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Eric A. Posner

Jonathan Masur

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CLIMATE REGULATION AND THE LIMITS OF COST-BENEFIT ANALYSIS

Jonathan S. Masur and Eric A. Posner

THE LAW SCHOOL
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Jonathan S. Masur and Eric A. Posner[1]

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Introduction

There is by now a broad consensus that global warming threatens significant harm to the welfare of people across the world and that national governments should take steps to curb warming and alleviate the harm caused by climate change.[2] After dragging its heels, the United States has joined most other countries in recognizing that action against climate change is needed. Nonetheless, the United States has not ratified any international climate change treaty. Congress has considered, but not passed, greenhouse gas regulation.[3] And the 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 is misleading: in fact, the American regulatory state has lurched into gear. Over the past two years, several federal 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 are likely to meet them when they turn to larger scale regulation involving power plants, motor vehicle regulation, and manufacturing. 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.

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[2] *See, e.g.*, William Nordhaus, A Question of Balance: Weight the Options on Global Warming Policies (2008); Nicholas Stern, The Economics Of Climate Change (2007); Richard B. Stewart & Jonathan B. Wiener, Reconstructing Climate Policy: Beyond Kyoto (2003); Cass R. Sunstein, *The World vs. the United States and China? The Complex Climate Change Incentives of the Leading Greenhouse Gas Emitters*, 55 UCLA L. Rev. 1675 (2008); Michael P. Vandenbergh, *Climate Change: The China Problem*, 81 S. Cal. L. Rev. 905 (2008). We agree with this consensus. *See* Eric A. Posner & David Weisbach, Climate Change Justice (2010); Daniel Abebe & Jonathan S. Masur, *International Agreements, Internal Heterogeneity, and Climate Change: The "Two Chinas" Problem*, 50 Va. J. Int'l L. 325 (2010).

[3] *See* Perry Bacon, Jr., *Lack of Votes for Senate Democrats' Energy Bill May Mean the End*, Wash. Post., July 23, 2010, *available at* 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 . . . .").

[44] 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. 31514 (Envtl. Prot. Agency June 3, 2010). We discuss this regulation below. *See infra* note 71and accompanying text.

[5] Massachusetts v. EPA, 549 U.S. 497 (2007).

The story begins in 2008, when the Ninth Circuit struck down the Department of Transportation's corporate average fuel economy (CAFE) standard for light trucks because the cost-benefit analysis used by DOT to determine the standard failed to take account of its beneficial effects for climate change.[6] The petitioners, which included a number of environmental groups, had tried to persuade the court that 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 DOT uses cost-benefit analysis, then it cannot arbitrarily include some benefits (reduction in automobile noise and congestion, for example) while excluding the benefits for the climate.[7] On remand, DOT set to work monetizing the climate benefits. Other agencies followed its path.

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.[8] They have harshly criticized Executive Order 12,296, a Clinton-era executive order that requires regulatory agencies to issue cost-benefit analyses for major regulations.[9] Yet this order supplied DOT with the authority to engage in cost-benefit analysis for the CAFE standards, which in turn led to judicial repudiation because DOT's cost-benefit analysis ignored climatic effects. In this instance, liberal defenders of cost-benefit analysis, who have argued that it promotes regulation where regulation is warranted, have been vindicated.[10]

Or have they? 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 the performance of the agencies.

In theory, the relevant monetary valuations for cost-benefit analysis of climate regulation would come from climate science and from 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 analysis of regulations.

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[6] *See* Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1198-1204 (9th Cir. 2008).

[7] *Id.* at 1201.

[8] *See, e.g.*, Frank Ackerman & Lisa Heinzerling, Priceless: On Knowing the Price of Everything and the Value of Nothing (2004); Amy Sinden, Douglas A. Kysar & David M. Driesen, *Cost-Benefit Analysis: New Foundations on Shifting Sand*, 3 Reg. & Governance 48, 50 (2009).

[9] The Clinton order renews an earlier order issued by President Reagan, which may explain the association between cost-benefit analysis and conservative, anti-regulatory sentiment. See Matthew Adler & Eric A. Posner, New Foundations of Cost-Benefit Analysis 1-5 (2006).

[10] *See* Richard L. Revesz & Michael A. Livermore, Retaking Rationality: How Cost-Benefit Analysis Can Better Protect the Environment and Our Health (2008); Cass R. Sunstein, Risk and Reason: Safety, Law, and the Environment (2002).

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 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 the specification of 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"—they are testing 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 estimated that the social cost of carbon fell somewhere between $0 and $20 per ton, and then declined to use any SCC figure in its cost-benefit analysis on the ground that the proposed regulation passed a cost-benefit analysis regardless of the value of the SCC.[11] In a 2009 regulation of fuel economy standards, the Department of Transportation calculated a separate $2 domestic SCC and a $33 global SCC, and then used these figures in a sensitivity test but not in the cost-benefit analysis.[12] Meanwhile, in 2008 the Environmental Protection Agency 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.[13]

In response to this confusion, the Office of Management and Budget convened an Interagency Working Group ("IWG") and gave it the task of resolving the disagreements among agencies. 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.[14] For 2010, the SCC is $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.

[11] Commercial Standard Sized Packed Terminal Air Conditioners and Packed Terminal Heat Pumps, 73 Fed. Reg. 58,772 (Dep't of Energy October 7, 2008).
[12] Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 Fed. Reg. 14,196 (Dep't of Transp., Nat'l Highway Traffic and Safety Admin. March 30, 2009).
[13] Regulating Greenhouse Gas Emissions Under the Clean Air Act, 73 Fed. Reg. 44,354 (Envt'l. Prot. Agency proposed July 30, 2008).
[14] *See* Energy Conservation Program: Energy Conservation Standards for Small Electric Motors, 75 Fed. Reg. 10874-01 app. 15A at 40 (Dep't of Energy Mar. 9, 2010) (Interagency Working Group on Social Cost of Carbon, Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866) [hereinafter IWG Report].

This Article examines the record of the agencies (Part I) and the reasoning in the IWG report (Part II). We write on a blank slate. Legal scholars have analyzed the prospects for an international agreement on climate change;[15] the possible forms of federal climate legislation;[16] the future of EPA regulation under the Clean Air Act;[17] and the possibility that greenhouse gases might be regulated by states and localities,[18] or through litigation.[19] But the national regulatory efforts already underway have escaped their notice.

Much of our Article is devoted to cataloging the errors in the analysis of the agencies and the IWG report. But we also develop a larger theme about the relationship between cost-benefit analysis and politics. Although we both 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—not about whether climate change will harm human beings, but 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

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[15] *E.g.*, Michael P. Vandenbergh & Mark A. Cohen, *Climate Change Governance: Boundaries and Leakage*, 18 N.Y.U. Envtl. L.J. 221 (2010) (describing mechanisms for bringing major polluting nations into compliance with international climate accords); Michael P. Vandenbergh, *Climate Change: The China Problem*, 81 S. Cal. L. Rev. 905 (2008) (analyzing the international nature of global warming and the need for an international solution); Jonathan B. Wiener, *Think Globally, Act Globally: The Limits of Local Climate Policies*, 155 U. Pa. L. Rev. 1961 (2007) (same); Cass R. Sunstein, *Of Montreal and Kyoto: A Tale of Two Protocols*, 38 Envtl. L. Rep. News & Analysis 10566 (2008) (discussing the need for, and difficulties with, an international climate accord).

