CARBON TAX REVIEW AND UPDATING: INSTITUTIONALIZING AN ACT-LEARN-ACT APPROACH TO U.S. CLIMATE POLICY

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Abstract

The design of climate change policy must address a number of key uncertainties, including the impacts of climate change, the economics of a carbon tax, and the global effort to combat climate change. A periodic review of each of these issues would provide new information and analysis, which could be used to reduce uncertainty and inform the updating of a carbon tax over time. This article proposes and describes a straightforward and predictable approach for reviewing and updating a U.S. carbon tax. Under this "structured discretion" approach, the U.S. president would recommend an update to the carbon tax every five years, which would be based on government agency reviews of the environmental, economic, and multilateral conditions related to climate change. Following a process that is modeled after the expedited consideration of trade agreements, the U.S. Congress would agree to vote on the recommended carbon tax update. This process could also be coordinated with the timing of the emission mitigation pledging rounds under the 2015 Paris Climate Agreement. I suggest that the institutionalization of such an act-learn-act approach to carbon tax design could improve the political viability of a carbon tax and promote its adaptability to changing environmental, economic, and multilateral conditions, which would likely increase net social welfare over time.

Keywords: carbon tax, policy evaluation, decision-making under uncertainty, international environmental agreements, retrospective review

JEL Codes: D81, F53, H23, Q54, Q58

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INTRODUCTION

The design of climate change policy faces the challenge of several key uncertainties. First, the potential benefits of reducing carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions are characterized by an array of uncertainties related to long-term economic growth, climate sensitivity, the effectiveness of emission mitigation policy, and the climate risk mitigation actions undertaken through adaptation and geoengineering (IWG SCC 2010; Greenstone et al. 2013; Aldy 2015; Taylor 2015). Second, the potential costs of reducing emissions are characterized by uncertainties about the relative costs of low-carbon and carbon-intensive energy sources, technological innovation, consumer responsiveness to energy price changes, as well as the cost-effectiveness of policy design (Aldy et al. 2010). Third, the distributional consequences of climate change and climate policy responses are also characterized by uncertainty (Burtraw et al. 2009; Metcalf 2009; Rausch et al 2011; Carleton et al. 2018). Finally, the competitiveness impacts of emission mitigation policy are uncertain, and may vary with the relative stringency of policies around the world, transportation costs, and the energy intensity of manufacturing (Ederington et al. 2005; Aldy and Pizer 2015; Aldy 2017b).

The efficiency and political durability of efforts to combat climate change will depend on the extent to which climate policy design accounts for these uncertainties and incorporates approaches to update policy in response to new information. Economists have long suggested that pricing carbon through a carbon tax could deliver incentives for cost-effective abatement, maximize social welfare (depending on how the tax rate is set), and produce revenues that could be used to address distributional concerns (e.g., Metcalf 2009; Aldy 2013). However, environmental stakeholders have questioned whether a carbon tax would deliver sufficient emission mitigation to combat climate change (Aldy 2016). Nevertheless, the implementation of a carbon tax would also create opportunities for learning over time about the effect of a tax on emissions and environmental outcomes, its economic impacts (e.g., welfare, distribution, revenue, competitiveness), and global progress in combating climate

change. This means that to be effective, a carbon tax policy should be designed to include an approach for reviewing its performance and updating it in light of this learning. This "act-learn-act" approach integrates climate policy into a decision-making under uncertainty framework (e.g., Manne and Richels 1992). Failure to account for uncertainties in carbon tax design risks implementing a carbon tax schedule that may appear appropriate today, but would likely be either too high or too low once some of the climate change uncertainties have been resolved in the future. Establishing a decision-making process that explicitly recognizes key uncertainties can ensure that policy actions create information that reduces uncertainties over time and that provides the basis for revisions to the carbon tax. Thus, such a policy framework would increase the likelihood of getting the price right on carbon. Moreover, in order for a carbon tax policy – and climate change policy more generally – to be politically viable and durable, it is also likely that it will need to be adaptive (Carlson and Burtraw 2019).

Such an iterative approach is also consistent with the pledge and review framework under the 2015 UN Paris Agreement, which requires countries to submit mitigation pledges, undergo expert and peer review on their progress in fulfilling their pledges, and participate in periodic rounds of multilateral review and updating of pledges. Incorporating a regularly-scheduled review and updating of *domestic* mitigation policies would inform and complement the international policy architecture, and would increase the credibility of mitigation pledges under the Paris Agreement by implementing these voluntary pledges through legally-binding domestic policies.

This article, which is part of a symposium on options for adding mitigation certainty to a carbon tax,[1] proposes and describes a straightforward and predictable approach for reviewing and updating a U.S. carbon tax. Under this "structured discretion" approach, the U.S. president would recommend an update to the carbon tax every five years, which would be based on government agency reviews of the

[1] The other articles are Brooks and Keohane (2020), which provides a political economy perspective on carbon tax provisions aimed at increasing the certainty of emission quantities; Hafstead and Williams (2020), which discusses a carbon tax adjustment mechanism; and Metcalf (2020), which presents an emissions assurance mechanism.

environmental, economic, and multilateral conditions related to climate change. While most of the discussion here focuses on the design of a U.S. carbon tax, the general concept (and institutional design) is applicable to all countries implementing emission mitigation policies. The remainder of the article is organized as follows. The next section presents an overview of carbon tax review and updating, including an illustration of how to institutionalize such a structured discretionary approach, with particular attention to the environmental, economic, and multilateral reviews that would inform an expedited Congressional approval process that is modeled after the U.S. approach to trade agreement review and approval. This is followed by an analysis of the potential welfare gains of carbon tax updating. The penultimate section examines carbon tax review and updating in the context of multilateral climate policy, including the potential for coordinating action at the domestic and international levels. The final section discusses policy implications and makes some suggestions for future research in this area.

INSTITUTIONALIZING CARBON TAX REVIEW AND UPDATING: AN ILLUSTRATION

This section presents an illustration of a structured discretionary approach to adjusting a carbon tax in light of new information over time, whereby the legislation establishing a carbon tax creates a periodic review and updating process. First I discuss the design of carbon tax rates and present a brief example of the review and updating concept. Then I explain how the review and updating process could work, including suggesting some guiding principles for the carbon tax review and then describing three specific reviews that are key for learning about and resolving policy-relevant uncertainty concerning the performance of the carbon tax: (1) a review of the environmental and public health impacts of climate change and climate change policy (the “Environmental Review”); (2) a review of the economic, distributional, and revenue implications of the domestic carbon tax (the “Economic Review”); and (3) a

review of the progress of the global community in implementing emission mitigation pledges (the "Multilateral Review"). I conclude with a description of the expedited Congressional updating process.

Designing Carbon Tax Rates

Many carbon tax proposals – introduced both by academics and in the U.S. Congress – established an initial carbon tax coupled with an annual growth rate in the tax, typically specified as the sum of a fixed rate plus a measure of inflation. Aldy (2016) suggested setting the carbon tax at $25 per ton with a five percent plus inflation annual growth rate.[2] The "Raise Wages, Cut Carbon Act of 2019" called for a tax of $40 per ton of CO_2 that increased at an annual rate of 2.5 percent plus an inflation adjustment (H.R. 3966, 116th Congress).[3] Finally, the Climate Leadership Council (2017) has proposed a carbon tax starting at $40 per ton of CO_2 and increasing 5 percent per year above inflation.

For the purposes of this article, I assume that any future carbon tax would be structured along these lines – i.e., an initial level of the tax, say $X per ton, coupled with an annual growth rate of Y percent plus inflation. Let's suppose that this initial carbon tax level and growth rate reflect the current state of policy-relevant evidence on climate policy design, but that over time, new information becomes available. How can the design of a carbon tax institutionalize an updating process that incorporates and responds to this new information?

