RESOLVING THE INHERENT UNCERTAINTY OF CARBON TAXES

INTRODUCTION

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Carbon dioxide emissions from fossil fuel combustion represent the single largest driver of anthropogenic climate change.[1] These emissions reflect the failure of businesses and individuals to account for the impacts of their fossil-fuel-use decisions on the global climate. Since these decision-makers bear an infinitesimally small fraction of the global climate change damages associated with their fossil fuel consumption, they do not have the incentive to reduce carbon pollution voluntarily. Economists have long called for pricing carbon to reflect the social damages associated with the impacts of carbon dioxide emissions on the global climate.[2]

By internalizing the climate change externalities associated with carbon emissions, carbon pricing can promote cost-effective emission abatement, deliver strong incentives for innovation, and improve governments' fiscal positions.[3] Through carbon pricing, governments provide strong incentives to private firms and individuals to identify and exploit the lowest-cost ways to reduce emissions and invest in the development of new technologies that could enable even greater emission mitigation in the future.[4] Carbon pricing by national governments may also illustrate a country's mitigation effort and serve as a focal point that enables progress in negotiating multilateral climate agreements.[5]

The prospect of pricing carbon through carbon tax or cap-and-trade policies has drawn considerable interest in the policy world. At the September 2014 United Nations climate summit, 73 countries and more than 1,000 companies advocated for "pricing

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1 *See Summary for Policymakers*, *in* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2013—THE PHYSICAL SCIENCE BASIS: CONTRIBUTION OF WORKING GROUP I TO THE FIFTH ASSESSMENT REPORT OF THE IPCC 3, 13 (2013).

2 *See* William D. Nordhaus, *Economic Growth and Climate: The Carbon Dioxide Problem,* 67 AM. ECON. REV. 341, 341–46 (1977); *see also* Joseph E. Aldy et al., *Designing Climate Mitigation Policy*, 48 J. ECON. LITERATURE 903, 904–05 (2010).

3 Joseph E. Aldy & Robert N. Stavins, *Using the Market to Address Climate Change: Insights from Theory and Experience*, 141 DAEDALUS 45, 45 (2012).

4 Joseph E. Aldy & Robert N. Stavins, *The Promise and Problems of Pricing Carbon*, 21 J. ENV'T & DEV. 152, 152 (2012).

5 *See* Joseph E. Aldy & William A. Pizer, *Alternative Metrics for Comparing Domestic Climate Change Mitigation and the Emerging International Climate Policy Architecture*, 10 REV. ENVTL. ECON. & POL'Y 3, 11 (2016); *see also* Martin L. Weitzman, *Internalizing the Climate Externality: Can a Uniform Price Commitment Help?*, 4 ECON. ENERGY & ENVTL. POL'Y 37, 44 (2015).

carbon."[6] A carbon tax directly sets a price on emissions, either as an output tax on producers of fossil fuels (coal, petroleum products, and natural gas) or a tax on the purchase of fossil fuels.[7] A cap-and-trade system, on the other hand, constrains the aggregate emissions of regulated sources by creating a limited number of tradable emission allowances—in sum equal to the overall cap—and requiring emission sources to surrender allowances to cover their emissions.[8] As firms buy and sell emission allowances, the carbon price emerges in the market. In either case, the carbon pricing policy can apply to the carbon content of fossil fuels marketed in the economy; an "upstream" approach that may be easier to administer than "downstream" approaches focused on end-of-pipe emissions.[9] While these two approaches deliver incentives for cost-effective abatement, they differ in terms of price and quantity certainty. A tax makes the carbon price certain, but the emissions resulting from a carbon tax policy uncertain. In contrast, a cap-and-trade program ensures emissions do not exceed the quantitative cap, but the resulting prices for emissions allowances are uncertain. This trade-off between price certainty and emissions certainty has important environmental, economic, and political economy implications for the design of climate policy.

Considerable attention has focused on designing a cap-and-trade program to address price uncertainty.[10] Meanwhile, designing a carbon tax program that explicitly addresses emissions uncertainty has drawn little attention in the academic and policy literatures. This Symposium serves to address this void in the literature. Dr. Hafstead, Professor Metcalf, and Professor Williams discuss the implementation of a rules-based approach that specifies a carbon tax schedule that automatically adjusts the carbon tax if emission benchmarks are not met.[11] This builds on a proposal in an earlier paper by Prof. Metcalf for a Responsive Emissions Autonomous Carbon Tax ("REACT").[12] Professor Aldy has proposed a structured discretionary approach that would create a fast-track legislative review of carbon tax updates recommended by the President every five years.[13] Professor Murray, Professor Pizer, and Ms. Reichert have reviewed a variety of ways of addressing potential emission reduction shortfalls under a carbon tax, including tax schedules conditional on emission outcomes, use of tax revenues to finance additional

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[6] *See We Support Putting a Price on Carbon*, THE WORLD BANK (Sept. 21, 2014), https://perma.cc/7Q9N-Y8HV.

[7] *See* Gilbert E. Metcalf, *A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change* 11 (Brookings Inst., Hamilton Project Discussion Paper 2007-12, 2007); *see also* Ian Parry et al., *How to Design a Carbon Tax*, *in* FISCAL POLICY TO MITIGATE CLIMATE CHANGE: A GUIDE FOR POLICYMAKERS (R. de Mooij, I. Parry & Michael Keen eds., 2012).

[8] *See* Robert N. Stavins, *A U.S. Cap-and-Trade System to Address Global Climate Change* 8 (Brookings Inst., Hamilton Project Discussion Paper 2007-13, 2007).

[9] Aldy & Stavins, *supra* note 4, at 155.

