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TAXING CARBON: WHAT, WHY, AND HOW

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The case for a carbon tax in the United States is strong. A well-designed tax could efficiently reduce the emissions that cause climate change, encourage innovation in cleaner technologies, and cut other pollutants. The resulting revenue could finance tax reductions, spending priorities, or deficit reduction—policies that could offset the tax's distributional and economic burdens, improve the environment, or otherwise improve Americans' well-being.

A carbon tax could thus help us build a cleaner, more efficient economy. But moving a carbon tax from the whiteboard to reality is challenging. A tax that works well in principle may stumble in practice. A real carbon tax will inevitably fall short of the whiteboard ideal. Practical design challenges thus deserve close attention. To help policymakers, analysts, and the public evaluate those challenges, this report examines the what, why, and how of implementing a carbon tax and using the revenue it would generate.

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WHY A CARBON TAX?

Businesses, consumers, and governments emit carbon dioxide, methane, nitrous oxide, and other greenhouse gases by burning fossil fuels, making cement, raising cattle, clearing land, and other activities. Those emissions build up in the atmosphere and trap heat, warm the globe, raise sea levels, shift rainfall patterns, boost storm intensity, and increase the risk of sudden climate changes. Rising carbon dioxide concentrations also alter the chemical balance of the oceans, harming coral reefs and other marine life. Greenhouse gas emissions thus create a host of potential economic and environmental threats, including increased property damage from storms, human health risks, reduced agricultural productivity, and ecosystem deterioration.[1]

The challenge for any effort to reduce climate change is that emissions come from millions of sources and activities. For this reason, setting emission limits on individual sources, mandating specific technologies, or establishing other direct regulations will be difficult and needlessly costly. Piecemeal regulations can reduce emissions, but even the best-intentioned approaches under control some sources, over control others, and overlook still others. Moreover, direct regulation does little to reward innovation beyond regulatory minimums.

Thus, market-based approaches that place a price on emissions are particularly attractive for combatting climate change. Establishing such a price would allow the market to do what it does best: encourage consumers and businesses to reduce emissions at the lowest cost and provide an ongoing incentive for innovators to develop new ways to reduce carbon emissions.

Policymakers could establish a price on emissions—for short, a price on carbon—by levying a tax or by setting a limit on emissions and allowing trading of emission rights. These two approaches have much in common. By putting a price on carbon, both a tax and a cap-and-trade system harness market forces to reduce emissions as efficiently as possible. If the government auctions emissions rights, rather than giving them away for free, a cap-and-trade system can also raise revenue just as a tax would.

The biggest difference between the two approaches is the balance they strike between certainty and uncertainty.[2] With a tax, the price of carbon emissions is specified, and the level of emissions depends on future technological and economic conditions. Under cap-and-trade, the situation is reversed: the emissions level from included activities is specified, and the price of carbon is determined in the market.

There are proponents of both methods. Additional design features can, however, bring the two approaches closer together. Policymakers could limit price uncertainty in a cap-and-trade system through price floors (at which the government buys back emission permits) and ceilings (at which it issues new permits or charges a tax for excess emissions). A cap-and-trade system could also allow banking of permits across years, thus reducing price volatility. A tax system could limit emissions uncertainty by scheduling tax increases if emissions exceed a threshold and tax decreases if emissions fall below a threshold.[3]

A carbon tax and a cap-and-trade system, particularly one with banking provisions and auctioned permits, can therefore be very similar.[4] We focus on a tax in this report, as it appears more politically viable than a cap-and-trade system at this time, though many issues apply equally to both, and either a cap-and-trade system or a carbon tax would achieve emissions reductions at lower social cost than would direct regulation.

WHAT SHOULD WE TAX?

For both efficiency and fairness, a tax should apply as broadly as feasible to all greenhouse gas emissions, regardless of source. Electric power plants, automobiles, home heating systems, factories, farms, ranches, and airplanes should all face the same carbon price. Unfortunately, that aspiration runs into four challenges:

the difficulty of monitoring emissions, the multiple ways carbon emissions are created, the greenhouse gases other than carbon dioxide, and the need to give credit for efforts to capture carbon emissions or remove them from the atmosphere.[5]

Taxing Carbon Dioxide When Monitoring Emissions Is Difficult

Most carbon emissions come from combustion of coal, oil, and natural gas. In principle, policymakers could require emitters to install monitoring equipment and then tax based on actual emissions. In practice, that would be prohibitively expensive except at the largest power plants. Because of the simple chemistry of combustion—an atom of carbon in fuel becomes a molecule of carbon dioxide—a close substitute is to tax the carbon content of fuel (box 1).

Taxing Carbon Dioxide From Industrial Processes

Taxing the carbon content of fuels captures only carbon dioxide emissions from processes that involve combustion. It thus does not cover processes like manufacturing cement and certain chemicals. Taxing those emissions would still be relatively straightforward, however, since many of these facilities already must report their carbon dioxide emissions through the Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Program.

Taxing Other Greenhouse Gases

Carbon dioxide is the most prevalent greenhouse gas, accounting for 83 percent of US emissions in 2012 according to one standard metric (table 1).[6] To be truly comprehensive, however, a tax should also apply to methane, nitrous oxide, hydrofluorocarbons, and other greenhouse gases, unless their sources have characteristics that make other policies more efficient. Most methane comes from natural gas systems, cattle, and landfills, and most nitrous oxide comes from agriculture. Incorporating these sources would expand the administrative burden of collecting the tax, so policymakers will have to decide which gases and sources are best suited to including in the tax base.

In doing so, policymakers must address the fact that greenhouse gases differ in their chemical and atmospheric properties. Methane, for example, traps more heat, gram-for-gram, than carbon dioxide does, but it has a shorter atmospheric lifetime. A cost-effective tax should reflect such differences, raising the tax rate for gases that are more potent and lowering it for gases that stay in the atmosphere for less time. Analysts have developed measures known as global warming potentials to make such comparisons. According to the potentials the EPA uses, methane is 21 times more potent than carbon dioxide over a century, and nitrous oxide is 310 times as potent (table 1). By those measures, a $10 per

BOX 1. WEIGHTS AND MEASURES

Like most analysts, we use "carbon tax" to mean a tax on carbon dioxide equivalents. As its name implies, carbon dioxide contains one atom of carbon (atomic weight 12) for every two of oxygen (16). A CO_2 molecule thus weighs about 3.7 (44/12) times as much as a carbon atom. To be comparable, a literal tax rate on carbon would be 3.7 times higher than the rates discussed here. Equivalence for other gases is determined by their global warming potentials.

Tax rates are typically reported in dollars per ton of CO_2 equivalents. This can cause confusion when the US short ton, 2,000 pounds, meets the metric ton, 1,000 kilograms (or about 2,200 pounds). We use the metric ton (ton) throughout.

Burning a gallon of gasoline produces just shy of 20 pounds of CO_2, or 0.009 ton. A $10 per ton tax on carbon dioxide would thus add about 9¢ to the price of a gallon of gasoline. No exact relationship exists for electricity because of differences in fuels and production efficiency. As a rough rule of thumb, a $10 per ton tax would add about 0.5¢ per kilowatt-hour to the price of electricity generated from a typical fuel mix.[1]

[1] Roberton C. Williams and Casey J. Wichman, "Macroeconomic Effects of Carbon Taxes," in *Implementing a US Carbon Tax*, Ian Parry, Adele Morris, and Roberton C. Williams III, ed., (New York, NY: Routledge, 2015).

ton tax on carbon dioxide would imply a $210 per ton tax on methane and a $3,100 per ton tax on nitrous oxide.[7]

That scaling is not without controversy, however. Global warming potentials are subject to uncertainty; in fact, the Intergovernmental Panel on Climate Change (IPCC) now uses different potentials (e.g., 28 for methane and 265 for nitrous oxide) than the EPA does.[8] Potentials do not account for the ocean acidification carbon dioxide causes. In addition, potentials depend on the discount rate used to value expected damages. The lower the discount rate, the more important long-lived gases like carbon dioxide are relative to shorter-lived gases like methane. Misestimating potentials reduces the potential efficiency of a carbon tax.[9]

Tax Credits for Avoided Emissions

An efficient system should give appropriate credit for actions that avoid emissions of previously taxed carbon. For example, if fuel does not get combusted, such as oil used as a feedstock for plastics, it should be exempt from the tax or receive a rebate of tax already paid. That approach is already used for the gasoline tax, which exempts the use of gasoline and diesel for farming and other off highway uses. Similarly, a power plant that employs carbon capture and storage should receive a tax rebate for any carbon that does not get emitted.[10]

HOW MUCH SHOULD THE TAX BE?

In principle, the carbon tax rate should reflect the damages that result from greenhouse gas emissions, a concept known as the social cost of carbon. More sophisticated analyses might dial that amount up or down to reflect other considerations, such as interactions with other taxes or benefits from reducing other pollutants (box 2). But the basic idea is to equate the incremental cost of reducing emissions with the incremental damage those emissions would cause.[11]

This social-cost-of-carbon approach provides a helpful conceptual framing for pricing carbon but several practical challenges arise. For one thing, we cannot easily observe or measure the social cost of carbon, for three reasons:

First, carbon dioxide and other emissions stay in the atmosphere for years, decades, or even centuries. The EPA estimates that methane remains in the atmosphere an average of 12 years, nitrous oxide for more than 100 years, and certain fluorinated gases for thousands of years.[12] Carbon dioxide varies: some emissions are absorbed in water and trees within a few decades and some remain in the atmosphere for centuries. Estimating the social cost of carbon thus requires long-term

Table 1. Major Greenhouse Gases and Global Warming Potentials

	Share of US greenhouse gas emissions, CO_2 equivalents, 2012 (%)	Global warming potential, 100 years
Carbon dioxide	82.5	1
Methane	8.7	21
Nitrous oxide	6.3	310
Hydrofluorocarbons and other fluorinated gases	2.5	140 – 23,900

Source: Environmental Protection Agency (EPA), "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012," (Washington, DC: EPA, 2014). http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Note: The global warming potential of a gas measures how much heat it traps over a century compared with the same mass of carbon dioxide.

projections of potential future harms, converting those harms into monetary costs, and discounting them into today's dollars.