Although Congress traditionally authorized regulatory agencies to review and update regulations under energy and environmental law, the institutional challenge for a carbon tax, is that Congress almost never gives the Executive Branch authority to update tax policy (Hines and Logue 2015). For example, the federal taxes on gasoline and diesel have not changed since legislation was passed in 1993. Excise taxes on alcohol and tobacco only change after Congress passes a bill the

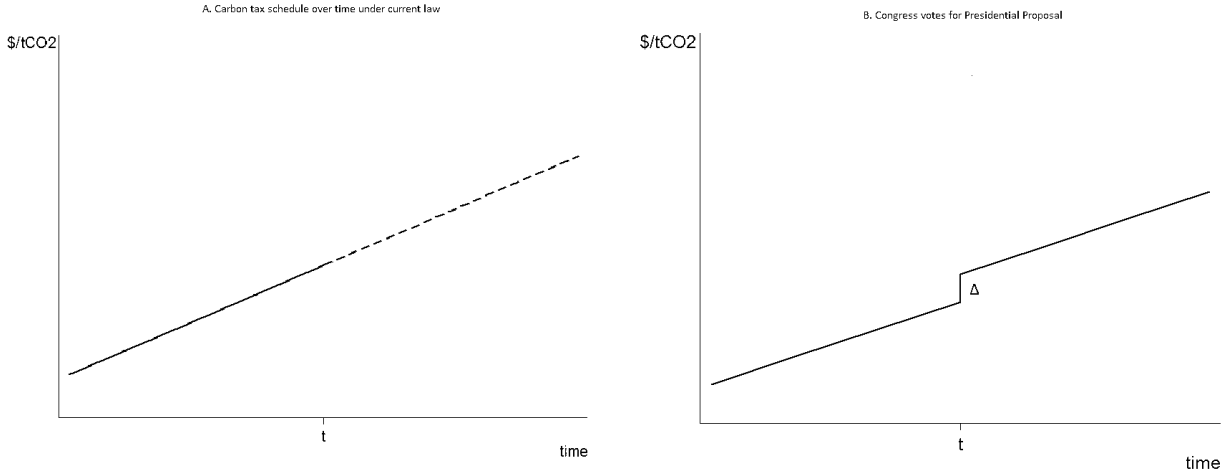
[2] See also Morris (2013) and Metcalf (2019) for similar examples.
[3] For other legislative examples, also see the "Energy Innovation and Carbon Dividend Act of 2018" (H.R. 7173, 115th Congress), the "MARKET CHOICE Act" (H.R. 6463, 115th Congress), the "American Opportunity Carbon Fee Act of 2017" (S. 1639, 115th Congress), and the "Climate Protection and Justice Act of 2015" (S. 2399, 114th Congress).

President signs into law. Congress sometimes delegates authority for technical adjustments to the Treasury Department and Internal Revenue Service – e.g., revising tax brackets for inflation – but it has never granted the Treasury Department the discretionary authority to adjust tax *rates*. Indeed, over the past decade, legislative proposals for a U.S. carbon tax include specific tax rates and annual growth rates, with no discretion delegated to the executive branch. Moreover, this institutional barrier may undermine political support for a carbon tax; environmental advocacy groups in particular may not support a carbon tax if it is difficult to adapt it to new information over time.

A Brief Example of Review and Updating

The structured discretionary approach I propose here addresses these institutional and political challenges by requiring a periodic review and updating of a carbon tax over time (see panel A of figure 1, which shows a carbon tax that increases over time). The review process begins with the president soliciting reports from executive branch experts on the science, economics, and multilateral impacts of a carbon tax and, as a result, proposes an increase of Δ in the carbon tax, to take effect at time t. If Congress votes in favor of the proposal, then the tax increases by Δ at time t (see panel B of figure 1). If Congress rejects the proposal, then the carbon tax schedule will continue under current law (as indicated in panel A). The counterfactual policy assumed here is a carbon tax that increases indefinitely (i.e., there is no sunset provision). Thus, the proposed review and updating approach is not a mechanism for extending or reauthorizing a policy; it simply institutionalizes a periodic process for adjusting the tax in response to new information.

Figure 1. Carbon Tax Policy over Time with Review and Updating



Notes: Panel A illustrates a carbon tax schedule over time as set out in a carbon tax law. The president proposes a change in the level of the tax for time t. If Congress votes for the proposal, then it takes effect as illustrated in Panel B.

Source: The author.

Guiding Principles for the Reviews

The legislation creating the review and updating process would also need to establish guiding principles for conducting the environmental, economic, and multilateral reviews. This would ensure that decision-makers, stakeholders, and the public understand how to evaluate the information presented in the reviews and the rationale for any recommended changes in the carbon tax. Major U.S. energy and environmental laws often include principles and goals to focus the attention of regulators as they carry out their required tasks. Likewise, the White House has issued regulatory review guidance that includes policy principles dating back to the Carter Administration in the 1970s (Aldy 2014a). Some potential

guiding principles for the carbon tax review, which are based on environmental policy precedent and intended to be illustrative rather than predictive, are described below.

Maximize net social benefits

First, the carbon tax could be reviewed with the goal of ensuring that it maximizes net social benefits. In terms of policy precedent for this principle, in 1981, Executive Order 12291 -- "Federal Regulation" -- established a "requirement" that "regulatory objectives shall be chosen to maximize the net benefits to society" (Section 2(c)). In 1993, Executive Order 12866, "Regulatory Planning and Review," replaced this Reagan-era order, establishing the principles and process for the review of federal government regulations that continue to guide regulatory policy today. Executive Order 12866 includes the requirement that regulatory agencies "shall assess both the costs and benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs" (Section 1(b)(6)). This framework reflects a multi-decade bipartisan consensus for weighing benefits and costs in regulatory policy. Although a carbon tax is clearly not a regulatory tool, its rationale – to correct a market failure – clearly falls within the standard rationale for regulatory interventions in the economy.

An emissions standard

Second, an emissions standard could be one of the principles for reviewing the carbon tax. More specifically, the United States could establish emission benchmarks – i.e., target emission levels for specific years in the future or for cumulative emissions over a period of time – that would serve as the primary environmental objective of the domestic carbon tax.[4] In fact, the United States has adopted voluntary emission goals under past agreements – to limit emissions to their 1990 levels (1992 Framework Convention on Climate Change), to limit emissions "in the range of 17 percent" below 2005

[4] See Metcalf (2020) and Hafstead and Williams (2020) for further discussion of emission benchmarking.

levels by 2020 (2009 Copenhagen Accord and 2010 Cancun Agreements), and to limit emissions to 26 to 28 percent below 2005 levels by 2025 (2015 Paris Agreement) – which could serve as the basis for the emission benchmarking. Alternatively, the carbon tax legislation could establish its own emission goals through 2050 – as was done in the 2009 American Clean Energy and Security Act (H.R. 2454, 111th Congress) – and beyond.

A temperature principle

Third, a temperature principle could guide the review of the performance of the carbon tax. The United States has been a party to agreements that have established aspirational goals to limit warming to below 2°C (2009 Copenhagen Accord) and to limit warming to well below 2°C (2015 Paris Agreement) relative to pre-industrial temperatures. Implementing such a principle would involve adapting to new science about the relationship between emissions and temperatures as well as new information on emission abatement efforts in other countries. For example, if new research showed that warming will be greater for a given quantity of emissions over this century than previous estimated, then the analysis undertaken based on this principle would suggest an increase in the carbon tax. This temperature principle could complement the emissions principle.[5]

Competitiveness principle

Fourth, a competitiveness principle could be used to ensure consideration of any adverse competitiveness impacts of the carbon tax on American manufacturing. Such a principle could draw attention to whether the domestic carbon tax causes domestic firms to have lower output or profits as a result of competing with foreign firms that are subject to less ambitious carbon taxes or other emission mitigation policies. It would also highlight the importance of mitigation efforts in other countries.

Impact on multilateral efforts

[5] Given that there has been some criticism of a temperature goal (Victor and Kennel 2014), a broader set of impacts-based measures of performance in mitigating climate change risks could also be considered.

Finally, the reviews could be informed by a principle that reflects the impact of the domestic carbon tax on progress in the multilateral effort to combat climate change. For example, does the U.S. carbon tax leverage additional mitigation effort by other countries? Would a significant ramping up of the domestic tax give the United States more negotiating leverage when engaging other countries under the Paris framework?