[10] *See, e.g.*, Darren Samuelsohn, *Behind "Safety Valve" Debate Resides 30+ Years of History*, CLIMATEWIRE (March 11, 2008), https://perma.cc/2H9N-WBCA.

[11] Marc Hafstead et al., *Adding Quantity Certainty to a Carbon Tax Through a Tax Adjustment Mechanism for Policy Pre-Commitment*, 41 HARV. ENVTL. L. REV. F. 41 (2017).

[12] Gilbert E. Metcalf, *Cost Containment in Climate Change Policy: Alternative Approaches to Mitigating Price Volatility,* 29 VA. TAX REV. 381 (2009).

[13] Joseph E. Aldy, *Designing and Updating a U.S. Carbon Tax in an Uncertain World*, 41 HARV. ENVTL. L. REV. F. 28 (2017).

emission abatement, and regulatory backstops—such as Clean Air Act regulatory authority.[14]

The balance of this Introduction provides a foundation on the design of carbon tax policy. Part I describes the role of pricing carbon in contemporary climate change policy, with a summary of experience with carbon tax and cap-and-trade policies around the world. The Part concludes with a brief description of what carbon tax and cap-and-trade policies share in common based on the academic literature. Part II focuses on how tax and cap-and-trade differ in terms of their economic and emission outcomes in light of the uncertainty characterizing the markets and economies in which these instruments are used. These differences have potentially important economic, environmental, and political economy implications for U.S. climate change policy.[15] Part III then highlights the proposals and key findings from each of the papers in this Symposium.

I. CARBON PRICING POLICY

A. Potential Solution to Externality

In the absence of policy, the social cost of burning fossil fuels exceeds the private cost because of "negative externalities": the harms caused by greenhouse gas ("GHG") emissions. As a result, GHG emissions are higher than is socially optimal. Economists agree that incentive-based policy instruments—those that use market forces to influence behavior—can be dramatically less expensive than other regulatory approaches to bring about a given reduction in emissions. Well-designed and implemented market-based policies can minimize the costs of delivering on environmental goals, i.e., they are cost-effective. Cap-and-trade programs and carbon taxes are the two leading examples of incentive-based policies. These policies put a price on emissions thereby raising the private cost to better reflect social cost. The higher price of fossil fuels induces substitution away from these fuels, thereby reducing carbon emissions.

As discussed above, carbon taxes and cap-and-trade programs each place a price on emissions, but the price-setting mechanism differs between the two policies. A carbon tax directly sets a price on emissions, whereas cap-and-trade programs set prices via market forces such that emissions are less than or equal to a cap on aggregate emissions.[16] To

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[14] Brian C. Murray et al., *Increasing Emissions Certainty Under a Carbon Tax*, 41 HARV. ENVTL. L. REV. F. 14 (2017).

[15] A carbon tax and cap-and-trade differ on additional margins as well, especially in terms of the political economy of policy choice and design. For example, the government agencies responsible for implementation would likely differ, as would the relevant Congressional oversight committees. The design of cap-and-trade has traditionally reflected insights gained from the implementation of the Acid Rain Program, while a pollution tax would benefit from experience and guidance on tax policy more broadly. The politics and processes of updating cap-and-trade—a regulatory instrument—could also differ considerably from that of a carbon tax implemented through the tax code. *See generally* Nathaniel O. Keohane, Richard L. Revesz & Robert N. Stavins, *The Choice of Regulatory Instruments in Environmental Policy*, 22 HARV. ENVTL. L. REV. 313 (1998).

[16] A carbon tax is an example of Pigouvian pricing, where a tax is levied on pollution-causing activities equal to their social marginal damages. In the absence of other distortions, this is socially efficient. *See* Arthur C. Pigou, *The Economics of Welfare* (1920). John H. Dales is credited with developing the idea of cap and trade as an

provide real-world context for the considerations in choosing and designing a carbon pricing policy, we start by reviewing cap-and-trade and carbon tax policies in practice.

B. Cap-and-Trade

Since 2005, the European Union has employed a carbon dioxide cap-and-trade program for emissions from power plants, factories, and other large sources.[17] In 2009, a group of northeastern and mid-Atlantic states began implementing a power sector carbon dioxide cap-and-trade program (the Regional Greenhouse Gas Initiative, or RGGI).[18] In 2012, California launched a cap-and-trade program covering most fossil fuel carbon dioxide emissions, including those from large power plants as well as the carbon embedded in refined petroleum products.[19] The California cap-and-trade program has linked with the Province of Québec carbon dioxide cap-and-trade program.[20] China implemented pilot carbon dioxide cap-and-trade programs in five cities and two provinces under its 2011–2015 five-year plan.[21] These efforts all build on the successful performance of cap-and-trade in reducing power sector sulfur dioxide emissions under the U.S. Acid Rain Program.[22]

The 2009–2010 Congressional debate over U.S. energy and climate policy proposals, including the American Clean Energy and Security Act ("ACES"),[23] which passed in the House of Representatives,[24] illustrates the potential design of an economy-wide cap-and-trade program and ways to address concerns about carbon price uncertainty. The ACES bill called for establishing annual GHG emission targets through 2050, including a target of cutting emissions 17 percent below 2005 levels in 2020 and 83 percent below 2005 levels in 2050.[25] These annual targets covered all fossil fuel carbon dioxide emissions and some non-carbon GHG emissions. The national emission caps were then disaggregated into emission allowances giving the holder of the allowance the right to emit one ton of carbon dioxide (e.g., for a power plant) or to market fossil fuels with one ton of embedded carbon (e.g., a petroleum refinery). The program would include a hybrid allocation/auction of emission allowances. Regulated firms could buy and sell these tradable allowances as well as invest in projects outside the capped emission

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alternative to Pigouvian pricing. *See generally* JOHN H. DALES, POLLUTION, PROPERTY, AND PRICES: AN ESSAY IN POLICY-MAKING AND ECONOMICS (1968).