Second, environmental and economic impacts depend on the stock of greenhouse gases over time; the larger that stock grows, the larger the damages from additional emissions are likely to be. Impacts thus depend on future economic developments, domestic climate policies, and policies elsewhere in the world. Estimating the marginal social cost of carbon thus requires complex modeling and assumptions about the trajectory of the world economy and carbon emissions, climate sensitivity, adaptation efforts, and the impacts of any climate change, all of which are uncertain.

Third, estimated costs depend critically on controversial assumptions. Most notable are the value to place on low-probability, catastrophic threats, the cost of adapting to climate change, and what discount rate to apply in valuing damages far in the future (box 3).

Estimates of the marginal social cost of carbon thus vary widely. In developing a cost to inform US climate policy, an interagency working group commissioned 150,000 simulations from three leading models, all using the same 3 percent real discount rate.[13] The resulting estimates fell mostly in the -$10 to $50 per ton range (in today's dollars), with a few lower and some significantly higher.[14] The central tendency was a cost of $27 per ton in 2015 and rising in the future. An update increased that figure to about $42 per ton in 2015, with estimates again ranging from slightly below zero to more than $100.[15] These wide ranges, and the underlying uncertainty about long-term economic and geophysical responses to rising greenhouse gas concentrations, have left some analysts pessimistic about the ability of such modeling efforts to identify an appropriate price for carbon.[16]

The social-cost approach also raises a profound conceptual issue: should policymakers focus on worldwide impacts or just domestic? Climate change is a global phenomenon with emissions affecting all nations.

BOX 2: THE CO-BENEFITS OF TAXING CARBON

Climate change is not the only harm associated with burning fossil fuels. Power plants, factories, vehicles, and other sources also emit air pollutants that directly harm human health, including fine particulate matter, sulfur dioxide, and nitrogen oxides. Vehicle use also imposes other external costs, including congestion, road damage, and accidents.[1]

Taxing carbon will reduce these non-climate harms. In principle, those harms should be addressed by policies specifically designed to reduce them, and climate benefits would be the rationale for a carbon tax. As of yet, however, those other harms are incompletely or imperfectly addressed. As a result, a carbon tax would generate "co-benefits"—improvements in human health and well-being unrelated to climate concerns.

The magnitude of those co-benefits depends on several factors, including the prevalence and value of potential health improvements (e.g., reduced asthma, bronchitis, heart attacks) and the scope of benefits included (e.g., just air pollution from fossil fuels or also congestion and accidents that result from driving). In a comprehensive analysis including both air pollution and vehicle externalities, Parry, Veung, and Heine estimate that the co-benefits of a carbon tax in the United States would be about $35 per ton.[2] In a narrower analysis of the co-benefits from its proposed regulations on power plants, the EPA estimates that the co-benefits of reduced air pollution are at least as large as potential climate benefits. These estimates thus suggest that, in the absence of new policies addressing those harms, a substantial carbon tax would improve US well-being even if we give no weight to climate change.[3]

[1] Ian Parry, Chandara Veung, and Dirk Heine, "How Much Carbon Pricing Is in Countries' Own Interests? The Critical Role of Co-Benefits," (working paper, Washington, DC: International Monetary Fund, 2014).

[2] *Ibid*.

[3] Environmental Protection Agency (EPA), "Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants." (Washington, DC: EPA. 2014).

A coordinated international response should focus on worldwide emissions and impacts. If a nation considers unilateral action, however, it must decide whether to focus on domestic costs and benefits or to consider other nations as well. The difference is large. Greenstone, Kopits, and Wolverton estimate that the United States bears only 7 to 10 percent of the worldwide marginal social costs of carbon.[17] If each new metric ton of carbon dioxide emissions imposes $40 in worldwide damages, only $3 to $4 would fall on the United States. They argue that the United States ought to use the global measure when evaluating regulatory policies, but this view is not universal. Indeed, policymakers take a US-only view when evaluating other energy and environmental policies that have international spillovers.[18]

By itself, the social-cost approach thus faces significant practical challenges. The social cost of carbon is almost certainly greater than zero, even if policymakers adopt a US-only perspective, but identifying a specific number is challenging given all the uncertainties. One alternative would be to calibrate the carbon tax path to hit (in expectation or with periodic updating) specified climate or emissions targets, such as those implied by

BOX 3. DISCOUNTING AND THE SOCIAL COST OF CARBON

Greenhouse gases stay in the atmosphere for years, decades, or even centuries. Much of their harm will thus occur far in the future. To calculate the social cost of carbon emitted today, we need to convert those future harms to a current value. One approach takes inspiration from financial decisions about saving, investing, borrowing, and lending. Those decisions reveal how people make tradeoffs between a dollar they can spend today and dollars in the future. People invest in new projects if they expect to earn a sufficiently high return, typically government interest rates (which reflect the time value of money) plus a risk premium. Emissions reductions are also an investment in the future, so this reasoning implies that social costs be discounted at a comparable rate.

Another approach begins with an ethical belief that future generations are as worthy as today's and their well-being should be weighted equally. Future costs should thus be discounted for only two reasons: the small (we hope) possibility of major catastrophe that moots concern about climate change (e.g., an asteroid strike) and the expectation that future generations will be wealthier than we are and thus better able to bear any costs of climate change (a widely held view for developed economies, but less clear for some developing nations exposed to climate change).

As Goulder and Williams document, these views imply very different discount rates.[1] Starting with the second approach, emphasizing intergenerational equity, Stern used an annual discount rate of 1.4 percent real (i.e., above inflation), reflecting a small risk of other catastrophes (0.1 percent) and growing future well-being (1.3 percent).[2] Nordhaus, a prominent exponent of the investment view, used a rate of 4.3 percent real, reflecting the same 1.3 percent growth in future well-being but 3.0 percent for potential investment returns.[3]

Because of this difference, Stern places a much higher cost on carbon emissions—and thus endorses more dramatic reductions—than Nordhaus does. Goulder and Williams report that their social-cost-of-carbon estimates differ by a factor of 10—$360 per ton in 2015 for Stern versus $35 per ton for Nordhaus—just because of discount rate differences.[4]

Some analysts have recently argued that small risks of environmental catastrophe (e.g., shifting ocean currents, rapid polar melting) may also justify low discount rates and high social costs of carbon.[5] In that risk management view, reducing carbon emissions resembles buying insurance, for which people often use low or negative discount rates, more than it does investing in the future.

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[1] Lawrence H. Goulder and Robert C. Williams, "The Choice of Discount Rate for Climate Change Policy Evaluation," (discussion paper, Washington, DC: Resources for the Future, 2012).

[2] Nicholas Stern, *The Economics of Climate Change*: The Stern Review, (Cambridge: Cambridge University Press).

[3] William Nordhaus, "A Review of the Stern Review on the Economics of Climate Change," Journal of Economic Literature 45, no. 3: 703–24.

[4] Goulder and Williams, "The Choice of Discount Rate."

[5] See, for example, Bob Litterman, "What is the Right Price for Carbon Emissions?," *Regulation* 36(2):38-43; Thomas S. Lontzek, Yongyang Cai, Kenneth L. Judd, and Timothy M. Lenton, "Stochastic Integrated Assessment of Climate Tipping Points Indicates the Need for Strict Climate Policy," *Nature Climate Change* (2015): 441–44; Gernot Wagner and Martin L. Weitzman, *Climate Shock: The Economic Consequences of a Hotter Planet*, (Princeton, NJ: Princeton University Press, 2015).

proposed EPA regulations, President Obama's climate commitments, or other policy goals. Policymakers would not need to estimate the social cost of carbon to implement this approach. The resulting tax would not be socially optimal if the chosen target was too high or too low, but would be a cost-effective way of achieving that target.

A third approach would be to enact whatever carbon tax is politically feasible, even if it may be less than many estimates of the social cost of carbon. This approach would establish the principle of a carbon tax, create incentives for conservation and innovation, and provide a framework that could later be integrated with a global system, possibly at a higher tax level. Adopting a carbon tax could also ease international negotiations by demonstrating a willingness to take action.

Under any approach, policymakers must decide how the tax rate will change over time. Most analysts recommend a rising trajectory because the social costs of carbon are expected to increase as greenhouse gases continue to accumulate and to allow producers and consumers to adjust to the new regime. A ton of carbon emitted in the future will likely do more harm than a ton emitted today. A trajectory of rising tax rates, if credible, would also encourage innovation in low-carbon technologies that will reduce future emissions and costs, while avoiding needlessly expensive reductions now. Starting the tax relatively low would also reduce transition costs, allow people to prepare, and possibly make a carbon tax more politically feasible. For those reasons, most proposals specify that the carbon tax should increase faster than the rate of inflation. There is disagreement, however, about how much increases should be. Some proposals would increase the tax rate about 2 percent faster than inflation each year, tracking estimates of the social cost of carbon, and others would increase it at 4 or 5 percent.

A related concern is how policymakers should update the carbon tax rate as we gain experience with carbon pricing and as our understanding of the science and economics of climate change improves. A few years of modeling improvements recently prompted the Obama administration to increase its estimate of the social cost of carbon more than 50 percent. Regulatory agencies have the authority to incorporate such changes, whether up or down, in their rulemaking process. Legislators should consider whether carbon tax policies should have similar responsiveness. For example, Congress could link carbon tax rates to a periodic review of climate science, emissions, economic outcomes, and policies in other nations. However, it would be highly unusual for Congress to delegate the power to set tax rates to the executive branch, a scientific panel, or any other body.