Summing up

These examples of possible carbon tax review principles vary in their implications for the reviews. Some principles – such as the emissions principle – would likely depend on only one of the reviews, while others would likely require a synthesis across reviews. For example, the principle to maximize net social benefits would draw on both the environmental impacts and the economic reviews and the competitiveness principle would require integration of the economic and multilateral reviews. Each principle could provide clear guidance for how to evaluate the performance of the carbon tax and, in light of the review of this performance, how to update the carbon tax. I describe the three types of reviews in more detail next.

The Environmental Review

The review of the environmental dimensions of climate change would examine the climate science and the impacts from a changing climate in order to determine the need for the carbon tax. This review of climate change science and impacts could build on existing efforts by the government to conduct a comprehensive assessment of climate science. For example, in 2009, the U.S. Environmental Protection Agency (EPA) issued its "Endangerment Finding"[6] for GHGs, which served as the rationale and basis for regulating GHG emissions in the transportation sector under the Clean Air Act. In addition, the quadrennial National Climate Assessment, authorized by Congress and produced by the US Global

[6] 74 FR 66496.

Change Research Program, compiles and presents information on the potential climate change damages to the United States (e.g., USGCRP 2018) and could be a key input into the review and updating proposed here.

The large number of categories of climate change impacts – heat-related mortality, coastal infrastructure exposure to storm surge, droughts, forest fires, vector-borne disease risk, etc. – pose a significant challenge to both communicating the latest science on climate impacts and informing the review and updating of a carbon tax. Synthesizing evidence and analysis of climate damages into a dollars per ton of CO_2 measure would translate the science into a form that could be used to directly guide tax review and updating. Specifically, the social cost of carbon (SCC) – the economic damage associated with the incremental emission of a ton of CO_2 – could integrate information on damages into a usable metric. Updating the SCC would be a critical input for updating a carbon tax, especially if policymakers establish maximizing net social benefits as a guiding principle. The U.S. government began producing a SCC for use across the federal government in 2009 (IWG SCC 2010). Since then, various scholars have identified ways of improving the methods for estimating the SCC and proposed how to institutionalize its use in U.S. policy making (Greenstone et al. 2013; Pizer et al. 2014; Metcalf and Stock 2017; National Academy of Sciences 2017).

The Economic Review

The review of the economics (e.g., costs, benefits, efficacy) of the carbon tax could serve as a performance evaluation of the policy. However, there is little precedent for such an analysis of tax policy. The Treasury Department and the Congressional Joint Committee on Taxation have produced revenue estimates of specific tax provisions – and occasionally distributional analyses of major tax bills – but they generally do not analyze the efficacy, costs, and benefits of tax instruments. This analytic

omission is all the more unfortunate in this context (i.e., taxing pollution to correct a market failure), because a benefit-cost analysis could play a critical role in setting the tax rate.

The experience with regulatory policy does, however, provide some precedent for evaluating the economic impacts of a carbon tax. U.S. regulatory agencies, especially those with the necessary energy and environmental expertise for conducting a carbon tax analysis (e.g., EPA, the Department of Energy - DOE), have a long track record of undertaking ex ante benefit-cost analyses of their regulatory proposals. A similar framework could be used for the review of a carbon tax. To be clear, the review of the carbon tax could best inform policymakers if it looks both forward (i.e., it presents a *prospective* analysis of the benefits and costs and other economic impacts of potential future changes to a carbon tax) and backward (i.e., it presents a *retrospective* analysis of the economic performance of the carbon tax to date). Specifically, the prospective carbon tax analysis could draw on the guidance that the U.S. Office of Management and Budget provides for regulatory impact analysis (Circular A-4), while the retrospective analysis could draw on the guidance issued by the Administrative Conference of the United States in its 2014 recommendation to regulatory agencies about how to undertake retrospective review of regulations (Aldy 2014a).[7]

A full assessment of the impacts of the carbon tax on the U.S. economy could rely on a variety of analytic and empirical tools. Simulation models of the U.S. energy economy could be calibrated to estimate the effects of a carbon tax for both prospective and retrospective analyses. For example, the EPA and the U.S. Energy Information Administration (EIA) have frequently used such models in their ex ante analyses of carbon pricing policies (e.g., the 2009 American Clean Energy Security Act, carbon tax scenarios in the EIA's Annual Energy Outlook). These models could also be calibrated to look backward to evaluate the actual performance and impact of a carbon tax on the U.S. economy and energy system.

[7] The plenary of the Administrative Conference of the United States adopted Recommendation 2014-5, "Retrospective Review of Agency Rules," on December 4, 2014. https://www.acus.gov/sites/default/files/documents/Recommendation%25202014-5%2520%2528Retrospective%2520Review%2529_1.pdf

Empirical statistical methods could be used to provide complementary estimates of the impacts of a carbon tax. For example, researchers could draw on the empirical strategies used to estimate the economic and environmental impacts of cap-and-trade programs, such as the Southern California Regional Clean Air Incentives Market (RECLAIM) and the Nitrogen Oxide Budget Program (Fowlie et al. 2012; Deschênes et al 2017; Curtis 2018). In addition, researchers could draw on previous research that has used energy prices as a proxy for carbon prices to estimate how a carbon tax may affect employment, output, and trade (Kahn and Mansur 2013; Aldy and Pizer 2015). Ex post statistical evaluations of carbon tax policy could also be used to account for the geographic variation in overlapping policies, such as the CO_2 cap-and-trade programs in California and the northeast states (Regional Greenhouse Gas Initiative) as well as state renewable power mandates.

The Multilateral Review

The review of other countries' progress in mitigating their emissions can also play an important role in informing the ambition of a country's carbon tax (or related emission mitigation policies). There may not be sufficient political support in the United States for an ambitious carbon tax if other major economies are not undertaking comparably stringent policies. For example, more than two decades ago, the Byrd-Hagel Senate Resolution called on U.S. negotiators to the 1997 UN Kyoto Conference to agree to emission commitments only if developing countries had also agreed to emission reductions.[8] In 2017, when President Donald Trump announced his intention to withdraw the United States from the Paris Agreement, he complained that it "disadvantages the United States to the exclusive benefit of other countries."[9] This suggests that a key requirement for climate policy in the United States is the comparability of effort among countries in combating climate change (Aldy and Pizer 2016). With this in

[8] S. Res. 98, 105th Congress.
[9] Statement by President Trump on the Paris Climate Accord, Washington, DC, June 1, 2017, https://www.whitehouse.gov/briefings-statements/statement-president-trump-paris-climate-accord/

mind, the review of other countries' domestic emission mitigation programs would indicate whether U.S. efforts to mitigate the risks posed by climate change are in line with (i.e., comparable to) those of its partners around the world (Aldy 2017a).

The review and analysis of other countries' progress would also complement the economic assessment. For example, if one country moves forward with a high carbon tax, while other countries fail to implement meaningful mitigation policies, then the costs could be higher and the benefits lower for the leading country (Aldy 2017b). The increase in costs would reflect the potential competitiveness pressures on domestic manufacturing, which could lose market share to producers operating in the untaxed (and otherwise unregulated) markets. To the extent that emissions reduction in the high-tax country occurs in part through emission leakage – the relocation of emission-intensive activities to untaxed markets – then the climate change benefits from domestic emission abatement would be reduced.[10]

Updating the Carbon Tax through an Expedited Legislative Process

The legislation establishing the carbon tax would also create a process for updating the tax over time. Specifically, based on the environmental, economic, and multilateral reviews, the President would submit a carbon tax adjustment recommendation to Congress (in the form of a Congressional resolution) every five years. It is important to note that the carbon tax statute would provide the President with the authority to adjust only the level and the annual growth rate of the tax, which would be in effect for a specified number of years into the future (e.g., five years).