[16] *E.g.*, David A. Super, *From The Greenhouse to the Poorhouse: Carbon-Emissions Control and the Rules of Legislative Joinder*, 158 U. Pa. L. Rev. 1093 (2010) (analyzing the leading legislative options for regulating carbon emissions); Lisa Schultz Bressman, *The Future of Agency Independence*, 63 Vand. L. Rev. 599 (2010) (discussing the ramifications of climate change legislation on agency structure and authority); Gilbert E. Metcalf & David Weisbach, *The Design of a Carbon Tax*, 33 Harv. Envtl. L. Rev. 499 (2009) (describing how a legislatively enacted federal carbon tax might be structured); Robert L. Glicksman, *Balancing Mandate and Discretion in the Institutional Design of Federal Climate Change Policy*, 102 Nw. U. L. Rev. Colloquy 196 (2008) (analyzing the question of how much authority Congress should delegate to the EPA to regulate climate change); Hari M. Osofsky, *Climate Change Legislation in Context*, 102 Nw. U. L. Rev. Colloquy 245 (2008) (considering various legislative proposals).

[17] *E.g.*, J.D. Ruhl & James Salzman, *Climate Change, Dead Zones, and Massive Problems in the Administrative State: A Guide For Whittling Away*, 98 Cal. L. Rev. 59 (2010) (noting the legal problems involved with agency regulation of a massive issue such as climate change); 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); Madeline June Kass, *A Nepa Climate Paradox: Taking Greenhouse Gases Into Account in Threshold Significance Determinations*, 42 Ind. L. Rev. 47 (arguing that federal agencies should take climate change into account when drafting NEPA analyses) (2009); 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 have been permitted to regulate climate change).

[18] *E.g.*, Katherine A. Trisolini, *All Hands On Deck: Local Governments and the Potential for Bidirectional Climate Change Regulation*, 62 Stan. L. Rev. 669 (2010) (suggesting the possibility of state or local regulation of greenhouse gas production); Hari M. Osofsky, *Is Climate Change "International"? Litigation's Diagonal Regulatory Role*, 49 Va. J. Int'l L. 585 (2009) (discussing regulation at local, state, federal, and international levels).

[19] *E.g.*, Randall S. Abate, *Public Nuisance Suits for the Climate Justice Movement: The Right Thing and the Right Time*, 85 Wash. L. Rev. 197 (2010) (proposing the use of private law as a means of forcing reductions in carbon emissions); Kirsten H. Engel, *Harmonizing Regulatory and Litigation Approaches To Climate Change Mitigation: Incorporating Tradable Emissions Offsets Into Common Law Remedies*, 55 U. Pa. L. Rev. 1563 (2007) (same).

American 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.[20] Cost-benefit analysis cannot cope with inherently political questions involving contested normative issues. In some cases, the source of conflict is so clear that no one seriously argues that regulatory agencies should solve them using cost-benefit analysis. Consider abortion, affirmative action, and religious accommodation. In other cases, the source of conflict is more subtle. We will argue that climate change is one such case. In Part III, we make this argument and suggest ways forward.

I. Carbon Pricing in Existing Regulations

In the past two years, fourteen federal regulations have addressed the benefits of reduced carbon dioxide emissions.[21] 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. They endeavor to prove that they would necessarily have opted for 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 ("DOT") new set of Corporate Average Fuel Economy ("CAFE") standards for Model Year 2011, issued on March 30, 2009.[22] CAFE standards are minimum requirements for the average fuel economy of a carmaker's entire fleet, adjusted by the number of each automobile sold. Thus, if Toyota sells 1000 pickup trucks, each of which averages 20 miles/gallon, and 3000 compact cars, each of which averages 30 miles/gallon,

[20] For a defense of this claim, see Adler & Posner, supra note 9.
[21] We cite them, infra.
[22] Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 Fed. Reg. at 14,196.

Toyota's corporate average fuel economy is approximately 27 miles/gallon.[23] If DOT issues a CAFE standard higher than 27, then Toyota must adjust by withdrawing some of the pickup trucks from the market, increasing its sales of compact cars, or improving the fuel efficiency of the cars and/or trucks.

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.[24] 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 DOT's CAFE standards for model years 2008-2011 for failing to monetize the benefit of reduced carbon emissions, DOT went back to the drawing board.[25] DOT solicited public comments and then settled on a range of three prices for the SCC derived from a 2008 paper by Richard Tol, who, as we will see, is one of the economists whose work the IWG incorporates.[26] Tol's 2008 paper is a survey of over two hundred separate estimates of the social cost of carbon published in peer-reviewed journals through 2006.[27] DOT selected as its middle value the mean price from Tol's survey: $33 per ton of carbon dioxide.[28] DOT's "high" estimate is one standard deviation above the mean from Tol's study: $80 per ton of CO_2.[29]

Like the IWG report, these prices include all global benefits, foreign and domestic. For its "low" estimate, DOT selected its best estimate of the purely *domestic* benefits of reducing carbon emissions.[30] 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 changes."[31] 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% of $33, or approximately $2. That left DOT with three values—$2, $33, and $80—that are roughly similar to the carbon prices subsequently calculated by the IWG.[32]

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[23] Corporate average fuel economy is calculated using the harmonic mean of the fuel economies of the fleet vehicles, rather than the arithmetic mean (which would yield a corporate average fuel economy of 27.5 miles/gallon using the hypothesized numbers). *See* Corporate Average Fuel Economy - Wikipedia, http://en.wikipedia.org/wiki/Corporate_Average_Fuel_Economy#Calculuation (last visited July 8, 2010).

[24] 74 Fed. Reg. at 14,412 (Table IX-3). According to the DOT, these savings comprise approximately three quarters of the total benefit of fuel economy regulation.

[25] *See* Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172 (9th Cir. 2008).

[26] Richard S.J. Tol, *The Social Cost of Carbon: Trends, Outliers, and Catastrophes*, Economics—the Open-Access, Open-Assessment E-Journal, 1, 2 (2008).

[27] *Id.*

[28] Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 Fed. Reg. at 14,346.

[29] *Id.* It is worth noting that one standard deviation from the mean is approximately the 85th percentile of the distribution. Accordingly, this $80 per ton price represents only an 85th percentile estimate, not an upper bound.