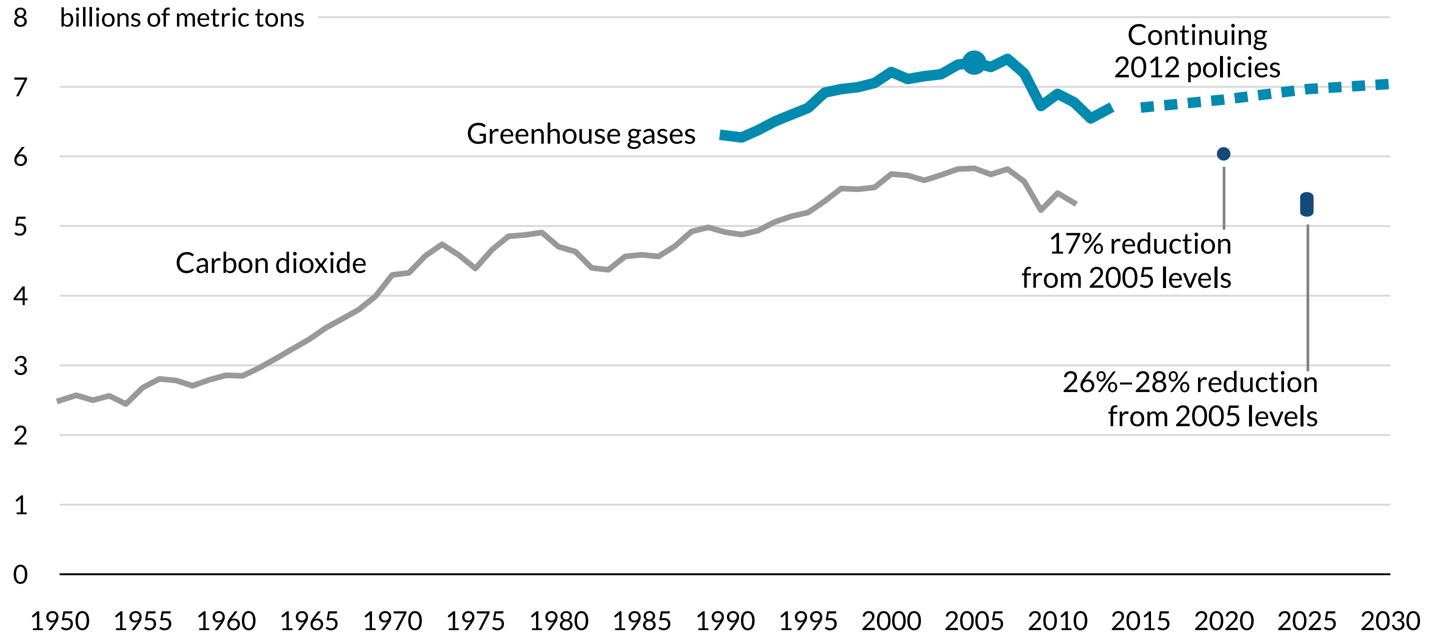
HOW MUCH WOULD A TAX REDUCE EMISSIONS?

A carbon tax would encourage producers to switch to cleaner energy sources and production methods and encourage consumers to invest in efficiency improvements and cut back on carbon-intensive purchases. Those responses would reduce US emissions of greenhouse gases. How much depends on the size of the tax, the scope of emissions that it covers, and the responsiveness of producers and consumers to a new price on carbon.

Atmospheric concentrations of greenhouse gases are now 40 percent higher than preindustrial levels, and they continue to rise. If all human emissions suddenly stopped, global temperatures would still rise another 0.3 degrees Celsius over the next 20 years.[19] But worldwide emissions continue to grow, and, absent new policies, we appear on track for a temperature increase of several degrees by the end of the century.

The United States accounts for about one-seventh of global emissions of greenhouse gases. US emissions have fallen in recent years, from 7.3 billion tons in 2005 to 6.7 billion tons in 2012 (figure 1). That reduction reflects the aftermath of the Great Recession, reduced production by coal-fired power plants (because of retirements, new mercury standards, and a switch to natural gas), and improved efficiency in cars and trucks. In addition,

Figure 1. Carbon Dioxide and Greenhouse Gas Emissions, with US Climate Commitments



Sources: EPA, "Inventory of US Greenhouse Gas Emissions and Sinks;" "CAIT Climate Data Explorer," World Resource Institute; US Department of State, 2014 US Climate Action Report to the UN Framework Convention on Climate Change, *(Washington, DC: US Department of State, 2014).*

investment in wind and, in particular, solar power is rising as a result of falling costs and subsidies that encourage adoption.

This downward trend may not continue, however. Absent further policy action, many analysts expect a growing economy will gradually boost emissions in coming years. In 2014, for example, the Obama administration projected that without new policy actions, emissions would top 7.0 billion tons by 2030.[20] There is some debate whether that projection fully reflects the falling cost of solar and wind power. But even if emissions were on track to be lower, further policy action is necessary to put them on a persistent downward path.

To that end, President Obama has outlined two emission reduction goals for the United States: in 2009 he pledged that greenhouse gas emissions would be reduced 17 percent from 2005 levels by 2020, and in 2014 he pledged to reduce emissions 26 to 28 percent below 2005 levels by 2025, or about 22 to 24 percent relative to the administration's business-as-usual projection.

A centerpiece of this effort is the Environmental Protection Agency's Clean Power Plan. Introduced in 2014, the proposed regulations would reduce carbon dioxide emissions from existing power plants. The EPA estimates that, in 2030, their emissions will have fallen about 30 percent from 2005 levels. While this reduction is significant, it does not address the two-thirds of emissions outside electricity production. Even if the Clean Power Plan reduces emissions as much as the EPA anticipates, it will only have reduced total emissions about 10 percent. Other policies, whether carbon pricing or expanded fuel-economy standards, will be needed to achieve the larger reductions the president envisions.

Many researchers have analyzed potential emissions reductions from carbon taxes, cap-and-trade systems, and other policies. Though these analyses can help policymakers design good carbon policies, it can be difficult to compare their findings. The economic models used to estimate the effects of a carbon tax often differ in design and scope, for example, as do assumptions about economic growth and other policies. The year in which a tax starts and the baseline against which changes are measured affect projections of potential emissions reductions. Further, analyses differ in what is taxed, for example all US emissions versus those from specific sectors, all greenhouse gases emissions versus only carbon dioxide emissions, or US emissions versus global emissions.

Despite these modeling differences, there is broad consensus that a carbon tax would reduce emissions. Several years ago, the Congressional Budget Office (CBO) reviewed carbon tax studies and concluded that a $25 per ton of CO_2-equivalent charge on greenhouse gas emissions from electricity, manufacturing, and transportation, rising 2 percent faster than inflation, would cut covered emissions by 10 percent in its first decade.[21] Emissions reductions from a $25 tax, rising at 2 percent real, would thus be somewhat larger than those from the Clean Power Plan, but they would be far short of President Obama's reduction target for 2025.[22] Achieving the 2025 goal with a tax alone would require a significantly higher-starting tax rate, faster escalation, or a combination of the two.

Other researchers have confirmed that a carbon tax that escalates over time can significantly reduce emissions. For example, Jorgensen and colleagues (2015) estimate that an initial $20 carbon tax, growing at 5 percent faster than inflation each year, would reduce emissions over 20 percent in its 15th year and over 30 percent in its 35th year.[23] McKibben and colleagues estimate that a carbon tax with an initial price of $15, growing at 4 percent real, could reduce emissions by 20 percent in its 25th year.[24] Shapiro and colleagues estimate that an initial $14 carbon tax, rising to $50 in 2030, would reduce emissions by 30 percent after 20 years.[25] As these and similar studies make clear, putting a price on carbon can materially lower future emissions; how much depends on the level of the tax and how fast it rises over time.

HOW MUCH REVENUE WOULD A TAX RAISE?

A carbon tax could raise a substantial amount of revenue. How much depends on the level and breadth of the tax and how producers and consumers respond to it. Most proposals would ramp up the tax rate over time to allow people to adjust and to reflect the rising social cost of carbon; revenue growth will depend on how fast the rate increases. Revenue projections also vary based on model assumptions. Models that assume a faster adjustment to the tax typically foresee less revenue growth (but larger emissions reductions). Estimates of carbon tax revenues thus vary widely.

For legislative purposes, the most important estimates are those of the Congressional scoring agencies, the Joint Committee on Taxation, and the Congressional Budget Office. In late 2013, they estimated the revenue effects of a tax on most greenhouse emissions starting at $25 per ton and increasing 2 percent faster than inflation.[26] Scaling those estimates to CBO's latest budget projections, they imply net revenue of about $90 billion in its first complete year and about $1.2 trillion over its first decade (table 2).

New revenues from a carbon tax will automatically be offset, in part, by lower receipts from income and payroll taxes. When a business uses a portion of its revenues to pay taxes, it has less remaining for wages and profits (this is simple accounting, distinct from any effect the tax may have on the overall economy), and the tax is a deductible business expense, which lowers business tax revenues. Applying their standard offset factor for excise taxes, the Joint Committee on Taxation and CBO estimate that revenues from personal income, corporate income, and payroll taxes will decline, on average, by about 25 percent of the new carbon tax receipts.[27] The $1.2 trillion in net receipts thus reflects $1.6 trillion in gross carbon revenues, offset by $0.4 trillion in lower income and payroll taxes.

The Congressional Budget Office's example carbon tax would be somewhat larger than existing federal excise taxes combined (on gasoline, tobacco, alcohol, and other products), but much smaller than the largest revenue sources. Over its first decade, this carbon tax would increase federal revenues by about 3 percent, lifting them from 18.2 percent of gross domestic product to about 18.7 percent, assuming no legislated changes in other taxes. That revenue gain is equivalent to about one-quarter of corporate tax revenues or a little less than one-tenth of payroll tax revenues.

