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What Should Policymakers Do about Climate Change?

By Jeffrey Miron and Pedro Braga Soares

What should policymakers do about the climate change that results from anthropogenic emissions of carbon dioxide (CO_2) and other greenhouse gases?[1]

For many, the answer is "whatever it takes to slash emissions," thus implying a broad range of carbon-reducing regulations, subsidies, tax credits, and more.[2] And this perspective usually argues for doing more of these policies, based on the assumption that climate change is an "existential" threat and that the only sensible goal is elimination of carbon-based fuels.[3]

Economics, however, gives a different answer. First, while economics accepts that carbon emissions generate externalities, implying that laissez faire might yield excessive emissions relative to the efficient outcome, it suggests these externalities are finite. This means policy should consider reducing emissions but only to the point where the marginal social benefits of reductions equal the marginal social costs of doing so. Second, economics suggests that, despite the theoretical case for policies that reduce emissions, existing government attempts are rife with problems: this implies that replacing the existing hodgepodge with a carbon tax might be better. Third, economics also predicts that while an ideal carbon tax would improve on the current regime, any real-world carbon tax will also suffer serious deficiencies and might be worse than laissez faire.

In this brief, we set aside whether the current scientific consensus on climate change is accurate and address how policymakers should respond if it is. For simplicity, we discuss only policies that target carbon emissions, but the same issues arise for greenhouse gas emissions more generally.

EXTERNALITIES AND THE LIMITS OF PRIVATE APPROACHES TO DEALING WITH CARBON EMISSIONS

Voluntary transactions are efficient in the sense that the buyer's willingness to pay is higher than the seller's willingness to sell; otherwise, the exchange would not happen. This is why markets promote welfare: they enable voluntary transactions.

When transactions affect third parties, however, the laissez faire outcome might be inefficient. Pollution is a classic

JEFFREY MIRON (left) is director of economic studies at the Cato Institute and director of graduate and undergraduate studies in the Department of Economics at Harvard University. **PEDRO BRAGA SOARES** is a graduate student in economics at Pontifical Catholic University of Rio de Janeiro, Brazil, and holds a BA in international relations.

example. Factories that emit noxious fumes into the air or dump toxic waste in rivers and lakes not only produce an economic "good" (whatever they manufacture) but also an economic "bad" (the pollution). Ideally the "bads" have negative prices, meaning that individuals and firms pay for generating them, thus discouraging their production.

Standard markets do not necessarily account for these costs on third parties (in our example, people who breathe the air near a factory or use the water in rivers and lakes). Economists call these types of costs externalities. Since third parties' consent is not required to generate these effects, the market outcome can generate too much production of "bads" relative to "goods."

Not all third-party effects are true externalities. When one individual outbids another in an auction, this produces a negative effect: the higher bidder gets the item, and the outbid party does not. But this is no real externality. The new bid just changes who owns the good, rather than changing the quantity, so no inefficiency results.[4] Economists distinguish these "pecuniary" externalities, arising from changes in market prices and competition, from real ones, such as pollution.

In other cases, externalities might be so small that the costs of addressing them almost certainly exceed their magnitude. Some people might be offended by tacky clothing, but the negative externalities are small enough that a (hard-to-enforce) "tacky dressing tax" makes little sense.

According to current science, carbon emissions are a real externality.[5] The price of fossil fuels reflects the direct costs of producing them and the benefits they provide users. But burning fossil fuels promotes climate change, which affects other parties, and this is not factored into prices. Absent intervention, therefore, market prices are too low, and use of fossil fuels too high, relative to the socially efficient outcome.

Let's illustrate. Suppose a driver gets a marginal benefit of $4.50 per gallon of gas, while the marginal cost to the retailer is $4.00. Assume the price is $4.00.[6] And assume that burning this extra gallon causes harm—from global warming—that third parties would pay $1.00 to avoid. If the driver buys the gallon, with no payment to third parties, the transaction generates a negative surplus of –$0.50.[7] That is, if third parties paid $0.50 to the buyer, which would make the buyer willing to forgo the purchase, the third parties would still be better off (earning a net loss of $0.50 instead of $1.00).