[30] *Id.*

[31] *Id.* at 14,349; *see also* Mark A. Delucchi, Summary of the Non-Monetary Externalities of Motor Vehicle Use, UCD-ITS-RR-96-3 (9) rev. 1, Institute of Transportation Studies, University of California, Davis, originally published September 1998, revised October 2004, pp. 49-51. Available at http:// www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-96-03(09)_rev1.pdf (last accessed March 23, 2009).

[32] *See infra* Part II.

These initial carbon prices were denoted in 2007 dollars. DOT decided to increase the prices by 2.4% 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 CO_2 in the earth's atmosphere." [33] Crucially, however, these 2.4% 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. DOT elected to apply a 3% discount rate to the social costs of carbon.[34] 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.[35]

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 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 MY 2011 cars and light trucks were unaffected by the choice among those values for reducing CO_2 emissions from fuel production and use."[36] DOT reported the results of its cost-benefit analysis for this optimized rule, along with rules 25% below (i.e., lower mandatory fuel efficiency) and 25% and 50% above (i.e., higher mandatory fuel efficiency) the optimal. 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 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 Automobiles (millions of 2007 dollars)[37]

	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs = Total Benefits[38]	Technology Exhaust
Total Benefits	1,707	1,948	2,321	2,763	3,676	9,356
Total Costs	940	1,145	1,918	2,545	4,009	18,120
Net Benefits	767	802	403	218	-334	-8,765

As part of this cost-benefit analysis, DOT estimated that its optimized regulation would eliminate 8.33 million tons of CO_2 emissions over the lifetime of the model year 2011

[33] Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 Fed. Reg. at 14,350.
[34] *Id.* at 14,355.
[35] For instance, the IWG's median carbon prices (discounted at 3%) grow at an approximate yearly rate of 2.1%, in constant dollars, between 2010 and 2020. IWG Report at 40.
[36] Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 Fed. Reg. at 14,351.
[37] *Id.* at 14,385 (Tables VII-4 through VII-6).
[38] As is obvious from the numbers, costs are not quite equivalent to benefits under this regulatory option.

automobiles.[39] It priced these emissions at $2/ton, for a total benefit of approximately $16 million. It is immediately apparent that if the social cost of carbon were much higher—$80 per ton, or even $64.9 per ton, the 95th percentile value from the SCC—the benefits from reduced CO_2 emissions would exceed the gap between the Optimized and 25% Above Optimized or 50% Above Optimized standards. Of course, in order to determine whether one of those options would in fact produce greater net benefits than the Optimized standard, it is necessary to know what reduction in emissions each of these alternatives would produce. To the best of our knowledge, DOT did not report these figures for the lifetime of model year 2011 automobiles. However, it did report expected reductions in CO_2 emissions from 2010 to 2100, assuming that its regulatory standards remained in force during that time. If we assume 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 2: CO_2 Emissions by Passenger Cars and Light Trucks with Alternative CAFE Standards for Model Year 2011 (million tons CO_2)[40]

Alternative	Cumulative Emissions, 2010-2100	Emissions Reductions from 2010-2100 Compared to No Action Alternative	Emissions Reductions Over the Lifetime of Model Year 2011 Automobiles
No Action	210,279	0	0
25% Below Optimized	209,076	1,203	7.44*
Optimized	208,932	1,347	8.33
25% Above Optimized	208,743	1,536	9.50*
50% Above Optimized	208,440	1,839	11.37*
Total Costs = Total Benefits	208,015	2,265	14.01*
Technology Exhaustion	204,228	6,052	37.43*

Consider the results of this analysis if the social cost of carbon is priced at the IWG's 3% 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 through 2021. If that is the case, the costs and benefits are as follows:[41]

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[39] *Id.* at 14,412.

[40] *Id.* at 14,390 (Table VII-11). Values labeled with "*" were calculated, not reported from the DOT regulation.

[41] DOT also claimed that reducing American oil consumption would produce "monopsony benefits"—lower oil prices for consumers due to the fact that a reduction in American monopsony consumption of oil would decrease world oil prices. *See id.* at 14,329. However, DOT decided to significantly reduce its estimation of these monopsony benefits when pricing CO_2 emissions at $33 and $80 per ton. *See id.* at 14,416 n. 473. DOT did not explain its reason for doing so, and we cannot make sense of this decision.

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% Discount Carbon Prices

	25% Below Optimized	Optimized	25% Above Optimized	50% Above Optimized	Total Costs = Total Benefits	Technology Exhaust
Total Benefits	1,868	2,128	2,526	3,008	3,978	1,0164
Total Costs	940	1,145	1,918	2,545	4,009	18,120
Net Benefits	948	983	606	463	-31	-8,044

The higher price on carbon does not alter the benefits so radically as to make regulations 25% Above or 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% Above the current point, but at least somewhat above 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 10, 20, or 50 years, they 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 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 DOT proceeded on the assumption that the discounted social costs will diminish with time.[42] Thus, if DOT's claim that its choice of CAFE standard was invariant to the price of carbon is correct, it is likely correct only under a particular set of parameters specified by 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 ("DOE") promulgated a regulation setting energy efficiency standards for General Service Fluorescent Lamps ("GSFL") and Incandescent Reflector Lamps ("IRL").[43] More efficient fluorescent and incandescent lamps reduce electricity consumption, and thus simultaneously eliminate greenhouse gas emissions.[44] In fact, according to DOE's analysis, the reduction in carbon emissions is one of the primary sources of benefits from mandating more efficient lamps.[45] However, because this regulation was completed before

[42] IWG Report 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 DOT.

[43] Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps, 74 Fed. Reg. 34,080 (Dep't of Energy July 14, 2009).

[44] 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 34,084 (predicting higher consumer prices).

[45] 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.

the publication of the IWG report, DOE was also forced to rely upon other sources when pricing the benefits of lower emissions. It chose to employ the Department of Transportation's prices from its CAFE standards: $2, $33, and $80 per ton.[46] DOE also decided to increase these values by 3% per year "to represent the expected increases, over time, of the benefits associated with reducing CO_2 and other greenhouse gas emissions."[47] As with the CAFE standards, however, these 3% increases were not pegged to constant dollars. DOE applied two discount rates to the benefits and costs of its regulation: 3% and 7%. Thus, at 3%, the social costs of carbon are constant (in constant dollars) over time; at 7% 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, DOE considered five different potential levels of energy efficiency, numbered in order of increasing stringency. That is, the higher the number, the greater the energy efficiency that would be required. 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% and 7% discount rates. DOE's estimates of reduced CO_2 emissions are presented as ranges, due to DOE's inability to predict whether more efficient lamps will obviate coal-fired or natural gas-fired plants.[48] In the interests of simplicity we focus here only on IRL, though the analysis is the same for both types of lamps. DOE's results are displayed below:

Table 4: Estimates of Value of CO_2 Emissions Reductions for IRL by Level of Regulation at Seven-Percent and Three-Percent Discount Rates[49]