The carbon tax statute would bypass certain elements of the standard legislative process to ensure that a vote is held on the recommended carbon tax adjustment. For example, the Congressional

[10] Such a review of other countries' actions could also inform the implementation of a border tax adjustment – a tariff on the carbon content of imports from countries with less ambitious climate policies than the United States. A number of carbon tax proposals have included a border tax adjustment, including the MARKET CHOICE Act of 2018 (H.R. 6463, 115th Congress), the Climate Leadership Council (2017), and Aldy (2016).

resolution would not be subject to either amendment or a Senate filibuster. In addition, the statute would specify that the resolution could come directly to the floors of the House of Representatives and Senate (i.e., without any explicit action by committees of jurisdiction or Congressional leadership). Given the revenue implications of the carbon tax adjustment, the House of Representatives would take the initial action on the resolution. The statute would specify that Congress has a certain number of working days to deliberate on the recommendation before it would be required to vote on it. If both chambers vote in favor of the recommendation, then the President would sign it into law. If at least one chamber votes against the recommendation, then the existing carbon tax schedule would remain in effect.

The creation (as part of the carbon tax design) of such a streamlined, mandatory process for considering a presidential recommendation reflects the importance of both building and restricting institutions for the updating process. Although a future Congress could always amend this process and potentially subject it to the conventional hurdles for legislation,[11] this type of expedited process already exists for rejecting new agency regulations (under the 1996 Congressional Review Act), and Congress has not revised these procedures in the more than two decades since Congressional review of regulations became law.[12]

In addition, the proposal for streamlined Congressional consideration has precedent in U.S. trade policy.[13] Since the 1970s, under the Trade Policy Act, Congress has agreed to hold votes on trade agreements negotiated by the Executive branch without filibuster or amendment. As with the proposed approach to carbon tax review and updating, the Trade Policy Act requires reports to Congress that show that the trade agreement submitted by the executive branch adheres to the trade policy principles and negotiating objectives contained in the authorizing statute.

[11] For a description of the standard legislative process, see, e.g., Schoolhouse Rock: America – I'm Just a Bill Music Video, https://www.youtube.com/watch?v=FFroMQlKiag.
[12] 5 USC 802 describes the expedited procedure under the Congressional Review Act.
[13] For a more detailed discussion of the analogy with trade policy, see Aldy (2017b).

The concept of an expedited review and approval process for adjustment to a carbon pricing policy also has a precedent in U.S. climate policy debates. In 2009, Senators Maria Cantwell and Susan Collins co-sponsored the CLEAR Act, which would have established emission caps that declined at a fixed percentage rate annually and provided the president with the authority to recommend to Congress an increase or decrease in the emission cap.[14] The bill also would have required the president to submit a report to accompany any proposed cap modification, and Congress would have had 30 days to consider the proposal through an expedited process.[15]

POTENTIAL WELFARE GAINS OF REVIEW AND UPDATING

A large economic literature has emphasized that policymakers can account for the uncertainty characterizing environmental problems by designing hybrid policy approaches that incorporate elements of both price instruments (such as a tax) and quantity instruments (such as emission caps), which would make society better off than if a tax or quantity policy were implemented alone (e.g., Weitzman 1974; Pizer 2002). In this section, I illustrate the potential welfare gains from the review and updating process using a highly stylized example. Consider two hypothetical carbon tax policies. Under policy 1, Congress passes a carbon tax that the president signs into law in 2010. This law implements an economy-wide carbon tax starting in 2015. The tax rate for 2015 and each year thereafter equals the SCC for that year, as set out in the initial report of the Interagency Working Group on the Social Cost of Carbon (2010). This means that the carbon tax would be $28/tCO2 in 2015, increasing to $32/tCO2 in 2020.[16] I assume that the carbon tax remains unchanged through 2020 (i.e., there is no mechanism for updating the carbon tax unless Congress chooses to pass a new law under its standard procedures).

[14] Section 4(a)(2)(C) of S. 2877 , 111th Congress.
[15] The U.S. Senate did not take any action on this bill.
[16] All SCC estimates cited here correspond to the IWGSCC's preferred values associated with a 3 percent discount rate and deflated to 2018 dollars using the Consumer Price Index–Urban deflator (commonly used for inflation

Under policy 2, Congress passes a law with the same tax schedule – i.e., the rate begins at $28/tCO2 in 2015 and increases annually – but it also includes a review and updating process every five years. Under this policy, the President can make a recommendation in 2015 to update the carbon tax effective in 2020, with the recommendation subject to a mandatory Congressional vote. Let's also suppose that improved understanding of the science and economics of climate damages over the 2010-2015 period results in the Interagency Working Group on the Social Cost of Carbon (2015) issuing updated SCC estimates. In this scenario, the President would recommend (based on the updated SCC estimate) a higher tax rate of $51/tCO2 in 2020. Assuming Congress votes in favor of this recommendation, the carbon tax law would be amended in 2015 and the change would take effect in 2020.[17]

adjustments). This example does not include inflation adjustments, as tax rates are presented in constant 2018 dollars. In practice, carbon taxes would be implemented in nominal dollars and adjusted annually for inflation.

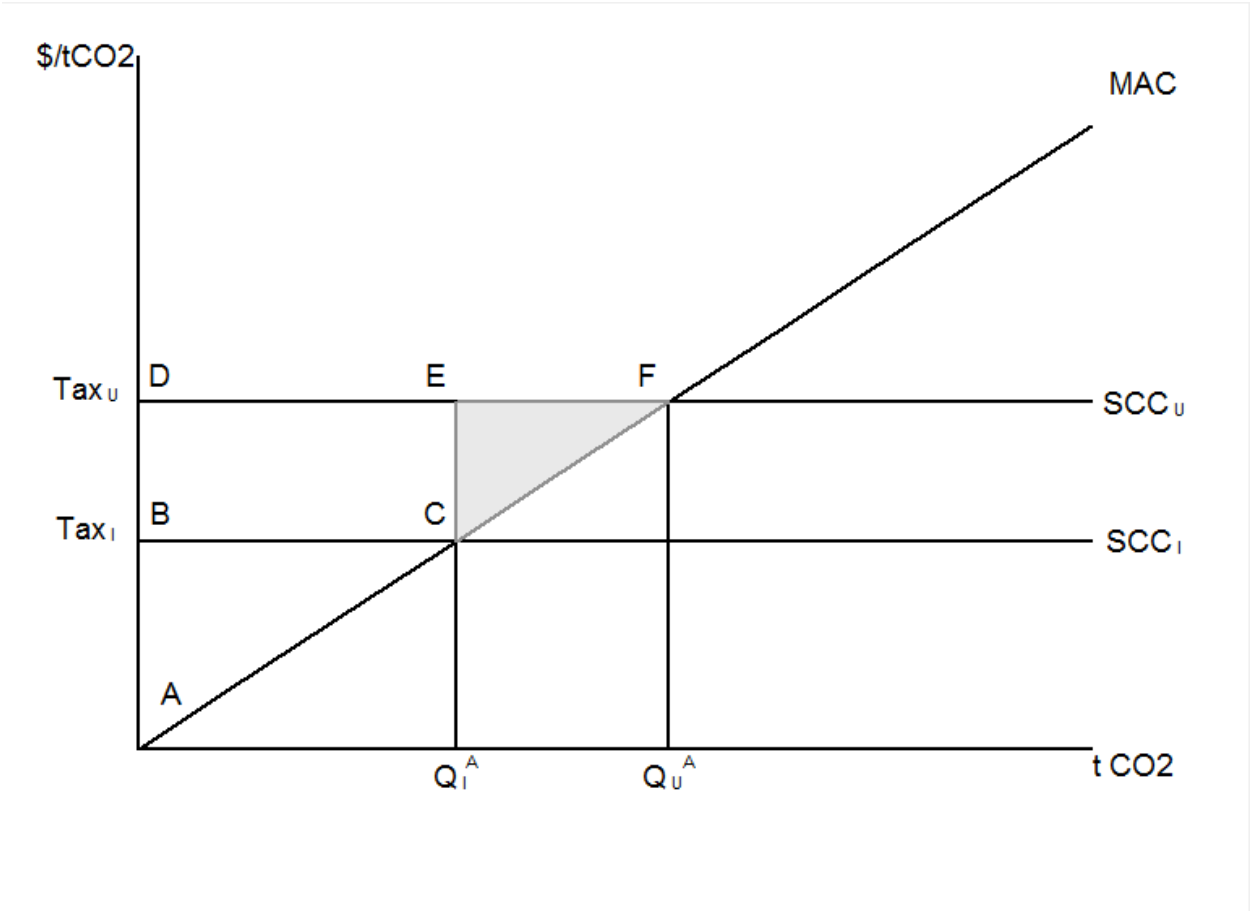
[17] Note that this illustration does not include the subsequent iterations of review and updating that would occur under policy 2 – the 2020 review to update the 2025 tax, the 2025 review to update the 2030 tax, etc.