The fact that externalities generate inefficiencies means private solutions are sometimes possible because the inefficiencies imply profit opportunities. This insight comes from economics Nobel laureate Ronald Coase.[8] As above, parties can privately negotiate payments between themselves that reduce inefficiencies caused by externalities, if transaction costs—meaning any impediment to mutually beneficial trades—are sufficiently low and property rights are well-defined.

The problem with carbon emissions is that the number of third parties is potentially enormous. So, transactions costs are plausibly large, and private contracting might leave major inefficiencies in place. In our example, imagine that hashing out the agreement between third parties, drivers, and gas retailers costs $10: a deal is not profitable anymore. In a sense, when transaction costs are $10, the transaction is no longer economically inefficient, since transaction costs are a part of total costs.

Furthermore, it is impossible to define property rights such that benefits can be restricted to contracting parties (one cannot restrict a cooler temperature to some locations). This might encourage free riding: individuals refuse to join negotiations but expect to profit from them.

But one could imagine government trying to correct the externality, such as by mandating that cars install filters that reduce externalities by $1.00 but cost only $0.50. Or government could impose a $1.00 fee on gas. In the former case, the gas purchase would still happen, but the overall surplus would be zero.[9] In the latter, gas purchases would only happen if private marginal benefits exceeded private marginal costs by more than $1.00, guaranteeing the surplus would be nonnegative. Both interventions would be efficient relative to the market alternative.

The problem is that in real life costs and benefits are not well known in advance, government does not always face proper incentives to adopt the right policy, and intervention can generate its own transaction costs.

A HOST OF REGULATIONS, SUBSIDIES, TAX CREDITS, LOANS, GRANTS, AND MORE

The current policy regime for addressing carbon emissions involves a maze of interventions. These include energy efficiency standards for motor vehicles, home appliances, industrial machinery, and aircraft;[10] fuel economy labeling requirements and mandatory greenhouse gas emissions reporting;[11] tax credits for biofuels, wind turbines, solar energy systems, renewable home energy, and high-efficiency domestic appliance manufacturers; tax benefits from donating electronics to recycling; loan and grant programs for biorefineries and renewable chemical manufacturing; Clean Renewable Energy Bonds (CREBs);[12] and research and development funding for nuclear power and renewables.[13] There are even proposals to impose stringent regulation on financial assets deemed vulnerable to climate risks.[14]

This approach to reducing emissions—use every possible policy, and aim to eliminate emissions—is misguided for several reasons.

First, many of the policies target externalities only indirectly, which means the policies might generate greater costs than benefits.[15] For example, weatherization assistance programs offer state-funded efficiency upgrades to low-income families, but because these households have low energy use, the fixed costs of the upgrades might be small relative to any benefit from reduced emissions. Recent research finds that weatherization assistance programs have generated upfront investments 2.5 times higher than actual savings, translating to a social rate of return of −9.5 percent annually.[16] This problem can easily occur when policy applies broadly and does not target the externality directly.

Subsidies for solar energy generation, for example, have different environmental benefits across states, depending on solar irradiance and grid characteristics. Optimal subsidies, therefore, should vary: places with high solar irradiance, all else being constant, enjoy greater benefits of switching to solar; likewise, a locality where energy sources are dirtier would profit more environmentally by switching to solar. Research suggests that environmental benefits vary a lot across the United States but that subsidy levels are uncorrelated with environmental benefits, reducing these benefits by $1 billion relative to efficient subsidies.[17] Furthermore, solar residential subsidies often favor wealthy households.[18]

Another example is tax credits for electric vehicles (EVs). The environmental benefits of EVs hinge on electricity sources being used to power them, but a blanket subsidy ignores local variations in electricity generation sources. If the electricity that powers an EV comes from coal plants, switching from fossil fuel engines to electric ones can increase emissions rather than reduce them. Research finds that a federal purchase subsidy for EVs generates, on average, net environmental externalities of −$742 (2015 dollars), which implies that EVs should be taxed, not subsidized.[19] Furthermore, new EVs tend to replace relatively fuel-efficient vehicles, which are owned by drivers who would buy electric cars even without being offered subsidies. This also leads to overestimates of emissions reductions based on random replacement of gasoline vehicles.[20] Unsafe battery disposal from EVs can also pose significant environmental harm because they contain heavy metals.[21]

Second, energy efficiency subsidies and mandates—such as requiring less use of carbon fuels—crowd out innovation that could mitigate emissions more efficiently. Suppose someone discovers a fuel additive that costs only $0.25 per gallon to the retailer and would reduce emissions externalities by $1 in the absence of emission filters.[22] If regulation has already mandated filters, the relevant parties have no incentive to adopt this more-efficient alternative.