Regulation Level	Estimated cumulative CO_2 emission reductions from 2012 to 2042 (MMt)	Value of estimated CO_2 emission reductions (billion 2008$) at 7% discount rate			Value of estimated CO_2 emission reductions (billion 2008$) at 3% discount rate		
		CO_2 value of $2/ton	CO_2 value of $33/ton	CO_2 value of $80/ton	CO_2 value of $2/ton	CO_2 value of $33/ton	CO_2 value of $80/ton
1	7 to 20	0.0 to 0.0	0.1 to 0.3	0.3 to 0.8	0.0 to 0.0	0.3 to 0.7	0.6 to 1.7
2	19 to 49	0.0 to 0.1	0.4 to 0.8	0.8 to 2.1	0.0 to 0.1	0.7 to 1.7	1.6 to 4.1
3	38 to 85	0.0 to 0.1	0.7 to 1.5	1.7 to 3.6	0.1 to 0.2	1.3 to 2.9	3.2 to 7.1
4	44 to 106	0.0 to 0.1	0.8 to 1.8	1.9 to 4.4	0.1 to 0.2	1.5 to 3.7	3.7 to 8.9
5	53 to 118	0.1 to 0.1	1.0 to 2.0	2.3 to 4.9	0.1 to 0.2	1.8 to 4.1	4.5 to 9.9

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 DOE's best guess, given an intermediate price of carbon (approximately $33/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. DOE reported net benefits at discount rates of 3%

[46] *See supra* Part II.A.1.
[47] Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps, 74 Fed. Reg. at 34,163.
[48] Coal-fired plants produce greater CO_2 emissions per unit of electricity.
[49] 74 Fed. Reg. 34,080, 34,164 (Table VII.28).

and 7%. 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:

Table 5: Annualized Benefits Net of Costs for IRL by Level of Regulation (in $millions/year, for the period 2012-2042)[50]

Regulation Level	Primary estimate at discount rate:		Low estimate at discount rate:		High estimate at discount rate:	
	7%	3%	7%	3%	7%	3%
1	18	29	-9	-2	44	61
2	326	352	203	215	449	489
3	459	532	**297**	**339**	620	725
4	532	590	179	207	885	973
5	**621**	**687**	247	280	**994**	**1093**

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, DOE opted to regulate IRL (and GSFL) at Level 4, despite the cost-benefit advantages of requiring greater energy efficiency.[51] The agency concluded that Level 5 regulation was "economically [un]justified," 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.[52] 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.

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.[53] The IWG

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[50] *Id.* at 34,171 (Table VII.34).
[51] *Id.* at 34,169-73.
[52] *Id.* (citing 42 U.S.C. § 6295(o)(2)(A)). 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).
[53] Energy Conservation Program: Energy Conservation Standards for Small Electric Motors, 75 Fed. Reg. 10,874 (Dep't of Energy March 9, 2010).

reportwas first published as an appendix to this rule,[54] and to our knowledge it has not been published again since. As the title would indicate, this regulation mandates energy efficiency guidelines for two types of small electric motors: "polyphase" small electric motors and "capacitor-start" small electric motors.[55] For each of these two types of motors, DOE considered eight different potential levels of energy efficiency, numbered in order of increasing stringency. (Again, the higher the number, the greater the energy efficiency that would be required.) 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. DOE then examined the effect of each potential regulation on carbon dioxide emissions from 2015, when the regulation will take effect, until 2045.[56] It estimated the likely reductions in CO_2 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. DOE's results are as follows:

Table 6: Estimates of Global Present Value of CO_2 Emissions Reductions for the Period 2015-2045 Under Polyphase Small Electric Motor Trial Standard Levels[57]

Regulation Level	Estimated cumulative CO_2 emission reductions, Mt	Global value of CO_2 emission reductions, million$ 2009			
		5% discount rate	3% discount rate	2.5% discount rate	3% discount rate, 95th percentile
1	2.3	8	40	68	122
2	4.6	16	81	138	248
3	8.3	28	146	248	445
4	9.3	32	165	280	502
4b	15.4	52	272	462	828
5	18.3	62	323	550	986
6	19.5	66	344	585	1049
7	21.2	72	375	638	1144

As an initial matter, it is a bit difficult to determine whether DOE has in fact priced its own carbon reductions correctly. Take, for instance, the very first row of Table 6 (Level 1 regulation). DOE estimated that this level of regulation would reduce CO_2 emissions by 2.3 million tons from 2015 to 2045. According to the IWG report, the price of one ton of CO_2 in 2015 is $5.70 at a 5% discount rate.[58] That price only rises over the next 30 years, reaching $14.20 in 2045. In addition, the IWG prices are in 2007 dollars, while the dollar values reported

[54] *See id.* at 10,911 (referencing "Appendix A of the Annex to Chapter 15 of the Technical Support Document").
[55] *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.
[56] *Id.* at 10,931.
[57] *Id.* at 10,931 (Table VI.31).
[58] IWG Report at 40.

in the DOE regulation are in 2009 dollars, which are less valuable. Thus, the global value of CO_2 emission reductions at Level 1 should be *at minimum* $13 million, and actually much more.[59] Yet the regulation values these CO_2 reductions at only $8 million. This problem exists with every one of the calculations, and we cannot explain these discrepancies.

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 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)[60]

Regulation Level	Consumer NPV (in billion$ 2009) at 3% discount rate with:			
	CO_2 value of $4.7/metric ton CO_2	CO_2 value of $21.4/metric ton CO_2	CO_2 value of $35.1/metric ton CO_2	CO_2 value of $64.9/metric ton CO_2
1	0.27	0.30	0.33	0.39
2	0.57	0.64	0.69	0.81
3	1.04	1.16	1.27	1.47
4	1.08	1.22	1.34	1.57
4b	**1.49**	**1.73**	**1.92**	**2.29**
5	0.83	1.11	1.34	1.79
6	0.13	0.42	0.66	1.14
7	(12.57)	(12.26)	(11.99)	(11.47)

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 DOE concluded that the choice of regulatory level was invariant to the choice of carbon price.

Yet it is clear that this conclusion is an artifact of the particular potential levels of regulation DOE chose to analyze. If DOE had not included Level 4b in the analysis, its choice of regulation would depend on the price it attached to CO_2 emissions. Per Table 7, if CO_2 emissions are priced at $4.70 or $21.40 per metric ton, Level 4 provides the greatest net benefits. If emissions are priced at $35.1 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. 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.

[59] 2.3 million tons of CO_2 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.

[60] 75 Fed. Reg. 10,874, 10,934 (Table VI.41).

Once again, it is the agency's decision to consider only particular discrete regulatory options, rather than an entire continuum of possibilities, that allows 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. The Department of Energy, like the Department of Transportation, will not be able to avoid choosing a price for carbon dioxide emissions when making regulatory decisions.

