Climate Regulation and the Limits of Cost-Benefit Analysis

Jonathan Masur

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Climate Regulation and the Limits of Cost-Benefit Analysis

Jonathan S. Masur & Eric A. Posner*

Over the past two years U.S. regulatory agencies have issued fourteen regulations that take into account the effect of industrial activities and products on the global climate. The regulatory activity so far has already set precedents on which future regulation will rest. Yet despite the potentially momentous consequences, it has received no comment in the law review literature. This Article examines the record of these agencies and criticizes the methods they have used to calculate the social cost of carbon emissions. We also develop a larger theme about the relationship between cost-benefit analysis and politics. The best case for cost-benefit analysis is that its recommendations are politically neutral in the sense of drawing on widely shared intuitions about human well-being. But cost-benefit analysis cannot cope with inherently political questions involving contested normative issues. Policymakers will have to find alternative tools when those questions predominate.

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INTRODUCTION

There is a broad consensus that global warming threatens the well-being of people around the world, and that national governments should take steps to curb warming and alleviate the harm that climate change causes.1 After dragging its heels, the United States has joined most other countries in recognizing that action against climate change is needed.2 Nonetheless, the United States has not ratified any international climate change treaty. Congress has considered, but not passed, greenhouse gas regulation.3 And the Environmental Protection Agency (EPA) has not yet proposed broad carbon dioxide regulation,4 despite having been authorized to do so by the Supreme Court.5 To all appearances, the federal government is at a point of stasis—deliberating, but not acting, on the issue of climate change.

Yet this appearance of stasis is misleading: in fact, the American regulatory state has lurched into gear. Over the past two years, several federal

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3. See Perry Bacon, Jr., Lack of Votes for Senate Democrats’ Energy Bill May Mean the End, WASH. POST, July 23, 2010, http://www.washingtonpost.com/wp-dyn/content/article/2010/07/22/AR2010072203614.html (“Conceding that they can’t find enough votes for the legislation, Senate Democrats on Thursday abandoned efforts to put together a comprehensive energy bill that would seek to curb greenhouse gas emissions . . . .”).
4. The EPA has taken the more limited step of requiring that major carbon dioxide emitters obtain permits. See Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 Fed. Reg. 31,514 (June 3, 2010) (to be codified at 40 C.F.R. pts. 51, 52, 70, 71). We discuss this regulation below. See infra note 83 and accompanying text.
5. Massachusetts v. EPA, 549 U.S. 497, 532 (2007) (“Because greenhouse gases fit well within the Clean Air Act’s capacious definition of ‘air pollutant,’ we hold that EPA has the statutory authority to regulate the emission of such gases from new motor vehicles.”).
agencies, most notably the Departments of Energy and Transportation, have issued fourteen regulations that take into account the effect of industrial activities and products on the global climate. The regulatory activity so far involves relatively small-scale projects, for example, energy standards for appliances like air conditioners and gas ranges. But these early efforts by agencies to engage in climate regulation reveal the numerous challenges they face, and how they will likely meet these challenges when they turn to larger-scale regulation involving power plants, motor vehicle regulation, and manufacturing. Although these efforts are setting precedents on which future regulation will rest, commentators have yet to acknowledge their existence or analyze their potentially far-reaching consequences.

The story begins in 2008, when the Ninth Circuit struck down the Department of Transportation’s (DOT) Corporate Average Fuel Economy (CAFE) standard for light trucks because the cost-benefit analysis the DOT used to determine the standard failed to take account of the standard’s beneficial effects for climate change. The petitioners, which included a number of environmental groups, had tried to persuade the court that the DOT should not have used cost-benefit analysis, which they believed was impermissible under the statute. The court rejected this argument but agreed with the petitioners that if the DOT uses cost-benefit analysis, then it cannot arbitrarily include some benefits—reduction in automobile noise and congestion, for example—while excluding the benefits of reducing greenhouse gas emissions. In response to this ruling, the DOT monetized the climate benefits.

So it was cost-benefit analysis that initiated climate regulation at the federal level. Environmentalists have frequently argued that cost-benefit analysis is a political tool that government agencies use to avoid regulation. They have harshly criticized Executive Order 12,866, a Clinton-era executive order that requires regulatory agencies to issue cost-benefit analyses for major regulations. Yet this order supplied the DOT with the authority to engage in cost-benefit analysis of CAFE standards, which in turn led to judicial repudiation because the DOT’s cost-benefit analysis ignored climatic effects. In

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7. Id. at 1201.
10. The Clinton order renewed an earlier order issued by President Reagan, which may explain the association between cost-benefit analysis and conservative, antiregulatory sentiment. See MATTHEW ADLER & ERIC A. POSNER, NEW FOUNDATIONS OF COST-BENEFIT ANALYSIS 1–5 (2006).
this instance, the argument that cost-benefit analysis promotes needed regulation may have been vindicated.\textsuperscript{11}

Or has it? A close reading of the cost-benefit analyses performed by agencies in connection with climate regulation reveals much to worry about. There is a wide gap between the theory of cost-benefit analysis and agencies' performance.

In theory, the relevant monetary valuations for cost-benefit analysis of climate regulation would come from climate science and economics. The science establishes the approximate effects of carbon emissions on the climate. The economics converts these effects into monetary valuations based on their impact on people's consumption patterns. Thus, one can establish that an additional metric ton of carbon emissions will cause long-term disruptions to climate patterns that will interfere with agriculture, raise sea levels, and so forth, which will either directly injure people (for example, through an increase in the price of food) or require expensive remedial measures (such as the construction of sea walls). Agencies should use this figure—known as the social cost of carbon (SCC)—in cost-benefit analyses of regulations.

However, the science does not produce fine-grained predictions with a high level of confidence. It is possible to predict that the median global temperature will rise, but not that temperatures or rainfall will be disrupted in a crucial agricultural region. Yet the latter information is necessary for an adequate cost-benefit analysis. The economics poses even greater difficulties. The three major economic models on which agencies rely are extraordinarily crude. The cost of climate change will be high, but it is not clear how high, and one cannot conduct cost-benefit analysis of a regulation without knowing what its economic effect will be.

The regulatory agencies recognize these problems and so far have performed curious evasive maneuvers. They calculate a range of costs rather than a point estimate, then they observe that their calculations depend on assumptions that are little more than guesses, and then they announce that specifying a precise figure is irrelevant because the regulation passes a cost-benefit test given any of the possible social costs of carbon. Agencies often refer to this as a "sensitivity test"—determining whether the regulation is sensitive to the price placed on alleviating carbon emissions. For example, in a 2008 regulation of air conditioners and heat pumps, the Department of Energy (DOE) estimated that the social cost of carbon fell somewhere between $0 and $20 per ton,\textsuperscript{12} and then declined to use any SCC figure in its cost-benefit


analysis on the grounds that the "economic value of emissions reduction is not priced in the marketplace." In a 2009 regulation of fuel economy standards, the DOT calculated separately a $2 domestic SCC and a $33 global SCC, and then used these figures in a sensitivity test but not in the cost-benefit analysis. Meanwhile, in 2008 the EPA estimated SCCs of $68 per ton (using a 2 percent discount rate) and $40 per ton (using a 3 percent discount rate) in an advance notice of proposed rulemaking under the Clean Air Act, but did not say which figure should be used.

In response to this confusion, the Office of Management and Budget convened an Interagency Working Group (IWG). The resulting document contains a highly sophisticated and carefully written survey of the academic work, emphasizing that many uncertainties remain in the science and economics. It proposes a range of SCCs reflecting different assumptions about the appropriate discount rate and the year in which the regulation is issued. For 2010, the SCC was $4.70 at a discount rate of 5 percent, $21.40 at a discount rate of 3 percent, and $35.10 at a discount rate of 2.5 percent. The IWG does not instruct agencies which discount rate to use. Since the IWG figures were issued, agencies have stopped making their own calculations and have instead relied on the IWG figures. But they have generally ignored the SCC when performing the cost-benefit analysis used to justify their regulations and instead employed it only in sensitivity tests.

This reluctance to employ the SCC in cost-benefit analysis extends to contexts beyond direct agency regulation. For instance, in June 2010, three months after the publication of the IWG report, the EPA performed an analysis of the American Power Act, a cap-and-trade climate bill. After extensively analyzing the potential costs of the legislation, the EPA announced that it would not even attempt to estimate the economic benefits of greenhouse gas...
reductions. This was despite the fact that the EPA had just finished a project designed to produce exactly such an estimate.

This Article examines the record of the agencies and the reasoning in the IWG report. In Part I, we show how agencies purported to conduct cost-benefit analyses, but structured their analyses so as to avoid relying on any given SCC value. In Part II, we turn to the IWG report to explore specific technical problems for arriving at a value for the SCC, and the political questions inherent in selecting a SCC for use in domestic regulation.

We write on a blank slate. Legal scholars have analyzed the prospects for an international agreement on climate change; the possible forms of federal climate legislation; the future of the EPA regulation under the Clean Air Act; and the possibility that greenhouse gases might be regulated by states and localities, or through litigation. But the national regulatory efforts already underway have escaped their notice.

20. Id. at 19.
23. See, e.g., Jason Scott Johnston, Climate Change Confusion and the Supreme Court: The Misguided Regulation of Greenhouse Gas Emissions Under the Clean Air Act, 84 Notre Dame L. Rev. 1 (2008) (arguing that the EPA should not have been permitted to regulate climate change under the Clean Air Act); Abigail R. Moncrieff, Reincarnating the “Major Questions” Exception to Chevron Deference as a Doctrine of Noninterference (Or Why Massachusetts v. EPA Got It Wrong), 60 Admin. L. Rev. 593 (2008) (arguing that the Supreme Court should have refused to interfere with the EPA’s decision not to consider regulating carbon dioxide); J.B. Ruhl & James Salzman, Climate Change, Dead Zones, and Massive Problems in the Administrative State: A Guide For Whittling Away, 98 Calif. L. Rev. 59 (2010) (noting the legal problems involved with agency regulation of massive issues such as climate change).
While much of our Article is devoted to examining the shortcomings in both the analyses performed by the agencies and the IWG report, in Part III we also develop a larger argument about the relationship between cost-benefit analysis and politics. Although we support cost-benefit analysis for routine agency action, we believe that some of the criticisms of cost-benefit analysis have plausibility in the context of climate change. Climate change poses two problems for cost-benefit analysis. First, there is tremendous uncertainty about which human beings will be harmed, and where, and how much, and what weight those harms should have in the cost-benefit calculation. In the absence of this information, agencies cannot conduct proper cost-benefit analyses. Second, climate change is an international problem, while U.S. regulatory practice, including its use of cost-benefit analysis, is oriented to activities with domestic effect. International relations pose inescapable political questions, which cost-benefit analysis cannot resolve.

These shortcomings demonstrate the limits of cost-benefit analysis as a policy tool. The best case for cost-benefit analysis is that its recommendations are politically neutral in the sense of drawing on widely shared intuitions about human well-being. Cost-benefit analysis cannot cope with inherently political questions involving contested normative issues. In some cases, such as abortion, affirmative action, and religious accommodation, the source of conflict is so clear that no one seriously argues that regulatory agencies should solve them using cost-benefit analysis. In other cases, the source of conflict is more subtle. Instead of looking to cost-benefit analysis to resolve political questions, in certain cases, policymakers must instead make political judgments. Climate regulation falls between these two extremes. It is clear that the costs and benefits of climate regulation are of great importance, and that economic analysis will have to play a role in climate regulation. But we argue that the formulaic approach to weighing costs and benefits that is embodied in the standard methods used by regulatory agencies is not appropriate for this problem.