Figure 2 illustrates the welfare gains of the carbon tax updating in 2020 under policy 2. With the opportunities for reducing emissions cost-effectively represented through an economy-wide marginal abatement cost function (MAC), and the initial tax set equal to the initial SCC ($Tax_I = SCC_I$), emissions abatement under policy 1 would be equal to Q^A_I. At the time the tax law is passed (in 2010), with the tax set to go into effect in 2015, the expected welfare gains from the tax would be the triangle ABC – i.e., the difference between the social benefits of reducing Q^A_I emissions and total abatement costs. The updated estimate of the SCC (SCC_U) reflects new information about climate damages in 2015. In this case, the expected welfare gains of Tax_I in 2020 under policy 1 would be indicated by the area ACDE.

When the new information about the SCC is used to update the tax under policy 2, such that in 2020 $Tax_U = SCC_U$, the quantity of abatement increases to Q^A_U, yielding larger net social benefits (represented by the triangle ADF). The increase in social welfare in the year 2020 of moving from policy 1 (no updating) to policy 2 (with review and updating) is indicated by triangle CEF. The magnitude of this increase (i.e., the size of triangle CEF) will depend on the size of the change in the carbon tax rates and the resulting change in emission abatement, as represented by the MAC function. In the example presented here, updating from Tax_I ($32) to Tax_U ($51) increases U.S. emission abatement by about 500 MMTCO2 ($Q^A_U - Q^A_I$ in Figure 2). This translates into a welfare gain of about $4.8 billion for the year 2020; the annual welfare gains for subsequent years would be comparable, assuming the updating continues to occur every five years.[18]

[18] See the on-line supplementary materials for details on these calculations and a description of the key assumptions.

Figure 2. The Welfare Gains of Updating a Carbon Tax based on New Climate Damages Information



Notes: Tax_I = the tax rate initially set in law. Tax_U = the updated tax rate based on the 2015 review. MAC = the marginal abatement cost function. SCC_I = the social cost of carbon estimated in 2010. SCC_U = the social cost of carbon estimated in 2015. Q_I^A = the quantity of emissions abated under Tax_I. Q_U^A = the quantity of emissions abated under Tax_U.

Source: The author.

CARBON TAX REVIEW AND UPDATING AND THE PARIS AGREEMENT

U.S. climate policy exists within a global climate policy architecture in which countries pledge emission mitigation goals and implement domestic programs to achieve their goals to meet these

commitments. A process for reviewing and updating a domestic carbon tax would complement several critical elements of the current international climate policy architecture.

Enhancing the Credibility of Pledge and Review

The 2015 UN Paris Agreement represents a pledge and review approach to international climate policy (Aldy and Stavins 2007): countries make voluntary commitments to mitigate their emissions and subject these voluntary pledges to review or, as referred to in various multilateral contexts, transparency and policy surveillance (Aldy 2014b). The carbon tax review process I have presented here could be an important input to the Paris Agreement's "transparency mechanism" (Article 13, Paris Agreement) -- i.e., the "review" in pledge and review, and the updating of the carbon tax could provide the basis for the periodic updating of mitigation goals set forth in the Paris Agreement (Article 4) -- i.e., the "pledge" in pledge and review.

Moreover, in such contexts—i.e., when parties to an agreement cannot resort to coercive enforcement – signaling the credibility of a voluntary pledge through legally-binding domestic policies (e.g., a carbon tax) that are subject to a public review of the policies' impacts would increase the effectiveness of international agreements.[19] This suggests that the review and updating of a domestic carbon tax could provide such credibility, with the public dissemination of information and analysis about the performance of the carbon tax through domestic review demonstrating the country's effort to deliver on its pledge.

Coordinating Domestic Updating and Mitigation Pledging under the Paris Agreement

To illustrate how this coordination of domestic and international climate policies might work, a U.S. carbon tax updating mechanism could be structured to coincide with the periodic rounds of

[19] Schelling (1956) makes this point in the context of bilateral bargaining and Chayes and Chayes (1991) make this point in the context of multilateral agreements.

emission mitigation pledging that has been institutionalized under the current multilateral climate policy regime. Specifically, the 2015 Paris Agreement calls on countries to update their mitigation pledges ("contributions" in the language of the agreement) in 2020 and every five years thereafter.[20] Thus, as noted earlier, the review and updating of the domestic carbon tax could provide the basis for the U.S. updating of its mitigation pledge in each of these five-year pledging rounds.

Given the process for updating pledges under the Paris Framework, this approach could also provide negotiating leverage for the United States. For example, under the structured discretionary approach to updating, the President could propose an increase in the carbon tax immediately before a multilateral pledging round, but ask Congress to act on the proposal *after* that round. Then, during the pledging negotiations, U.S. negotiators would signal that the ambition of other countries' pledges would determine whether the President would encourage Congress to approve the proposed carbon tax increase. More specifically, if other countries make more ambitious mitigation pledges – and perhaps complement these pledges with credible signals of more ambitious domestic implementation – then the President would work with Congress to pass the carbon tax increase, but if other countries' mitigation pledges are insufficiently ambitious, then the President would ask Congress to vote against the carbon tax increase proposal.

A Model for Other Countries

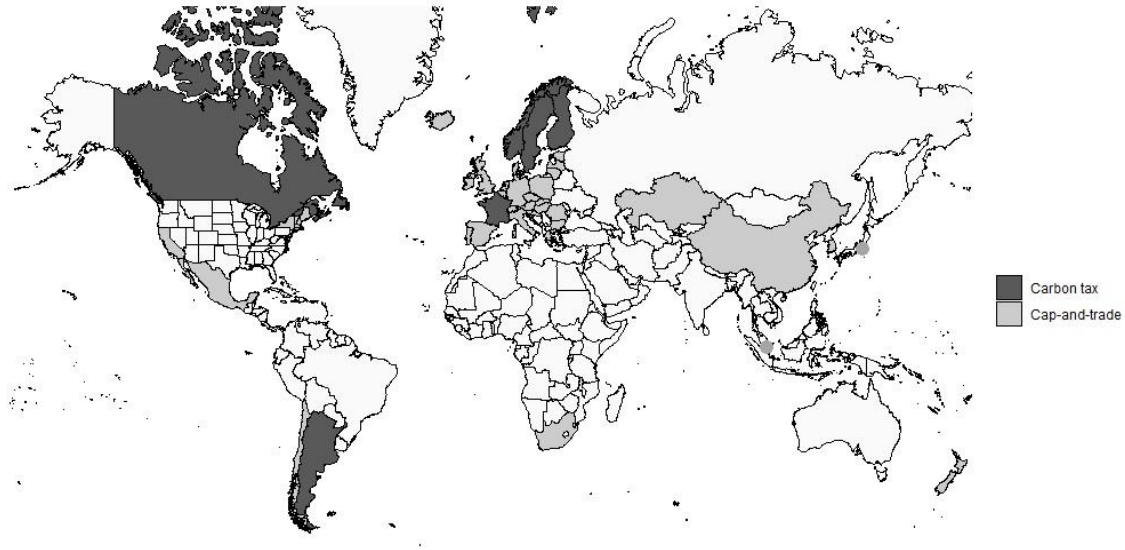
A U.S. carbon tax that includes a process of reviewing and updating could also serve as a model for other countries – in terms of both the domestic implementation of emission mitigation pledges and the domestic review of the policy's performance, which could feed into the Paris Agreement's multilateral mechanism for review. This approach also illustrates how domestic carbon taxes could could be used to achieve quantitative goals for national emissions. Every country that submitted an emission

[20] Section III, Paragraph 24 of Paris Agreement, URL: http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.

mitigation pledge under the Paris Agreement — which includes every major developed and developing country — did so in the form of a quantitative goal (Aldy and Pizer 2016; Aldy et al. 2016). These quantitative emission mitigation pledges may, at first glance, appear to imply that a country should focus only on a quantity-based policy instrument, such as cap-and-trade, rather than a carbon tax. However, in practice, no country that has implemented a cap-and-trade program has designed it to cover all of the emissions covered by its international emission mitigation commitments or pledges. For example, the EU Emissions Trading Scheme covered approximately half of the EU GHG emissions that were used to determine compliance with its 2008-2012 Kyoto emissions target. China's plans for a national cap-and-trade program will initially focus only on the power sector. The balance of emission reductions are to be achieved through other policy instruments, such as fuel economy standards, tailpipe emission standards, land use policy, and, in some countries (e.g., Canada, Denmark, France, Mexico, Sweden, and Switzerland), a carbon tax.

