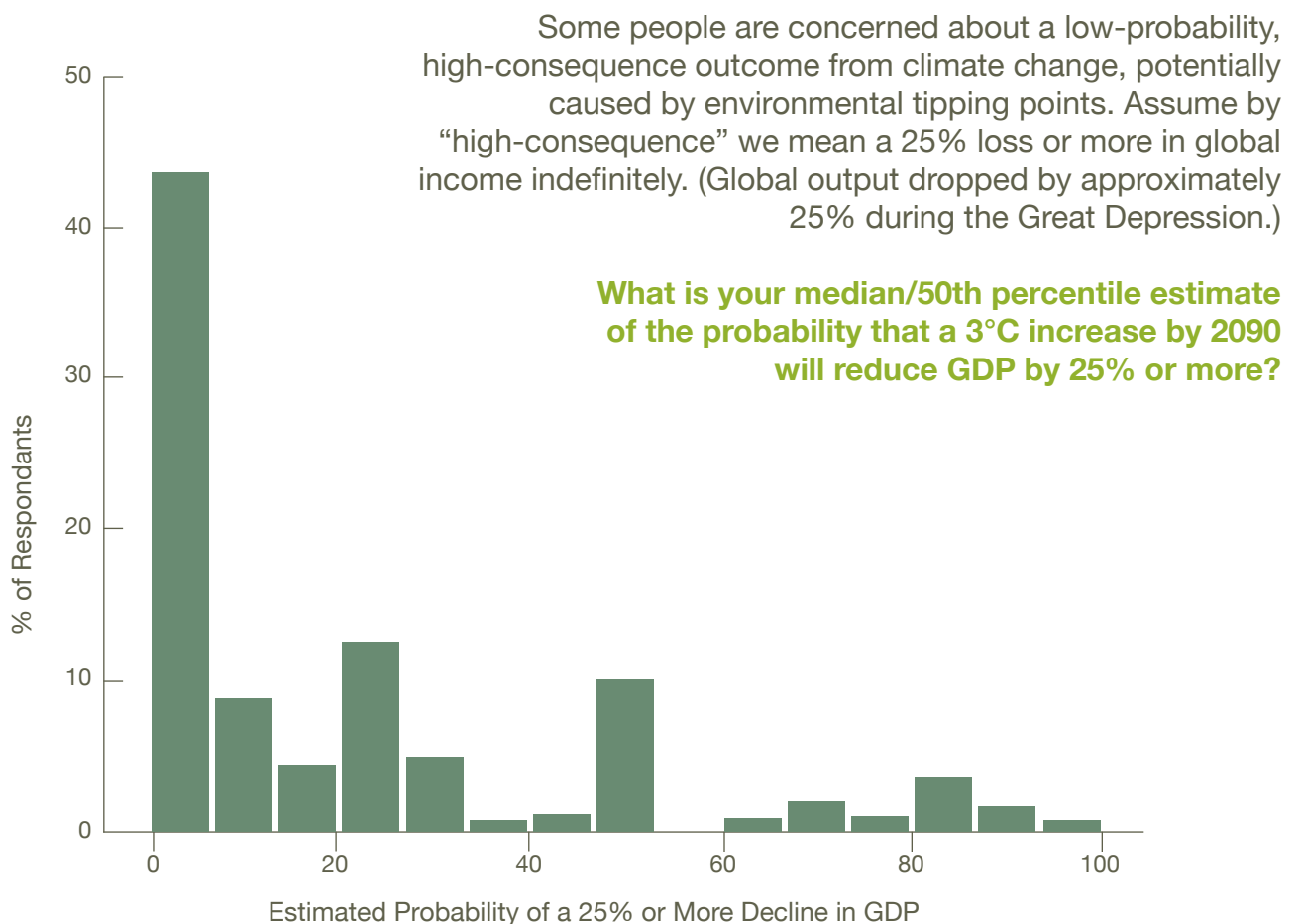


Figure 14.

On average, respondents' best estimate of the probability of a "high-consequence" outcome was between 10% and 20%.<sup>56</sup> The mean and median probabilities were 22% and 10%, respectively. Our respondents estimated a higher probability of catastrophic outcomes than the Nordhaus survey revealed for an identical warming scenario.<sup>57</sup> This finding could be especially striking for policymakers, as expert economists believe there is at least a 10-20% chance of a catastrophic economic outcome before the end of the century, based on a business-as-usual emissions path.