26. For a defense of this claim, see ADLER & POSNER, supra note 10.
I. CARBON PRICING IN EXISTING REGULATIONS

In the past two years, fourteen federal regulations have addressed the benefits of reduced carbon dioxide emissions. Some of these regulations predate the IWG report and draw upon other calculations of the social cost of carbon; others obtain their carbon prices directly from the IWG report. Agencies that depend on pricing carbon run squarely into the problem that there is no single price: the IWG, for instance, offers four different prices. The agencies attempt to skirt the problem by claiming that their regulatory choices do not depend upon the precise cost of carbon selected and that they would have chosen the identical regulation under any of the possible carbon prices.

In the Sections that follow, we survey three representative regulations: two promulgated before the IWG report and one that employs the IWG's carbon prices. These Sections have two purposes. First, we provide a detailed picture of how federal agencies have already taken up the task of regulating carbon. Second, we demonstrate that for all of these regulations, the choice of a carbon price is in fact significant. Agencies cannot simply pretend that their regulatory decisions are invariant to the SCC; they must actually select a cost of carbon if they are to regulate intelligently.

A. Model Year 2011 CAFE Standards

One of the earliest federal regulations to incorporate a social cost of carbon was the Department of Transportation’s new set of Corporate Average Fuel Economy standards for Model Year 2011, issued on March 30, 2009. CAFE standards are minimum requirements for the average fuel economy of a carmaker’s entire fleet, adjusted by the number of each automobile sold.

According to the DOT, the majority of the benefits from stricter CAFE standards stem from savings in the production and distribution of gasoline: if drivers use less fuel, less money need be spent on producing and distributing that fuel. Nonetheless, one of the most obvious additional benefits of requiring that automakers produce fuel-efficient automobiles is the reduction in greenhouse gas emissions. After the Ninth Circuit overturned the DOT’s CAFE standards for model years 2008–2011 for failing to monetize the benefit of reduced carbon emissions, the DOT went back to the drawing board. The DOT solicited public comments and then settled on a range of three prices for the SCC derived from a 2008 article by Richard Tol, who, as we will see, is one

27. We cite them throughout this Part, infra.
29. Id. at 14,413 tbl.IX-3. According to the DOT, these savings comprise approximately three-quarters of the total benefit of fuel economy regulation. See id.
of the economists whose work the IWG incorporates. Tol’s 2008 article is a survey of over two hundred separate estimates of the social cost of carbon published through 2006, over half of which are peer reviewed. The DOT selected as its middle value the mean price from Tol’s survey: $33 per ton of carbon dioxide. The DOT’s “high” estimate is one standard deviation above the mean from Tol’s study: $80 per ton of CO₂. Like the IWG report, these prices include all global benefits, foreign and domestic.

For its “low” estimate, the DOT selected its best estimate of the purely domestic benefits of reducing carbon emissions. It calculated this price by adjusting Tol’s $33 estimate downward based on the “U.S. share of world economic output (which ranges from 20–28 percent) and published estimates of the relative sensitivity of the U.S. economy to climate damages compared to the world economy as a whole.” The DOT calculated that the United States would suffer between 0 and 14 percent of the global costs of climate change, chose the midpoint of that range (7 percent), and calculated the domestic cost of carbon as 7 percent of $33, or approximately $2. That left the DOT with three values—$2, $33, and $80—that are roughly similar to the carbon prices subsequently calculated by the IWG.

These initial carbon prices were denoted in 2007 dollars. The DOT decided to increase the prices by 2.4 percent in each subsequent year “because the increased pace and degree of climate change—and thus the resulting economic damages—caused by additional emissions are both expected to rise in proportion to the existing concentration of CO₂ in the earth’s atmosphere.” Crucially, however, these 2.4 percent increases were not pegged to constant dollars. In other words, if the value of one ton of carbon dioxide were $1.00 in 2007 (in 2007 dollars), it would be $1.024 in 2008 (in 2008 dollars). In order to determine the value of that 2008 ton of carbon dioxide in constant (2007) dollars, it would be necessary to discount the $1.024 price back to 2007 dollars.


32. Tol, supra note 31. It is worth noting, however, that approximately half of these estimates derive from work by Tol himself (independently and with co-authors). See id. at 11–16 (listing the sources for his meta-study).


34. Id. It is worth noting that one standard deviation from the mean is approximately the eighty-fifth percentile of the distribution. Accordingly, this $80 per ton price represents only an eighty-fifth percentile estimate, not an upper bound.

35. Id.


37. 2011 CAFE Standards, supra note 14, at 14,349.

38. See infra Part II.

The DOT elected to apply a 3 percent discount rate to the social costs of carbon. This meant that in constant dollars, the social costs of carbon would decrease over time. This approach contrasts with the IWG report, which has carbon prices that increase steadily over time (in constant dollars), a point to which we return below.

The DOT then ran a set of models meant to estimate the costs and benefits of different CAFE standards and selected what it believed to be the “optimized” rule—the one that would generate the greatest net benefits. The DOT reported the results of its cost-benefit analysis for this optimized rule, along with rules 25 percent below (that is, lower mandatory fuel efficiency) and 25 percent and 50 percent above (higher mandatory fuel efficiency) the optimal. The DOT also reported cost-benefit numbers for two other potential standards: 1) the standard that would generate costs approximately equal to benefits; and 2) the standard at the point of “technical exhaustion”—the greatest fuel efficiency possible given current technology. The results of the DOT’s cost-benefit analysis are reproduced in Table 1 below.

### Table 1: Benefits and Costs of Possible CAFE Standards
(Versus Baseline of No Action) Over Lifetime of Model Year 2011

<table>
<thead>
<tr>
<th>Automobiles (millions of 2007 dollars)</th>
<th>25% Below Optimized</th>
<th>25% Above Optimized</th>
<th>50% Above Optimized</th>
<th>Total Costs = Total Benefits</th>
<th>Technology Exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Benefits</td>
<td>1,707</td>
<td>1,948</td>
<td>2,321</td>
<td>2,763</td>
<td>3,676</td>
</tr>
<tr>
<td>Total Costs</td>
<td>940</td>
<td>1,145</td>
<td>1,918</td>
<td>2,545</td>
<td>4,009</td>
</tr>
<tr>
<td>Net Benefits</td>
<td>767</td>
<td>802</td>
<td>403</td>
<td>218</td>
<td>-334</td>
</tr>
</tbody>
</table>

As part of this cost-benefit analysis, the DOT estimated that its optimized regulation would eliminate 8.33 million tons of CO\textsubscript{2} emissions over the lifetime of the model year 2011 automobiles. It priced these emissions at $2 per ton, for a total benefit of approximately $16 million.

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40. Id. at 14,350, 14,355.
41. For instance, the IWG’s median carbon prices (discounted at 3 percent) grow at an approximate yearly rate of 2.1 percent, in constant dollars, between 2010 and 2020. See IWG REPORT, supra note 17, at 40.
42. 2011 CAFE Standards, supra note 14, at 14,386 tbls.VII-4 to VII-6.
43. As is obvious from the numbers, costs are not quite equivalent to benefits under this regulatory option.
44. See 2011 CAFE Standards, supra note 14, at 14,412–13 (summing the car and truck...
The agency tested this "optimized" rule to determine whether it was sensitive to the choice of carbon price, and concluded that "the optimized CAFE standards for [model year (MY)] 2011 cars and light trucks were unaffected by the choice among those values for reducing CO₂ emissions from fuel production and use." In other words, the DOT claimed that it would have selected the same "optimized" rule irrespective of the price it placed on carbon. Yet it is difficult to know whether this assertion can be believed.

In order to determine whether the DOT's choice of regulatory standard was in fact sensitive to the price it placed on carbon, it is necessary to know how much each of the regulatory options would have reduced emissions by model year 2011 cars. To the best of our knowledge, the DOT did not report these figures for the lifetime of model year 2011 automobiles. However, it did report expected reductions in CO₂ emissions from 2010 to 2100, assuming that its regulatory standards remained in force during that time. Assuming that emissions reductions from 2010 to 2100 are proportional to emissions reductions for model year 2011 automobiles, we can calculate expected reductions for model year 2011 vehicles under each regulatory scenario. Those results and calculations are listed in Table 2 below.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No Action</td>
<td>210,279</td>
<td>0</td>
<td>0*</td>
</tr>
<tr>
<td>25% Below Optimized</td>
<td>209,076</td>
<td>1,203</td>
<td>7.44*</td>
</tr>
<tr>
<td>Optimized</td>
<td>208,932</td>
<td>1,347</td>
<td>8.33*</td>
</tr>
<tr>
<td>25% Above Optimized</td>
<td>208,743</td>
<td>1,536</td>
<td>9.50*</td>
</tr>
<tr>
<td>50% Above Optimized</td>
<td>208,440</td>
<td>1,839</td>
<td>11.37*</td>
</tr>
<tr>
<td>Total Costs = Total Benefits</td>
<td>208,015</td>
<td>2,265</td>
<td>14.01*</td>
</tr>
<tr>
<td>Technology Exhaustion</td>
<td>204,228</td>
<td>6,052</td>
<td>37.43*</td>
</tr>
</tbody>
</table>

Table 2: CO₂ Emissions by Passenger Cars and Light Trucks with Alternative CAFE Standards for Model Year 2011 (million tons CO₂)

values).

45. Id. at 14,351.
46. See id. at 14,390 tbl.VII-11. Values labeled with "*" were calculated, not reported from the DOT regulation.
Consider the results of this analysis if the social cost of carbon is priced at the IWG’s 3 percent discount value ($21.40 per ton in 2010). Let us suppose that the lifetime emissions for model year 2011 automobiles are evenly distributed across the years 2010–2021. If that is the case, the costs and benefits are as follows:

Table 3: Benefits and Costs of Possible CAFE Standards (Versus Baseline of No Action) Over Lifetime of Model Year 2011 Automobiles (millions of 2007 dollars) at IWG 3 Percent Discount Carbon Prices

<table>
<thead>
<tr>
<th></th>
<th>25% Below Optimized</th>
<th>25% Above Optimized</th>
<th>50% Above Optimized</th>
<th>Total Costs = Total Benefits</th>
<th>Technology Exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Benefits</td>
<td>1,868</td>
<td>2,128</td>
<td>2,526</td>
<td>3,008</td>
<td>3,978</td>
</tr>
<tr>
<td>Total Costs</td>
<td>940</td>
<td>1,145</td>
<td>1,918</td>
<td>2,545</td>
<td>4,009</td>
</tr>
<tr>
<td>Net Benefits</td>
<td>948</td>
<td>983</td>
<td>606</td>
<td>463</td>
<td>-31</td>
</tr>
</tbody>
</table>

The higher price for carbon does not alter the benefits so radically as to make regulations “25% Above Optimized” or “25% Below Optimized” preferable. But the gap in net benefits between these regulatory choices has narrowed. Moreover, the “Optimized” CAFE standard is meant to be the regulation that provides the greatest net benefits. With a different price on carbon, that optimal point may well shift upward—perhaps not all the way to 25 percent above the current point, but at least somewhat above the DOT’s chosen standard.

In addition, these costs and benefits reflect model year 2011 cars only. If the regulations remained in place and costs and benefits were computed for the next ten, twenty, or fifty years, the regulations would generate even greater reductions in carbon emissions. If those reductions were valued in accordance with the IWG report, the “optimal” CAFE standards would be more stringent (that is, require greater fuel efficiency) than the DOT’s calculations reveal. This is due in large part to the fact that under the IWG report the discounted social costs of carbon increase over time, while the DOT proceeded on the assumption that the discounted social costs will diminish with time.48 Thus, if

47. As is obvious from the numbers, costs are not quite equivalent to benefits under this regulatory option.
48. See IWG REPORT, supra note 17, at 40. In addition, the lower the discount rate, the faster the rate of increase in the price of carbon. Thus, the lower the SCC discount rate, the greater the gap over time between benefits calculated according to the IWG report and benefits calculated by the DOT.
the DOT’s claim that its choice of CAFE standards was invariant to the price of carbon is correct, it is likely correct only under a particular set of parameters specified by the DOT itself. As the price of carbon and the regulatory time frame increase, stricter CAFE standards appear more attractive.