In fact, the World Bank (2018) estimates that the countries that together account for more than one-half of global GHG emissions plan to use -- or will consider using -- carbon pricing as an approach for implementing their nationally determined contributions under the 2015 Paris Agreement. As shown in figure 3, national and sub-national governments around the world are pursuing both tax and cap-and-trade programs. The example of reviewing and updating a U.S. carbon tax could be generalized to other countries and other policy instruments. In particular, the iterative nature of the review and updating of pledges under the international climate policy architecture designed in Paris creates an opportunity for countries to coordinate their domestic policy reviews and updates with their international commitments.

Figure 3. National and Sub-National Carbon Pricing Policies



Source: Constructed by the author based on World Bank (2018).

CONCLUSIONS: POLICY IMPLICATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

This article has shown how institutionalizing an act-learn-act approach in the design of a carbon tax can ensure that domestic climate change policy adapts to new information about the risks and opportunities related to climate change. In particular, I have presented an approach that would regularly review the economic, environmental, and multilateral impacts of a domestic carbon tax in order to inform an expedited Congressional vote on carbon tax changes recommended by the president. Such an approach increases the likelihood that learning will improve the implementation of domestic climate change policy, increase social welfare, and enhance the political durability of a carbon tax. In addition, I have argued that a carbon tax review and updating scheme could serve as a model for other countries and provide negotiating leverage to facilitate greater emission mitigation ambition under the Paris Agreement. I conclude with a discussion of policy implications and advantages as well as some suggestions for future research in this area.

Ensuring the Predictability of Carbon Tax Policy

While some observers may have concerns that this review and updating approach would weaken the appeal of a carbon tax by undermining the certainty of the carbon price, a well-designed approach could actually help to ensure the predictability of carbon tax policy. First, the review and updating process could be staggered over time to provide reasonable periods of price certainty.[21] Second, the information provided through the review and reporting of the latest scientific, economic, and multilateral implications of a carbon tax would enable the private sector to formulate expectations about the future of carbon tax policy in a way that is similar to how forward guidance and related communications provided by central banks can inform markets.[22] This suggests that regularly-timed communications about the future of carbon tax policy could make future policy changes more predictable.

This type of communication would likely require more frequent publication of data, beyond the reports accompanying the periodic presidential recommendation. For example, some of the key data that would be used as inputs in the analysis supporting these recommendations – such as CO_2 emissions, tax revenues, energy prices, as well as reporting on the actions by other countries – could be released by government agencies on an annual (or more frequent) basis. To enhance the information value of such data releases, the agencies could describe the implications of the data in light of the policy principles that Congress establishes under the review mechanism. For example, suppose that Congress establishes a 2030 emission goal that is X percent below 2005 levels. Annual reporting of CO_2 emissions could signal to stakeholders whether the current carbon tax policy is on track to achieve this objective. If it appears

[21] In the example presented here, the reviews would occur every five years, with any change in the tax rate effective for five years after the review. This means the carbon tax would be known with certainty for a 5-10 year period.

[22] In fact, there is an extensive literature showing that central banks have enhanced the predictability of their monetary policy decisions through such regular communications (Blinder et al. 2008; Kool and Thornton 2012).

that emissions may exceed this goal, then stakeholders could update their expectations about a future change in the carbon tax rate.

Legislative Implications

The updating of a carbon tax would require a Congressional vote and thus the mobilization of political capital for a potential legislative battle every five years. For reasons unrelated to climate policy, the president may opt not to initiate such a battle and thus decide against proposing a tax update. Moreover, future Congresses may be more or less inclined to vote for a change in the carbon tax in response to a given change in information. This means that political factors – which are distinct from the results of the environmental, economic, and multilateral reviews – may determine the evolution of carbon tax rates over time. In such cases, the resulting carbon tax rates may be inconsistent with the objective of maximizing social welfare and/or inadequate to achieve long-term climate change goals.

Ensuring the Policy is Adapted to Reflect the Most Recent Evidence

The institutionalization of a regular, periodic discretionary process of review and updating would ensure the integration of the most recent, rigorous evidence into the design and implementation of climate policy. There are many examples of such adaptive policy design in regulatory reviews of U.S. energy and environmental policy. For example, the Clean Air Act authorizes the EPA to review and revise, when necessary, the national ambient air quality standards (NAAQS) for major air pollutants, such as fine particulate matter and ozone, every five years.[23] Under the 2007 Energy Independence and Security Act, Congress requires DOE to review and update minimum energy efficiency standards for appliances every six years.[24]

Broadening Political Support and Increasing Legitimacy of the Carbon Tax Policy

Integrating a review and updating mechanism into the design of a carbon tax has important implications for both securing an initial political coalition that is strong enough to approve a carbon tax

[23] 42 USC 7409(d).
[24] 42 USC 6313(a)(6(C).

and ensuring its long-term durability. More specifically, the business community and conservative leaders have proposed swapping a carbon tax for existing regulatory authorities, such as under the Clean Air Act (Climate Leadership Coalition 2017), while the environmental community has expressed reservations about a carbon tax because of the possibility of uncertain and inadequate emission outcomes (Aldy 2016). This suggests that a carbon tax that includes a built-in updating procedure could act as a hybrid price-quantity instrument that bridges the divisions among these stakeholders (Brooks and Keohane 2020). By providing information to stakeholders and the public on the performance and impacts of the carbon tax, the review process would help to increase the legitimacy of the policy. Reliance on the insights, methods, and communication approaches of regulatory review (prospective and retrospective) for the evaluation of carbon tax policy would result in greater transparency concerning the policy's impacts, which could broaden public acceptance (Cogliansese 2013; Aldy 2014a; Sunstein 2014).

Suggestions for Future Research

There are several areas of research that would be useful to inform the review and updating of a carbon tax.

Identify the appropriate timing for carbon tax reviews and updating

The technical challenges and resource requirements of the reviews suggest that further analysis is needed to identify the appropriate timing for the review and updating of the carbon tax. Past experience with regulatory reviews, in which the EPA and the DOE occasionally fell behind schedule on NAAQS and appliance standard reviews and rule-makings, respectively, suggests a downside to conducting frequent reviews.

Determine initial carbon tax levels and the form of updates

I have assumed that the carbon tax would be set at some level – i.e., X dollars per ton -- that would increase by some rate Y plus inflation each year. Thus, research is needed on how the decision to include a review and updating mechanism would likely affect the choice of X and Y at the start of the carbon tax program. In particular, does the opportunity to periodically update the tax level or the rate of change affect (on either welfare or political economy grounds) the choice of the initial tax level and growth rate? It is also important to determine whether to adjust the tax rate or the annual growth rate in the carbon tax during the updating stage. Such research could also address the issue of certainty versus predictability in the carbon price.