D. Further Agency Regulation Involving the SCC

We have discussed three of the 14 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[61]). 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).[62] One involved EPA (fuels and fuel additives).[63] And one involved both DOT and EPA (vehicle emissions).[64]

All of the regulatory impact statements accompanying these regulations resemble the three we have discussed. They typically report a range of SCCs, with the statements for the most

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[61] Energy Conservation Program for Commercial and Industrial Equipment: Packaged Terminal Air Conditioner and Packaged Terminal Heat Pump Energy Conservation Standards, 73 Fed. Reg. 58,772-01 (Dep't of Energy Oct. 7, 2008); Energy Conservation Standards for Commercial Ice-Cream Freezers; Self-Contained Commercial Refrigerators, Commercial Freezers, and Commercial Refrigerator-Freezers Without Doors, 74 Fed. Reg. 1,092 (Dep't of Energy Jan. 9, 2009); Energy Conservation Standards for Certain Consumer Products and for Certain Commercial and Industrial Equipment, 74 Fed. Reg 16,040 (Dep't of Energy Apr. 8, 2009); Energy Conservation Standards and Test Procedures for Commercial Heating, Air-Conditioning, and Water-Heating Equipment, 74 Fed. Reg. 36,312-01 (Dep't of Energy July 22, 2009); Energy Conservation Standards for Refrigerated Bottled or Canned Beverage Vending Machines, 74 Fed. Reg. 44,914-01 (Dep't of Energy Aug. 31, 2009); Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters, 75 Fed. Reg. 20,112-01 (Apr. 16, 2010); Energy Conservation Standards for Certain Consumer Products and for Certain Commercial and Industrial Equipment, 75 Fed. Reg. 1122-01 (Jan. 8, 2010).

[62] Notice of Funding Availability for Supplemental Discretionary Grants for Capital Investments in Surface Transportation Infrastructure Under the American Recovery and Reinvestment Act, 74 Fed. Reg. 28,755-01 (Dep't of Transp. June 17, 2009); Notice of Funding Availability for the Department of Transportation's National Infrastructure Investments Under the Transportation, Housing and Urban Development, and Related Agencies Appropriations Act for 2010, 75 Fed. Reg. 30,460-02 (Dep't of Transp. June 1, 2010).

[63] Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 Fed. Reg. 14,670-01 (Envtl. Prot. Agency Mar. 26, 2010).

[64] Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 75 Fed. Reg. 25,324 (Envtl. Prot. Agency and Dep't of Transp. May 7, 2010).

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.[65]

Meanwhile, the EPA has begun deliberating about climate regulation under the Clean Air Act. In Massachusetts v. EPA,[66] 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.[67] On December 7, 2009, the EPA announced its conclusion that greenhouse gases threaten public health.[68] This finding authorizes the EPA to regulate carbon dioxide emissions in a variety of ways, including requiring that CO_2 emitters to install the "best available" technology to mitigate emissions. Such regulation would impose significant costs on the American economy, but it might also produce substantial benefits by 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 interested private parties.[69] In fact, the Obama administration has indicated that the EPA's finding is principally intended to compel Congress to pass greenhouse gas legislation.[70] The EPA has taken the more limited step of requiring that major CO_2 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.[71] 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.[72] It did not so much as mention the SCC. If Congress does not act and the EPA eventually promulgates much broader carbon dioxide 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.

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[65] In some cases, the regulations ask for applications for funds, and ask applicants to use an SCC in determining the environmental effects of their proposed project.
[66] Massachusetts v. E.P.A., 549 U.S. 497 (2007).
[67] *Id.* at 533.
[68] News Release, Envtl. Prot. Agency, EPA: Greenhouse Gases Threaten Public Health and the Environment / Science overwhelmingly shows greenhouse gas concentrations at unprecedented levels due to human activity (Dec. 7, 2009), *available at* http://yosemite.epa.gov/opa/admpress.nsf/7ebdf4d0b217978b852573590040443a/08d11a451131bca585257685005bf252!OpenDocument.
[69] *See* 5 U.S.C. § 553 (describing the rulemaking process that the EPA must undertake before regulating).
[70] *See* Sindya N. Bhanoo, *The E.P.A. Announces a New Rule on Polluters*, N.Y. Times, May 14, 2010, at A13, *available at* http://www.nytimes.com/2010/05/14/science/earth/14permit.html.
[71] Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 Fed. Reg. 31514 (Envtl. Prot. Agency June 3, 2010). 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 31600. This is "due to the lack of available capture and control technologies" for carbon dioxide. *Id.*
[72] *Id.* at 31598-31601.

II. Problems

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 of various types, problems that render its conclusions unconvincing. At a fundamental level, the IWG's error was in failing to recognize the political nature of certain issues, treating them instead as technical matters; and in failing 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 Integrated Climate and Economy"),[73] PAGE ("Policy Analysis of the Greenhouse Effect"),[74] and FUND ("Climate Framework for Uncertainty, Negotiation, and Distribution").[75] The three models differ in some significant respects (several of which we describe below), but for the most part they operate in a similar fashion. The user enters a set of economic parameters, including pre-existing baseline projections of economic growth and technological improvements, developed within the standard economic literature.[76] 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.[77]

From these projected emissions, the climate models predict changes in the concentration of greenhouse gases in the atmosphere.[78] 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.[79] 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

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[73] DICE was developed by William Nordhaus, an economist at Yale University. William Nordhaus, A Question of Balance: Weighing the Options on Global Warming Policies (2008); William Nordhaus and John Boyer, Warming the World: Economic Models of Global Warming (2000).
[74] PAGE was developed by Chris Hope, of the Cambridge University Judge Business School. Chris Hope, *Optimal Carbon Emissions and the Social Cost of Carbon Under Uncertainty*, 8 The Integrated Assessment Journal 107 (2008); Chris Hope, *The Marginal Impact of CO2 From PAGE2002: An Integrated assessment Model Incorporating the IPCC's Five Reasons for Concern*, 6 The Integrated Assessment Journal 19 (2006).
[75] FUND was developed by Richard Tol, a professor at the Economic and Social Research Institute in Dublin. Richard Tol, *Estimates of the Damage Costs of Climate Change. Part I: Benchmark Estimates*, 21 Environmental and Resource Economics 47 (2002); Richard Tol, *Estimates of the Damage Costs of Climate Change. Part II: Dynamic Estimates*, 21 Environmental and Resource Economics 135 (2002).
[76] The IWG report employed five sets of parameters derived from the Stanford Energy Modeling Forum exercise. *See* IWG Report at 16.
[77] Abebe & Masur, *supra* note. 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.*
[78] IWG Report at 6.
[79] *Id.*

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 that additional unit of carbon. 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 *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. 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 does 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 would in 2010 because it will combine with an already carbon-saturated atmosphere.

The IWG does not specify a discount rate.[80] Instead, the IWG reports average social costs of carbon at discount rates of 5%, 3%, and 2.5%. The IWG also reports the 95th percentile probabilistic value for the social cost of carbon (at a 3% 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%, and thus the social costs of carbon increase with time in constant dollars, rather than decreasing. Table 8 reproduces the Interagency Group's chart of social costs of carbon at various discount rates from 2010 through 2021.