[17] For a general overview of the initial design and implementation of the EU Emission Trading Scheme, see generally A. Denny Ellerman & Barbara Buchner, *The European Union Emissions Trading Scheme: Origins, Allocation, and Early Results*, 1 REV. ENVTL. ECON. POL'Y 66 (2007).

[18] Joseph E. Aldy & Robert N. Stavins, *The Promise and Problems of Pricing Carbon: Theory and Experience,* 21 J. ENVTL. DEV. 152, 164 (2012); *see also* REG'L GREENHOUSE GAS INITIATIVE, ABOUT THE REGIONAL GREENHOUSE GAS INITIATIVE (RGGI) (2017), https://perma.cc/C9RG-9DAD.

[19] *See* Cal. Envtl. Prot. Agency, Air Res. Bd., *Cap-and-Trade Program*, https://perma.cc/LXX4-EW56.

[20] *See* Agreement Between the California Air Resources Board and the Gouvernement du Québec Concerning the Harmonization and Integration of Cap-and-Trade Programs for Reducing Greenhouse Gas Emissions, Sept. 27, 2013, https://perma.cc/5LHC-X3CQ.

[21] *See* Clayton Munnings et al., *Assessing the Design of Three Pilot Programs for Carbon Trading in China* (Res. for the Future, Discussion Paper 14-36, 2014), https://perma.cc/NWJ5-6YCY.

[22] Richard Schmalensee & Robert N. Stavins, *The SO_2 Allowance Trading System: The Ironic History of a Grand Policy Experiment*, 27 J. ECON. PERSPECTIVES 103 (2013).

[23] H.R. 2454, 111th Cong. (2009), https://perma.cc/JEZ5-BGT2.

[24] 155 CONG. REC. H7471 (daily ed. June 26, 2009), https://perma.cc/PKV8-U62J.

[25] *See* H.R. 2454, 111th Cong. §721 (2009), https://perma.cc/JEZ5-BGT2.

sources—such as in the forestry sector or developing countries—and generate so-called carbon emission offsets that could also be used for compliance purposes.

Given considerable uncertainties over the cost of low-carbon technologies, the performance and cost-savings of trading, the availability and costs of offsets, economic growth, energy prices, and other factors, economic models produced a wide range of expected allowance prices.[26] Unexpectedly high allowance prices could impose high costs on families and businesses and undermine the political support for the cap-and-trade program. With the aim of providing a ceiling on allowance prices, the ACES bill included a "carbon allowance reserve."[27] If allowance prices reached a given price specified in the bill, then allowances associated with future years' targets would be sold early at this trigger price. This would reduce some of the uncertainty about carbon prices, in particular the risk of higher than expected allowance prices, and result in higher near-term emissions in exchange for lower emissions in the future. California and RGGI each use similar mechanisms as well; and they also include price floors in their allowance auctions that further limits the variation in prices in their respective allowance markets.

C. Carbon Tax

A number of national and regional governments have employed a carbon tax.[28] In the 1990s, the Governments of Denmark, Finland, Norway, and Sweden imposed carbon taxes on fossil fuel consumption in their economies.[29] These tax rates have evolved over time, and vary among sources in these economies, with energy-intensive manufacturing effectively exempt from the tax in Denmark[30] and Norway,[31] but other sources in Sweden bearing taxes in excess of €100/tCO_2.[32] In practice, an array of loopholes and exceptions in the northern European carbon tax policies have resulted in relatively low effective carbon prices and considerable variation in the price per unit of emissions across types of emission sources.[33] In 2008, the province of British Columbia imposed a carbon tax of C$10/t$CO_2$, which increased in several steps until reaching its current level of C$30/t$CO_2$ in 2012.[34] The British Columbia carbon tax differs from the European

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[26] For illustrations of the range of expected allowance prices under H.R. 2454 across a variety of scenarios, see EPA, EPA ANALYSIS OF THE AMERICAN CLEAN ENERGY AND SECURITY ACT OF 2009 H.R. 2454 IN THE 111TH CONGRESS (2009), https://perma.cc/R2JP-A44V; U.S. ENERGY INFO. ADMIN., REPORT NO. SR/OIAF-2009-05, ENERGY MARKET AND ECONOMIC IMPACTS OF H.R. 2454, THE AMERICAN CLEAN ENERGY AND SECURITY ACT OF 2009 (2009), https://perma.cc/8R29-KUKE.
[27] *See* H.R. 2454, 111th Cong. §726 (2009), https://perma.cc/JEZ5-BGT2.
[28] *See* WORLD BANK GROUP, STATE AND TRENDS OF CARBON PRICING 2016 at 11 (2016), https://perma.cc/CS4Y-5R8A.
[29] Aldy & Stavins, *supra* note 4, at 167.
[30] Stefan Speck, *The Design of Carbon and Broad-Based Energy Taxes in European Countries*, 10 VERMONT J. ENVTL. L. 31, 45 (2008).
[31] NORWEGIAN MINISTRY OF THE ENV'T, NORWAY'S FIFTH NATIONAL COMMUNICATION UNDER THE FRAMEWORK CONVENTION ON CLIMATE CHANGE 10 (2009), https://perma.cc/B7EN-2NA5.
[32] Speck, *supra* note 30, at 50.
[33] Aldy & Stavins, *supra* note 4, at 168.
[34] Brian Murray and Nicholas Rivers, *British Columbia's Revenue-Neutral Carbon Tax: A Review of the Latest "Grand Experiment" in Environmental Policy*, 86 ENERGY POL'Y 674, 676 (2015).