## Additional Analysis on Climate Damages

Using some of our survey results on climate damages, we are able to construct climate damage curves and calculate the social cost of carbon based on new assumptions provided by our respondent pool. We used the data from questions 5, 13, and 14 as inputs in the DICE-2013 model to create a variety of new damage curves and calculate the SCC. An in-depth explanation of these steps and the resulting damage curves under various assumptions is available in the working paper that expands on our analysis.<sup>58</sup>

### The Social Cost of Carbon for emissions from 2010 to 2050 in 2015 U.S. dollars, using damage functions calibrated from our survey results

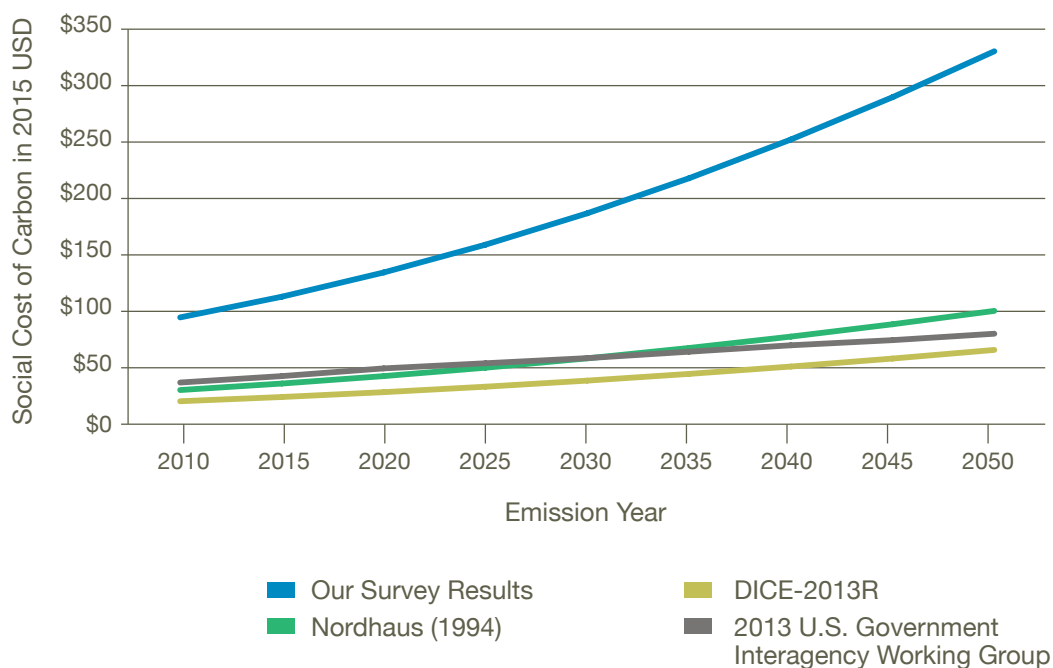


Figure 15.

The social cost of carbon estimates that result from this modeling are far greater than the estimates from the U.S. government's Interagency Working Group, the DICE-2013 model, and Nordhaus's 1994 estimate. An increase to the SCC of this magnitude could have profound implications for climate policy decisionmaking.

# Conclusions

While the scientific community has established a fairly clear consensus on the threat of climate change, few attempts have been made to assess the level of consensus among economic experts. Policymakers and journalists sometimes suggest that the economic community is hesitant to support ambitious climate policies due to their costs. 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.

The views of the 365 economic experts who participated in our survey have some potentially important policy implications. These experts expressed significant concern about the economic damages from climate change, and they believed that climate impacts will be felt across many sectors of the U.S. economy, not just in developing countries. The experts supported unilateral U.S. policies to reduce emissions, believing that such action could induce reciprocity from other countries.

Respondents felt that climate change will begin to have a net negative impact on the global economy very soon – the median estimate was “by 2025” – and they estimated substantially larger economic damages from climate change than the estimates found in landmark surveys from the 1990s.<sup>59</sup> These experts also believed that market-based approaches are the most economically efficient way to reduce emissions, and that the current U.S. values for discount rates (to analyze climate regulations) and the social cost of carbon undervalue emissions reductions.

From a methodological perspective, these results indicate that considerable work is still necessary to improve the values used for climate impact assumptions and discount rates. Climate change researchers must grapple with significant uncertainties, and these uncertainties may not be greatly reduced with future work. As such, relying on a handful of integrated assessment models – which tend to underestimate climate impacts relative to our findings – may be a problematic way to develop policy.<sup>60</sup> One potential path forward could be to solicit expert opinion on what assumptions should be used in integrated assessment models.