Evaluate how updating influences political support for a carbon tax

The review and updating mechanism proposed here considers an instrument design that addresses the political challenges that confront U.S. climate change policy. Further research is needed on how such a mechanism would affect the likelihood that some environmental advocates would agree to halt conventional regulatory approaches to GHG emissions, such as under the Clean Air Act, in exchange for a tax, as some in the business community have called for. The opportunity to update a carbon tax over time – in a way that is analogous to the periodic updating of air quality standards under the Clean Air Act – may alleviate concerns among environmental advocates that swapping a tax for existing regulatory approaches would undermine the efficacy of long-term climate change policy.[25]

Assess the implications of coordinating updating with Paris Agreement pledging

The opportunity to coordinate domestic policy review with the multilateral system of review and pledge updating highlights the need for additional research in this area. For example, how would such coordination affect incentives for pledging in the future? How should the domestic update be coordinated with the multilateral pledging schedule in order to leverage action by others? What are the prospects for such leveraging if multiple countries simultaneously pursue this strategy?

[25] See Aldy (2018) for further discussion of this topic.

Examine the complementarity of structured discretionary and emission benchmarking approaches

Finally, research is needed on how the proposed structured discretionary approach to updating could complement a carbon tax approach that focuses on reducing emission uncertainty through emission benchmarking (e.g., Metcalf 2020). The emission-benchmarking approach targets one source of uncertainty — the uncertainty surrounding emission outcomes for a given carbon tax profile. Put another way, the benchmarking approach enables an assessment – and tax updating – that is based on pricing carbon through a carbon tax that achieves our quantitative emission goals. But what if we learn that our goals should change? The structured discretionary approach discussed here would *institutionalize* the review and updating process, thus facilitating carbon tax adjustments that are able to account for a broader set of environmental, economic, and multilateral considerations over time. This suggests that research is needed to explore how carbon tax design could include both emission benchmarking -- which would address the short-term uncertainty over attaining emission goals -- with structured discretion -- which would incorporate learning about the scientific, environmental, economic, and multilateral dimensions of the climate change problem.

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References

Aldy, Joseph E. (2017a). Designing and Updating a U.S. Carbon Tax in an Uncertain World. *Harvard Environmental Law Review* 41: 28-40.

Aldy, Joseph E. (2017b). Frameworks for Evaluating Policy Approaches to Address the Competitiveness Concerns of Mitigating Greenhouse Gas Emissions. *National Tax Journal* 70(2): 395-420, 2017.

Aldy, Joseph E. (2016). Long-term Carbon Policy: The Great Swap. Published by the Progressive Policy Institute. November 2016. http://www.progressivepolicy.org/wp-content/uploads/2016/11/The-Great-Swap-1.pdf (accessed March 3, 2019).

Aldy, Joseph E. (2015). Pricing Climate Risk Mitigation. *Nature Climate Change* 5: 396-398.

Aldy, Joseph E. (2014a). Learning from Experience: An Assessment of the Retrospective Reviews of Agency Rules and the Evidence for Improving the Design and Implementation of Regulatory Policy. Report produced for the Administrative Conference of the United States, Washington, DC. November. https://www.acus.gov/sites/default/files/documents/Aldy%2520Retro%2520Review%2520Draft%252011-17-2014.pdf (accessed March 20, 2019).

Aldy, Joseph E. (2014b). The Crucial Role of Policy Surveillance in International Climate Policy. *Climatic Change* 126(3-4): 279-292.

Aldy, Joseph E. (2013). The Case for a U.S. Carbon Tax. *Oxford Energy Forum* 91: 13-16.

Aldy, Joseph E., Krupnick Alan, Newell Richard, Parry Ian, and William Pizer. (2010). Designing climate mitigation policy. *Journal of Economic Literature* 48(4): 903-34.

Aldy, Joseph E. and William A. Pizer (2016). Alternative Metrics for Comparing Domestic Climate Change Mitigation Efforts and the Emerging International Climate Policy Architecture. *Review of Environmental Economics and Policy* 10: 3-24.

Aldy, Joseph E. and William A. Pizer. (2015). Competitiveness Impacts of Climate Change Mitigation Policies. *Journal of the Association of Environmental and Resource Economists* 2(4): 565-595.

Aldy, Joseph E., William Pizer, Massimo Tavoni, Lara Aleluia Reis, Keigo Akimoto, Geoffrey Blanford, Carlo Carraro, Leon E. Clarke, James Edmonds, Gokul C. Iyer, Haewon C. McJeon, Richard Richels, Steven Rose, and Fuminori Sano. (2016). Economic Tools to Promote Transparency and Comparability in the Paris Agreement. *Nature Climate Change* 6(11): 1000-1004.

Aldy, Joseph E. and Robert N. Stavins. 2007. Architectures for an International Global Climate Change Agreement: Lessons for the Policy Community. In: *Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World*, Joseph E. Aldy and Robert N. Stavins, eds. New York: Cambridge University Press, 350-367.

Blinder, Alan, Michael Ehrmann, Marcel Fratzscher, Jakob De Haan, and David-Jan Jansen. (2008). Central bank communication and monetary policy: A survey of theory and evidence. *Journal of Economic Literature*, *46*(4), 910-45.

Brooks, Susanne A., and Nathaniel O. Keohane. 2020. "The Political Economy of Hybrid Approaches to a Carbon Tax: A Perspective from the Policy World." *Review of Environmental Economics and Policy* xx:xx-xx.[Typesetter – please insert correct final citation/title information; this article is part of the same symposium]

Burtraw, Dallas, Richard Sweeney, Margaret Walls. (2009). The incidence of US climate policy: alternative uses of revenues from a cap-and-trade auction. *National Tax Journal*, 497-518.

Carleton, Tamma, Michael Delgado, Michael Greenstone, Trevor Houser, Solomon Hsiang, Andrew Hultgren, Amir Jina, Robert Kopp, Kelly McCusker, Ishan Nath, James Rising, Ashwin Rode, Hee Kwon Seo, Justin Simcock, Arvid Viaene, Jiacun Yuan, and Alice Tianbo Zhang. (2018). Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits. *EPIC Working Paper.*

Carlson, Ann E. and Dallas Burtraw. (2019). Conclusion. In: *Lessons from the Clean Air Act: Building Durability and Adaptability into US Climate and Energy Policy*, A. Carlson and D. Burtraw, eds., Cambridge University Press, 225-238.

Chayes, Abram and Antonia Handler Chayes. (1991). Compliance without Enforcement: State Behavior under Regulatory Treaties. *Negotiation Journal* 7(3): 311-330.

Climate Leadership Coalition. (2017). The Conservative Case for Carbon Dividends. February. http://clcouncil.org/media/2017/03/The-Conservative-Case-for-Carbon-Dividends.pdf (accessed March 29, 2019).

Coglianese, Cary. (2013). Moving Forward with Regulatory Lookback. *Yale Journal on Regulation*, *30*(57).

Curtis, E. Mark. (2018). Who loses under cap-and-trade programs? the labor market effects of the nox budget trading program. *Review of Economics and Statistics*, *100*(1), 151-166.

Deschênes, Olivier, Michael Greenstone, and Joseph Shapiro. (2017). Defensive investments and the demand for air quality: Evidence from the NOx budget program. *American Economic Review*, *107*(10), 2958-89.

Ederington, Josh, Arik Levinson, and Jenny Minier. (2005). Footloose and pollution-free. *Review of Economics and Statistics*, *87*(1), 92-99.

Fowlie, Meredith, Stephen P. Holland, and Erin T. Mansur. (2012). What do emissions markets deliver and to whom? Evidence from Southern California's NOx trading program. *American Economic Review*, *102*(2), 965-93.

Greenstone, Michael, Elizabeth Kopits, and Ann Wolverton. 2013. Developing a social cost of carbon for US regulatory analysis: A methodology and interpretation. *Review of Environmental Economics and Policy 7*(1): 23-46.

Hafstead, Marc A. C., and Roberton C. Williams III. 2020. Designing and Evaluating a U.S. Carbon Tax Adjustment Mechanism to Reduce Emissions Uncertainty. *Review of Environmental Economics and*

Policy xx (xx):xx-xx. [Typesetter – please insert correct final citation/title information; this article is part of the same symposium

Hines, James and Kyle D. Logue. (2015). Delegating Tax. *Michigan Law Review* 114: 235-274.

Interagency Working Group on the Social Cost of Carbon. (2010). Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. Washington, DC: US Government.

Interagency Working Group on the Social Cost of Carbon. (2015). Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. Washington, DC: US Government.