efforts in applying a common carbon price across all fossil fuels in the economy, without exemptions or modifications. In 2016, Prime Minister Justin Trudeau called on all Canadian provinces to implement a carbon pricing regime or the federal government will do so for them.[35] Emerging economies have also explored the use of carbon tax policies as a means for implementing their emission reduction programs. South Africa has proposed a R120/tCO_2 tax (approximately US$10/t$CO_2$ at current exchange rates).[36] South Africa has described the carbon tax as one of the primary means for implementing its emission mitigation pledge ("nationally determined contribution") under the 2015 Paris Agreement.[37]

Despite the partisan nature of the U.S. climate policy debate,[38] conservative thought-leaders and cabinet members of past Republican administrations have supported a carbon tax. In 2008, Arthur Laffer, whose work has informed much of Republican tax policy since the 1980s, and former Representative Bob Inglis (R-SC) wrote in the *New York Times* that "fiscal conservatives would gladly trade a carbon tax for a reduction in payroll or income taxes, but we can't go along with an overall tax increase."[39] George Shultz, who served as Secretary of the Treasury and State in Republican administrations, and Nobel laureate Gary Becker advocated for a carbon tax in the *Wall Street Journal* in 2013 on the condition of revenue neutrality, since this would "mean that it will not have a fiscal drag on economic growth."[40] In February 2017, a group of Republican elder statesmen including former members of the Nixon, Reagan, Bush I, and Bush II cabinets proposed a carbon tax of $40/t$CO_2$.[41] This Republican carbon tax proposal would return tax revenue through equal per capita "carbon dividend" payments to everyone with a Social Security number and simultaneously remove existing regulations on carbon emissions.[42]

The prospect of replacing a complicated mix of regulations with a carbon tax has appealed to conservative thought leaders. In the *Weekly Standard*, Irwin Stelzer of the Hudson Institute (and formerly the American Enterprise Institute) called for a carbon tax to finance a reduction in the payroll tax, noting that "it gives conservatives a market-

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[35] Kathleen Harris, *Justin Trudeau Gives Provinces until 2018 to Adopt a Carbon Price Plan*, CBC NEWS (Oct. 3, 2016), http://www.cbc.ca/news/politics/canada-trudeau-climate-change-1.3788825.

[36] WORLD BANK GROUP, PARTNERSHIP FOR MARKET READINESS, MODELING THE IMPACT ON SOUTH AFRICA'S ECONOMY OF INTRODUCING A CARBON TAX 1 (2016), https://perma.cc/YBS7-ZAGN.

[37] REPUBLIC OF SOUTH AFRICA, DEPT. OF ENVTL. AFFAIRS, SOUTH AFRICA'S 1ST BIENNIAL UPDATE REPORT (2014), https://perma.cc/5SR6-Q24U.

[38] For an illustration of the partisan contrast on climate change in the 2016 presidential election, see Joseph E. Aldy, *The Political Economy of Clinton's Ambitious Energy Program,* 1 NATURE ENERGY 16,162, at 1–3 (2016); *see also* Michael Giberson, *Trump's Policy May Undermine Pro-Growth Intentions,* 1 NATURE ENERGY 16,156 at 1–3 (2016).

[39] Bob Inglis & Arthur B. Laffer, *An Emissions Plan Conservatives Could Warm To*, N.Y. TIMES (Dec. 28, 2008), https://perma.cc/GP6G-PH5G.

[40] George P. Shultz & Gary S. Becker, *Why We Support a Revenue-Neutral Carbon Tax*, WALL ST. JOURNAL (April 7, 2013), https://perma.cc/4VYP-Y28E.

[41] This group, under the aegis of the Climate Leadership Council, introduced their primary ideas through several op-eds. *See, e.g.*, Martin S. Feldstein et al., *A Conservative Case for Climate Action*, N.Y. TIMES (Feb. 8, 2017), https://perma.cc/7BHX-RLW9; George P. Shultz & James A. Baker III, *A Conservative Answer to Climate Change*, WALL ST. JOURNAL (Feb. 7, 2017), https://perma.cc/66FK-TLVS.

[42] JAMES A. BAKER ET AL., CLIMATE LEADERSHIP COUNCIL, THE CONSERVATIVE CASE FOR CARBON DIVIDENDS (2017), https://perma.cc/K6M6-3N28.

based tool to replace regulations and relieves them of a need to sign on to the climate change thesis by providing a true, conservative rationale—consumption taxes that ease the burden of taxation on work are pro-growth."[43] Greg Mankiw, former Chair of the Council of Economic Advisers in the George W. Bush Administration, called for a carbon tax as a lower-cost way to reduce emissions than a collection of regulations and stated in the *New York Times* that "using the new revenue to reduce personal and corporate income tax rates, a bipartisan compromise is possible to imagine."[44]

Several congressional bills introduced over the past three years illustrate the potential design of a carbon tax. For example, the Climate Protection and Justice Act of 2015 would have set a "carbon pollution fee" of $15 per metric ton of carbon dioxide in 2017 that increases a specified amount each year through 2035 and then 5% plus the rate of inflation annually thereafter.[45] The Tax Pollution, Not Profits Act would set a carbon tax of $30 per metric ton of carbon dioxide in 2016 that increases 4% plus the rate of inflation each year.[46] The American Opportunity Carbon Fee Act sets a fee of $45 per metric ton of carbon dioxide in 2015 that increases 2% plus the rate of inflation each year.[47] In each of these cases, the carbon tax would apply to the carbon content of fossil fuels. They share the common structure of specifying the tax at some $X per metric ton of carbon dioxide, and then increasing the tax by a rate of Y percent each year, plus a measure of inflation (such as the urban Consumer Price Index). None of these bills address the issue of uncertainty in emission outcomes.