[80] IWG Report at 17-23.

Table 8: Annual SCC Values: 2010–2050 (in 2007 dollars per ton)

Discount rate: / Year	5%	3%	2.5%	95th
2010	4.7	21.4	35.1	64.9
2011	4.9	21.9	35.7	66.5
2012	5.1	22.4	36.4	68.1
2013	5.3	22.8	37.0	69.6
2014	5.5	23.3	37.7	71.2
2015	5.7	23.8	38.4	72.8
2016	5.9	24.3	39.0	74.4
2017	6.1	24.8	39.7	76.0
2018	6.3	25.3	40.4	77.5
2019	6.5	25.8	41.0	79.1
2020	6.8	26.3	41.7	80.7
2021	7.1	27.0	42.5	82.6

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 in every year from 2010 through 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—and 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%.

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.[81] 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.[82] 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.[83] In addition, each of the models assumes

[81] IWG Report at 5 ("The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them.")
[82] *Id.* at 30.
[83] *Id.* at 30-33. 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 at nearly 50%, assuming 2.5 degree global warming. *Id.* 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%, again assuming

that humans will adapt at relatively low cost to many of the results of climate change, though these assumptions are never justified.[84] Indeed, the rate and cost of adaptation is one of the foremost issues that confounds attempts to estimate the costs of warming. Finally, each of the models assumes risk neutrality.[85] However, people are risk averse, and insurance markets may not be able to handle the increased risk caused by climate change.[86] 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 entirely.

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 these additional 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 and sensitivity, the Interagency Group 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.[87] Four of these initial sets of parameters were "business as usual" scenarios—best estimates of the current state of the economy and its likely growth over the coming decades.[88] 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.[89]

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

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2.5 degree warming.) *See also* Martin L. Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 Rev. Econ. & Statistics 1 (2009); Martin L. Weitzman, *A Review on the Economics of Climate Change*, 45 J. Econ. Lit. 703 (2007).

[84] IWG Report at 31.

[85] *Id.*

[86] Intergovernmental Panel on Climate Change (IPCC), IPPC Fourth Assessment Report Climate Change 2007: Impacts, Adaptation, and Vulnerability 380-81 (2007).

[87] These five sets of economic parameters were borrowed from the Stanford Energy Modeling Forum exercise. *Id.* at 16. This modeling exercise developed ten different sets of economic parameters; the Interagency Group selected five of the ten. *Id.*

[88] *Id.*

[89] *Id.* at 16-17.

primarily through coal and other "dirty" forms of energy production, global carbon emissions could rise significantly faster than economists and scientists currently predict.[90]

This raises a larger issue regarding these parameters and the manner in which they are employed by the models.[91] 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. 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.[92] 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 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.[93] A regulation that led to lower carbon emissions might simultaneously offset those reductions by inducing 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.[94]

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% of the estimates from the PAGE model.[95] For its part, the median PAGE estimate is lower than all but 5% of the estimates from the DICE model. In other words, FUND

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[90] Abebe & Masur, *supra* note.

[91] For discussion, see Daniel A. Farber, *Modeling Climate Change and its Impacts: Law, Policy, and Science*, 86 Tex. L. Rev. 1655 (2008); *see also* Daniel A. Farber, *Rethinking the Role of Cost-Benefit Analysis*, 76 U. Chi. L. Rev. 1355, 1386-97 (2009) (arguing that cost-benefit analysis cannot handle climate change because of scientific uncertainty).

[92] Abebe & Masur, *supra* note.

[93] IWG Report at 13.

[94] This inter-gas leakage is an echo of the even more serious problem of international emissions leakage that we discuss below.

[95] IWG Report at 10. Recall that damages under these models are probabilistic, and thus they produce probability distributions of possible damages.

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:

$$Q(t) = \Omega(t)[1\text{-}\Lambda(t)]*A(t)K(t)^{\gamma}L(t)^{1-\gamma},$$

where $Q(t)$ is aggregate global economic output.[96] 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.

DICE's innovation is to multiply the neoclassical production function by a damage function, $\Omega(t)[1\text{-}\Lambda(t)]$, where $\Omega(t)$ maps global mean temperature changes to a damage variable, and $\Lambda(t)$ 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 and Boyer explain:

> 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.[97]

"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

[96] Nordhaus & Boyer, supra at 41.
[97] Nordhaus & Boyer, supra at 41-42.

functions, then the SCC just reflects the average of three arbitrary guesses.[98] If this is the case, it is hard to have much confidence in the SCC calculated by the IWG.[99]

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 95th percentile carbon costs (at a 3% discount rate) as a means of establishing an upper bound on the likely benefits of emissions reductions.[100] This 95th percentile figure is an average of the 95th percentile values of all three models. But the models generate very different 95th percentile predictions—for instance, FUND's 95th percentile value is only a small fraction of PAGE's. Moreover, FUND does not include any potential catastrophic outcomes. In this sense, the 95th percentile figure 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 95th 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.[101] 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.[102] In this respect it appears that the IWG selected what amounts to a political solution to a technical problem, choosing to eschew difficult technical decisions regarding which models to employ. This approach ill serves the regulatory agencies who must rely upon the IWG report.

The IWG assumes that the benefits of curbing carbon emissions are linear with the number of tons of carbon emitted, at least for small reductions in emissions. That is, the IWG assumes that the benefit of reducing carbon emissions by 20 tons in 2010 is exactly twice the benefit of reducing emissions by 10 tons in the same year: $420 versus $210 (at a 3% discount rate).[103] This may be a reasonable assumption for very small reductions in national emissions,

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[98] 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.

[99] For a general and somewhat more optimistic discussion of climate modeling, see Daniel A. Farber, *Modeling Climate Change and its Impacts: Law, Policy, and Science*, 86 Tex. L. Rev. 1655 (2008).

[100] IWG Report at 26.

[101] 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. *Id.* at 8. 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.

[102] *See* Adam M. Samaha, *Dead Hand Arguments and Constitutional Interpretation*, 108 Colum. L. Rev. 606, 653 (2008) ("Unfortunately, the premises for Condorcetian confidence are lacking. . . . For the Theorem to hold . . . the mean accuracy of all voters must be better than random--for instance, greater than 50% for binary choices . . . .").

[103] IWG Report at 3.

but only for very small reductions. The relationship between the amount of carbon emitted into the atmosphere and the warming it causes is likely 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.[104] 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*. The report itself is explicit on this point.[105] If EPA is to 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. But it is possible that a number of independent regulations, in combination, will together reduce emissions by more than a small fraction. The United States produced approximately 1.65 billion tons of CO_2 in 2004.[106] Over the past two years, federal agencies have promulgated a number of regulations that are expected to cause significant reductions in carbon dioxide emissions, many of them in the millions of tons annually.[107] 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_2 emissions by more than 300 million tons over the next thirty years.[108] 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,[109] coupled with improvements in energy efficiency standards for household appliances[110] and related policies, might lead to abatement of emissions that are too great to be priced accurately using the IWG's analysis.[111] 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 understate the benefits from reducing carbon emissions by a significant degree.[112]

[104] *Id.* at 7.