Third, figuring out, even roughly, what the correct standards should be and enforcing them can be costly. Gathering all the information about costs and benefits to all parties of a transaction is a necessary, but unachievable, step to enact efficient regulations. To make matters worse, once regulations are enacted they can bring about unintended consequences in behavior.

Take the Corporate Average Fuel Standards (CAFE), which require vehicles to achieve a certain number of miles per gallon. This might encourage more driving, since fuel cost per mile decreases, at least partially offsetting the fuel savings.[23] This is known as a “rebound effect.” The standards might also induce carmakers to change valuable vehicle features or use more expensive materials to reduce weight and achieve the required standards.[24] Since CAFE standards increase the costs of new vehicles, they might also prompt owners to hold onto their existing vehicles for longer, thus again offsetting some of the efficiency gains.[25] All of this means that CAFE regulations are highly inefficient compared to a simple gas tax. And research finds that, to get the same gas use reduction, the cost of toughening CAFE regulations is at least six times greater than an equivalent gas tax increase.[26]

Furthermore, various policies rely on unrealistic assumptions about consumer behavior or expected savings, such as assuming that consumers do not demand more energy when costs are lower due to higher efficiency, which leads to benefits being overstated. For instance, California building codes' energy efficiency requirements appear to yield savings that are significantly short of projections.[27]

Thus, the maze of regulation, credits, and subsidies that is currently in place—and likely to expand—is almost certain to create many inefficiencies, misaligned incentives, and high compliance costs. That is why many economists would replace this hodgepodge with a budget-neutral carbon tax.[28]

THE CARBON-TAX APPROACH

An alternative approach to regulation, subsidies, and mandates is carbon taxation, with the tax on all activities that generate carbon emissions equal to the negative externalities these emissions generate. Recent research that tries to incorporate the latest developments in climate modelling, for example, estimates a mean social cost of carbon of $125 per metric ton of CO_2, assuming a 3 percent discount rate.[29] In our earlier example, this would translate to a carbon tax of roughly $1.00 per gallon of gas.[30] This amount, although significant, is not huge. In fact, some countries already have gas taxes this high.[31]

Most economists prefer this approach to the maze of existing and proposed policies.[32] This approach is simple in theory: it unambiguously raises the price of activities that emit carbon and it incentivizes all carbon-related behavior to recognize the externalities.[33]

If properly set, such a tax forces parties to any transaction to consider the burden their production and consumption decisions impose on others; parties will only agree if the remaining surplus is greater than the externality. If, as in our example, the externality amounts to $1.00, the difference between the buyers' willingness to pay and the sellers' willingness to accept must exceed $1.00 for the transaction to occur. And since the tax applies to all emissions-generating activities, shifting from one to another to avoid the tax is not possible.

Because taxes lead to higher costs, individuals and companies face an incentive to adjust their actions in ways that reduce their carbon emissions. So, if a new technology comes along that reduces $1.00 worth of emission externalities but costs less than $1.00, then drivers and gas retailers have the incentive to use it. Individuals might also choose to drive less, while others prefer to switch partially to bicycles or other modes of transportation. Similarly, a higher carbon price incentivizes research and development into alternative technologies without the need for explicit subsidies. This releases government from picking technologies or mandating ways of doing things.

And a carbon tax generates revenue that can offset preexisting distortionary taxation. Keeping the carbon tax budget-neutral is important to keep it separate from debates about the proper size of government. Thus, repealing the existing mess of anti-emissions policies, and replacing it with a well-designed, budget-neutral carbon tax, could be an enormous improvement.

SHORTCOMINGS OF A REAL-WORLD CARBON TAX

A real-world carbon tax, however, is not the same as a theoretical carbon tax.