D. Commonalities in Pricing Carbon Through Cap-and-Trade and Tax Policies

On many dimensions, the academic literature has considered tax and cap-and-trade instruments as nearly identical substitutes. In the U.S., there has been considerable discussion of carbon pricing in the academic literature for decades. This scholarship has included explicit proposals for a carbon tax or cap-and-trade, typically of the form of an economy-wide instrument applied to the carbon content of fossil fuels that expands over time.[48]

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[43] Irwin M. Stelzer, *A Deal over Climate Change*, THE WEEKLY STANDARD (Feb. 29, 2016), https://perma.cc/5DQ9-VSML.
[44] Gregory N. Mankiw, *A Carbon Tax that America Could Live With*, N.Y. TIMES (Aug. 31, 2013), https://perma.cc/VE3P-YAJK.
[45] S. 2399, 114th Cong. §§ 101, 196 (2015).
[46] H.R. 2202, 114th Cong. § 4691 (2015).
[47] S. 1548, 114th Cong. (2015).
[48] *See generally* JOSEPH E. ALDY, PROGRESSIVE POLICY INST., LONG-TERM CARBON POLICY: THE GREAT SWAP (2016); Adele C. Morris, *Proposal 11: The Many Benefits of a Carbon Tax*, *in* 15 WAYS TO RETHINK THE FEDERAL BUDGET 63–69 (Michael Greenstone et al. ed., 2013); Joseph E. Aldy, *The Case for a US Carbon Tax*, 91 OXFORD ENERGY F. 13 (2013); Joseph E. Aldy et al., *A Tax-Based Approach to Slowing Global Climate Change*, 61 NAT'L TAX J. 493 (2008); William D. Nordhaus, *To Tax or Not To Tax: Alternative Approaches to Slowing Global Warming*, 1 REV. ENVTL. ECON. & POL'Y 26 (2007); Metcalf, *supra* note 7; James M. Poterba, *Tax Policy to Combat Global Warming: On Designing a Carbon Tax* (Nat'l Bureau of Econ. Research, Working

Researchers have employed energy-economic integrated assessment models to simulate the economic and emission impacts of a carbon tax or cap-and-trade program. In simplifying the real world, these models implement a carbon tax or cap-and-trade as if they were identical instruments: in the former case, the modeler simply sets the carbon price in the model at the carbon tax; in the latter case, the modeler searches for the carbon price that delivers the quantity target reflected in the emissions cap. These models have been employed to evaluate the impacts of an array of climate change policy proposals and agreements, including: (1) returning U.S. carbon dioxide emissions to their 1990 levels by 2000;[49] (2) implementing industrialized countries' Kyoto Protocol targets over 2008–2012;[50] (3) achieving the voluntary emission commitments by major economies in the 2009 Copenhagen Accord;[51] and (4) delivering on the emission pledges made by nearly all countries under the 2015 Paris Agreement.[52]

A carbon tax or a cap-and-trade program in which the emission allowances are auctioned by the government can each generate significant revenue, potentially in the hundreds of billions of dollars annually. This raises important questions about how the revenues are returned to the economy. Related to this issue is the fact that a carbon pricing policy may interact with existing taxes in ways that exacerbate the social cost of the policy. These questions have inspired an extensive literature that has analyzed these tax-interaction effects and suggested ways of using carbon pricing revenues to lower pre-existing taxes on capital and labor in a way that can reduce the total costs to the economy of climate change policy. A key lesson from this literature is that how revenues are used can dramatically affect the overall economic cost of the policy. [53]

Either a carbon tax or cap-and-trade would raise the price of energy. As a result, energy-intensive manufacturing may face higher input costs and this may adversely affect their competitive position relative to foreign firms that do not face comparable domestic climate regulation. A number of papers have attempted to estimate the potential impacts of either carbon pricing instrument on manufacturing production and net imports[54] as

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Paper No. 3649, 1991); Stavins, *supra* note 8; Jerry Taylor, *The Conservative Case for a Carbon Tax* (Niskanen Ctr., Working Paper, 2015).

[49] *See, e.g.*, Darius W. Gaskins, Jr. & John P. Weyant, *Model Comparisons of the Costs of Reducing CO_2 Emissions*, 83 AMER. ECON. REV. 318 (1993).

[50] *See, e.g.*, Symposium, *The Costs of the Kyoto Protocol: A Multi-Model Evaluation*, 20 ENERGY J. 2285 (1999).

[51] *See, e.g.*, Warwick J. McKibbin, Adele C. Morris, & Peter J. Wilcoxen, *Comparing Climate Commitments: A Model-Based Analysis of the Copenhagen Accord*, 2 CLIMATE CHANGE ECON. 79 (2011).

[52] *See, e.g.*, Joseph E. Aldy et al., *Economic Tools to Promote Transparency and Comparability in the Paris Agreement*, 6 NATURE CLIMATE CHANGE 1000 (2016); Yunguang Chen & Marc A.C. Hafstead, *Using a Carbon Tax to Meet US International Climate Pledges* (Res. for the Future, Discussion Paper 16-48, 2016), https://perma.cc/3YY5-YHWG.