[106] Abebe & Masur, *supra* note.
[107] *See infra* Part II.A., *infra*.
[108] *See* Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps, 74 Fed. Reg. 34,080, 34,164 (Table VII.27) (2009); *infra* Part II.A.2.
[109] *E.g.*, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, 75 Fed. Reg. 25,324 (Envtl. Prot. Agency and Dep't of Transp. May 7, 2010).
[110] Energy Conservation Standards for Certain Consumer Products and for Certain Commercial and Industrial Equipment, 75 Fed. Reg. 1122-01 (Jan. 8, 2010).
[111] *See supra* Part I.A.1.
[112] 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.

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The IWG report is an admirable attempt to price the benefits of regulatory reductions in carbon dioxide emissions. Nonetheless, it is rife with uncertainty and error, and internal disagreements between the models used to generate the final prices do not inspire confidence. Many of these errors are likely errors of underestimation—the social costs of carbon may well be higher. Moreover, a consistent theme emerges from these errors: in many cases, the IWG adopted "political" solutions, designed to appease all sides, where more difficult technical decisions were called for.

C. International Leakage

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.[113]

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.[114]

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, the last sentence does not follow from the sentences that precede it.

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, 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

[113] For recent discussions in the law review literature, see Michael P. Vandenbergh & Mark A. Cohen, *Climate Change Governance: Boundaries and Leakage*, 18 NYU Envt'l L.J. 221 (2010); Robert N. Stavins, *A Meaningful U.S. Cap-and-Trade System to Address Climate Change*, 32 Harv. Envtl. L. Rev. 293 (2008); Jonathan B. Wiener, *Climate Change Policy, and Policy Change in China*, 55 UCLA L. Rev. 1805 (2008).
[114] IWG Report at 11-12.

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.[115] 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).[116]

Consider another way in which leakage occurs. 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 one hundred percent, with the result that the American regulation produces no social gains and only costs. 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 (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.[117] It is also possible that foreign manufacturing processes are less carbon-intensive than American manufacturing processes.[118] In any of these cases, the reduction in carbon emissions from American manufacturers will only be partly offset—say 10 or 30 or 70 percent—by the increase in carbon emissions from foreign manufacturers. The extent of these offsets will vary from industry to industry.

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 excessively

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[115] Foreign production of automobiles might increase carbon emissions because energy is "dirtier" in, for instance, China than it is in the United States. Because Chinese electricity producers rely more heavily on coal and have installed fewer pollution-controlling technologies than American producers, each unit of energy produced in China generates correspondingly greater quantities of carbon emissions. Abebe & Masur, *supra*.

[116] For a discussion, see, e.g., Mustafa H. Babiker, *Climate Change Policy, Market Structure, and Carbon Leakage*, 65 J. Intern'l Econ. 421 (2005).

[117] Neither of these possibilities appears to be true, but they could be in other industrial contexts.

[118] This is likely true with respect to some countries, but not with respect to others. The United States ranks 92nd among the 133 nations (for which there are data) in the carbon intensity of its energy production. That is to say, 91 countries produce less carbon per unit of energy than the United States; 41 produce more. World Resources Institute, Climate Analysis Indicators Tool, Carbon Intensity of Energy Use in 2006, *available at* http://cait.wri.org/cait.php?page=carberg&mode=view. Notably, China, Australia, Ireland, Israel, Italy, and Denmark have less carbon-efficient economies than the United States; Japan, India, Canada, and most European countries are more efficient. *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.

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, 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, and it is highly unlikely that they could eliminate leakage.[119] Because these laws do not yet exist, agencies must take into account leakage.

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 all Annex B countries in the Kyoto treaty (major developed nations) adopt a carbon tax and the non-Annex B countries do not.[120] 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 to 25 percent as a result of leakage. Constraints on emissions in the European Union, the United States, and other Annex B countries would increase production and consumption of carbon-intensive goods by 15 to 25 percent in China, India, and other non-Annex B countries.

These figures are suggestive of the problem of leakage if climate regulation were to occur in the United States alone rather than in all Annex B countries. Leakage would now occur not only in China and India, but also in the European Union (the largest economy in the world), Japan (the second largest national economy), Canada (the tenth largest), and Australia (the thirteenth largest). To be sure, the European Union already has a system of carbon regulation, which would limit leakage to some extent, but there is some question how effective that system actually is.[121] Overall, leakage in a scenario in which the United States alone (or the United States and the European Union) engage in carbon regulation, and other countries do not, would certainly be higher than 15 to 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 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 i comes to results that conflict with other studies that estimate leakage rates from as little as 3 percent to

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[119] *See* Paul-Erik Veel, *Carbon Tariffs and the WTO: An Evaluation of Feasible Policies*, 12 J. Int'l Econ L. 749, 755-60 (2009).

[120] Joshua Elliott, Ian Foster, Sam Kortum, Todd Munson, Fernando Pérez Cervantes, & David Weisbach, *A Quantitative Examination of Trade and Carbon Taxes* (unpub. m.s., 2010).

[121] *See* Frank Convery, Denny Ellerman, and Christian De Perthuis, The European Carbon Market in Action: Lessons From the First Trading Period (2008), available at http://mit.dspace.org/bitstream/handle/1721.1/44619/MITJPSPGC_Rpt162.pdf?sequence=1.

more than 100 percent.[122] None of these studies examine the specific case in question where the United States but no other country (or only the European Union) adopt significant constrains 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 used by agents that regulate products like mortor vehicles that draw on petroleum as their energy source. Petroleum is traded on global markets to a much greater degree than coal is, and thus susceptible to greater leakage. Similarly, regulations concerning methods of production, such as the production of steel, are much more susceptible to leakage than regulations concerning domestic usage, such as regulations of the efficiency of automobiles[123] or small electric motors.[124] 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 currently take account of this? It would be wrong for agencies to assume that leakage is zero or very low because a climate treaty that eliminates leakage will eventually come into existence. A climate treaty might or might not eventually come into existence. 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 of other countries. This is not true for virtually all other forms of regulation. Consider regulation of arsenic in municipal water supplies.[125] 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 by Americans.

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[122] Joseph Aldy & William A Pizer, *The Competitiveness Impacts of Climate Change Mitigation Policies*, The Pew Center on Global Climate Change (2009) (noting problem of leakage); Babiker, supra (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.M. Babiker & T.F. Rutherford, *The Economic Effects of Border Measures in Subglobal Climate Agreements*, 26 *Energy J.* 99, 106-08 (2005) (estimating leakage from 7 percent to 39 percent dependant on whether the U.S. 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, Border Tax Adjustments and the EU-ETS: A Quantitative Assessment, CPB Documents 171 (2008) (estimating a 3.3 percent leakage rate for reductions made by the European Union).