The trajectory of net carbon revenues is also an important consideration. In many proposals, an increasing carbon tax rate causes revenues to increase over time. Such growth is particularly important for policy proposals that would pair a carbon tax with offsetting tax reductions or spending increases. A revenue-neutral or deficit-neutral policy over a conventional 10-year budget window may increase or decrease the deficit in later decades if the trajectory of carbon revenues differs from the trajectory of other tax and spending changes. A proposal that pairs a carbon tax with a corporate income tax reduction, for example, could be revenue-neutral over its first 10 years but increase revenues in its second decade.[28]

If carbon tax rates increase significantly each year, carbon receipts should eventually flatten and decline as a result of reduced carbon use. Modeling efforts differ in when that might happen. Rausch and Reilly, Tuladhar, Montgomery, and Kaufman, and McKibbin and colleagues, for example, consider scenarios in which carbon revenues do not peak until sometime after 2050.[29] Taxes with narrower tax bases may have different results: Palmer, Paul, and Woerman modeled a tax on the power-generating sector and found that revenues peak within two decades, then decline.[30] The ultimate time pattern of carbon revenues depends on the starting level of the tax, the rate it increases, which emitters are covered, and the responsiveness of those emitters.

Table 2. How Potential Carbon Revenues Compare to Existing Taxes, Projected Revenues 2016–25

	$ trillions	% of GDP
Carbon tax considered by CBO		
Carbon Tax Receipts	1.6	0.7
Lower Income and Payroll Tax Receipts	-0.4	-0.2
Net Carbon Tax Revenues	1.2	0.5
Existing Taxes		
Individual Income	21.0	9.2
Payroll	13.2	5.8
Corporate Income	4.6	2.0
Excise	1.1	0.5
Other	1.8	0.8
Total	41.7	18.2

Source: CBO, Options for Reducing the Deficit; *CBO, "The Budget and Economic Outlook 2015 to 2025," (Washington, DC: CBO 2015); TPC calculations scaling up 2013 estimate.*

WHAT SHOULD WE DO WITH THE REVENUE?

Revenue from a carbon tax could be used to pay for offsetting tax cuts, to reduce the budget deficit, or to assist individuals and firms who will be particularly hurt by the new tax. Revenues could also subsidize alternative energy technologies and climate adaptation, reinforcing the benefits of the carbon tax in reducing climate change. Or they could be used for new spending programs unrelated to offsetting the cost of the tax or promoting environmental objectives.[31] The distributional, economic, and environmental impacts of any carbon tax proposal will depend on both the tax itself and what combination of these options policymakers choose.

Revenue Recycling

Analysts have paid significant attention to the first possibility, recycling carbon revenues into reductions in other taxes. That focus reflects a mix of substantive and political considerations. A carbon tax may be easier to enact when framed as part of a revenue-neutral tax reform that promotes environmental benefits and economic efficiency instead of as a tax increase. Indeed, more than 100 Republican members of Congress, including several presidential aspirants, have signed a "No Climate Tax" pledge to "oppose any legislation relating to climate change that includes a net increase in government revenue."[32] At the same time, a carbon tax is regressive, imposing higher burdens, relative to income, on lower- than on upper-income taxpayers. Some relief for those least able to pay thus seems appropriate. A carbon tax raises energy costs and could harm economic performance (before considering environmental benefits), so using some revenue to offset those harms, such as by reducing other taxes that weaken the economy, would also make sense.

Choosing recycling options involves trade-offs among competing goals of offsetting the burden of the tax on low-income households and improving incentives to work, save, and invest. Among revenue-recycling options, reducing the corporate tax rate and across-the-board income tax rate cuts would provide relatively large improvements in incentives to work, save, and invest. They also provide the largest gains to upper-income taxpayers and offset only a portion of the burden of the carbon tax on low- and middle-income households. Conversely, uniform refundable credits provide the most relief to low- and middle-income taxpayers, but they do not improve economic incentives and thus do not offset any long-run economic costs of a carbon tax. Directing some carbon revenues into the Social Security Trust Fund and then cutting payroll taxes is an intermediate solution, providing relatively more relief to middle-income than to low-income taxpayers (many of whom are retirees with no earnings) or to upper-income taxpayers (who have additional income from investment returns). Cutting payroll taxes improves work incentives, but does nothing to relieve tax burdens on saving and investment.

Deficit Reduction

Another potential use of carbon tax receipts is lowering the budget deficit. Despite recent improvements, the federal budget outlook appears unsustainable under current tax and spending policies as population aging and rising health care costs drive up retirement and health spending.[33] The result will be rising deficits and debt that crowd out private investment and reduce economic growth unless policymakers choose to reduce spending on public services, such as defense, infrastructure, scientific research, and other appropriated programs, reduce the growth of spending on Social Security, Medicare, and Medicaid, or raise revenues. Reducing the growth of spending is likely part of the solution, but it may not be sufficient unless the public is willing to accept much lower income-replacement rates and reduced medical benefits for future retirees. On the revenue side, a carbon tax is a promising option given its other benefits.

Assistance to Workers and Communities

Congress may also wish to use some of the revenues to help individuals, industries, and communities hit particularly hard by a carbon tax. A tax could have a severe impact on profits and employment in coal mining, which is geographically concentrated. Temporary financial assistance to affected workers and communities could ease economic distress as the nation transitions away from using coal to generate electricity. It could also be seen as fair compensation to individuals and firms hurt by an unanticipated policy change and might reduce political opposition to a carbon tax.

Investing in Clean Energy and Adaptation

Moving to a less carbon-intensive economy will require major innovations in clean energy and energy efficiency. Adapting to climate changes will similarly require substantial investments to limit the harms from rising sea levels, altered rainfall patterns, and the like. Revenues from a carbon tax could be used to finance such investments. This linkage may make sense, as a political matter, depending on policymaker interests and other demands for revenue. On purely economic grounds, however, a substantial carbon tax would reduce the need for both kinds of investments.[34] A carbon tax will stimulate private research on and development of clean energy, for example, accelerating the pace at which new energy sources come on line. And by reducing emissions, it would reduce the future need to adapt.

HOW WOULD A TAX AFFECT THE ECONOMY?

Taxes often distort economic incentives and reduce the value of economic activity. Taxes on goods and services, for example, can prompt consumers to work less or to substitute home production for market work. Taxes on income have the same effect, and can also cause people to save and invest less for the future. Taxes on specific goods and services cause consumers to replace them with less-taxed alternatives they would otherwise not prefer. And taxes on select production methods cause firms to substitute to less-efficient, untaxed methods to reduce their tax liability.

These efficiency costs—often known as *excess burden* because they are a burden on top of the taxes that people pay—are a real downside of most taxes.[35] Policymakers should therefore take care to ensure that the benefits that flow from taxes—the goods, services, and income supports that the government provides—justify the direct cost and excess burden of taxation.

Economists use a variety of models to estimate the efficiency cost of taxes (separate models are typically used to estimate the benefits that those revenues finance). Those models calculate the cost of taxation based on estimates or assumptions about the size of consumer responses to changes to prices, worker responses to their after-tax wages, saver responses to their after-tax return to saving, and business responses to the relative costs of productive inputs (capital, labor, and intermediate inputs, including fuels). Taxes on activities for which there are good substitutes in production or consumption impose larger efficiency costs per dollar raised than taxes on activities for which there are no close substitutes. This happens because households and businesses substantially reduce their participation in the taxed activity, so the burden is the forgone benefit of their preferred activity rather than the tax payments themselves. Taxes imposed on broad tax bases at lower rates typically impose less efficiency costs than taxes on narrower bases at higher rates.

For this reason, economists have generally found that taxes that discriminate among goods or production methods impose larger efficiency costs than taxes on broad measures of consumption or income. If one ignores their environmental benefits, carbon taxes generally fit into the former category, imposing three distortions: they distort the choice between work and leisure, just as all consumption and income taxes do; they raise the prices of selected goods and services, causing consumers to switch to less preferred options; and they raise production costs by causing producers to switch to more costly forms of energy or to use other more costly inputs. The second and third changes are, of course, the whole point of a carbon tax. The goal is for households to consume and firms to less intensively produce carbon. Those changes come at a cost, however, which is what the economic models attempt to quantify.

Table 3. Ranking of Total Change in Economic Well-Being from Recycling Carbon Tax Revenues

Efficiency Loss	Jorgenson and colleagues	McKibbin and colleagues[a]	Rausch and Reilly	Tuladhar, Montgomery, and Kaufman	Williams and Wichman
Smallest (or gain)	Reduce capital income tax rates[b]	Reduce capital income tax rates[b]	Half cut in personal income tax rates and half cut in investment taxes	Reduce corporate income tax rates	Capital income tax cuts
Intermediate	Reduce labor income tax rates	Reduce labor income tax rates	Lump sum transfers	Reduce personal income tax rates	Labor income tax cuts
Largest	Lump sum transfers	Lump sum transfers	Reduce personal income tax rates	Lump sum transfers	Lump sum transfers

Sources: Jorgenson et al. "Carbon Taxes and Fiscal Reform in the United States;" McKibbin et al. "Carbon Taxes and U.S. Fiscal Reform;" Rausch and John Reilly "Carbon Taxes, Deficits, and Energy Policy Interactions;" Tuladhar, Montgomery, and Kaufman "Environmental Policy for Fiscal Reform;" Roberton C. Williams and Casey J. Wichman, "Macroeconomic Effects of Carbon Taxes," in Implementing a US Carbon Tax, *Ian Perry, Adele Morris, and Roberton C. Williams III, ed., (New York, NY: Routledge, 2015).*

[a] *Uses long-term change in GDP as metric.*
[b] *Positive efficiency gain.*

A number of economists have used simulation models to estimate the long-run effects on economic well-being of substituting a carbon tax for other ways of raising revenue (table 3).[36] The estimated effects from these models are sensitive to specific details about how they are constructed, including the specification of how different taxes enter the model, the degree of disaggregation among consumer and producer goods, the method of modeling international trade and investment flows, and the specification of how households form their expectations concerning future prices. The models are especially sensitive to assumptions about the size of behavioral responses, in particular the responsiveness of saving to changes in after-tax returns.

Nonetheless, recent research by five separate modeling groups reaches broadly similar conclusions about the relative effects of different ways of recycling revenue from a carbon tax.[37] With one exception, the modelers find that the biggest net efficiency loss occurs when the government returns the carbon tax receipts as lump-sum payments to individuals. This result reflects the fact that the carbon tax adds to the total excess burden of taxation, but the lump-sum rebate does not remove any of the distorting effects of existing taxes.