Economists who study climate change can offer a great deal of relevant insight in climate policy debates. This survey reveals widespread consensus among economic experts that the damages from climate change could be severe, and that aggressive policies to address these risks are economically desirable.

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# Endnotes

- <sup>1</sup> For more discussion of these issues, see the report on the Institute for Policy Integrity's 2009 survey of economists: 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>.
- <sup>2</sup> One illustrative discussion of these issues can be found in [Economist, 2011] R. A. (2011, February 9). "Are Economists Erring on Climate Change." *The Economist*. Available at: [http://www.economist.com/blogs/freeexchange/2011/02/climate\\_policy](http://www.economist.com/blogs/freeexchange/2011/02/climate_policy) See also Buchanan, M. (2015, November 3). What Economists Don't Get About Climate Change. *Bloomberg View*. Available at: <http://www.bloombergvew.com/articles/2015-11-03/what-economists-don-t-get-about-climate-change>
- <sup>3</sup> See Holladay et al., (2009).
- <sup>4</sup> The discussion in this section is partially adapted from the Institute for Policy Integrity's 2009 survey report. See Holladay et al., (2009).
- <sup>5</sup> Among other examples, the IPCC findings are discussed in the text of the EPA's Clean Power Plan. See p. 64683 of the final version of the rule, available at: <http://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22842.pdf>
- <sup>6</sup> See Holladay et al., (2009)
- <sup>7</sup> Sunstein, C. R. (2005). Group judgments: Statistical means, deliberation, and information markets. *NYU Law Review*, 80, 962. Available at: <http://www.nyulawreview.org/sites/default/files/pdf/NYULawReview-80-3-Sunstein.pdf>
- <sup>8</sup> See McKibben, B. (2007, March). Warning on Warming, *N.Y. Review Of Books*, Mar. 15, 2007, available at <http://www.nybooks.com/articles/19981> (reviewing the IPCC Fourth Assessment Report).
- <sup>9</sup> See Rahmstorf, S., Foster, G., & Cazenave, A. (2012). Comparing climate projections to observations up to 2011. *Environmental Research Letters*, 7(4), 044035 Available at: <http://iopscience.iop.org/article/10.1088/1748-9326/7/4/044035/pdf>. See also Stefan Rahmstorf et al., (2007) Recent Climate Observations Compared to Projections, 316 SCI. 709 and Scherer, G. (2012, December). How the IPCC Underestimated Climate Change. *Scientific American*. Retrieved from: <http://www.scientificamerican.com/article/how-the-ipcc-underestimated-climate-change/>
- <sup>10</sup> See Surowiecki, J. (2004). *The Wisdom Of Crowds*. Knopf. In particular, the Condorcet Jury Theorem states that the probability of a correct answer, by a majority of the group, increases toward certainty as the size of the group increases, if each individual person is more likely than not to be correct.
- <sup>11</sup> See Armstrong, J.S. (2001). Combining Forecasts, in *Principles Of Forecasting*. 416, 428-31
- <sup>12</sup> Gigone, D. and Hastie, R. (1997). Proper Analysis of the Accuracy of Group Judgments, 121 *Psych. Bulletin* 149
- <sup>13</sup> See Pindyck, R. S. (2015). The Use and Misuse of Models for Climate Policy (No. w21097). National Bureau of Economic Research. Specifically, Pindyck 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 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."
- <sup>14</sup> This is not technically a calculation of the SCC. Unlike integrated assessment models that calculate the difference between the cost of climate change in a baseline scenario and the cost of climate change under the baseline scenario with one additional unit of carbon dioxide, Pindyck's method divides total benefits from avoiding catastrophic impacts and the total (i.e., non-marginal) emissions reduction necessary to avoid this risk. As such, Pindyck's approach should be interpreted as the average benefit of avoiding catastrophic impacts of climate change.
- <sup>15</sup> Because we disaggregated our sample into various subcategories, our dataset also allows us to compare the results of questions across various definitions of expertise: those who have published multiple articles on relevant topics versus those with a single publication; those publishing in mainstream economic journals versus environmental economic journals; 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. This subgroup analysis is presented in the working paper that offers an expanded look at our results: <http://policyintegrity.org/files/publications/EconomicClimateConsensus.pdf>

<sup>16</sup> See Holladay et al., (2009)

<sup>17</sup> Nordhaus, W.D. (1994). Expert opinion on climatic change. *American Scientist*, 45-51.