**B. Energy Conservation Standards for Fluorescent and Incandescent Lamps**

On July 14, 2009, the Department of Energy promulgated a regulation setting energy efficiency standards for General Service Fluorescent Lamps (GSFL) and Incandescent Reflector Lamps (IRL). More efficient fluorescent and incandescent lamps reduce electricity consumption, and thus simultaneously decrease greenhouse gas emissions. In fact, according to the DOE’s analysis, the reduction in carbon emissions is one of the primary sources of benefits from mandating more efficient lamps.

However, because this regulation was completed before the publication of the IWG report, the DOE was also forced to rely upon other sources when pricing the benefits of lower emissions. It chose to employ the DOT’s prices from its CAFE standards: $2, $33, and $80 per ton. The DOE also decided to increase these values by 3 percent per year “to represent the expected increases, over time, of the benefits associated with reducing CO2 and other greenhouse gas emissions.” As with the CAFE standards, however, these 3 percent increases were not pegged to constant dollars. The DOE applied two discount rates to the benefits and costs of its regulation: 3 percent and 7 percent. Thus, at 3 percent, the social costs of carbon are constant (in constant dollars) over time; at 7 percent they decrease fairly rapidly. This is again in contrast to the IWG, which concluded that the social cost of carbon will increase steadily over time.

For each of these two types of lamps, the DOE considered five different potential levels of energy efficiency, numbered in order of increasing

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50. The principal cost of such regulation is the greater expense required to produce more efficient lamps, a cost that will most likely be passed along to consumers. See id. at 34,083–84 (predicting higher consumer prices).

51. See id. Reducing consumption of electricity also produces other environmental benefits, such as reducing emissions of sulfur dioxide, mercury, and nitrous oxide. Id. We focus here on carbon dioxide, as it is responsible for the lion’s share of the benefits and is most subject to uncertainty in pricing.

52. See id. at 34,163; supra Section II.A.


54. Id. at 34,162 (“DOE converted the estimated yearly reductions in CO2 emissions into monetary values that represented the present value, in that year, of future benefits resulting from that reduction in emissions, which were then discounted from that year to the present using both 3-percent and 7-percent discount rates.”).

55. Id. at 34,164.
stringency. That is, the higher the number, the greater the energy efficiency that would be required. The DOE calculated the benefits of reduced carbon emissions for the two lamps at each of these five potential levels of efficiency, and at the 3 percent and 7 percent discount rates. The DOE’s estimates of reduced CO₂ emissions are presented as ranges. In the interests of simplicity we focus here only on IRL, though the analysis is the same for both types of lamps. The DOE’s results are displayed below.

Table 4: Estimates of Value of CO₂ Emissions Reductions for IRL by Level of Regulation at 7 Percent and 3 Percent Discount Rates

<table>
<thead>
<tr>
<th>Regulation Level</th>
<th>Estimated cumulative CO₂ emission reductions from 2012 to 2042 (MMt)</th>
<th>Value of estimated CO₂ emission reductions (billion 2008$) at 7% discount rate</th>
<th>Value of estimated CO₂ emission reductions (billion 2008$) at 3% discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO₂ value of $2/ton</td>
<td>CO₂ value of $33/ton</td>
<td>CO₂ value of $80/ton</td>
</tr>
<tr>
<td>1</td>
<td>7 to 20</td>
<td>0.0 to 0.0</td>
<td>0.1 to 0.3</td>
</tr>
<tr>
<td>2</td>
<td>19 to 49</td>
<td>0.0 to 0.1</td>
<td>0.4 to 0.8</td>
</tr>
<tr>
<td>3</td>
<td>38 to 85</td>
<td>0.0 to 0.1</td>
<td>0.7 to 1.5</td>
</tr>
<tr>
<td>4</td>
<td>44 to 106</td>
<td>0.0 to 0.1</td>
<td>0.8 to 1.8</td>
</tr>
<tr>
<td>5</td>
<td>53 to 118</td>
<td>0.1 to 0.1</td>
<td>1.0 to 2.0</td>
</tr>
</tbody>
</table>

The DOE then calculated the annual benefits (net of costs) at each level of regulation. It offered “primary,” “low,” and “high” estimates of these benefits. The “primary” estimate is the DOE’s best guess, given an intermediate price of carbon (approximately $33 per ton) and median estimates of the reduction in emissions. The “low” and “high” estimates are based on lower and higher estimates of both price and emissions. The DOE reported net benefits at discount rates of 3 percent and 7 percent. The results are displayed below, with the level of regulation that would provide the highest net benefit (for each emissions estimate and discount rate) in bold.

56. Id. at 34,164 tbl.VII.28.
These tables make clear that the optimal level of regulation depends upon the price of carbon and estimated emissions reductions. Consider Table 5, which reports the net benefits of IRL regulation. At low estimates of emissions and price, Level 3 regulation provides the greatest net benefits. Indeed, the advantages over Levels 4 and 5 are quite pronounced. But at primary or high estimates, Level 5 regulation is optimal and provides substantially greater net benefits than Levels 3 or 4. In addition, it is hard to know where the crossover point lies. There are obviously carbon prices and emissions estimates above the “low” estimates at which Level 3 is optimal, and there are also prices and emissions estimates below the “primary” estimates at which Level 5 is superior. Indeed, there may be some combination of price and emissions between the low and primary estimates at which Level 4 regulation provides the greatest net benefits.

In the end, the DOE opted to regulate IRL (and GSFL) at Level 4, despite the cost-benefit advantages of requiring greater energy efficiency. The agency concluded that Level 5 regulation was “economically unjustified,” contrary to the results of its own cost-benefit analysis, because it would place excessive burdens on producers and some consumers who would be forced to pay higher prices for more efficient lamps. In some sense, then, the choice of a price for carbon was irrelevant to the final regulatory decision. But if the agency had followed its own cost-benefit analysis, the particular price put on carbon emissions would have been important—and perhaps decisive.

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57. See id. at 34,170–71 tbl.VII.34.
58. Id. at 34,169–73.
59. See id. at 34,172. We have our doubts about the normative soundness of this conclusion. See Jonathan S. Masur & Eric A. Posner, Against Feasibility Analysis, 77 U. CHI. L. REV. 657 (2010).
C. Energy Conservation Standards for Small Electric Motors

The first regulation to employ the IWG's SCC was the Department of Energy's Energy Conservation Standards for Small Electric Motors, promulgated on March 9, 2010. The IWG report was first published as an appendix to this rule, and to our knowledge it has not been published again since. As the title indicates, this regulation mandates energy efficiency guidelines for two types of small electric motors: "polyphase" small electric motors and "capacitor-start" small electric motors. For each of these two types of motors, the DOE considered eight different potential levels of energy efficiency, numbered in order of increasing stringency. The regulatory levels for capacitor-start motors are numbered 1 through 8; the levels for polyphase motors are numbered 1 through 7, with an additional level "4b" that represents an adjusted set of regulations that the agency believed would more closely approach optimal levels. The DOE then examined the effect of each potential regulation on carbon dioxide emissions from 2015, when the regulation will take effect, until 2045. It estimated the likely reductions in CO₂ emissions that would result from increased efficiency (and thus diminished need for electrical power generation), and then priced the benefits of these reduced emissions using the four different carbon prices reported by the IWG. Again, in the interests of simplicity, we focus here only on polyphase motors, though our analysis of capacitor-start motors is essentially the same. The DOE's results are as follows:

61. See id. at 10,911 (referencing "Appendix A of the Annex to Chapter 15 of the Technical Support Document").
62. Id. at 10,932. For our purposes, the differences between these two types of motors are irrelevant. We mention them both only to explain that the agency's analysis proceeded in two parts.
63. Again, the higher the number, the greater the energy efficiency that would be required.

<table>
<thead>
<tr>
<th>Regulation Level</th>
<th>Estimated cumulative CO₂ emission reductions, Mt</th>
<th>Global value of CO₂ emission reductions, million$ 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5% discount rate</td>
</tr>
<tr>
<td>1</td>
<td>2.3</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>4.6</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>8.3</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>9.3</td>
<td>32</td>
</tr>
<tr>
<td>4b</td>
<td>15.4</td>
<td>52</td>
</tr>
<tr>
<td>5</td>
<td>18.3</td>
<td>62</td>
</tr>
<tr>
<td>6</td>
<td>19.5</td>
<td>66</td>
</tr>
<tr>
<td>7</td>
<td>21.2</td>
<td>72</td>
</tr>
</tbody>
</table>

As an initial matter, it is difficult to determine whether the DOE has in fact priced its own carbon reductions correctly. Take, for instance, the very first row of Table 6 (Level 1 regulation). The DOE estimated that this level of regulation would reduce CO₂ emissions by 2.3 million tons from 2015 to 2045. According to the IWG report, the price of one ton of CO₂ in 2015 is $5.70 at a 5 percent discount rate. That price only rises over the next thirty years, reaching $14.20 in 2045. In addition, the IWG prices are in 2007 dollars, while the dollar values reported in the DOE regulation are in 2009 dollars, which are less valuable. Thus, the global value of CO₂ emission reductions at Level 1 should be at minimum $13 million, and actually much more. Yet the regulation values these CO₂ reductions at only $8 million. This problem exists for each of these calculations, and we cannot explain these discrepancies.

The DOE then calculated the benefits of regulation (net of costs) for the two types of motors, at eight possible levels of regulation, across the four standard prices for carbon dioxide from the IWG report. The results are

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65. Id. at 10,931–32 tbl.VL31.
66. IWG REPORT, supra note 17, at 40.
67. Id.
68. See Energy Conservation Program: Energy Conservation Standards for Small Electric Motors, 75 Fed. Reg. at 10,931–32 tbl.VL31. 2.3 million tons of CO₂ at $5.70 comes to $13.11 million. However, the overall figure must be higher because 1) the regulation reports values in 2009 dollars while the IWG report lists carbon dioxide prices in 2007 dollars; and 2) the social costs of carbon are greater than $5.70 in every year subsequent to 2015.
displayed in Table 7 (polyphase motors). The level of regulation that will provide the highest net benefit at each price of carbon is in bold.

Table 7: Total Net Benefits at Various Social Costs of Carbon for Polyphase Small Electric Motors (2015–2045) 69

<table>
<thead>
<tr>
<th>Regulation Level</th>
<th>Consumer NPV (in billion$ 2009) at 3% discount rate with:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO₂ value of $4.7/metric ton CO₂</td>
</tr>
<tr>
<td>1</td>
<td>0.27</td>
</tr>
<tr>
<td>2</td>
<td>0.57</td>
</tr>
<tr>
<td>3</td>
<td>1.04</td>
</tr>
<tr>
<td>4</td>
<td>1.08</td>
</tr>
<tr>
<td>4b</td>
<td>1.49</td>
</tr>
<tr>
<td>5</td>
<td>0.83</td>
</tr>
<tr>
<td>6</td>
<td>0.13</td>
</tr>
<tr>
<td>7</td>
<td>(12.57)</td>
</tr>
</tbody>
</table>

As the reader can observe, the level of regulation that provides the greatest net benefits is not affected by the choice of carbon price. For polyphase motors, Level 4b delivers the greatest net benefits irrespective of the price of carbon dioxide. It is on the basis of this finding that the DOE concluded that the choice of regulatory level was invariant to the choice of carbon price. 70

Yet it is clear that this conclusion is an artifact of the particular potential levels of regulation the DOE chose to analyze. If the DOE had not included Level 4b in the analysis, its choice of regulation would depend on the price it attached to CO₂ emissions. Per Table 7, if CO₂ emissions are priced at $4.70 or $21.40 per ton, Level 4 provides the greatest net benefits. If emissions are priced at $35.10 per ton, Levels 4 and 5 provide equivalent benefits. And if emissions are priced at $64.90 per ton, Level 5, a more energy-efficient standard, provides the greatest benefits. The DOE evades a decision between Levels 4 and 5 by settling on an intermediate option—Level 4b—that is superior to both. But this raises the implication that there may be other intermediate possibilities—imagine Level "4a" or "4c"—that are superior to Level 4b at some prices of carbon and inferior at others.