Reducing tax rates on capital income (either through a reduction in tax rates on all returns to investment income or a cut in the corporate tax rate) offsets the efficiency cost of carbon taxes the most. This result reflects the relatively high burden that standard economic models assign to the cost of taxing capital income. Lower capital income taxes will increase the share of income that is saved and invested instead of consumed. As a result, it will increase living standards in the long run by raising the amount of capital per worker, thereby raising worker productivity and wages.

In some of the models, the increase in economic efficiency from using carbon tax revenues to reduce capital income taxes is large enough to outweigh the efficiency cost of the carbon tax. According to these estimates, a carbon tax/capital income swap will raise economic well-being without even accounting for the environmental benefits of reducing greenhouse gas emissions. In that sense, the tax swap can be said to result in a *double dividend* consisting of both net economic benefits and environmental benefits (box 4).

The models used to reach these economic conclusions have shortcomings. Taxes enter the models in simple ways that do not reflect the full complexity of the tax law. In particular, the models generally do not account for different ways of taxing capital income having different effects on domestic saving and investment in an economy with international capital mobility. The models also assume perfect competition and so do not reflect the extent to which a portion of the corporate income tax is a tax on economic rents or super-normal returns instead of a tax on the marginal return to additional equity-financed investments.[38] Further, it may be unrealistic to assume that policymakers would shift the burden of taxes from capital income to labor income in the presence of a carbon tax when, faced with the same potential efficiency gains from tax reform, they have not made a similar tax shift today.

Nonetheless, both economic reasoning and the results of simulation models suggest that the net burden of a carbon tax can be substantially reduced by using some or all of the revenue to reduce other taxes that distort economic behavior. And even absent a double dividend, the economic benefits from reduced emissions will almost always exceed the net economic cost of substituting a carbon tax for other revenue sources.

WHO WINS AND LOSES?

The distributional effects of a carbon tax are complex, involving current and future generations across the globe and individuals affected not just by climate change but also by other harms from fossil fuel use. In current policy debates, however, a particularly salient question is how the financial impacts of the tax will be distributed. Who bears the burden of a carbon tax and who benefits from any accompanying policies?

Given the recent focus on revenue-neutral carbon policies, we consider four options that would recycle all carbon revenues into other tax reductions: (1) reducing payroll tax rates; (2) reducing the corporate tax rate; (3)

BOX 4. A DOUBLE DIVIDEND?

The main objective of a carbon tax is to reduce environmental damage by encouraging producers and consumers to cut back on activities that release greenhouse gases. This is its first *dividend*. A carbon tax can also generate a second dividend: an improvement in economic efficiency by using the resulting revenue to reduce distortionary taxes, such as those on income or payroll.

Some observers wrongly believe that the second dividend always occurs. Setting aside environmental benefits for a moment, a carbon tax, like other excise or consumption taxes, creates economic distortions. By reducing real earnings, it lowers the return to working just as direct taxes on earnings do. The naïve view ignores these distortions and instead focuses solely on the economic benefit of reductions in other distortionary taxes and the environmental benefit.

The second dividend can exist but only when the economic distortions from a carbon tax (not counting environmental benefits) are less than the distortions of the taxes it replaces. This is most likely if those taxes fall on capital income (table 3). Jorgenson and colleagues and McKibbin and colleagues, for example, estimate that there are net efficiency gains from using carbon tax revenues to reduce capital income taxes, even if we ignore environmental benefits.[1] If their estimates are correct, one can say there is a double dividend. Other researchers, however, find that reduced capital income taxes do not fully offset the distortions from a carbon tax, even though they reduce efficiency losses more than would lump sum grants or reduced taxes on labor income.

The starting place for a carbon tax is important as well. If a country already has in place a regulatory framework with effects on marginal costs and prices similar to a carbon tax, it will be easier for the tax to generate the second dividend. In essence, the regulatory framework is already generating distortions similar to those a carbon tax would produce, without collecting any revenue for the government. When enacted, a carbon tax would have a smaller impact on economic efficiency, while generating revenue that can be used to reduce distorting taxes. Whether the first dividend—environmental benefits—exists then depends on whether the tax generates at least as much environmental gain as the regulatory approach.

[1] Jorgenson, et al. "Carbon Taxes and Fiscal Reform in the United States;" McKibbin et al. "Carbon Taxes and U.S. Fiscal Reform."

reducing all individual income tax rates by a constant percentage; and (4) providing equal lump-sum refundable tax credits to all households (this option is, functionally, a spending program, but could be implemented through the revenue system). These are simple generic options. There are many more complicated and refined options possible, including more targeted ways of reducing corporate tax burdens, such as reforming the taxation of foreign profits of US multinational corporations, and more targeted ways of reducing individual and payroll tax rates and providing credits, such as phasing out the benefits of the rate cuts or credits at higher income levels. In addition, policymakers could create combinations of these policies.

By raising the prices of fossil fuels and goods and services made with them, a carbon tax reduces the purchasing power of workers and, in the long run, of individuals who receive government benefits (such as Social Security) linked to growth in real earnings. The tax also redistributes purchasing power from people who spend more of their money on carbon-intensive goods and services to people who spend relatively less on those products. Unlike an income tax, however, the portion of a carbon tax that flows through directly in higher energy prices to consumers or operating costs of businesses does not reduce what economists call the "normal" rate of return on investment, which reflects the compensation individuals receive for delaying consumption. A carbon tax thus falls mostly on earnings and on super-normal investment returns and economic rents (such as the returns attributable to innovative activity) but only to a small extent on normal investment returns.[39]

Investment income is concentrated in upper-income groups, and lower-income households spend a relatively larger share of their total consumption on carbon-intensive products like gasoline, home heating oil, and electricity. For those reasons, a carbon tax is regressive: it imposes a relatively larger burden as a share of income on lower-income households than on higher-income ones. A $20 carbon tax in 2015 (a bit smaller than the tax CBO considers) would be a hit of 0.8 percent of pre-tax income for households in the lowest quintile (bottom fifth) of the income distribution (figure 2, table 4).[40] Households in the middle quintile would face a hit of 0.7 percent of pre-tax income, while households in the top 1 percent would face a hit of only 0.3 percent.

The net effect of a carbon tax plus recycling varies greatly among the options. Offsetting the carbon tax with cuts in corporate or individual income tax rates leaves households in the bottom 90 percent of the income distribution worse off, on average, and leaves households in the top 5 percent as net winners. An equal per-adult refundable credit (with each child receiving half the adult amount) more than offsets the burden of a carbon tax for households in the bottom 60 percent of the distribution, but raises tax burdens on average for upper-income taxpayers. The combination of a carbon tax and a reduction in payroll tax rates leaves households in the bottom two quintiles and the top 1 percent slightly worse off, while leaving the tax burdens in the middle quintile approximately unchanged and reducing net tax burdens for those in the top two quintiles, but below the top 1 percent.

The distributional effects shown here compare the combination of a carbon tax with various recycling options against a baseline in which the government takes no action on climate change. The distribution would be different if we measured policy impacts against a baseline in which the government had adopted other policies to mitigate climate change. Suppose, for example, the carbon tax were replacing a cap-and-trade policy with the same effect on the price of carbon. If these tradable permits were allocated to firms at no charge in proportion to their existing emissions of carbon from burning fossil fuels instead of being auctioned off to the highest bidders, a revenue-neutral carbon tax would have little or no effect on energy prices. Instead, it would redistribute income from permit recipients to the beneficiaries of the tax cut paid for by carbon tax receipts. For most revenue recycling scenarios, this shift to a carbon tax would benefit lower and middle-income households because upper-income business owners are the main beneficiaries of government grants of emission rights, and benefits

Figure 2. The Distributional Effects of a Carbon Tax, Recycling Options, and Revenue-Neutral Tax Plans

These charts show how the impact of tax options varies by income. Households are arranged from lowest to highest income in five groups ("quintiles"), with impacts measured as a percent of pre-tax income. These figures illustrate a $20 per ton tax in 2015; impacts would scale proportionally for higher or lower tax rates.

Source: Urban-Brookings Tax Policy Center Microsimulation Model.

of most of the tax-cut options are distributed more evenly among taxpayers. Using a carbon tax to replace regulations would have a similar effect to the extent that producers are allowed to benefit from higher prices on the amounts of carbon-based fossil fuels that they continue to be permitted to use.

In short, the distributional effects of a carbon tax depend heavily on how policymakers decide to deploy the resulting revenue. They also depend on what one assumes would be the policy on climate changes in the absence of a carbon tax.

WHAT IF OTHER COUNTRIES DO NOT LIMIT THEIR CARBON EMISSIONS?

The United States accounts for one-seventh of the world's greenhouse gas emissions. US policies will thus have a material impact on the future trajectory of greenhouse gases and climate change. But the United States alone cannot solve this challenge, particularly given the rapid growth in industrial production, electricity use, and driving in China, India, and other emerging economies. Coordinated, global actions are required to avoid the worst threats from climate change.

Table 4. The Distributional Effects of a Carbon Tax with Revenue Recycling (Percent of Pre-Tax Income)

		Carbon Tax with Revenue Recycled Through			
		1	2	3	4
Tax units ranked by income percentile	Carbon tax alone	Refundable credit (equal per-capita)	Payroll tax rate	Corporate income tax rate	Personal inome tax rates (equal percent)
0–20th	0.8	-1.1	0.2	0.6	0.8
20–40th	0.7	-0.8	0.1	0.5	0.6
40–60th	0.7	-0.2	0.0	0.4	0.4
60–80th	0.6	0.1	-0.1	0.2	0.2
80–90th	0.6	0.2	-0.2	0.1	0.1
90–95th	0.6	0.3	-0.1	0.0	-0.1
95–99th	0.5	0.3	0.0	-0.2	-0.4
Top 1 percent	0.3	0.3	0.2	-0.9	-0.9
All	0.6	0.0	0.0	0.0	0.0

Source: Urban-Brookings Tax Policy Center Microsimulation Model.

These illustrative calculations consider a carbon tax of approximately $20 per metric ton in 2015.