[53] *See generally* A. Lans Bovenberg & Lawrence H. Goulder, *Optimal Environmental Taxation in the Presence of Other Taxes: General-Equilibrium Analyses*, 86 AMER. ECON. REV. 985 (1996); Lawrence H. Goulder, *Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General Equilibrium Analysis*, 29 J. ENVTL. ECON. AND MGMT. 271 (1995); Lawrence H. Goulder et al., *The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting*, 72 J. PUB. ECON. 329 (1990); Ian W. H. Parry, *Pollution Taxes and Revenue Recycling*, 29 J. ENVTL. ECON. & MGMT. S64 (1995); Ian W.H. Parry et al., *When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets*, 37 J. ENVTL. ECON. & MGMT. 52 (1999).

[54] *See generally* MEREDITH L. FOWLIE, MAR REGUANT, & STEPHEN P. RYAN, MEASURING LEAKAGE RISK (2016), https://perma.cc/CC8C-JZ69; Joseph E. Aldy, *Frameworks for Evaluating Policy Approaches to Address*

well as explore ways to design carbon pricing policy in a way to mitigate adverse impacts on competitiveness.[55]

The higher energy prices expected under a carbon tax or cap-and-trade also have important distributional consequences. Lower-income households typically allocate a larger fraction of their budget to energy consumption than higher-income households, so a carbon-pricing policy could be regressive. A variety of papers have attempted to estimate the burden of carbon pricing across the U.S. income distribution[56] as well as ways to mitigate adverse distributional consequences.[57] In addition, some research has examined the regional distribution of the costs associated with carbon pricing, reflecting U.S. heterogeneity in the carbon intensity of electricity generation, transportation demand, and other factors.[58]

II. IMPLICATIONS OF UNCERTAINTY FOR CARBON PRICING

A carbon tax and cap-and-trade differ in what they control. While obvious, it is worth stating explicitly: a carbon tax sets the price on emissions and market forces determine the quantity of emissions (at the level that equilibrates supply and demand). A cap-and-trade system, in contrast, sets an aggregate limit on emissions and market forces determine the market-clearing price for trading in emissions up to that cap. In a world without any uncertainty, the two approaches lead to equivalent outcomes: the tax rate under the carbon tax equals the equilibrium price on allowances under cap-and-trade, and both produce the same quantity of emissions. However, in a world with uncertainty (such as macroeconomic and cost shocks, technological innovation, etc.), setting tax rates or

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the Competitiveness Concerns of Mitigating Greenhouse Gas Emissions, NAT'L TAX J. (forthcoming 2017); Joseph E. Aldy & William A. Pizer, *The Competitiveness Impacts of Climate Change Mitigation Policies*, 2 J. ASS'N ENVTL. & RES. ECONOMISTS 565 (2015).

[55] *See, e.g.*, Carolyn Fischer & Alan K. Fox, *Comparing Policies to Combat Emissions Leakage: Border Carbon Adjustments Versus Rebates*, 64 J. ENVTL. ECON. & MGMT. 199 (2012); Carolyn Fischer & Alan K. Fox, *The Role of Trade and Competitiveness Measures in U.S. Climate Policy*, 101 AMER. ECON. REV. 258 (2011); Wayne Gray & Gilbert E. Metcalf, *Carbon Tax Competitiveness Concerns: Assessing a Best Practices Income Tax Credit* (Res. for the Future, Discussion Paper 17-10, 2017); Sam Kortum & David Weisbach, *Border Adjustments for Carbon Emissions* (Res. for the Future, Discussion Paper 16-09, 2016); Joel P. Trachtman, *WTO Law Constraints on Border Tax Adjustment and Tax Credit Mechanisms to Reduce Competitive Effects of Carbon Taxes* (Res. for the Future, Discussion Paper 16-03, 2016).

[56] *See generally* JARED C. CARBONE ET AL., RES. FOR THE FUTURE, DEFICIT REDUCTION AND CARBON TAXES: BUDGETARY, ECONOMIC, & DISTRIBUTIONAL IMPACTS (2013); Dallas Burtraw et al., *The Incidence of U.S. Climate Policy: Alternative Uses of Revenues from a Cap-and-Trade Auction*, 62 NAT'L TAX J. 497 (2009); Terry M. Dinan & Diane Lim Rogers, *Distributional Effects of Carbon Allowance Trading: How Government Decisions Determine Winners and Losers*, 55 NAT'L TAX J. 199 (2002); Kevin A. Hassett et al., *The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis*, 30 ENERGY J. 155 (2009); Aparna Mathur & Adele C. Morris, *Distributional Effects of a Carbon Tax in Broader U.S. Fiscal Reform*, 66 ENERGY POL'Y 326 (2014); Sebastian Rausch et al., *Distributional Impacts of Carbon Pricing: A General Equilibrium Approach with Micro-Data for Households*, 33 ENERGY ECON. S20 (2011); Roberton C. Williams III et al., *The Initial Incidence of a Carbon Tax Across Income Groups*, 68 NAT'L TAX J. 195 (2015).

[57] *See* Metcalf, *supra* note 7.

[58] *See generally* Burtraw et al., *supra* note 56; Hassett et al., *supra* note 56; Rausch et al., *supra* note 56; Roberton C. Williams III et al., *The Initial Incidence of a Carbon Tax Across U.S. States*, 67 NAT'L TAX J. 807 (2014).

aggregate caps that *ex ante* lead to the same expected economic outcomes can lead to very different *ex post* realized outcomes.[59]

A sizable economics literature asks under what circumstances is one instrument more economically efficient than the other in a world with uncertainty.[60] Reducing uncertainty about emissions reductions also has the potential to improve the efficiency of the carbon tax. Roberts and Spence[61] first examined hybrid policy instruments—those that combine elements of an emissions tax and a quantity-based policy (such as a cap-and-trade system), and thus provide more emissions certainty than a tax and more price certainty than cap-and-trade—and showed that well-designed hybrid policies are generally more efficient than either pure tax or pure quantity-based policy. More recent scholarship has focused on concerns about price uncertainty in a cap-and-trade program.[62] This has resulted in research and policy proposals for the design of hybrid cap-and-trade programs that would operate as conventional cap-and-trade programs so long as allowance prices due not exceed a specified threshold. If they do, then the policy would effectively convert into a tax instrument.