Once again, it is the agency’s decision to consider only particular discrete regulatory options, rather than an entire continuum of possibilities, that allows

69. Id. at 10,935–36 tbl.VI.41.
70. See id.; see also id. at 10,939–40 (summarizing the DOE’s conclusions).
it to conclude that it should impose the same regulation regardless of the price of carbon. The agency chooses its options—for example, Level 4b, but not Levels “4a” or “4c”—such that one level of regulation is superior to all others at each of the four carbon prices. But that is quite different than saying that the optimal level of regulation is unrelated to the price of carbon. In fact, the agency was most likely compelled to investigate Level 4b precisely because the choice between Level 4 and Level 5 depended entirely on the social cost of carbon. Accordingly, the Department of Energy, like the Department of Transportation, will not be able to avoid choosing a price for CO₂ emissions when making regulatory decisions.

D. Further Agency Regulation Involving the SCC

We have discussed three of the fourteen regulations that report an SCC. Of the remaining regulations, seven involved the Department of Energy: air conditioners and heat pumps; commercial refrigerators and freezers; residential gas ranges and ovens; commercial heating, air conditioning, and water-heating equipment; refrigerated bottled or canned beverage vending machines; residential water heaters, direct heating equipment, and pool heaters; and commercial clothes washers. Two of the remaining regulations involved the Department of Transportation: applications for funding under the American Recovery and Reinvestment Act and for funding for national infrastructure. One involved the EPA: fuels and fuel additives. And one involved both the DOT and the EPA: vehicle emissions. The DOT and the EPA have since


74. Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel
proposed a fifteenth regulation, also concerning vehicle emissions.\textsuperscript{75} Unlike most prior regulations, these last two DOT/EPA actions specifically mention greenhouse gas regulation as among their primary goals.\textsuperscript{76}

All of the regulatory impact statements accompanying these regulations resemble the three discussed above. They typically report a range of SCCs, with the statements for the most recent regulations using the IWG’s figures. And they all exclude the SCCs from the actual cost-benefit analysis, instead merely reporting them or using them in a sensitivity analysis.

Meanwhile, the EPA has begun deliberating about climate regulation under the Clean Air Act. In \textit{Massachusetts v. EPA},\textsuperscript{77} the Supreme Court held that if anthropogenic carbon dioxide is leading to global warming and causing harm to humans, it is an “air pollutant” under the Clean Air Act and the EPA must regulate it.\textsuperscript{78} On December 7, 2009, the EPA announced its conclusion that greenhouse gases threaten public health.\textsuperscript{79} This finding authorizes the EPA to regulate CO\textsubscript{2} emissions in a variety of ways, including requiring CO\textsubscript{2} emitters to install the “best available” technology to mitigate emissions.\textsuperscript{80} Such regulation would impose significant costs on the U.S. economy, but it might also produce substantial benefits by dramatically reducing carbon dioxide emissions and mitigating the negative effects of global warming. Its effects would overshadow the comparably trivial regulations that we have discussed so far.

The EPA is at a very early stage in the process of regulating carbon dioxide under the Clean Air Act—it has not published proposed regulatory text or officially solicited comments from private parties.\textsuperscript{81} In fact, the Obama administration has indicated that the EPA’s finding is principally intended to compel Congress to pass greenhouse gas legislation.\textsuperscript{82} The EPA has taken the

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76. Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, 75 Fed. Reg. at 74,152 (“Reducing fuel consumption . . . directly reduces the motor vehicle tailpipe emissions of carbon dioxide (CO\textsubscript{2}), which is the principal greenhouse gas emitted by motor vehicles.”); Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 75 Fed. Reg. at 25,324 (“This joint Final Rule is consistent with the National Fuel Efficiency Policy announced by President Obama on May 19, 2009, responding to the country’s critical need to address global climate change and to reduce oil consumption.”).


78. Id. at 533.


80. \textit{See infra} note 83 and accompanying text.


82. \textit{See} Sindya N. Bhanoo, \textit{The E.P.A. Announces a New Rule on Polluters}, \textit{N.Y. TIMES}, May
more limited step of requiring that major CO₂ emitters—those that produce more than 100,000 tons of carbon dioxide per year—obtain permits and install the best available technology before initiating new sources of pollution. However, in the cost-benefit analysis that accompanied that regulation, the EPA refused to quantify the benefits of reduced carbon emissions, deeming them too uncertain. It did not so much as mention the SCC. If Congress does not act and the EPA eventually promulgates much broader CO₂ regulation, it will be essential that the agency conduct a full cost-benefit analysis in order to ascertain whether such regulation is justified. An essential component of that cost-benefit analysis, perhaps the preeminent part, will be a calculation of the benefits of reduced carbon emissions.

II. PROBLEMS WITH CALCULATING A SOCIAL COST OF CARBON

In this Part, we turn our attention to the Interagency Working Group’s report on the Social Cost of Carbon, the definitive federal administrative statement on the subject. We demonstrate that it suffers from a variety of problems that render its conclusions unconvincing. At a fundamental level, the IWG’s errors are its failure to recognize the political nature of certain issues, treating them instead as technical matters, and its failure to recognize the technical nature of other issues, seeking political solutions where none were available.

A. The IWG Report

We begin with a discussion of the IWG’s method for pricing carbon. The IWG’s estimate of the social costs of carbon is based on predictions derived from three separate computer models of climate change and economic harm. These models, all developed by academics and widely used in estimating future climate harms, are known as DICE (Dynamic model of Integrated Climate and the Economy), PAGE (Policy Analysis of the Greenhouse Effect),


83. Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 Fed. Reg. 31,514 (June 3, 2010) (to be codified at 40 C.F.R. pts. 51, 52, 70, 71). We describe this regulation as more limited both because it regulates only a small subset of carbon emitters and because the impact of requiring that even a large emitter install the “best available” technology will likely be “relatively small.” Id. at 31,600. This is “due to the lack of available capture and control technologies” for carbon dioxide. Id. The D.C. Circuit rejected a motion to stay this regulation, Coal. for Responsible Regulation, Inc. v. E.P.A., No. 09-1322 et al., 2010 WL 5509187 (D.C. Cir. Dec. 10, 2010), and the regulation took effect on January 2, 2011.


86. Chris Hope, of the Cambridge University Judge Business School, developed PAGE. See

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FUND (Climate Framework for Uncertainty, Negotiation, and Distribution). The three models differ in some significant respects (several of which are described below), but for the most part, they operate in a similar fashion. The user enters a set of economic parameters, including preexisting baseline projections of economic growth and technological improvements, developed within the standard economic literature. These projections include predictions of future greenhouse gas emissions, which are a function of GDP and a society’s “carbon intensity”: the amount of carbon a nation’s economy must generate in order to produce wealth.

From these projected emissions, the climate models predict changes in the concentration of greenhouse gases in the atmosphere. Those changes in greenhouse gas concentrations are, in turn, used to predict changes in temperature, and the models then project economic harms (in the form of diminished worldwide GDP) from the expected temperature increases. These models thus involve both climate science—translations of greenhouse gas concentrations into temperature changes—and environmental economics—predictions of the effect of warming on GDP.

In order to generate values for the social costs of carbon, the Interagency Group ran the three models using standard baseline projections of economic growth and technological development (the parameters described above) and determined the models’ predicted effects of warming on GDP. The models are all probabilistic, and thus they each generate a probability distribution of possible outcomes. The Interagency Group obtained the mean outcome for each model, and then averaged these three means. The Group then re-ran the same models using the same baseline projections, but with one additional ton of carbon emissions, in order to determine the marginal effect on global GDP of

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89. Abebe & Masur, supra note 1, at 360. Not surprisingly, carbon intensity is primarily a function of a society’s level of technology: higher-technology societies are able to produce greater wealth with lower pollution. Id.

90. IWG REPORT, supra note 17, at 6.

91. Id.

92. Id. at 5.

93. Id. at 24–25.

94. Id. at 5, 25.
that additional unit of carbon.\textsuperscript{95} The average reduction in GDP across all three models from this second run, minus the average reduction in GDP from the first (baseline) run, is the social cost of carbon: the amount of money saved for every marginal ton of atmospheric carbon that is \textit{not} emitted.

Rather than declare a single value for the social cost of carbon, the IWG reports different values for every year from 2010 to 2050.\textsuperscript{96} The yearly values differ both because the cost of carbon must be discounted to present value, and because one additional unit of carbon will likely affect the environment differently in 2020 than it did in 2010. This is due to the fact that the relationship between atmospheric concentrations and carbon is not linear, and there will likely be more carbon in the atmosphere in 2020 than in 2010. Accordingly, an additional ton of carbon will likely cause greater warming in 2020 than it did in 2010 because it will combine with an already carbon-saturated atmosphere.

The IWG does not specify a discount rate.\textsuperscript{97} Instead, the IWG reports average social costs of carbon at discount rates of 5 percent, 3 percent, and 2.5 percent.\textsuperscript{98} The IWG also reports the ninety-fifth percentile probabilistic value for the social cost of carbon (at a 3 percent discount rate), as a means of providing something of an upper bound on the likely costs. The IWG predicts that the additional harm from carbon emissions in later years will outpace the rate of monetary discounting, even at a discount rate of 7 percent, and thus the social costs of carbon increase with time in constant dollars. Table 8 reproduces the Interagency Group's chart of social costs of carbon at various discount rates from 2010–2021.

The use of these carbon prices in federal regulations is meant to be straightforward. Suppose a regulation will reduce carbon emissions by 10,000 tons per year every year from 2010–2020. An agency would simply multiply the emissions avoided by the price of a ton of emissions in the appropriate year to calculate the full carbon-related benefit from the regulation. The agency would need to choose which discount rate to use—but the IWG provides no guidance on this issue. In this example, the regulation would generate a carbon-related benefit of $2.62 million, assuming a discount rate of 3 percent. Although the IWG methodology is relatively straightforward, this simplicity masks significant shortcomings. Not only does the report ignore critical political questions by treating them as technical matters, a point to which we will return in detail below, but the internal logic of the report's technical methodology is itself fraught with problems.