The first problem is setting the tax at the right level. This requires information about the full range of carbon-emitting activities, including not only harmful effects but also beneficial ones, such as colder countries benefiting from global warming and carbon dioxide fertilization effects.[34] By tallying all social costs and benefits of carbon emissions, an economist could calculate the marginal social (external) cost of carbon, that is, the net social harm from additional carbon emissions.[35]

Integrated climate models that are used to estimate the social cost of carbon have several steps. Long-term projections of population and GDP growth are translated into greenhouse gas emission estimates. Then emissions are converted to climate impacts, mainly through temperature increases, which yield projected damage figures based on estimates of the impact of temperature on economic activity, such as agricultural yields. Finally, future damages are discounted to obtain present value estimates of the social cost of carbon emissions.

Needless to say, this process is rife with uncertainty, and varying assumptions lead to wildly different estimates.[36] A meta-analysis of more than 500 studies finds estimates of the social costs of carbon ranging from −$13.36 per ton of CO_2 to $2,386.91 per ton of CO_2.[37] Estimates also vary with the discount rate applied to future costs. In another study, estimates range from $56.2 per ton of CO_2 to $785 per ton of CO_2 depending on the discount factor chosen.[38] Thus, the information requirements for an optimal carbon tax may not be so much less than those for existing policies. The problem is even harder because activities have different carbon intensities (coal, gasoline, oil, deforestation, cattle, and more), generating emissions of different greenhouse gases. If these emissions are not properly calculated, carbon taxation could distort relative prices and lead to inefficiencies. Moreover, carbon emissions may have other third-party effects besides global warming, such as pollution, which a complete analysis should address.

A further complication is that if only some countries adopt carbon taxes (a virtual certainty, especially after one accounts for noncompliance with treaties), thereby raising their own production costs, carbon-intensive activities may shift to countries with lower or no such taxes, a problem known as "leakage." In fact, production using relatively low-carbon natural gas could move to areas that use relatively high-carbon coal, such as China, thus increasing emissions on net. An ideal carbon tax must therefore be harmonized across countries, which is a challenging political feat.

A possible remedy is for countries that want to go it alone is to tax imports based on their carbon footprint and subsidize exports based on carbon taxes elsewhere, then foreign and domestic goods would face the same carbon tax rates. Ideally, country A imposes carbon taxes on imports from country B only to reflect the difference between country A's carbon taxes and country B's. Keeping track of all regional and international carbon duties is no easy task. And duty drawbacks—that is, tax refunds on goods to be reexported—could allow for rerouting of goods through intermediary countries, making accurate net duty accounting all but impossible.[39]

Since we care about *net* emissions, moreover, these border taxes should apply only to emissions that have not been offset through carbon capture and storage or similar methods. Taxing net emissions, however, is hard. One could devise a subsidy that mirrors the carbon tax for carbon offsetting. To work, this would require transferring tax credits from carbon emitters to carbon capturers, adding compliance and monitoring costs.[40] If only *gross* emissions are taxed, this might discourage carbon offset, even if offsetting emissions is more efficient than preventing them.

Identifying sources of carbon emissions is not an easy task, either. In many cases, one could add carbon taxes to ordinary sales taxes, according to the carbon intensity of the goods being transacted. But in other cases, carbon emissions may result from activities that do not immediately translate to market transactions, such as grazing cattle or deforestation, thus making it hard for governments to correctly identify these sources of emissions.

Political economy and public choice issues add to the challenge of enacting an ideal carbon tax. As a result, one might get lower-than-optimal tax rates, non-budget-neutral taxes, or a carbon tax on top of extant regulations and subsidies. A carbon tax below the marginal social cost of carbon might be better than none at all, but budget nonneutrality or an add-on tax could be worse than doing nothing.

Since replacing fossil fuels overnight would be prohibitively costly, a carbon tax forces voters to recognize that a cleaner economy must use less energy overall. But making energy more expensive means some people will experience welfare losses in the short run, even if they gain in the future due to reduced climate change.[41] Since some voters may not be around to enjoy those future benefits, and others may be impatient, it is no surprise that carbon taxes are politically unappealing.[42] In Washington State, for example, voters twice rejected ballot initiatives to enact carbon taxes.[43] Indeed, many governments subsidize fossil fuels despite the negative externalities.[44]

Carbon taxes are also plausibly more salient than complicated regulations and subsidies. Consumers can see gas taxes in a way they cannot see, for example, regulations on motor vehicle engine efficiency.[45] So governments resort to inefficient regulations since their costs stay mostly out of sight. This difference presumably explains the political popularity of many current policies, but it in no way justifies their inefficiencies.