The contributors to this Symposium focus on a different question: How could one design a carbon tax to provide a level of certainty with respect to emission quantities as well as price?

In thinking about this problem, it is useful to distinguish between uncertainty about emissions and uncertainty about abatement (i.e., emissions reductions). Suppose that an economy's opportunities for abating emissions can be used to construct a marginal abatement curve—a function that represents the amount of emissions abatement that would occur at a given carbon price, not unlike a supply function for the amount of a given type of good or service that would be produced at a given price. Emission abatement in any given year will be determined by the intersection of the tax rate and the marginal abatement curve. This reflects the fundamental premise of market-based instruments; firms minimize their total cost of compliance by undertaking emission abatement such that they equate their marginal costs of abatement with the carbon price. Observed emissions equal business-as-usual ("BAU") emissions, i.e. emissions in the absence of a carbon tax, less abatement. This implies that any "certainty" mechanism can provide certainty over emissions but not over emissions reductions—even in the case of a

[59] Weitzman wrote the seminal paper comparing and contrasting the two instruments in a world with uncertainty. *See* Martin L. Weitzman, *Prices vs. Quantities*, 41 REV. ECON. STUD. 477, 477–91 (1974).

[60] This literature builds on *id. See also* Joseph E. Aldy & W. Kip Viscusi, *Environmental Risk and Uncertainty*, *in* HANDBOOK OF THE ECONOMICS OF RISK AND UNCERTAINTY 601, 634–44 (M. J. Machina & W. K. Viscusi ed. 2014); Gary W. Yohe, *First Principles and the Economic Comparison of Regulatory Alternatives in Global Change*, *in* COST-BENEFIT ANALYSES OF CLIMATE CHANGE 17, 17–28 (1998); Aldy et al., *supra* note 2; Lawrence H. Goulder & Ian W. H. Parry, *Instrument Choice in Environmental Policy*, 2 REV. ENVTL. ECON. & POL'Y 152, 152–74 (2008); Richard Newell & William Pizer, *Regulating Stock Externalities Under Uncertainty*, 45 J. ENVTL. ECON. & MGMT. 416, 416–32 (2003); William Pizer, *Combining Price and Quantity Control to Mitigate Global Climate Change*, 85 J. PUB. ECON. 409, 409–34 (2002); Marc J. Roberts & A. Michael Spence, *Effluent Charges and Licenses Under Uncertainty*, 5 J. PUB. ECON. 193, 193–208 (1976).

[61] *See* Roberts & Spence, *supra* note 60.

[62] *See* Brian C. Murry et al., *Balancing Cost and Emissions Certainty: An Allowance Reserve for Cap-and-Trade*, 3 REV. ENVTL. ECON. & POL'Y 84, 84–103 (2009); *see also* Joseph E. Aldy & William A. Pizer, *Issues in Designing U.S. Climate Change Policy*, 30 ENERGY J. 179, 188 (2008).

pure cap and trade system with no safety valve. [63] We can track and limit emissions but without knowing BAU emissions, we cannot say what the actual emission reductions were.

Uncertainty in predicting emissions arises from three sources: (1) unexpected shifts in BAU emissions over time; (2) errors in estimates of the marginal abatement curve at the start of the policy; and (3) unexpected shifts in the marginal abatement cost curve over time. Errors in predicting BAU emissions can arise from unexpected changes in the growth rate of the economy, perhaps as part of business-cycle impacts; changes in relative fuel prices that might, for example, shift the mix of coal versus natural gas electricity power production; and unforeseen changes in the mix of economic activity in the U.S., among other forces. Ex ante estimates of the marginal abatement curve could be wrong due to inaccurate estimates of the ease of substituting away from fossil fuels in production or errors in estimating the elasticity of consumer demand for carbon-intensive goods. Unexpected shifts in the marginal abatement curve over time can arise due to changes in the cost and availability of low- and zero-carbon fuel technologies.

As a result, neither the emission abatement nor the level of emissions under a carbon tax can be predicted with certainty. There are political reasons that quantity certainty is valuable. For example, prevailing climate goals are stated in terms of emission quantities. In 2009, President Obama pledged to reduce U.S. GHG emissions to 17% below 2005 levels by 2020,[64] then pledged to reduce emissions 26–28 percent below 2005 levels by 2025 in the lead up to the 2015 Paris climate conference.[65] Indeed, the vast majority of the contributions pledged under the 2015 Paris Agreement establish quantity-based emission goals for more than 180 countries.[66] Any country implementing a carbon tax as a part of its domestic emission mitigation program may wish to update its tax in order to provide some certainty that it will achieve its emission pledge. Such an approach to a carbon tax could enhance the confidence that other countries have in a given nation's commitment in delivering on its contribution.[67]

The environmental community and some political leaders have long focused on the certainty of environmental outcomes, and the prospect of their support for a carbon tax may depend on how it is designed to address concerns about emissions uncertainty. The traditional focus on cap-and-trade reflects this emphasis on environmental certainty. In launching the International Carbon Action Partnership in 2007, European Commission President Jose Barroso stated "Why is it important that we talk about cap-and-trade

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[63] Alternatively, one could define emissions reductions relative to some fixed and known level of emissions (e.g., emissions in a particular year in the past). Under that alternative definition, uncertainty about emissions and uncertainty about emissions reductions are the same. But that is a less useful definition for evaluating policy, because under that definition, measured "emissions reductions" will be some mix of unexpected changes in BAU emissions and actual emissions reductions caused by the policy.