\textsuperscript{95} Id. at 25.
\textsuperscript{96} IWG REPORT, supra note 17, at 40–41.
\textsuperscript{97} See id. at 18–24.
\textsuperscript{98} Id. at 40–41.
Table 8: Annual SCC Values: 2010–2021 (in 2007 dollars per ton)

<table>
<thead>
<tr>
<th>Year</th>
<th>Discount rate:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>2010</td>
<td>4.7</td>
</tr>
<tr>
<td>2011</td>
<td>4.9</td>
</tr>
<tr>
<td>2012</td>
<td>5.1</td>
</tr>
<tr>
<td>2013</td>
<td>5.3</td>
</tr>
<tr>
<td>2014</td>
<td>5.5</td>
</tr>
<tr>
<td>2015</td>
<td>5.7</td>
</tr>
<tr>
<td>2016</td>
<td>5.9</td>
</tr>
<tr>
<td>2017</td>
<td>6.1</td>
</tr>
<tr>
<td>2018</td>
<td>6.3</td>
</tr>
<tr>
<td>2019</td>
<td>6.5</td>
</tr>
<tr>
<td>2020</td>
<td>6.8</td>
</tr>
<tr>
<td>2021</td>
<td>7.1</td>
</tr>
</tbody>
</table>

B. Technical Problems Internal to the IWG’s SCC Calculation

There is, to say the least, a great deal of uncertainty surrounding both climate science and environmental economics. The IWG is admirably modest and forthright about these limitations, and the last few pages of the document list a number of analytical shortcomings. To begin with, the models do not account for all potential non-catastrophic harms because of data limitations. For instance, the models do not attempt to quantify the effects of ocean acidification or the economic and political consequences of population migration that result from warming. Nor do they account fully for the possibility of catastrophic harm. For instance, the FUND model does not account for the possibility of catastrophic harms of any sort, obviously biasing its estimates of harm downward. The other models may be underestimating the probability of catastrophic events by significant margins as well. In addition,

99. Id. at 40 tbl.A1.
100. Id. at 5 ("The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them."); id. at 30–31 (describing limitations of the IWG analysis).
101. Id. at 30.
102. Id. at 30–33; see also Martin L. Weitzman, On Modeling and Interpreting the Economics of Catastrophic Climate Change, 91 REV. ECON. & STAT. 1 (2009); Martin L. Weitzman, A Review of the Stern Review on the Economics of Climate Change, 45 J. ECON. LIT. 703 (2007). There are a number of possible climate change-related “tipping points”: points at which some drastic climatic event occurs with potentially extreme economic or sociological consequences. These include, for instance, the collapse of the Greenland Ice Sheet or the West Antarctic Ice Sheet, each of which would raise sea levels substantially. Climate scientists estimate the likelihood of one of these events occurring
each of the models assumes that humans will adapt at relatively low cost to many of the results of climate change, though these assumptions are never justified. Indeed, the rate and cost of adaptation is one of the foremost issues that confounds attempts to estimate the costs of global warming. Finally, each of the models assumes risk neutrality. However, people are risk averse, and insurance markets may not be able to handle the increased risk caused by climate change. Rather than calculate a rate of risk aversion and open itself up to criticism for its choice, the IWG made the more politic (but less useful) choice to elide the issue.

The IWG is to be commended for acknowledging the weaknesses of its own analysis. But by the same token, the IWG’s recommendations are not adequately defended. Many of its errors are likely errors of underestimation: it is likely that the IWG does not incorporate all the potential harms of global warming, and thus underestimates the benefits of curbing emissions. But others go the other direction. We describe three of the most significant errors and shortcomings below.

_The models use weakly defended assumptions_. The models require the input of a set of economic starting points: estimates of how economic growth and technological development would proceed absent any global warming. The models are obviously sensitive to these initial parameters: high economic growth will lead to greater carbon emissions, and thus greater warming and climate-related harms. In order to accommodate this uncertainty, the IWG used five different sets of initial parameters, ran each model with each set of parameters, and then took the average result across all three models under all five sets of starting points. Four of these initial sets of parameters were at approximately 50 percent, assuming 2.5-degree Celsius global warming. IWG REPORT, supra note 17, at 33. These “tipping points” would not necessarily generate economic catastrophes (as they are defined by the climate models), but it is worth noting that the probability of such an event occurring is nearly an order of magnitude higher than the probability of an economic catastrophe under the DICE or PAGE models. PAGE puts the likelihood of a catastrophe at nearly zero, while DICE estimates it at 4 percent, again assuming 2.5-degree warming. Id.

103. _Id._ at 31.

104. _Id._ at 10, 30–31 (describing the uncertainties surrounding the costs of adaptation and the importance of arriving at reliable estimates); Alejandro E. Camacho, _Transforming the Means and Ends of Natural Resources Management_, 89 N.C. L. Rev. 1405, 1412 (2011) (“[U]ncertainty is amplified by the fact that the effects of global climate change on ecosystems will be influenced by two other factors for which there remains limited information: the extent of mitigation strategies to be employed to abate further climatic change and the collateral effects on biota from adaptation strategies . . . .”) (citation omitted); Michael D. Mastrandrea, _Calculating the Benefits of Climate Policy: Examining the Assumptions of Integrated Assessment Models_ 30–37 (Pew Ctr. on Global Climate Change, Working Paper, 2009), available at http://www.pewclimate.org/docUploads/mastrandrea-calculating-benefits-climate-policy-12-22-09.pdf.

105. IWG REPORT, supra note 17, at 31.


107. These five sets of economic parameters were borrowed from the Stanford Energy
“business as usual” scenarios—best estimates of the current state of the economy and its likely growth over the coming decades.\textsuperscript{108} One of them was a more optimistic set of parameters—it was actually named “MERGE Optimistic”—that assumed that technological developments would limit atmospheric carbon concentrations at relatively low levels for decades into the future.\textsuperscript{109}

The IWG was right to average across a variety of initial economic parameters as a means of addressing the uncertainty surrounding future economic growth and the sensitivity of climate models to economic projections. But what could be the justification for choosing four standard sets of assumptions and one optimistic scenario? Why did the Group not employ one pessimistic scenario, to balance its use of the optimistic scenario? It is entirely possible that global growth will drive carbon emissions to levels beyond what standard assumptions would predict. For instance, if the Chinese economy continues to expand at a high rate and this expansion is fueled primarily through coal and other dirty forms of energy production, global carbon emissions could rise significantly faster than economists and scientists currently predict.\textsuperscript{110}

This raises a larger issue regarding these parameters and the manner in which they are employed by the models.\textsuperscript{111} All of the economic parameters, and all of the models, assume that worldwide carbon intensity—carbon emissions per dollar of GDP—will decline steadily. They assume that the worldwide economy will become “cleaner” over time, producing fewer and fewer carbon emissions per dollar of GDP. This is a reasonable assumption for developed economies that have already industrialized and are in the process of developing cleaner technologies. But industrializing economies exhibit precisely the opposite behavior: carbon intensity increases as the economy begins to rely more and more heavily on coal and other carbon-intensive sources of energy, and only decreases later once a certain level of technology and prosperity has been achieved.\textsuperscript{112} For instance, Chinese carbon intensity rose through the late 1970s, and carbon intensity is still rising in parts of western China that are still industrializing.\textsuperscript{113} As other nations in Asia, Africa, and South America continue to industrialize in the coming decades, carbon intensity in those regions may well rise, rather than fall. This will not likely offset the overall decline in

\begin{thebibliography}{11}
\bibitem{108} Modeler Forum exercise. IWG REPORT, \textit{supra} note 17, at 16. This modeling exercise developed ten different sets of economic parameters; the Interagency Group selected five of the ten. \textit{Id.}
\bibitem{109} \textit{Id.} at 16–17.
\bibitem{110} See Abebe & Masur, \textit{supra} note 1, at 378–81.
\bibitem{112} Abebe & Masur, \textit{supra} note 1, at 362–66.
\bibitem{113} \textit{Id.} at 353, 369.
\end{thebibliography}
carbon intensity throughout the world, led by technological advances in the United States, Europe, and China. But it could render assumptions regarding consistent declines in carbon intensity unrealistic and thereby indicate that the IWG underestimates future harms due to climate change.

In another important respect the IWG’s analysis may be overly optimistic. None of the three models incorporates emissions of any greenhouse gas other than carbon dioxide. A regulation that led to lower carbon emissions might simultaneously cause industry to switch to fuels that generate higher emissions of some other greenhouse gas such as methane (an even more potent greenhouse gas). If firms have the capacity to switch production from some activity that generates carbon dioxide to another activity that generates methane, the SCC will overestimate benefits from reductions in carbon emissions.

The models are crude and inconsistent. At the low levels of emission reductions relevant here, the DICE, FUND, and PAGE models produce highly divergent results. Recall that the models are probabilistic; they each produce a range of possible outcomes of varying probabilities. FUND is the most optimistic: its median estimate of damage from global warming is lower than all but 5 percent of the estimates from the PAGE model. For its part, the median PAGE estimate is lower than all but 5 percent of the estimates from the DICE model. In other words, FUND estimates are at the extreme low end of PAGE estimates, and PAGE estimates are at the extreme low end of DICE estimates.

What accounts for these inconsistencies? It is hard to be certain because only the DICE model is fully transparent. The authors of the other models have not released all of their equations and calculations to the public (which indeed is an additional reason why it might not be proper for the government to rely on them). But we can use the DICE model to illustrate a problem that, we suspect, exists in the other models as well.

The central equation in the DICE model is:

\[ Q(t) = \Omega(t)[1-A(t)]^*A(t)K(t)^*L(t)^{1-y}, \]

where \( Q(t) \) is aggregate global economic output. The equation after the “*” is just the standard neoclassical production function, where \( A(t) \) is factor productivity, \( K(t) \) is capital stock, and \( L(t) \) is labor inputs. In the neoclassical production function, economic output is a function of capital investment and labor. Long-run growth is determined by technological innovation and population changes, which are exogenously assumed. Although neoclassical economic growth models have received criticism, they are consistent with much empirical evidence, and are widely used.

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114. See IWG REPORT, supra note 17, at 13.
115. This inter-gas leakage is an echo of the even more serious problem of international emissions leakage that we discuss below.
116. IWG REPORT, supra note 17, at 10. Recall that damages under these models are probabilistic, and thus they produce probability distributions of possible damages.
117. NORDHAUS, supra note 85, at 41.
DICE’s innovation is to multiply the neoclassical production function by a damage function, \( \Omega(t) [1 - A(t)] \), where \( \Omega(t) \) maps global mean temperature changes to a damage variable, and \( A(t) \) maps abatement expenditures to an abatement variable. As temperature increases, the damage percentage and abatement costs increase, lowering aggregate economic growth. Because capital spent on abatement expenses is diverted from capital devoted to economic growth, aggregate output is maximized when the marginal cost of abatement expenditures equals the marginal cost of climate-related economic harm. The SCC can be backed out of this model: it is the price of carbon at which the optimal investment in abatement will be made.

As we noted, the economic growth model is relatively uncontroversial, but where does the damage function come from? Nordhaus explains:

The aggregate damage curve is built up from estimates of the damages of the 12 regions, including assumed sectoral change and underlying income elasticities of different outputs. It includes estimated damages to major sectors such as agriculture, the cost of sea-level rise, adverse impacts on health, and nonmarket damages, as well as estimates of the potential costs of catastrophic damages. It is clear that this equation is extremely conjectural, given the thin base of empirical studies on which it rests.118

“Extremely conjectural” is right. The damage function is essentially a guess. And if, as we suspect, the models differ in large part because their authors chose arbitrarily different damage functions, then the SCC just reflects the average of these three guesses.119 If this is the case, it is hard to have much confidence in the SCC calculated by the IWG.120

In addition, the manner in which results are reported, coupled with the wide spread among the three models, conveys an excessively optimistic sense of the potential magnitude of the climate risk. Recall that the IWG reports the ninety-fifth percentile carbon costs (at a 3 percent discount rate) as a means of establishing an upper bound on the likely benefits of emissions reductions.121 This ninety-fifth percentile figure is an average of the ninety-fifth percentile values of all three models. But the models generate very different ninety-fifth percentile predictions—for instance, FUND’s ninety-fifth percentile value is only a small fraction of PAGE’s. Moreover, FUND does not include any potential catastrophic outcomes. In this sense, the ninety-fifth percentile figure

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118. Id. at 41–42.
119. The models use different economic growth models, but these are unlikely to be the source of much difference, because all economic growth models attempt to explain the same thing—observed economic growth in different countries.
120. For a general and somewhat more optimistic discussion of climate modeling, see generally Farber, Modeling Climate Change and Its Impacts, supra note 111 (arguing that climate models are more advanced than economic models in establishing lower-end estimates of the impacts of global temperature change, and should have more influence on the policy-making process).
121. IWG REPORT, supra note 17, at 26, 34.
is not a realistic bound on the potential harm from climate change; it is a high estimate mitigated by the much more optimistic figures produced by FUND. Regulators (and the public) should not be misled into thinking that there is little chance that carbon costs will exceed the ninety-fifth percentile figure reported by the IWG.