(1) Multiply all payroll tax rates by 0.908. The combined Old Age, Survivor, and Disability Insurance and Hospital Insurance tax rates decline from 15.3 to 13.9 percent. The combned Old Age, Survivor, and Disability Insurance rate declines from 12.4 to 11.3 percent.

(2) Reduce the corporate tax rate to approximately 28.5 percent.

(3) Multiply all ordinary income tax rates and Alternative Minimum Tax rates by 0.93. (The ordinary rates change from 10 to 39.6 percent to 9.3 to 36.8 percent.)

(4) Provide each tax unit with a per-capita refrundable credit of $726 per adult and $363 per dependent child.

If the United States enacts a substantial carbon tax, it may be acting sooner and more aggressively than other nations. Being a relatively early mover raises two related concerns: whether emissions reductions in the United States might be offset by leakages that increase emissions elsewhere in the world and whether a substantial carbon tax would hamper the international competitiveness of American businesses.

Leakage can occur through two channels. First, a US carbon tax will reduce demand for domestic and imported fossil fuels. That demand reduction will drive down the worldwide prices of oil, coal, and other internationally traded fuels. Those lower world prices will boost fossil fuel consumption in other countries, offsetting some of the benefit from lower US consumption. The extent of this offset will depend on the price responsiveness of world supply and demand for fossil fuels. The offset will be larger if the world demand is highly responsive and supply is less responsive to changes in the world price.

Some empirical work has been done on both demand and supply responses. A recent survey of the literature finds demand elasticities generally fairly low, ranging between 0.6 and 0.8, while supply elasticities are low for oil and gas (less than one), but much higher for coal (ranging up to 20 in some studies).[41] Taken together, these studies suggest a fairly wide potential range for carbon leakage. Most estimates based on computable general equilibrium models fall in the 10 to 30 percent range, but some other models find much higher leakage rates.[42]

Second, a US carbon tax may shift some purchases from goods produced in the United States to goods produced abroad in locations subject to lower or no taxes. In the extreme, if the tax simply shifts purchases of carbon-intensive goods from the United States to other countries, it will have no effect on greenhouse gas emissions, but it will make some US industries unable to compete in world markets.

To prevent shifts in production, a unilateral US carbon tax would have to apply to imports and exempt exports. Taxing imports and exempting exports prevents foreign producers from gaining an advantage in serving US and foreign markets. Exempting exports also avoids any incentive for US firms to move production abroad to serve foreign markets. Such border adjustments would mean that US consumers would pay the tax regardless of where production occurs, and US producers would collect and pass forward the US tax only if they sell to US consumers. This would make the tax neutral with respect to decisions on the location of production. In that way, it would parallel existing US taxes on highway motor fuels, alcoholic beverages, and tobacco and value-added taxes in most countries, all of which apply to imports and exempt exports.

Imposing such border adjustments would be straightforward for fossil fuels and refined products like gasoline and home heating oil. Exempting exports and taxing imports of these fuels and fuel products would not create a conflict with existing trade agreements because they would not be viewed as discriminatory taxes. The difficulty comes with taxing the fossil fuel content of goods manufactured using fossil fuels as direct or intermediate inputs. A US carbon tax will raise their prices only if they are manufactured in the United States. To make a carbon tax fully neutral among production locations, there would need to be a series of import duties on the carbon content of all imports and a series of rebates on the carbon content of all exports.

Such complete border adjustment is impractical for technical and legal reasons.[43] There is no way the United States can practically measure the carbon content of goods manufactured overseas because it depends on the production technologies used in making both the goods and on the methods used in manufacturing intermediate inputs (such as steel in automobiles). Complex sets of import duties that the United States cannot show are directly related to any specific characteristic of an imported product might also run afoul of trade agreements.

Fortunately, the absence of border adjustments creates problems only for the limited subset of industries that are both energy-intensive and trade-exposed (EITE). These EITE industries make up a relatively small share of the economy, about 12 percent of manufacturing output and 6 percent of manufacturing employment, mostly in the chemical paper, nonmetallic minerals, and primary metals sectors.[44] The potential leakage as a share of carbon use in these sectors is, however, significant.

In the absence of complete border adjustments, there are options for selective relief for US producers, all imperfect. Most promising are exempting firms in EITE industries from the carbon tax or subsidizing their output. Exemption has the benefit of simplicity and would mute political opposition from affected sectors. But it would not provide an incentive for affected industries to reduce emissions. Output subsidies are more complex and require the use of uniform assumptions about carbon intensity for different industries, when, in fact, carbon intensity can often vary among producers of the same goods (e.g., producers in regions that use hydropower instead of coal-generated electricity). Output subsidies, however, if combined with retention of the carbon tax, would provide an incentive at the margin for affected firms to reduce their carbon intensity.[45]

Border adjustments for EITE outputs would more directly preserve the tax on US consumers while exempting exports, but they would be complex and necessarily imprecise. The United States cannot measure the carbon intensity of imported goods absent details about production technologies used in their manufacture and in the manufacture of their intermediate inputs. It could assume an average carbon intensity based on estimates from US production, but this might either over or under tax the carbon content of imports. Measuring the carbon-content amounts necessary to compute export rebates would also be complicated, as some exports embody imported inputs and carbon intensity varies among firms supplying intermediate inputs to domestic firms.

Deciding how to treat exports involves a trade-off between environmental concerns and competitiveness. Exempting exports from a carbon tax preserves the international competitiveness of US producers but reduces America's ability to unilaterally combat climate change. This is particularly true for industries that are unlikely to move abroad and that have some ability to pass a US carbon tax on to foreign buyers. For that reason, some proposals would provide only partial border adjustments, taxing imports but not exempting exports.

These concerns over competitiveness complicate the implementation of a carbon tax, but they do not eliminate its basic rationale of providing incentives to reduce greenhouse gas emissions. They do mean, however, that for political and economic reasons some adjustments may be required for sectors that would be vulnerable to international competition from non-taxing jurisdictions. There are a variety of ways to provide these adjustments, but all would either be complex, weaken incentives to use less carbon-intensive production methods, or be subject to challenge under international trade agreements.

WOULD A TAX WEAKEN THE CASE FOR OTHER REGULATIONS AND SUBSIDIES?

In the absence of a broad, substantial price on carbon, policymakers have attempted to reduce carbon emissions through a mix of narrower policies. The Environmental Protection Agency is developing emissions standards for new and existing power plants, the Department of Transportation has expanded vehicle fuel economy standards, and the Department of Energy has expanded appliance energy efficiency standards. Tax subsidies and renewable fuel standards favor renewable and low-carbon fuels, such as wind, solar, biomass, geothermal, and nuclear, and biodiesel and electric vehicles.

A sufficiently high and broad carbon tax would reduce the benefit of these policies. If policymakers contemplate such a tax, it would be appropriate to reassess these policies to see whether their benefits justify their costs. Some policies will pass that test if they deliver sufficient environmental or economic benefits beyond reduced emissions of greenhouse gases or if the carbon tax is below a reasonable estimate of the social cost of carbon. But others may become redundant or impose more costs than benefits.

From a political perspective, moreover, rolling back regulations and tax breaks may be needed to build a coalition willing to enact a carbon tax. In an attempt to identify a center of gravity in thinking, Morris suggests pairing a carbon tax with the repeal of clean-energy tax breaks, rolling back some energy efficiency standards, and suspending EPA regulations.[46] Suspension is a compromise between wholesale repeal and the status quo, which includes a substantial role for EPA regulation. Under suspension, the EPA's authority and regulations would continue to exist for some time while we monitor the performance of a carbon tax and its effect on emissions. Taylor, laying out a conservative case for a carbon tax, would go further and preempt state and regional cap-and-trade programs and renewable fuel standards, eliminate vehicle fuel economy standards, and permanently repeal EPA authority to regulate greenhouse gases.[47]

The environmental implications of such proposals depend on the relative impacts of potential carbon taxes and existing alternatives. A sufficiently high carbon tax could reduce emissions more than existing policies, for example, but an insufficiently low tax would not. From an environmental perspective, therefore, the impacts of pairing a carbon tax with the suspension or elimination of other policies depends on policy specifics.

A carbon tax would also reduce the benefit of federal subsidies for clean energy and energy efficiency. The tax would encourage private innovation and, at the margin, reduce the need for government support. That does not mean, however, that a carbon tax would eliminate the need for federal support for research and development. Absent such support, the private sector would still have insufficient incentives to invest in the sorts of basic research that can create new technologies, because the benefits to consumers and businesses from such inventions can dwarf the returns that accrue for innovators. It thus makes sense to continue federal support for basic research and development on clean energy, as in other areas of technology. Support beyond that level makes sense if the carbon tax falls short of a reasonable estimate of the social cost of carbon.

WHAT CAN WE LEARN FROM OTHER COUNTRIES?

Despite the practical and political challenges, many countries have already priced carbon. About 40 countries have put a price on some of their carbon emissions, covering about 12 percent of annual global greenhouse gas emissions (figure 3).[48] Most have done so through emissions trading systems, but 15 countries and jurisdictions tax some of their carbon emissions (table 5).

Carbon pricing continues to expand. In 2013, eight new carbon markets opened, and the total allowances in emission trading systems were valued at about $30 billion in May 2014. In 2015, South Korea opened the world's second-largest trading system, covering nearly two-thirds of its emissions. Other countries have developed plans for carbon pricing: in 2013, South Africa released a policy paper proposing a carbon tax for implementation in 2016, and a national Chinese emissions trading system is slated to start in 2016.

Those expansions in carbon pricing have been accompanied by one prominent reversal. Australia introduced a combined trading and tax system in 2012, but then repealed it in 2014 amid concerns about energy prices and economic growth.