[64] Executive Office of the President, *President Obama's Climate Action Plan* (June 2013), https://perma.cc/5N2Q-7PZQ.

[65] EPA, *Cover Note, INDC, and Accompanying Information* (March 31, 2015), https://perma.cc/ZN79-67QE.

[66] United Nations Framework Convention on Climate Change, *Intended Nationally Determined Contributions Web Portal* UNITED NATIONS (2016), https://perma.cc/XP3F-9B5Y.

[67] *See* Aldy & Pizer, *supra* note 5.

schemes? First and foremost, they provide *environmental certainty*."[68] In 2009, Michael Oppenheimer and Nathaniel Keohane of Environmental Defense Fund lead with environmental certainty in arguing for cap-and-trade over a carbon tax (in an admittedly different political context before cap-and-trade failed in the U.S. Senate in 2010).[69] Likewise, a Natural Resources Defense Council policy brief notes that "a cap would also provide greater environmental certainty for reducing emissions than a tax."[70] Securing the support of environmental advocates could require designing a carbon tax in a way that addresses this concern about emission outcomes. This is analogous to the interests of the business community in preferring the design of a cap-and-trade program that delivers some certainty about carbon prices and costs, e.g., through a safety valve or carbon allowance reserve.

III. IDEAS FOR ADDRESSING EMISSION UNCERTAINTY IN CARBON TAX DESIGN

This Symposium advances myriad ideas for addressing emission uncertainty in the design of a U.S. carbon tax.

Professor Murray et al. examine a variety of options for addressing emission certainty under a carbon tax, highlighting three general approaches. First, the carbon tax could be adjusted based on a transparent formula that could be tailored to deliver a desired degree of certainty. Second, regulatory tools could be deployed as a backup mechanism in the event that the carbon tax failed to meet emission benchmarks.[71] While the first option could be symmetric—i.e., the carbon tax formula could be structured to adjust the tax up or down in response to emission outcomes—this option would only apply if emissions exceeded a specified quantity. Third, some of the revenues raised by the carbon tax could be dedicated to financial support for emission mitigation activities. For example, these revenues could underwrite emission offset efforts in agricultural and forestry sectors that would likely fall outside the scope of the carbon tax policy.

The Essay by Professor Aldy assumes that the federal government has established a carbon tax schedule. This Essay describes the design of a predictable process for updating the carbon tax in light of new information. Under this "structured discretion" approach, every five years the President would recommend an adjustment to the carbon tax based on analyses by the Environmental Protection Agency, the Department of the Treasury, and the Department of State on the environmental, economic, and diplomatic dimensions of climate policy. Similar to the expedited, streamlined consideration of regulations under the Congressional Review Act and trade deals under trade promotion

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[68] Jose Manuel Durao Barroso, President, European Comm'n, The International Carbon Action Partnership: Turning Vision into Reality (Oct. 29, 2007), https://perma.cc/RG6G-NFQ7 (emphasis in original).

[69] Michael Oppenheimer & Nathaniel Keohane, *Four Reasons to Use Cap-and-Trade to Fight Global Warming*, THE HUFFINGTON POST (August 13, 2009), https://perma.cc/68NG-HLRA.

[70] NAT. RES. DEF. COUNCIL, CAP 2.0: POLICY SOLUTIONS FOR CURBING GLOBAL WARMING AND BUILDING THE CLEAN ENERGY ECONOMY 4 (2009), https://perma.cc/Y26Q-NGQK.

[71] For example, Senator Sanders' 2015 carbon tax bill, S. 2399, 114th Cong. § 101 (2015), included such a regulatory backstop. Recent proponents of a carbon tax, however, have argued that a carbon tax should be accompanied by phasing out EPA's greenhouse gas regulatory authority under the Clean Air Act. *See, e.g.*, ALDY, *supra* note 48; Feldstein et al., *supra* note 41; Shultz & Baker, *supra* note 41.

authority, Congress would vote up or down on the presidential recommendation for a carbon tax adjustment, without the prospect of filibuster or amendment. This process could be synchronized with the updating of nationally determined contributions under the Paris Agreement to leverage greater emissions mitigation ambition by other countries in future pledging rounds. The communication of guiding information and the latest data and analysis could serve as "forward guidance" for carbon tax adjustments, akin to the Federal Reserve Board's communication strategy.

Dr. Hafstead et al. discuss a carbon tax schedule that permits automatic adjustments to the carbon tax in response to emissions exceeding specified benchmarks. Their Tax Adjustment Mechanism for Policy Pre-Commitment ("TAMPP") would raise the probability of meeting targeted emission reduction milestones over the next few decades. For example, if a country has a final target for the year 2030, the TAMPP could be designed with several interim benchmarks that would inform automatic adjustments to the tax. The Essay provides guidance on several key elements of the TAMPP, including control period, the type, frequency, and size of adjustment, and adjustment triggers, to ensure that the TAMPP is cost-effective and politically realistic. The Essay describes the precedent in U.S. tax law for automatic adjustments to tax schedules based on future information (such as inflation adjustments). The Essay closes with a discussion of a research agenda to inform the design and implementation of such a tax adjustment mechanism.

A carbon tax policy could employ a mix or hybrid of these approaches to provide greater certainty about emission outcomes, as noted by Professor Murray and colleagues. When the U.S. government returns to serious consideration of climate change legislation, these ideas can inform the deliberations about carbon pricing policy and carbon tax design in particular. Building broad political support for a carbon tax policy and delivering a climate change policy that credibly combats the risks posed by greenhouse gas emissions will likely require some kind of emissions certainty mechanism.