[123] *See* Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 Fed. Reg. at 14,196 (Dep't of Transportation March 30, 2009).

[124] Energy Conservation Program: Energy Conservation Standards for Small Electric Motors, 75 Fed. Reg. 10,874 (Dep't of Energy March 9, 2010).

[125] *See, e.g.,* National Primary Drinking Water Regulations, 66 Fed. Reg. 6976, 6981 (Jan. 22, 2001) (codified at 40 C.F.R. pts. 9, 141, 142).

By contrast, when American industry reduces carbon emissions, the beneficiaries are mainly foreigners. The population of the United States is less than five 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. Most of the costs will be passed on to consumers, who are mostly Americans. Market share will be lost in both domestic and foreign markets because foreign manufacturers do not face the same regulations.

Thus, we can distinguish the *global SCC* and the *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 (including Americans). For example, if global food prices increase as a result of harm to 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 EPA may end up regulating climate emissions:

> 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 . . . .[126]

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."[127]

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.[128] 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 EPA should regulate, or attempt to regulate, foreign motor vehicle manufacturers, even those who

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[126] 42 U.S.C. § 7521(a)(1).
[127] 42 U.S.C. § 7602(g).
[128] Recently affirmed by the Supreme Court in *Morrison v. National Australia Bank*, 2010 WL 2518523 (U.S. 2010).

produce only for their domestic markets. Such an interpretation is questionable, to say the least.[129]

However, the Clean Air Act has a clause that provides for extraterritorial effect with respect to countries that reciprocate by regulating their domestic industry so as to benefit the United States.[130] This suggests that neither the domestic nor global SCC should be used. 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 analysis, which does 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 Part 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 to 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. DOT took the midpoint, 7 percent, and multiplied it by the $33 global SCC, yielding a domestic SCC of approximately $2.[131]

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.[132] Speculations as to the sensitivity of the American economy are 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

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[129] For a recent explanation for the presumption of extraterritoriality in litigation involving environmental laws, see Jonathan Remy Nash, *The Curious Legal Landscape of the Extraterritoriality of U.S. Environmental Laws*, 50 Va. J. Int'l L. 997 (2010).
[130] 42 U.S.C. § 7415(c).
[131] See supra.
[132] *See, e.g.,* Mark A. Delucchi, S*ummary of the Non-Monetary Externalities of Motor Vehicle Use*, UCD-ITS-RR-96-3 (9) rev. 1, Institute of Transportation Studies, University of California, Davis, originally published September 1998, revised October 2004, pp. 49-51. Available at http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-96-03(09)_rev1.pdf.

moral obligations to foreigners, then American regulatory agencies should discount (partially or completely) the negative effects of American activities on foreigners. Philosophers take different positions on this question. Cosmopolitans believe that moral obligations to help or not to harm others do not turn on their nationality; communitarians and nationalists believe that they do.[133] 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.[134] 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?[135]

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 one sixth and 1/2000th of an American life.[136] 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.

There are two reasons for doubting that agencies should treat costs to foreigners and costs to Americans as 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.[137] However, countries disagree about how significant climate change is, and how the costs of responding to climate

[133] See generally Simon Caney, Justice Beyond Borders: A Global Theory 3-16 (2005) (describing competing approaches to international relations including the cosmopolitan, realist, statist, and nationalist approaches).

[134] See W. Kip Viscusi and Joseph E. Aldy, *The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World*, 27 J Risk & Uncertainty 5, 26-30 & tble. 4 (2003) (showing a range of valuations for a statistical life from $0.8 million in South Korea to $19.9 million in the United Kingdom, in 2000 U.S. dollars).

[135] *See* Eric A. Posner & Cass R. Sunstein, Dollars and Death, 72 *U. Chi. L. Rev.* 573 (2005).

[136] Wojciech Kopczuk, Joel Slemrod, and Shlomo Yitzhaki, The Limitations of Decentralized World Redistribution: An Optimal Taxation Approach, 49 *European Econ. Rev*. 1051, 1075 (2005).

[137] *See* Cass Sunstein, *Of Montreal and Kyoto: A Tale of Two Protocols*, 31 Harv. Envt'l. L. Rev. 1 (2007).

change should be allocated among countries. Countries must resolve these disagreements—in effect, choosing a global SCC—before they can cooperate.

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.[138] 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 wrong 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.

In the years leading up to the Montreal Protocol, which restricts the use of chlorofluorocarbons and other compounds that cause stratospheric ozone depletion, 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.[139] 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.

Second, the treatment of foreigners is a highly sensitive political question. 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. Congress is the institutional actor best positioned to decide these normatively and politically fraught questions. 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.[140] An interagency regulatory group, working behind closed doors with no public notice or participation, is not the proper mechanism for resolving such issues.

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).[141] It emerges from three climate models of questionable reliability.

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[138] *See* Rachel Brewster, *Stepping Stone or Stumbling Block: Incrementalism and National Climate Change Legislation* 28 Yale L. & Pol'y Rev. 245 (2010) (arguing that incremental domestic action may retard the development of an international agreement on climate change).
[139] *See id.* at 9-17 (describing U.S. domestic regulation and international negotiations).
[140] Elena Kagan, *Presidential Administration*, 114 Harv. L. Rev. 2245 (2001).
[141] This is in addition to the fact that scientific uncertainty makes cost-benefit analysis difficult. *See supra* Part II.B.

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 rather than technocratic. 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. regulators need not fear leakage as much and can regulate carbon more strictly. 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 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.

The broader point is that cost-benefit analysis will be ineffective whenever a regulation raises principally normative and political questions, rather than technocratic 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 has little purchase.

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 DOT failed to take into account the SCC.[142]

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. 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 actual figure that emerges from climate models. A climate treaty could also render agency regulation unnecessary by creating a cap-and-trade scheme. 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 provides that the government must treat the treaty-based SCC as if it were the real social cost of carbon, 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.[143] 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 (for example, that a high SCC would encourage rather than discourage other countries to join a climate treaty). If Congress will not act, then the Obama administration should suspend Executive Order 12,296 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);[144] and initiate notice-and-comment rulemaking as a second-best means of addressing the political questions that cost-benefit analysis cannot answer.

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[142] Ctr. for Biological Diversity, 538 F.3d 1172.

[143] *See* 5 U.S.C. § 706(2)(A) (ordering courts to set aside agency action that is "arbitrary [or] capricious").

[144] 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.

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, 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 cost-benefit executive order does not provide a foundation for further agency regulation. Congressional or executive intervention is necessary.

Readers with comments should address them to:

Professor Jonathan S. Masur
University of Chicago Law School
1111 East 60th Street
Chicago, IL 60637
jmasur@uchicago.edu

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