Once a carbon tax bill goes through Congress, political logrolling will carve out exemptions and benefits to industries with political clout. This will add inefficiency to a real-world carbon tax. Therefore, even if an ideal carbon tax is preferable to the plethora of existing policies, the case for a real-world carbon tax is not compelling. Technical, informational, and political hurdles might greatly reduce the efficiency of a carbon tax in the real world.

These concerns raise the possibility that, even if anthropogenic climate change will impose significant costs, the least bad policy response might be doing nothing other than focusing policy on accelerating economic growth. This maximizes the amount of resources available to adapt to climate change.

CONCLUSION

Given current scientific knowledge, a plausible rationale exists for government intervention to address climate change. Nevertheless, a rationale for some kind of intervention does not indicate which kind is the most cost-effective, nor does it mean that even the most thoughtful intervention, given all the likely unintended consequences, is necessarily better than doing nothing.

Replacing the existing hodgepodge of interventions with a well-designed, easily enforced, and budget-neutral carbon tax would theoretically be an improvement; at a minimum, it would reduce existing distortionary taxes on "goods" while adding a tax on activities that are plausibly "bads" (even if climate change is a non-issue).

But determining whether a real-world carbon tax would improve on current policy, and whether this approach is desirable given the practical realities, is a far tougher challenge. Perhaps the greatest difficulty will be ensuring that an actual carbon tax *replaces* existing interventions rather than merely adding carbon taxes on top of them.

NOTES

1. Other greenhouse gases include methane (CH_4) and nitrous oxide (N_2O), but carbon dioxide (CO_2) accounts for 80 percent of U.S. greenhouse gas emissions. Throughout this brief, we use "carbon" as a stand-in for carbon dioxide and the other greenhouse gases. See "Overview of Greenhouse Gases," Environmental Protection Agency, July 27, 2021.

2. Degrowth proponent Jason Hickel calls for stabilizing world GDP in order to prevent environmental catastrophe. As for concerns that degrowth freeze poverty and reduce welfare, Hickel says that an interventionist approach would achieve both environmental improvement and welfare enhancement that capitalism is unable to provide. Hickel states: "This should not come as a surprise, because the point of capitalism is surplus extraction, elite accumulation, and reinvestment for expansion—not meeting human needs. To the extent that the system does meet human needs, this is generally the result of political interventions (i.e., unions, labour rights, public provisioning, etc.)." Jason Hickel, "Degrowth," *jasonhickel.org* (blog), October 27, 2020.

3. A report by the Breakthrough Institute, a climate think tank, says that climate change "now represents a near- to mid-term existential threat to human civilization" and that "to reduce or avoid such risks and to sustain human civilisation, it is essential to build a zero-emissions industrial system very quickly. This requires the global mobilization of resources on an emergency basis, akin to a wartime level of response." See David Spratt, Ian Dunlop, and Admiral Chris Barrie, "Existential Climate-Related Security Risk: A Scenario Approach," Breakthrough Institute Policy Paper, May 2019.

4. In fact, the higher bid increases welfare, since the seller now gets a higher price and the winner bidder's willingness to pay for the auctioned good should be higher than the outbid party.

5. William Nordhaus, "Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternative Approaches," *Journal of the Association of Environmental and Resource Economists* 1, nos. 1/2 (2014): 273–312.

6. In this example we are assuming perfect competition, so the price equals the marginal costs to producers. More generally, prices could be anywhere between $4.00 and $4.50 for the transaction to happen.

7. Total economic surplus is the difference between total benefits and total costs in dollar terms ($4.50 benefits to the driver minus the $4.00 costs to the retailer and the $1.00 negative externalities).

8. Ronald Coase, "The Problem of Social Cost," in *Classic Papers in Natural Resource Economics*, ed. Chennat Gopalakrishnan (London: Palgrave Macmillan, 1960), pp. 87–137.