<sup>18</sup> See 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; and Tol, R. S. (2014). Correction and Update: The Economic Effects of Climate Change. *The Journal of Economic Perspectives*, 221-225.

<sup>19</sup> Schauer, M. J. (1995). Estimation of the greenhouse gas externality with uncertainty. *Environmental and Resource Economics*, 5(1), 71-82. Schauer (1995)

<sup>20</sup> U.S. Government Accountability Office (2008). *Expert Opinion on the Economics of Policy Options to Address Climate Change*. Available at: <http://www.gao.gov/assets/280/275448.pdf>

<sup>21</sup> See Capstick et. al (2015). International trends in public perceptions of climate change over the past quarter century. *Wiley Interdisciplinary Reviews: Climate Change*, 6(1), 35-61.

<sup>22</sup> See Ansolabehere, S., & Konisky, D. M. (2014). *Cheap and clean: how Americans think about energy in the age of global warming*. MIT Press.

<sup>23</sup> See Resources for the Future, New York Times, Stanford University (2015). Global Warming National Poll. RFF. Available at <http://www.rff.org/Documents/RFF-NY-Times-Stanford-global-warming-poll-Jan-2015-topline-part-3.pdf> [RFF, 2015]

<sup>24</sup> An initial survey was conducted in 2008 before the biannual surveys began in 2010. See Leiserowitz et al. (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>.

<sup>25</sup> We used the response rate definition from the 2011 AAPOR's Standard Definitions (R6 on page 45). See: 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](http://www.aapor.org/AAPORKentico/AAPOR_Main/media/MainSiteFiles/StandardDefinitions2011_1.pdf)

<sup>26</sup> RFF (2015) and MIT (2008), respectively

<sup>27</sup> Even so, responses to one question 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. See note 55 for additional information.

<sup>28</sup> We chose the 1994 date for several reasons: this cutoff includes the vast majority of papers on climate change; it matched the cutoff used in the 2009 Institute for Policy Integrity survey; and it was 20 years before the beginning of this project.

<sup>29</sup> This broad definition of "climate change" is consistent with the approach used in Holladay et al., (2009).

<sup>30</sup> Our economics journal rankings came from Kalaitzidakis et al. (2003) and Kalaitzidakis et al. (2011). Our environmental economics journal rankings came from Rousseau (2008) and Rousseau et al. (2009). See 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; Rousseau, S. (2008). Journal evaluation by environmental and resource economists: A survey. *Scientometrics*, 77(2), 223-233; and Rousseau, S., Verbeke, T., & Rousseau, R. (2009). Evaluating environmental and resource economics journals: A TOP-curve approach. *Review of Environmental Economics and Policy*, rep002.

<sup>31</sup> Our environmental journal rankings together revealed five publications with the highest ratings. One journal, the *Journal of Environmental Economics and Management (JEEM)*, appeared in both the economics and environmental economics rankings.

<sup>32</sup> 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.

<sup>33</sup> We sampled a larger group of economic experts than Holladay et al. (2009) because we chose to add the top envi-

ronmental 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. The 2009 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%.

<sup>34</sup> For example, the group that received the survey included authors who proposed an economic model that predicted a potentially positive effect on global agriculture from climate change, and others who subsequently criticized that model and approach.

<sup>35</sup> The working paper is available at: <http://policyintegrity.org/files/publications/EconomicClimateConsensus.pdf>

<sup>36</sup> We launched our survey on April 30, 2015 and closed it 18 days later.

<sup>37</sup> 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%. 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%.

<sup>38</sup> Though it is unclear from the academic 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 surveys was 11% (Fan and Yan, 2010). With regards to these studies, our response rates are above or close to average.

<sup>39</sup> See link. Mention confidence intervals

<sup>40</sup> In addition to helping us understand our respondent base (given that all responses were anonymous), this question al-

lowed 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. This analysis is available in the working paper that analyzes our findings: <http://policyintegrity.org/files/publications/EconomicClimateConsensus.pdf>

<sup>41</sup> These nine respondents published papers 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.

<sup>42</sup> Ansolabehere, S., & Konisky, D. M. (2014).

<sup>43</sup> Resources for the Future, New York Times, Stanford University (2015).