To be sure, there is nothing wrong with using a variety of models that make different predictions. Under conditions of uncertainty, this may be the only wise course of action. But the extreme discrepancies between these three models—FUND and DICE are essentially inconsistent with one another—does not inspire confidence. It seems likely that one of the three models is simply incorrect and is skewing the overall results improperly. It was perhaps an overabundance of caution—both scientific and political—that led the Interagency Group to employ all three models, rather than attempting to select the most reliable one or two among them. If the IWG had excluded one or more of these models, it might have opened itself up to criticism for having cherry-picked available science in order to buttress preferred conclusions. Yet the inclusion of an inaccurate model is no better than the exclusion of an accurate one.

The IWG assumes a linear relationship between benefits and reductions in emissions. That is, the IWG assumed that the benefit of reducing carbon emissions by twenty tons in 2010 was exactly twice the benefit of reducing emissions by ten tons in the same year: $428 versus $214 (at a 3 percent discount rate and an SCC of 21.4). This may be a reasonable assumption for very small reductions in national emissions, but only for very small reductions. The relationship between the amount of carbon emitted into the atmosphere and the warming it causes could well be quadratic, cubic, or even exponential, rather than linear. Similarly, the relationship between global temperature changes and economic harm is likely nonlinear. Indeed, the DICE and PAGE models assume that the relationship between temperature change and economic harm obeys a power law: DICE assumes that economic damages increase as the square of the change in global temperature, while PAGE uses a variety of values ranging from a linear relationship to an assumption that damages increase as the cube of temperature changes. It is for this reason that the IWG report is unsuitable for measuring the benefits of major greenhouse gas regulation such as the EPA might undertake in response to Massachusetts v. EPA. To its credit, the report itself is explicit on this point.

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122. For instance, we find it remarkable that the majority of climate-related damages in North America anticipated by FUND are in the form of increased demand for air-conditioning. See id. at 8 n.4. We are not experts, but this hardly seems an accurate portrayal of the harm likely to befall farmers and workers in North America in the event of significant climate change.
123. See IWG REPORT, supra note 17, at 2–3.
124. Id. at 7.
125. See id. at 3–4 (stating that the purpose of the SCC figures presented in the report is limited to “mak[ing] it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulator actions that have small, or ‘marginal’
calculate the costs and benefits of across-the-board regulation of carbon dioxide, it must undertake a separate analysis and cannot rely upon a number of simplifying assumptions made in the course of this report.

If a regulation causes only a very small reduction in overall carbon emissions, it is appropriate to approximate these higher-order effects as linear as the IWG report does. But it is possible that a number of independent regulations, in combination, will together reduce emissions by more than a small fraction. Over the past two years, federal agencies have promulgated a number of regulations that are expected to cause significant reductions in CO\textsubscript{2} emissions, many of them in the millions of tons annually.\textsuperscript{126} For instance, the Department of Energy’s July 2009 regulation regarding the energy efficiency of fluorescent and incandescent lamps is expected to reduce domestic CO\textsubscript{2} emissions by more than 300 million tons over the next thirty years.\textsuperscript{127} If enough of these regulations were put into force over the same period of time, they could have nonlinear—quadratic, or even exponential—effects on global warming. For instance, significant increases in CAFE standards, coupled with improvements in energy efficiency standards for household appliances and related policies, might lead to abatement of emissions that are too great to be priced accurately using the IWG’s analysis.\textsuperscript{128} The effects of these small reductions in combination might be nonlinear, and might be more beneficial than the IWG’s simple model would indicate. By considering these reductions in piecemeal fashion, agencies might miss significant interaction effects between regulations. If this is the case, the IWG report would underestimate the benefits from reducing carbon emissions by a significant degree.\textsuperscript{129}

\textit{impacts on cumulative global emissions}" (emphasis added)).

126. See supra Part I.


128. See supra Part II.A.

129. On the other hand, the relationship could be less than linear, meaning that the Appendix actually overstates benefits of reducing emissions. However, given the widespread belief among climate modelers that damages scale more than linearly with increases in global temperature, this seems unlikely. See INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, WORKING GROUP II, CLIMATE CHANGE 2001: IMPACTS, ADAPTATION, AND VULNERABILITY 78 (2001) (contribution of the working group to the Third Assessment Report of the IPCC) (presenting evidence that environmental systems have “strongly nonlinear, complex, and discontinuous responses” to ecological pressure); ROBERT U. AYRES & JÖRG WALTER, THE GREENHOUSE EFFECT: DAMAGES, COSTS, AND ABATEMENT 4 (1991), available at http://www.iiasa.ac.at/Admin/PUB/ Documents/RR-91-012.pdf (stating that increases in CO\textsubscript{2} cause nonlinear ecological changes); SAMUEL FANKHAUSER, VALUING CLIMATE CHANGE: THE ECONOMICS OF THE GREENHOUSE 60-61 (1995) (stating that each subsequent ton of CO\textsubscript{2} released creates greater damage than the previously released ton of CO\textsubscript{2}); Darwin C. Hall & Richard J. Behl, Integrating Economic Analysis and the Science of Climate Instability, 57 ECOLOGICAL ECON. 442, 443-44 (2006), available at http://upi-yptk.ac.id/Ekonomi/Hall_Integrating.pdf (arguing that the environment has a nonlinear response to changing inputs); Timothy M. Lenton et al., Tipping Elements in the Earth’s Climate System, 105 PROC. NAT. ACAD. SCI. 1787 (2008), available at http://www.pnas.org/content/105/6/1786.full.pdf (describing several
The IWG report is an admirable attempt to price the benefits of regulatory reductions in CO₂ emissions. Nonetheless, it does not provide an adequate scientific and economic basis for its conclusions. This may be due in part to the IWG adopting “political” solutions, designed to appease all sides, where more difficult technical decisions were called for. These problems, however, are at least amenable to technical solutions through further refinement of the IWG models. Perhaps more troubling, as we shall next discuss, are a number of more fundamental problems that cannot be addressed in such a technical fashion.

C. International Leakage and Its Role in Cost-Benefit Analysis

The carbon-absorbing property of the atmosphere is a global public good. People everywhere in the world benefit when the atmosphere absorbs carbon because the harmful effects of global warming and other disruptions to the climate are avoided. When one country limits emissions, and other countries do not, the first country provides benefits to the world, enjoys only a small share of these benefits, and incurs the full costs of its behavior. The result is that countries acting unilaterally will reduce carbon emissions inadequately.¹³⁰

The IWG report recognizes this problem, noting:

Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.¹³¹

¹³⁰ For recent discussions on the inadequacy of CO₂ emission reduction, see Robert N. Stavins, A Meaningful U.S. Cap-and-Trade System to Address Climate Change, 32 HARV. ENVTL. L. REV. 293, 324–27 (2008) (advocating linking U.S. climate change regulations with foreign and international regulatory scheme to achieve an optimal reduction in carbon emissions); Vandenbergh & Cohen, supra note 21 (discussing the difficulty of using unilateral measures to incentivize Chinese reductions in carbon emissions); Jonathan B. Wiener, Climate Change Policy and Policy Change in China, 55 UCLA L. REV. 1805 (2008) (discussing the need for the United States and China to work together to develop coordinated climate change regulations).

¹³¹ IWG REPORT, supra note 17, at 11–12.

The difficulty lies in the fact that other countries, with the limited exception of the member states of the European Union, have not taken significant steps to reduce emissions. Thus, it is wrong to calculate the SCC for U.S. regulation on the assumption that other countries have taken those steps.

To understand why, one must understand the problem of leakage. Leakage occurs when carbon-emitting activities in one country migrate to another country where regulation of carbon emissions is weaker. Suppose, for example, that the U.S. government limits carbon emissions of automobile manufacturers, raising the cost of production, and hence the price of automobiles, and reducing the demand for American-made cars. All else equal, American consumers will, at the margin, stop buying American-made cars and instead buy foreign-made cars that are not subject to the American-imposed carbon cap. As a result, foreign automobile manufacturers will expand production and hence generate greater carbon emissions—potentially offsetting or even exceeding the reduction in carbon emissions that took place in the United States. Because the harm to the climate is independent of the source of the emissions, the American cap will have no effect on climate change. Its only effect will be job loss in the short term, and, in the long term, a transfer of carbon-intensive industry from American soil to foreign soil, which may well be less economically efficient (as it requires transportation of cars back to the United States, loss of comparative advantage efficiencies, and so on).\footnote{132. See, e.g., Mustafa H. Babiker, Climate Change Policy, Market Structure, and Carbon Leakage, 65 J. INT’L ECON. 421, 439–40 (2005) (discussing the effects of international leakage on bilateral trade).}

Leakage also occurs when regulation shifts consumption to unregulated economies. Suppose that American climate regulation increases the cost of oil for American industry and consumers, resulting in a decline in demand. Because American demand for oil declines, and oil is bought and sold on a global market, the global price of oil will decline. As the global price of oil declines, people in other countries will buy more of it. Depending on the precise shape of the supply and demand curves, the quantity of oil consumed in the new equilibrium may be close to the quantity of oil consumed prior to the introduction of American climate regulation. Foreign-produced oil originally intended for the American market will be sent to other countries, outside of American regulatory control. In this extreme scenario, leakage is 100 percent, with the result that the American regulation produces no social gains and only costs (higher prices for American consumers).

However, there are two constraints on leakage. The first might be described as physical or technological. In our first example, it may turn out to be the case that the increase in the price of cars will have a limited effect on demand since demand is relatively inelastic. Perhaps, for example, the cost of transporting cars from overseas is very high or American automobile
manufacturers simply produce more desirable cars.\textsuperscript{133} It is also possible that foreign manufacturing processes are less carbon-intensive than American manufacturing processes.\textsuperscript{134} In any of these cases, the reduction in carbon emissions from American manufacturers will only be partly offset by the increase in carbon emissions from foreign manufacturers. The extent of these offsets will vary from industry to industry. In sum, leakage is not a problem in markets that are local because of physical or technological constraints.

The second constraint is legal. Suppose the U.S. government enacts a law that bans or taxes the importation of all foreign automobiles, or those that were produced using carbon-intensive manufacturing processes. Such a law would require foreign producers either to abandon the American market or to produce less carbon-intensive cars for export to the United States. In either case, the leakage problem would be mitigated. In reality, however, laws that address leakage by restricting trade would have to overcome a number of hurdles, including international trade law and the difficulty of determining the carbon intensity of particular goods. Although such laws may help mitigate the degree of leakage, it is unlikely that they could completely eliminate it.\textsuperscript{135} Because these laws do not yet exist, agencies must take leakage into account.

Scholars have produced a number of estimates of leakage. At this stage, the estimates are highly speculative. A study by Joshua Elliott and his coauthors considers the problem of leakage in a scenario in which Annex B countries in the Kyoto treaty (major developed nations) adopt a carbon tax and the non-Annex B countries do not.\textsuperscript{136} Using a new computable general equilibrium model of the economic effects of climate change, they find that a regional tax would reduce emissions only one third as much as an equivalent global tax, and that the effectiveness of the regional tax would be reduced a further 15–25 percent as a result of leakage.\textsuperscript{137} Constraints on emissions in the European Union, the United States, and other Annex B countries would

\textsuperscript{133} Neither of these possibilities appears to be true, but they could be in other industrial contexts.