9. In our example, the driver gets a surplus of $0.50 ($4.50 worth of benefits minus the $4.00 paid to the retailer); likewise, the retailer gets $0 worth of surplus ($4.00 price minus the $4.00 of costs). Adding externalities of −$1.00, this yields a surplus of −$0.50. When the filter is installed, negative externalities disappear, but the driver gets a surplus of $0, since he must pay an extra $0.50 per gallon for the filter.

10. Federal and state governments regulate energy efficiency standards for all household appliances, including boilers, ceiling fans, refrigerators, furnaces, TVs, and more, not to mention water savings standards for dishwashers, faucets, toilets, and showerheads. See National Appliance Energy Conservation Act of 1987, Pub. L. No. 100-12, 101 Stat. 103 (1987); and Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594 (2005).

11. See, for example, "Greenhouse Gas Reporting Program (GHGRP)," Environmental Protection Agency, November 9, 2021, https://www.epa.gov/ghgreporting.

12. For a comprehensive review of state and federal tax

credits, check "Database of State Incentives for Renewables and Efficiency (DSIRE)," N.C. Clean Energy Technology Center (North Carolina State University), November 16, 2021, https://www.dsireusa.org/. There are 30 federal policies in place and 170 state policies in California.

13. *Federal Support for Developing, Producing, and Using Fuels and Energy Technologies, Before the Subcommittee on Energy Committee on Energy and Commerce U.S. House of Representatives*, 115th Cong. (March 29, 2017) (testimony of Terry Dinan, Senior Adviser of the Microeconomic Studies Division of the Congressional Budget Office).

14. "FEDS Notes: Climate Change and Financial Stability," Board of Governors of the Federal Reserve, March 19, 2021.

15. Going back to our earlier example, we had a driver willing pay up to $4.50 for an extra gallon and a retailer willing to accept $4.00 to sell it, but this had a marginal negative externality of burning the fuel of $1.00. A government-mandated emissions filter would cost this driver an average of $0.50 per gallon to prevent $1.00 worth of negative externalities. This is clearly efficient, but the emissions filter involves a fixed cost. If another buyer drives significantly less, it could be that the filter now costs more than $1.00 per gallon to prevent only $1.00 of externalities. In this case, the filter mandate would be inefficient.

16. Meredith Fowlie, Michael Greenstone, and Catherine Wolfram, "Do Energy Efficiency Investments Deliver? Evidence from the Weatherization Assistance Program," NBER Working Paper no. 21331, July 2015.

17. Steven E. Sexton et al., "Heterogeneous Environmental and Grid Benefits from Rooftop Solar and the Costs of Inefficient Siting Decisions," NBER Working Paper no. 25241, November 2018.

18. Severin Borenstein, "Private Net Benefits of Residential Solar PV: The Role of Electricity Tariffs, Tax Incentives, and Rebates," *Journal of the Association of Environmental and Resource Economists* 4, no. S1 (2017): S85–122.

19. Stephen P. Holland et al., "Environmental Benefits from Driving Electric Vehicles?," NBER Working Paper no. 21291, June 2015.

20. Jianwei Xing, Benjamin Leard, and Shanjun Li, "What Does an Electric Vehicle Replace?," *Journal of Environmental Economics and Management* 107 (2021): 102432.

21. S. Panero et al., "Impact of Household Batteries in Landfills," *Journal of Power Sources* 57, nos. 1–2 (1995): 9–12. Energy storage provided by EVs can also increase carbon emissions because it makes sources that are more expensive to turn on and off, such as coal, relatively cheaper (for example, by absorbing cheap coal energy overnight and discharging it during the day when other cleaner sources are used). See Eric S. Hittinger and Inês M.L. Azevedo, "Bulk Energy Storage Increases United States Electricity System Emissions," *Environmental Science and Technology* 49, no. 5 (2015): 3203–10.

22. We are assuming the benefits of the emissions filter go to $0 in this case. It is important to note that it makes no difference whether nominally the retailer or the driver is forced to bear the cost of the improvement. Economic incidence of costs depends on elasticities of demanders and suppliers.

23. Bento et al. survey recent evidence on rebound effects and find estimates varying from a 0 to 15 percent rebound (a 15 percent rebound means that a 100 percent efficiency gain would translate only to a 85 percent decrease in fuel savings). See Antonio M. Bento et al., "Estimating the Costs and Benefits of Fuel-Economy Standards," *Environmental and Energy Policy and the Economy* 1, no. 1 (2020): 129–57.