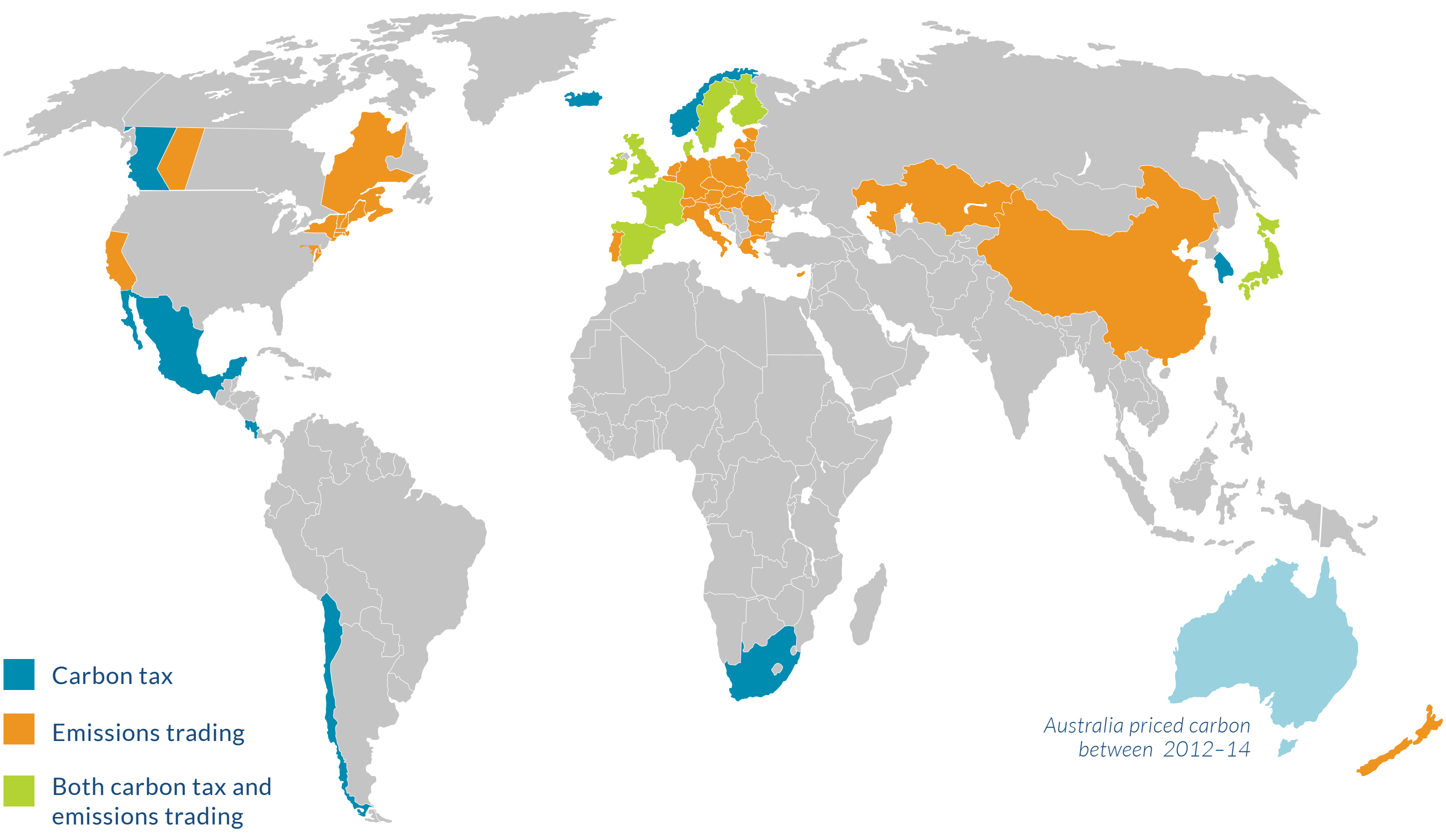
There are several lessons we can draw from other countries' experience with pricing carbon:

1. Carbon pricing reduces emissions. In the three years that Australia had a carbon pricing mechanism (set at $19/metric ton of carbon dioxide equivalent and rising annually), emissions in affected sectors fell from 1.5 to 9 percent. British Columbia has had a carbon tax set at \$26/metric ton of carbon dioxide equivalent since 2008, and emissions fell around 10 percent between 2008 and 2011.[49] A survey of carbon taxes in Finland, Denmark, the Netherlands, and Sweden found that all reduced emissions more than if there were no policy changes; the reductions ranged from about 1.5 percent to nearly 6 percent.[50]

2. Reductions reflect significant changes in energy industries. Since the introduction of Denmark's carbon tax in the early 1990s, the makeup of energy supply has markedly changed. Natural gas and combustible renewables have grown as reliance on oil, coal, and peat declined, though reliance on oil has remained somewhat stable since 2000.[51] Similarly, a survey of Norway's energy system following the introduction of a carbon tax in 1991 found that energy production from natural gas increased substantially, while production from gasoline and heavy oil fell.[52]

3. Carbon tax measures are often intended to be part of a revenue-neutral or budget-neutral package. Policymakers often try to offset the burden of carbon taxes by pairing them with offsetting tax cuts or spending increases. British Columbia's carbon tax was paired with reductions in the provincial corporate income tax and the lowest personal income tax rates, a low-income tax credit, and a rebate for rural taxpayers. That package was intended to be revenue-neutral, but it ended up reducing revenue as business and individual tax cuts outweighed revenue from the new tax. The United Kingdom had a similar experience; revenues from its Climate Change Levy were used to pay for reductions in payroll taxes, and the net result was an unintended tax cut.[53]

Figure 3. Carbon Pricing around the World



In designing its carbon tax, South Africa modeled revenue-recycling scenarios, introducing new tax incentives, such as energy-efficiency credits, for individuals and businesses to reduce carbon dioxide emissions. In this way, the revenues from a carbon tax would be used to further reduce carbon emissions.

4. In geographically large nations, subnational governments often act before national ones. In Canada, for example, British Columbia introduced a carbon tax in 2008, and Quebec introduced a trading system in 2013. In China, seven subnational governments introduced pilot trading programs in 2013 and 2014. And in the United States, greenhouse gas trading programs exist in the Northeast (since 2009) and California (since 2013).

5. Carbon pricing often does not cover all emissions. While some carbon taxes cover most greenhouse gas emissions (British Columbia and Japan cover 70 percent each; South Africa covers 80 percent), others

Table 5. Carbon Taxes Around the World

Country/jurisdiction	Year adopted	Tax rate (US$/t$CO_2$e)[a]	Coverage	Coverage rate (% of GHG)
British Columbia	2008	25	Purchase or use of fuels	70
Chile	2014	5	Emissions from the power sector	55
Costa Rica	1997	3.5% on hydrocarbon fossil fuels	Fossil fuels	85
Denmark	1992	31	Consmption of fossil fuels, with exemptions	45
Finland	1990	40	Heat, electricity, transportation and heating fuels	15
France	2014	8	Fossil fuel products, based on CO_2 content	35
Iceland	2010	10	Imports of liquid fossil fuels	50
Ireland	2010	23	Fossil fuels not covered by EU ETS	40
Japan	2012	2	Fossil fuels by CO_2 content	70
Mexico	2014	1–4 /tCO_2	Fossil fuel sales and imports	40
Norway	1991	4–69	Mineral oil, gasoline, and natural gas	50
South Africa	2016	10 /tCO_2	Emissions from fuel combustion and non-energy industrial processes	80
Sweden	1991	168	Fossil fuels for heating and motor fuels	25
Switzerland	2008	68	Fossil fuels not used for energy or covered by EU ETS	30
United Kingdom	2013	16	Fossil fuels used to generate electricity	25

Source: World Bank, "Putting a Price on Carbon with a Tax"; World Bank, State and Trends of Carbon Pricing 2014.

Note: GHG = greenhouse gases. EU ETS = European Union Emissions Trading System.

[a] Amounts have been converted to US dollars using the latest available exchange rate. Tax rates are for 2013 or 2014, except for British Columbia (2012), Chile (2018), and South Africa (2016).

have a reduced scope (Finland's applies to just 15 percent; Sweden and the United Kingdom cover just 25 percent).[54] A reduced scope can be the result of a limited geographical or industrial application of the tax. Finland, for example, levies the tax only on transport and heating fuels and electricity, with rates levied primarily by carbon dioxide content.

Carbon taxes thus do reduce emissions and can finance offsetting tax cuts. But details matter. A carbon tax will be most efficient if it has a broad base, covering as many greenhouse gas emissions as practical, and if policymakers carefully calibrate any offsetting tax cuts to the amount of revenue the tax actually generates.

NOTES

1 IPCC (Intergovernmental Panel on Climate Change), *Climate Change 2014: Synthesis Report*, ed. The Core Writing Team, Rajendra K. Pachauri, and Leo Meyer (Geneva, Switzerland: IPCC, 2015). https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf.

2 Taxes and cap-and-trade approaches can also differ politically. A cap-and-trade system would create a valuable new asset, tradable emission rights, that legislators could allocate to build support for the system (or for less salutary reasons). In principle, the same is true of revenue from a tax, but in practice the public may find allocation of emission rights less salient than redistribution of tax revenue.

3 Gilbert E. Metcalf, "Cost Containment in Climate Change Policy: Alternative Approaches to Mitigating Price Volatility," *University of Virginia Tax Review* 29, no. 2 (2009): 381–405. doi: 10.3386/w15125.

4 For a detailed comparison of taxes, cap and trade, and hybrids, see Lawrence H. Goulder and Andrew Schein, "Carbon Taxes Versus Cap and Trade: A Critical Review," *Climate Change Economics* 4, no. 3 (2013). doi: 10.3386/w19338.

5 This section builds on the discussion in Donald B. Marron and Eric J. Toder, "Tax Policy Issues in Designing a Carbon Tax," *American Economic Review: Papers and Proceedings* 104, no. 5 (2014): 563–8. doi: 10.1257/aer.104.5.563.

6 Environmental Protection Agency (EPA), "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012," (Washington, DC: EPA, 2014). http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

7 Global warming potentials are so high for certain refrigerants and other industrial gases that a carbon tax may be equivalent to eliminating their release; in those cases, it may make as much practical sense to phase those gases out as to create a tax system for them.