\textsuperscript{134} This is likely true with respect to some countries, but not with respect to others. The United States ranks eighty-second among the 134 nations (for which there are data) in the carbon intensity of its energy production. That is to say, eighty-one countries produce less carbon per unit of energy than the United States; fifty-two produce more. \textit{Carbon Intensity of Energy Use in 2007, WORLD RESOURCES INSTITUTE CLIMATE ANALYSIS INDICATORS TOOL, http://cait.wri.org/cait.php?page=carberg &mode=view (registration required).} Notably, China, Australia, Ireland, Israel, Italy, and Denmark have less carbon-efficient economies than the United States; Japan, India, Canada, and the European Union countries, as a whole, are more efficient. \textit{Id.} Though energy is not the only input to production, the carbon efficiency of energy production is roughly correlated with the carbon efficiency of production more generally.


\textsuperscript{136} Joshua Elliott, et al., \textit{A Quantitative Examination of Trade and Carbon Taxes} (manuscript at 22–30) (on file with authors).

\textsuperscript{137} \textit{Id.} at 4.
increase production and consumption of carbon-intensive goods by 15–25 percent in China, India, and other non-Annex B countries.

The leakage rate for the United States would be even higher if climate regulation were to occur in the United States alone rather than in all Annex B countries. Leakage would now occur not only to China and India, but also to the European Union (the largest economy in the world), Japan (the second largest national economy), Canada (the tenth largest), and Australia (the thirteenth largest). Overall, leakage in a scenario in which the United States alone (or the United States and the European Union) engages in carbon regulation, and other countries do not, would certainly be higher than 15–25 percent.

To account for this problem, agencies must incorporate leakage estimates into their cost-benefit analyses involving the SCC. Consider a regulation that reduces carbon emissions in the United States by one metric ton. Using the IWG’s figure for a discount rate of 3 percent, the benefit of the regulation would be $21.40. If we conservatively assume that leakage is 25 percent, this means that the one-ton reduction of carbon emissions will be offset by a quarter-ton rise of carbon emissions in another part of the world. Accordingly, either the agency should discount the expected carbon emission by one quarter, or discount the SCC by one quarter. In either event, the benefit of the regulation would be reduced to $16.05.

Unfortunately, the calculation would not be this simple. The Elliott et al. study conflicts with other studies that estimate leakage rates from as little as 3 percent to more than 100 percent. None of these studies examines the specific case where the United States (or the European Union) unilaterally adopts significant constraints on carbon emissions. The studies also address different types of leakage—for example, leakage that results from regulation of coal versus leakage that results from regulation of petroleum, which need not be the same. Agencies that regulate products like appliances that draw on coal as their energy source must use leakage numbers different from those for motor vehicles that draw on petroleum. Petroleum is traded on global markets to a much greater degree than coal is, and thus susceptible to greater leakage.

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139. See Babiker, supra note 132, at 441 (estimating leakage rates as high as 130 percent and as low as 50 percent for countries required to reduce emissions by the Kyoto Protocol); Mustafa H. Babiker & Thomas F. Rutherford, The Economic Effects of Border Measures in Subglobal Climate Agreements, 26 Energy J. 99, 106–08 (2005) (estimating leakage from 7–39 percent depending on whether the United States is included in the Kyoto coalition countries and on what type of protective measures, such as tariffs or exemptions, Kyoto coalition countries take to reduce leakage); Ton Manders & Paul Veenendaal, Neth. Bureau for Econ. Policy Analysis, No. 171, Border Tax Adjustments and the EU-ETS: A Quantitative Assessment 23 tbl.4.4 (2008) (estimating a 3.3 percent leakage rate for reductions made by the European Union).
Similarly, regulations concerning production, such as the production of steel, are much more susceptible to leakage than regulations concerning usage, such as regulations of the efficiency of automobiles\textsuperscript{140} or small electric motors.\textsuperscript{141} Production can be transferred overseas to evade regulation, while usage by Americans cannot. Further research into leakage rates will be necessary before the SCC can be appropriately discounted.

In sum, leakage poses two problems. First, the degree of leakage in current conditions is unknown. Second, and more important, cost-benefit analyses that ignore leakage will overestimate the benefits of a regulation. The amount of leakage will eventually depend on international cooperation, and in particular, a climate treaty. How might agencies account for this? Agencies might ignore leakage under the assumption that a climate treaty will eventually come into existence. This would be wrong, however, as a climate treaty might not ever be ratified. Or, agencies could assume that leakage is high. But if agencies assume that leakage is very high, they will rarely engage in climate regulation. We return to this dilemma in Part III.

D. Valuation of Harms to Foreign Countries

Climate regulation is distinctive because optimal domestic climate regulation depends on the climate regulation taking place in other countries. This is not true for virtually all other forms of regulation. Consider regulation of arsenic in municipal water supplies.\textsuperscript{142} The adverse effect of arsenic is felt overwhelmingly by Americans; the cost of remedial measures also shows up in the water bills paid by Americans living in the cities affected by the regulation. Aside from a few tourists and other foreign visitors, the costs and benefits are felt exclusively by Americans. By contrast, when American industry reduces carbon emissions, the beneficiaries are mainly foreigners. The population of the United States is less than 5 percent of the global population; and future population growth will occur disproportionately outside the United States. Accordingly, reduction of carbon emissions today will benefit far more foreigners, living today and in the future, than Americans. Meanwhile, the costs will be felt mostly although not exclusively by Americans. The foreign effects of climate regulation create difficult methodological and normative questions that we will examine in this Section.

Let us start by distinguishing the \textit{global SCC} and the \textit{domestic SCC}. When U.S. industries emit an additional ton of carbon dioxide, the climate-related harm will be partly felt by Americans and entirely felt by the global population. For example, if global food prices increase as a result of harm to

\textsuperscript{140} See 2011 CAFE Standards, \textit{supra} note 14.
agricultural productivity, the reduction in wealth will be felt mostly outside the United States, where 95 percent of the global population is located. Accordingly, the domestic SCC will be less than the global SCC. A cost-benefit analysis that takes into account the well-being only of Americans will use the domestic SCC; a cost-benefit analysis that takes into account the well-being of the global population will use the global SCC. A cost-benefit analysis using a global SCC will yield more stringent regulations than cost-benefit analysis using a domestic SCC.

Should agencies such as the EPA use the global SCC or the domestic SCC in its cost-benefit analysis? The legal answer is that it depends on the statute. However, statutes are almost always silent about extraterritorial effect. Consider the statute under which the EPA will regulate carbon emissions from motor vehicles:

The Administrator shall by regulation prescribe (and from time to time revise) in accordance with the provisions of this section, standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare. . . .

The question is whether the relevant "public" in the statute includes only Americans or the global population. In most statutes, two considerations would suggest the narrower interpretation. First, courts frequently apply a canon of interpretation that disfavors extraterritorial application of laws. The presumption is that Congress has no interest in regulating overseas because doing so may offend the sovereignty of other countries, while producing few benefits for Americans. Second, the contrary interpretation implies that the EPA should regulate, or attempt to regulate, foreign motor vehicle manufacturers, even those who produce only for their domestic markets. Such an interpretation is questionable, to say the least.

However, the Clean Air Act has a clause that provides for consideration of extraterritorial effect with respect to countries that reciprocate by regulating their domestic industry so as to benefit the United States. This suggests that

143. 42 U.S.C. § 7521(a)(1) (2006). The term, "air pollutant," means "any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive . . . substance or matter which is emitted into or otherwise enters the ambient air." Id. § 7602(g).


146. 42 U.S.C. § 7415(c) ("This section shall apply only to a foreign country which the Administrator determines has given the United States essentially the same rights with respect to the prevention or control of air pollution occurring in that country as is given that country by this section.").
neither the domestic nor global SCC should be used. According to this, the SCC should be calculated so as to take into account impacts on countries that enter a climate treaty or otherwise engage in climate regulation, and no others. Notice how far removed this approach is from cost-benefit analyses which do not limit benefits on the basis of the political behavior of governments.

The fourteen regulations that we have been discussing were not issued under statutes with reciprocity provisions. Yet some of them distinguish domestic and global SCCs. As we noted in Section I.A, the Model Year 2011 CAFE rule began with a $33 price for the global SCC. It then separately calculated a domestic SCC on the basis of the U.S. share of world economic output, about 20–28 percent, and estimates of the sensitivity of the U.S. economy to climate change. According to this calculation, the United States would suffer between 0 and 14 percent of the global cost of climate change. The DOT took the midpoint, 7 percent, and multiplied it by the $33 global SCC, yielding a domestic SCC of approximately $2.148

The calculation is dubious. The cost of climate change is not a function of the size of a country’s economy, but its geography (for example, whether it is low-lying and subject to flooding), its mean temperatures (hotter places suffer more from increased heat than colder places), the health of the population (healthier people are less susceptible to disease, which increases in warmer climates), and so forth. Scientists have not yet been able to predict regional variation in the effects of climate change with any confidence, and for this reason the major climate models do not yet make predictions for individual countries—although some economists have tried. Speculation as to the sensitivity of the American economy to climate change is merely that. It follows that even if a global SCC can be calculated, a domestic SCC cannot be estimated to any reasonable degree of confidence—although we can be confident that it is less than the global SCC.

Even if American regulatory agencies have the authority to take account of costs to foreigners, should they use their discretion to act in that way? This question can be broken down into three inquiries—normative, political, and institutional.

The normative question is whether Americans have the same moral obligations to foreigners who live overseas as they have toward other Americans. If Americans have weaker moral obligations to foreigners, then American regulatory agencies should partially or completely discount the negative effects of American activities on foreigners. Philosophers take different positions on this question. Cosmopolitans believe that moral

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148. See supra Section I.A.
149. See, e.g., DELUCCHI, supra note 36 (attempting to calculate the effects of climate change caused by motor vehicle use on the United States).
obligations to help or not to harm others do not turn on their nationality; communitarians and nationalists believe that they do.\textsuperscript{150} We do not take a position on this debate; we note only that if Americans owe stronger duties to other Americans than to foreigners, then the social cost of carbon should reflect a discount for costs incurred by foreigners. And even if Americans should treat foreigners the same as other Americans, there is still a question whether to incorporate foreigners' own valuations, which, in fact, differ from those of Americans, or to use American valuations—that is, to value foreigners' well-being the same as Americans value their own well-being.\textsuperscript{151} Suppose, for example, that Chinese and Italians assign a lower value to morbidity and mortality risks than Americans. Should American regulatory agencies use Chinese and Italian valuations or American valuations for climate effects on Chinese and Italians?\textsuperscript{152}

The political question is whether elected officials and appointees who head regulatory agencies should treat costs to foreigners the same as costs to Americans even if they believe it is appropriate to do so—or, as a practical matter, whether they can be expected to do so in a democracy. Suppose that most elected officials are cosmopolitans but most Americans are nationalists. For instance, one study suggests that Americans implicitly value a foreign life at between 1/6th and 1/2000th of an American life.\textsuperscript{153} Even if we should all be cosmopolitans, it is plausible to believe that elected officials have a duty to advance the interests of the Americans they represent, as do the regulatory agencies that derive their authority from the decisions of elected officials. In a more practical sense, electoral pressures may dictate that governments treat foreigners, who do not have the vote, differently from the way they treat citizens.

The institutional question addresses how regulatory agencies should act, given that they have specialized missions. Even if the cosmopolitan view is correct, and even if politicians believe that they should take account of the interests of foreigners, it may well be the case that regulatory agencies should not—unless explicitly directed to do so by elected officials.