Kahn, M. E., & Mansur, E. T. (2013). Do local energy prices and regulation affect the geographic concentration of employment?. *Journal of Public Economics 101*: 105-114.

Kool Clemens J.M., and Daniel L. Thornton. (2012). How Effective Is Central Bank Forward Guidance?. *Federal Reserve Bank of St. Louis Working Paper Series*, (2012-063).

Manne, Alan Sussmann. and Richard G. Richels. 1992. *Buying greenhouse insurance: the economic costs of carbon dioxide emission limits*. MIT Press.

Metcalf, Gilbert. (2019). *Paying for Pollution: Why a Carbon Tax is Good for America*. Oxford University Press.

Metcalf, Gilbert E. 2020. An Emissions Assurance Mechanism: Adding Environmental Certainty to a U.S. Carbon Tax. *Review of Environmental Economics and Policy* xx (xx):xx-xx. [Typesetter – please insert correct final citation/title information; this article is part of the same symposium

Metcalf, Gilbert E. (2009). Designing a carbon tax to reduce US greenhouse gas emissions. *Review of Environmental Economics and Policy 3*(1): 63-83.

Metcalf, Gilbert E., & Stock, James H. (2017). Integrated assessment models and the social cost of carbon: a review and assessment of US experience. *Review of Environmental Economics and Policy*, *11*(1), 80-99.

Morris, Adele C. (2013). Proposal 11: The Many Benefits of a Carbon Tax. *15 Ways to Rethink the Federal Budget*, Brookings, 63-69.

National Academy of Sciences. (2017). Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon. National Academies Press: Washington, DC.

Pizer, William A. (2002). Combining price and quantity controls to mitigate global climate change. *Journal of public economics*, *85*(3), 409-434.

Pizer, William A., Matthew Adler, Joseph E. Aldy, David Anthoff, Maureen Cropper, Kenneth Gillingham, Michael Greenstone, Brian Murray, Richard Newell, Richard Richels, Arden Rowell, Stephanie Waldhoff, and Jonathan Wiener. (2014). Using and improving the social cost of carbon. *Science*, *346*(6214), 1189-1190.

Rausch Sebastian, Gilbert E Metcalf, John M. Reilly, and Sergey Paltsev. (2011). Distributional impacts of a US greenhouse gas policy. *US Energy Tax Policy*, 52-112.

Schelling, Thomas C. (1956). "An Essay on Bargaining." *American Economic Review* 46(3): 281-306.

Sunstein, Cass. (2014). The Regulatory Lookback. *BUL Rev.*, *94*, 579.

Taylor, Jerry. (2015). The Conservative Case for a Carbon Tax. *Washington, DC: The Niskanen Center*.

USGCRP. (2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart, eds. U.S. Global Change Research Program, Washington, DC.

Victor, David G., and Charles F. Kennel. (2014). Climate policy: ditch the 2 C warming goal. *Nature News*, *514*(7520), 30.

Weitzman, Martin L. (1974). Prices vs. quantities. *The review of economic studies*, *41*(4), 477-491.

World Bank. (2018). State and Trends of Carbon Pricing 2018. Washington, DC: World Bank Group.

CARBON TAX REVIEW AND UPDATING: INSTITUTIONALIZING AN ACT-LEARN-ACT APPROACH TO U.S. CLIMATE POLICY

Online Appendix. Calculating the Welfare Implications of a Carbon Tax Review and Updating Mechanism

Policy Cases

Policy 1: Carbon tax signed into law in 2010 establishes a carbon tax starting in 2015 equal to the 2015 social cost of carbon based on IWGSCC (2010). The tax increases each year consistent with the social cost of carbon in this report. The tax in 2020 is set equal to the social cost of carbon for the year 2020 in this initial IWGSCC report.

Policy 2: Carbon tax signed into law in 2010 establishes a carbon tax starting in 2015 equal to the 2015 social cost of carbon based on IWGSCC (2010). The tax increases each year consistent with the social cost of carbon in this report. On five-year intervals, starting in 2015, the president reviews the science, economics, and diplomacy of a carbon tax and proposes an update to the Congress that it must vote on. The update would take effect five years after the proposal, i.e., 2020. In this scenario, the president recommends an updated carbon tax for 2020 based on the updated social cost of carbon from the IWGSCC (2015) report. Congress votes for the recommendation. The tax in 2020 is set equal to the social cost of carbon for the year 2020 in the updated IWGSCC report.

Social Cost of Carbon

The initial social cost of carbon estimates are drawn from 3% average column of Table A1 (page 39) of IWGSCC (2010). The updated social cost of carbon estimates are drawn from 3% average column of the executive summary table (page 3) of IWGSCC (2015). All social cost of carbon estimates are converted to 2018 dollars using the CPI-Urban deflator accessed from the Federal Reserve Economic Data website hosted by the St. Louis Federal Reserve Bank (https://fred.stlouisfed.org/series/CPIAUCSL#0).

Marginal Abatement Cost Function

The 2014 Annual Energy Outlook (EIA 2014) includes two carbon tax side cases: (1) a carbon tax of $10/tCO2 starting in 2015 that increases 5 percent plus inflation each year, and (2) a carbon tax of $25/tCO2 starting in 2015 that increases 5 percent plus inflation each year (https://www.eia.gov/outlooks/aeo/data/browser/#/?id=17-AEO2014&region=1-0&cases=ref2014~co2fee10~co2fee25&start=2011&end=2040&f=A&sourcekey=0 and https://www.eia.gov/outlooks/archive/aeo14/assumptions/pdf/0554(2014).pdf). All carbon tax rates are converted to 2018 dollars using the CPI-Urban deflator. Combining these side cases with the AEO2014 reference case enables a back-of-the envelope construction of an economy-wide marginal abatement cost function. I estimate linear marginal abatement cost functions based on the 2020 tax rates ($14 and $35/tCO2 in 2018$, respectively) and abatement associated with the two cases (315 MMTCO2 and 921 MMTCO2, respectively). For the illustration in the text, I employ this function, Q^A = 26.39*tax, in which the quantity of abatement is measured in millions of metric tons of carbon dioxide, based on the high end tax rate in comparison with the reference case. Alternative assumptions about the marginal abatement cost function yield welfare gains that differ (plus and minus) by as much as 15 percent as the estimate of $4.8 billion in the text.

Key Assumptions

This back-of-the-envelope analysis is predicated on a number of key assumptions. Let me elaborate on these here.

(1) I assume that the updating mechanism in 2015 tracks exactly the updated social cost of carbon and that Congress votes for the recommended change.
    a. I assume that the president only considers the new, updated social cost of carbon when proposing an adjustment to the carbon tax.
    b. I assume a probability of 1 that Congress votes for the presidential recommendation.

(2) I assume that the marginal benefits of reducing a ton of carbon dioxide can be represented by the IWGSCC estimates of the social cost of carbon.
    a. I assume that integrated assessment models provide credible information about the damages associated with carbon dioxide emissions. Nordhaus 2014, cf., Pindyck 2013.
    b. I assume that the social cost of carbon is a credible representation of the marginal benefits, which depends on emission abatement efforts in other countries and the global trajectory of emissions over time.
    c. I assume that the global benefits of reducing emissions is the appropriate welfare measure (e.g., Pizer et al. 2014).
    d. This approach explicitly assumes that the marginal benefits function – by being equal to the SCC in each corresponding case – is horizontal over the plausible levels of emission abatement.

(3) I assume that the 2014 Annual Energy Outlook provides a credible basis for the marginal abatement cost function.
    a. While more recent Annual Energy Outlooks have included carbon tax side cases, the 2014 Annual Energy Outlook best matched the hypothetical policy scenario. This AEO started its carbon tax in 2015. It also provides some lead time until 2020 for firms to consider abatement opportunities, in contrast to the carbon tax side cases in the 2018 Annual Energy Outlook.
    b. I assume that the linear tax-abatement quantity relationship for taxes below $35/tCO2 can be applied to tax rates as high as $51/tCO2.
    c. I abstract away from tax-interaction effects.
    d. I abstract away from international emission leakage that may reduce the net emission reduction when calculating gross benefits.