8 IPPC, *Climate Change 2014*.

9 Brian C. O'Neill, "Economics, Natural Science, and the Costs of Global Warming Potentials," *Climate Change* 58, no. 3 (2003): 251–60. doi: 10.1023/A:1023968127813.

10 In a similar vein, policymakers may also want to reward efforts to remove greenhouse gases from the atmosphere (e.g., by planting trees on lightly vegetated land) or to reduce emissions that result from clearing land.

11 This section builds on the discussion in Marron and Toder, "Tax Policy Issues."

12 EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks."

13 Interagency Working Group on Social Cost of Carbon, *Social Cost of Carbon for Regulatory Impact Analysis: Under Executive Order 12866*, (Washington, DC: White House, 2010); and Michael Greenstone, Elizabeth Kopits, and Ann Wolverton, "Developing a Social Cost of Carbon for US Regulatory Analysis: A Methodology and Interpretation," *Review of Environmental Economics and Policy* 7, no. 1 (2013): 23–46. doi: 10.1093/reep/res015.

14 Negative values occur if the benefits of climate change (e.g., increased agricultural productivity from greater carbon dioxide in the atmosphere) exceed the costs. The models do not suggest that is a likely outcome. But some allow that possibility under certain assumptions.

15 Interagency Working Group on Social Cost of Carbon, *Technical Update for the Social Cost of Carbon for Regulatory Impact Analysis: Under Executive Order 12866*, (Washington, DC: White House, 2013), https://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf. The working group expresses costs in 2007 dollars; for example, the revised social cost of carbon for 2015 is $37 in 2007 dollars. We have updated to 2015 dollars using the consumer price index.

16 Robert S. Pindyck, "The Use and Misuse of Models for Climate Policy," (working paper, National Bureau of Economic Research, Cambridge, MA: National Bureau of Economic Research, 2015). doi: 10.3386/w21097.

17 Greenstone, Kopits, and Wolverton, "Developing a Social Cost of Carbon."

18 Ted Gayer and Kip Viscusi, "Determining the Proper Scope of Climate Change Benefits," (Washington, DC: The Brookings Institution, 2014), http://www.brookings.edu/research/papers/2014/06/04-determining-proper-scope-climate-change-benefits-gayer.

19 Matthews, H. Damon and Kirsten Zickfeld, "Climate response to zeroed emissions of greenhouse gases and aerosols," *Nature Climate Change* 2, 338-341 (2012). doi: 10.1038/nclimate1424.

20 US Department of State, *2014 U.S. Climate Action Report to the UN Framework Convention on Climate Change*, (Washington, DC: US Department of State), http://www.state.gov/documents/organization/219038.pdf.

21 CBO (Congressional Budget Office), *Options for Reducing the Deficit: 2014 to 2023*, (Washington, DC: CBO, 2013), https://www.cbo.gov/content/options-reducing-deficit-2014-2023.

22 In 2013, emissions were 9 percent below 2005 levels; the tax CBO considers would reduce emissions roughly another 9 percent over the next decade, in the same range as the 10 percent reduction from the Clean Power Plan. The Clean Power Plan, though, applies only to existing power plants, while the CBO-analyzed tax would apply to electricity, transportation, and manufacturing sources.

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25 Robert Shapiro, Nam Pham, and Arun Malik, "Addressing Climate Change without Impairing the US Economy: The Economics and Environmental science of Combining a Carbon-Based Tax and Tax Relief," (Washington, DC: The US Climate Task Force, 2008), http://www.sonecon.com/docs/studies/CarbonTaxReport-RobertShapiro-2008.pdf.

26 CBO, *Options for Reducing the Deficit*.

27 CBO, “The Role of the 25 Percent Revenue Offset in Estimating the Budgetary Effects of Legislation,” (Washington, DC: CBO, 2009), http://www.cbo.gov/sites/default/files/01-13-25percentoffset.pdf.

28 Donald B. Marron and Eric Toder, “Carbon Taxes and Corporate Tax Reform,” in *Implementing a US Carbon Tax*, ed. Ian Parry, Adele Morris, and Roberton C. Williams III (New York, NY: Routledge, 2015), http://www.taxpolicycenter.org/UploadedPDF/412744-Carbon-Taxes-and-Corporate-Tax-Reform.pdf.

29 Sebastian Rausch and John Reilly, “Carbon Taxes, Deficits, and Energy Policy Interactions.” National Tax Journal 68, no.1 (2015): 157–78 doi: 10.17310/ntj.2015.1.07; Sugandha D.Tuladhar, W. David Montgomery, and Noah Kaufman, “Environmental Policy for Fiscal Reform: Can a Carbon Tax Play a Role?” *National Tax Journal* 68, no. 1 (2015): 179–94 doi: 10.17310.ntj.2015.1.08; McKibben et al., “Carbon Taxes and U.S. Fiscal Reform.”

30 Karen Palmer, Anthony Paul, and Matt Woerman, “The Variability of Potential Revenue from a Tax on Carbon,” *Considering Carbon Tax* 12-03 (Washington, DC: Resources for the Future, 2012), http://www.rff.org/RFF/Documents/RFF-IB-12-03.pdf.

31 Marron and Morris analyze the pros and cons of different ways of using revenue from corrective taxes. Marron, Donald B. and Adele C. Morris, “A Guide to Corrective Taxes and Using Their Revenue,” (Washington, DC: The Urban Institute, forthcoming).

32 Howard Gleckman, “What’s Up with the No Climate Tax Pledge?” *TaxVox* (blog) June 2, 2015, http://taxvox.taxpolicycenter.org/2015/06/02/whats-up-with-the-no-climate-tax-pledge/.

33 William G. Gale, Samuel Brown, and Fernando Saltiel, “Carbon Taxes as Part of the Fiscal Solution,” in *Implementing a US Carbon Tax*, ed. Ian Parry, Adele Morris, and Roberton C. Williams III (New York, NY: Routledge, 2015), http://www.brookings.edu/research/papers/2013/03/12-carbon-tax-gale.

34 Marron and Morris, “A Guide to Corretive Taxes and Using Their Revenue.”

35 The direct burden of taxes is the sacrifice of private consumption necessary to fund the public services that tax revenues support. The term “excess burden” is used to refer to the additional loss in economic welfare as a result of behavioral responses to taxes. If, for example, a tax that funds $100 worth or public services reduces private economic activities by amounts households value at $120, the excess burden is equal to $20.

36 Effects on economic well-being are related, but not identical, to the effects on Gross Domestic Product (GDP). For example, a tax that induced households to engage voluntarily in less paid work will reduce GDP by more than it reduces economic well-being because households get some value from the increased time spent on household production or leisure.

37 Jorgenson et al. “Carbon Taxes and Fiscal Reform in the United States;” McKibbin et al. “Carbon Taxes and U.S. Fiscal Reform;” Rausch and Reilly, “Carbon Taxes, Deficits, and Energy Policy Interactions;” Tuladhar, Montgomery, and Kaufman, “Environmental Policy for Fiscal Reform;” and Williams, Brown, and Saltiel, “Carbon Taxes as Part of the Fiscal Solution.”

38 Several researchers have noted, for example, that a substantial portion of the corporate revenue base would remain if corporate investment were expensed, which would remove the corporate-level tax on the marginal return to investment. What remains in the corporate base would be economic rents from intangible assets, such as patents or brand reputation. See, for example, William M. Gentry, and R. Glenn Hubbard, “Distributional Implications of Introducing a Broad-Based Consumption Tax,” in *Tax Policy and the Economy*, vol. 11 (Chicago: University of Chicago Press1997): 1–47 doi: 10.3386/w5832; Eric Toder and Kim Rueben, “Should We Eliminate Taxation of Capital Income?” in *Taxing Capital Income*, ed. Henry J. Aaron, Leonard E. Burman, and C. Eugene Steuerle, (Washington, DC: Urban Institute Press, 2007): 89–141 http://www.americantaxpolicyinstitute.org/pdf/FallConference2005/toderruebenatpi.pdf; and Julie-Anne Cronin, Emily Lin, Laura Power, and Michael Cooper, “Distributing the Corporate Income Tax:

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39 The portion of a tax that falls on fuel used in the production (though not the use) of capital goods does reduce the normal return to the extent that firms recover these added costs only over time through depreciation. Because our estimates do not account for the portion of the tax that falls on the normal return to capital, and because these returns are highly concentrated among upper income individuals, our results over-state the degree to which a carbon tax is regressive.

40 CBO, *Options for Reducing the Deficit*.

41 Jared Carbone, Carolyn Fischer, and Thomas Sterner, "The Net Emissions Effects of Fuel Taxes," presented at Fiscal Policies and the Green Economy Transition: Generating Knowledge – Creating Impact, Venice, Italy, January 2015, http://www.greengrowthknowledge.org/sites/default/files/Sterner_The_net_emissions_effects_of_fuel_taxes.pdf.

42 Christoph Böhringer, Edward J. Balistreri, and Thomas F. Rutherford, "The Role of Border Carbon Adjustment in Unilateral Climate Policy: Overview of an Energy Modeling Forum Study (EMF 29)," *Energy Economics* 34 supp. 2 (2012): S97–S110 http://www.rff.org/Documents/Events/120904_BCA_Workshop/border_carbon_adjustments_paper.pdf. Examples include Balestreri and colleague's model based on New Trade Theory, as well as sector-specific models. See Edward J. Balistreri and Thomas F. Rutherford, "Subglobal carbon policy and the competitive selection of heterogeneous firms," *Energy Economics* 34 supp.2 (2012): S190–S197 doi: 10.1016/j.eneco.2012.08.002.

43 Charles McLure, "Selected International Aspects of Carbon Taxation," *American Economic Review* 104, no. 5 (2014): 552–6. doi: 10.1257/aer.104.5.552

44 Carolyn Fischer, Richard Morgenstern, and Nathan Richardson, "Carbon Taxes and Energy-Intensive Trade-Exposed Industries." in *Implementing a U.S. Carbon Tax*, ed. Ian Parry, Adele Morris, and Roberton C. Williams III (Routledge: Oxford and New York, 2015): 159–77.

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