<sup>44</sup> 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>

<sup>45</sup> 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. These results are available here: <http://policyintegrity.org/files/publications/EconomicClimateConsensus.pdf>

<sup>46</sup> Policymakers and journalists, including those who advocate for climate change policies, often use rhetoric and examples that focus almost exclusively on how climate change will affect future generations. Some examples can be found in Stecker, T. (2013, February) and Walsh, B. (2013, October). See Stecker, T. (2013, February). Scientists Detail Severe Future Impacts of Climate Change. *Scientific American*. Retrieved from: <http://www.scientificamerican.com/article/scientists-detail-severe-future-impacts-of-climate-change/> and Walsh, B. (2013, October). Why We Don’t Care About Saving Our Grandchildren From Climate Change. *Time*. Retrieved from: <http://science.time.com/2013/10/21/why-we-dont-care-about-saving-our-grandchildren-from-climate-change/>

<sup>47</sup> Tol, R. S. (2013b). The economic impact of climate change in the 20th and 21st centuries. *Climatic Change*, 117(4), 795-808.

- <sup>48</sup> For examples of this “free-riding” argument, see Sen. Jim Inhofe, Statement on China’s Climate Announcement, Sept. 25, 2015 (“The Obama administration will use regulatory overreach to claim our nation’s commitment, while China’s pledge has no guarantee of enforcement. This is a great deal for the Chinese who are slated to continue increasing emissions . . .”); Valerie Volcovici, “China Climate Announcements Turn Tables on Congress Foes,” *Reuters*, Sept. 25, 2015 (quoting Donald Trump, “[Climate change is] not a big problem at all. . . If you look at China, they’re doing nothing about it.”); Steve Benen, “Rubio Needs a New Excuse to Ignore the Climate Crisis,” *MSNBC.com*, Oct. 2, 2015 (explaining that Marco Rubio remains against U.S. regulation following China and India’s announcement, and that Rubio’s campaign still stands by his quote from two years ago: “There are other countries that are polluting in the atmosphere much greater than we are at this point. China and India, they’re not going to stop doing what they’re doing.”).
- <sup>49</sup> See *supra* note 48
- <sup>50</sup> 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).
- <sup>51</sup> We chose this scenario both because it approximates a business-as-usual emissions path and because it matches the main scenario from Nordhaus’ 1994 survey, allowing us to compare our data directly. As a point of reference, the newest version of FUND predicts a 3.3°C increase by 2090 and a 3°C increase by 2083. DICE-2013 predicts a 3.1°C increase by 2080 and 3.5 by 2090. The scenario we used is also similar to the A1B scenario from IPCC (2007) and assumes a bit more emissions mitigation than the A2 scenario.
- <sup>52</sup> Nordhaus, W. D. (1994).
- <sup>53</sup> Schauer (1995). This study used the following scenario: a 2.5 degree Celsius increase relative to pre-industrial temperature. Answers had a variance of 71.3%.
- <sup>54</sup> See Howard (2015) for additional details.
- <sup>55</sup> 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 avail-
- able 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.
- <sup>56</sup> The variance in responses for this question was quite high. 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.
- <sup>57</sup> Nordhaus (1994) 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.
- <sup>58</sup> The working paper is available at: <http://policyintegrity.org/files/publications/EconomicClimateConsensus.pdf>
- <sup>59</sup> The surveys from Nordhaus (1994) and Schauer (1995) still represent some of the most recent attempts to gauge economic consensus on these issues before our survey. While our respondents predicted much higher impacts than found in these surveys, the variance in our results is high, indicating a need for future research.
- <sup>60</sup> Pindyck (2015) has suggested replacing current integrated assessment models with surveys to help estimate the social cost of carbon, 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.

# Appendix A

## List of Journals Used in Survey

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

Environmental Economics Journals
<i>American Journal of Agricultural Economics</i>
<i>Ecological Economics</i>
<i>Environment and Resource Economics</i>
<i>Journal of Environmental Economic Management</i>
<i>Land Economics</i>

# Appendix B

## Survey Questions

### 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 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

## 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

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

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.

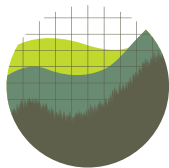
What is your best guess of the percentage of total impacts (market plus non-market) that will be borne by the market sector? Please provide the % of impacts in the market sector. (Assume a 3°C rise by 2090.) \_\_\_\_\_

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. \_\_\_\_\_





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