With respect to the institutional question, there are two reasons for doubting that agencies should treat costs to foreigners and costs to Americans as

\begin{itemize}
\item \textsuperscript{150} See generally Simon Caney, \textit{Justice Beyond Borders: A Global Political Theory} 3–16 (2005) (describing competing approaches to international relations including the cosmopolitan, realist, statist, and nationalist approaches).
\item \textsuperscript{153} Wojciech Kopczak, Joel Slemrod, and Shlomo Yitzhaki, \textit{The Limitations of Decentralized World Redistribution: An Optimal Taxation Approach}, 49 \textit{EUROPEAN ECON. REV.} 1051, 1075 (2005).
\end{itemize}
the same. First, the treatment of foreigners is a diplomatic question, one that is addressed by different institutions such as the State Department, the White House, and sometimes Congress. To see the problem here, imagine that the optimal approach to climate change is joint action by multiple countries, as is surely the case. The United States and other countries do best if all countries reduce greenhouse gas emissions by a reasonable amount. However, countries disagree about how significant climate change is, and how the costs of responding to climate change should be allocated among countries. Countries must resolve these disagreements—in effect, choosing a global SCC—before they can cooperate. U.S. regulatory agencies cannot calculate the optimal SCC for U.S. purposes until they know how foreign countries will act; and how foreign countries will act depends in part on their negotiations with the U.S. government, which could be hamstrung if its own agencies committed it to specific regulatory outcomes before it could obtain concessions from other countries.

It is possible that unilateral action by the United States will induce reciprocal behavior by other countries. But the opposite is more probable: if the United States reduces greenhouse gas emissions unilaterally, other countries will fail to reciprocate, preferring to free ride. Suppose the United States can compel other countries to reduce greenhouse gas emissions only by threatening not to reduce greenhouse gas emissions itself. If so, then it would be ill advised for American regulatory agencies to reduce carbon emissions in a way that reflects the interests of foreigners until directed to do so by the political branches.

The Montreal Protocol is an example of how unilateral action by the United States adversely affected its ability to negotiate further reductions with other countries. The United States acted first, issuing regulations that greatly reduced use of these compounds by consumers and domestic manufacturers. When it came time to negotiate a treaty with other countries, the United States had difficulty persuading them to take similar steps. These countries may have preferred to free ride on American efforts, which conferred benefits on them without imposing costs. The final treaty was less stringent than the United States sought. It is possible that this disappointment resulted from the self-imposed reduction in bargaining power on the part of the United States, although one cannot know for sure.

The second reason for doubting that agencies should treat costs to foreigners and costs to Americans as the same is that the treatment of

154. See, e.g., POSNER & WEISBACH, supra note 1, at 29–33.
156. See Rachel Brewster, Stepping Stone or Stumbling Block: Incrementalism and National Climate Change Legislation, 28 YALE L. & POL'TY REV. 245, 246–47 (2010) (arguing that incremental domestic action may retard the development of an international agreement on climate change).
158. See id.
foreigners is a highly sensitive political question. Thus, Congress is the institutional actor best positioned to decide these normatively and politically fraught questions. As noted above, it is not clear whether elected officials should take account of foreign interests to the same extent as domestic interests. And as a practical matter, elected officials must pay attention to the views of voters. If Congress will not act, then the administration should at least employ notice-and-comment rulemaking in order to increase the degree of political accountability and participation that attends the decision. An interagency regulatory group, working behind closed doors with no public notice or participation, is not the proper mechanism for resolving issues which raise difficult political and moral questions and are not merely technical.

III. THE LIMITS OF COST-BENEFIT ANALYSIS

Many of the problems in the IWG report are technical. The SCC chosen by the IWG ignores some significant costs, neglects catastrophic risks, and assumes away risk aversion. Because the figure assumes a linear relationship between the benefits of carbon reduction and the quantity of carbon reduction, it cannot be used for large-scale regulations or even small-scale regulations if they aggregate to a large scale. The SCC reflects arbitrarily chosen damage functions—or, more precisely, the average of several arbitrarily chosen damage functions. It emerges from three climate models of questionable reliability.

Guesswork is not always fatal to cost-benefit analysis. Judgment is needed to distinguish between reasonable estimates and estimates that are excessively wide of the mark. Our judgment is that the IWG report relies on too many unwarranted assumptions and cannot be relied on. But technical problems can be repaired through further research. Computer models of climate change are improving and will eventually provide reasonable estimates of the SCC.

The more serious problem for cost-benefit analysis of climate change is that climate regulation requires a series of judgments that are political and institutional rather than technical. We review those judgments here.

First, optimal U.S. climate regulation depends on what other countries do. If other countries do not engage in their own climate regulation, then U.S. climate regulation should probably be less strict, given the possibility of leakage. If other countries do engage in their own climate regulation, then U.S.

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160. Similar to the treatment of foreigners is the treatment of benefits to people living in the distant future. The treatment of such people is a normative question (typically discussed under the rubric of intergenerational equity), not a technocratic question, and thus not one that can be answered with cost-benefit analysis. See Eric A. Posner, Agencies Should Ignore Distant-Future Generations, 74 U. CHI. L. REV. 139, 143 (2007).
161. This is in addition to the fact that scientific uncertainty makes cost-benefit analysis difficult. See supra Section II.B.
regulators need not fear leakage as much and can regulate carbon more strictly. Thus, a given regulation may be cost-justified if China also acts but not if China fails to act. Yet cost-benefit analysis does not permit for speculation about how other countries will behave. Agencies such as the DOT and the DOE are in no position to predict whether China will regulate carbon or not, and so cannot, consistent with the norms of cost-benefit analysis, use an SCC that assumes action on the part of the China.

Second, climate regulation by the United States might itself affect how other countries act. There are two possibilities. One is that if the United States moves first, it provides leadership that motivates other countries to engage in climate regulation. The other is that if the United States moves first, other countries free ride and refuse to engage in climate regulation. Cost-benefit analysis cannot predict the likely diplomatic consequences of agency actions.

Third, U.S. climate regulation will affect the well-being of many more foreigners than Americans. Yet there is no agreed-upon formula for evaluating the benefits of avoided harms for non-Americans living in other countries. An agency might use American valuations; or it might defer to the valuations used in foreign countries; or it might exclude foreign costs and benefits. The right approach depends on normative questions that are prior to cost-benefit analysis, and institutional and political questions that cost-benefit analysis does not address.

Fourth, although a scientific consensus holds that anthropogenic climate change will cause significant harm to people around the world, there is no scientific consensus regarding how much of that harm will be experienced by Americans in the United States. If cost-benefit properly takes into account only effects in the United States, then agencies should engage in only limited climate regulation compared to what they should engage in if it were proper to take account of global effects.

The broader point is that cost-benefit analysis will be ineffective whenever a regulation raises principally normative, political, and institutional questions, rather than technical ones. This is why cost-benefit analysis is considered inapplicable to abortion and Establishment Clause questions, for instance. Without some mechanism for evaluating the normative and political questions central to those subjects, cost-benefit analysis can lead one astray. To be sure, policymakers should take into account the costs and benefits of various approaches to climate regulation, but the costs and benefits—unlike in normal cost-benefit analysis—are not the only considerations. They will have to make an all-things-considered moral and political judgment that addresses scientific uncertainty, the value of foreign lives, the likely reactions of foreign countries, and the other imponderables for which cost-benefit analysis is not suited.

We suspect that all of these difficulties have caused agencies to avoid relying on a single SCC in their regulatory impact statements, for fear that a court would find the cost-benefit analysis defective because the SCC figures
are unsupported. However, ignoring these problems does not solve them. As we noted earlier, the Ninth Circuit struck down an earlier CAFE rule because the DOT failed to take into account the SCC.\textsuperscript{162}

Yet if the IWG’s cost-benefit analysis is not suited to the task of pricing carbon, what should the government do? In an ideal world, the United States and other countries would enter into a climate treaty that would establish the SCC. Note that this SCC would be a political figure, reflecting a compromise that different nations reach for political purposes, rather than a figure determined using traditional economic methodology. The reason is that even though the science and the economics is the same across countries, countries make different political calculations which reflect local conditions. The SCC that they can tolerate will thus reflect different political and institutional factors; and the compromise SCC will reflect the relative bargaining power of each country. But the figure could be easily plugged into cost-benefit analyses used by agencies for regulation—at least, as long as agencies are given proper executive or congressional authorization to use a politically stipulated figure rather than the figure that emerges from climate models. A climate treaty could also render agency regulation unnecessary by creating a cap-and-trade scheme in which firms would be given tradable permits to emit limited greenhouse gas emissions and would either pollute within the limits or purchase permits from others. Because people would have to pay for the harm they cause to the climate, they would fully internalize the climatic costs of their activity, and additional regulation administered by the regulatory agencies would be unnecessary. Congress would need to pass a law that requires the government to use the treaty-based SCC so as to ensure that additional regulations beyond American treaty commitments are not issued.

However, a climate treaty is still far off; what should U.S. regulatory agencies do in the meantime? We believe that agencies conducting cost-benefit analysis cannot use the IWG’s SCC. The SCC is highly arbitrary: it assumes that foreign harms should be treated identically to domestic harms; assumes that there will be zero leakage; and assumes away the possibility of a diplomatic solution. Even the choice of which of the IWG’s four SCCs to use is arbitrary. It may well be for this reason that agencies are at such pains to argue that the choice of SCC will not affect the regulatory decision. As a matter of policy and law, cost-benefit analysis cannot use arbitrary valuations.\textsuperscript{163} It is possible that a case could be made for a much lower SCC, using lower bound estimates for American impacts that are scientifically supportable, or even for a higher SCC. But we think that the more honest and plausible approach would be for Congress to stipulate an SCC that reflects its political judgments.

\textsuperscript{162} Ctr. for Biological Diversity v. Nat’l Highway Traffic Safety Admin., 538 F.3d 1172, 1227 (9th Cir. 2008).

Congress would need to make the all-things-considered moral and political judgment that we described above—one in which it takes account of scientific uncertainty, the possible reactions of foreign countries, and the costs and benefits, including the proper weighting of foreigners and future generations, and so forth.

If Congress will not act, then the Obama administration should suspend his cost-benefit analysis executive order for regulations touching on climate change and order agencies to use a figure that will encourage other countries to enter a climate treaty (if in fact such a figure exists), and initiate notice-and-comment rulemaking as a second-best means of addressing the political questions that cost-benefit analysis cannot answer.

CONCLUSION

Contrary to popular perception, the U.S. government has already begun engaging in climate regulation. Congressional paralysis on climate legislation has not stood in the way because U.S. regulatory agencies derive authority from their authorizing statutes and the cost-benefit executive order, which requires them to take into account all the possible benefits of regulation.

That is the good news. The bad news is that the agencies’ regulatory efforts have been inadequate. Simultaneously miscalculating the SCC and ignoring their own numbers, agencies manage to do cost-benefit analysis poorly and then disregard it. Much improvement can take place through purely technical adjustment, and the IWG has led the way. Many of the problems that we have identified can be resolved through further research or reasonable guesswork. But it is important to understand that although more precise domestic and global SCC figures can be useful information for political actors and can greatly enhance the transparency of regulatory action, they cannot be used in a conventional cost-benefit analysis performed at the agency level because serious political issues remain as a result of the global nature of climate change and the uncertainties that continue to surround it. For this reason, the existing cost-benefit executive order does not provide a foundation for further climate regulation. Congressional or executive intervention is necessary.


165. Whether such an order would be lawful would depend on the proper interpretation of the particular statutes involved, taking into account the conflicting pressures of the Chevron doctrine, which confers discretion on the executive to achieve policy objectives, and the presumption against extraterritoriality.