24. Roger H. Bezdek and Robert M. Wendling, "Potential Long-term impacts of changes in US vehicle fuel efficiency standards," *Energy Policy* 33, no. 3 (2005): 407–19.

25. Mark R. Jacobsen and Arthur A. Van Benthem, "Vehicle Scrappage and Gasoline Policy," *American Economic Review* 105, no. 3 (2015): 1312–38.

26. Valerie J. Karplus et al., "Should a Vehicle Fuel Economy Standard Be Combined with an Economy-Wide Greenhouse Gas Emissions Constraint? Implications for Energy and Climate Policy in the United States," *Energy Economics* 36 (2013): 322–33.

27. Arik Levinson, "How Much Energy Do Building Energy Codes Save? Evidence from California Houses," *American Economic Review* 106, no. 10 (2016): 2867–94.

28. "Carbon Tax," IGM Forum, University of Chicago, December 20, 2011, https://www.igmchicago.org/surveys/carbon-tax/.

29. Discount rates are a way to compare benefits and costs across time. For the social cost of carbon estimates, see Kevin Rennert et al., "The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates," Resources for the Future Working Paper no. 28, September 2021.

30. Using mean estimates of social costs of carbon $125 per metric ton of CO_2 and the fact that one gallon of gasoline emits 8.887×10^{-3} metric tons of CO_2, one gets a rough

estimate of $1.00 (more precisely, $1.11) worth of carbon costs per extra gallon of fuel burnt.

31. In Brazil, for example, gasoline costs roughly $4.18 per gallon (Brazilian Real (BRL) 22.74 per 3.79 liters, using an exchange rate of 5.44 BRL/USD), 39 percent of which are taxes, amounting to a total tax bill of approximately $1.60 per gallon. See "Preços de Venda de Combustíveis," Petrobras, October 4, 2021.

32. Economist Greg Mankiw has created the "Pigou Club," named after economist Arthur Cecil Pigou, who lends his name to Pigouvan taxes (externality correcting taxes). The informal club, whose members include Daron Acemoglu, Noam Chomsky, Bill Gates, and Leonardo DiCaprio, publicly advocates for carbon and other Pigouvian taxes.

33. Some economists favor an approach where governments set targets or objectives and award prizes for them to sponsor innovation. Alternatively, government could precommit to buy a product, say carbon dioxide capture and storage, at a given price; these are called advanced markets commitments (AMCs). This approach has the advantage of avoiding government micromanagement and incentivizing private firms to innovate. The main problem, of course, is knowing what to award the prize for and how to set an appropriate award amount. For more details on these mechanisms, see Michael Kremer, Jonathan Levin, and Christopher M. Snyder, "Advance Market Commitments: Insights from Theory and Experience," *AEA Papers and Proceedings* 110 (2020): 269–73; and Alexander Tabarrok, "Grand Innovation Prizes to Address Pandemics: A Primer," Mercatus Center Special Edition Policy Brief, March 19, 2020.

34. Arianna Di Paola, et al., "The Expansion of Wheat Thermal Suitability of Russia in Response to Climate Change," *Land Use Policy* 78 (2018): 70–77; and Charles A. Taylor and Wolfram Schlenker, "Environmental Drivers of Agricultural Productivity Growth: CO2 Fertilization of US Field Crops," NBER Working Paper no. 29320, October 2021.

35. Because internal costs (i.e., costs to parties to a transaction) are already factored into prices, a carbon tax should reflect only the external costs of carbon intensive activities. So, the marginal social cost of carbon, for the purposes of carbon taxation, should only take into account external costs.

36. It is unclear whether uncertainty should lead us to take earlier and stronger action as a form of insurance, since reducing emissions also requires sunk investment costs, prompting us to postpone actions. For more details, see Robert S. Pindyck, "What We Know and Don't Know about Climate Change, and Implications for Policy," *Environmental and Energy Policy and the Economy* 2, no. 1 (2021): 4–43.

37. Pei Wang et al., "Estimates of the Social Cost of Carbon: A Review Based on Meta-Analysis," *Journal of Cleaner Production* 209 (2019): 1494–507.

38. Rennert et al., "The Social Cost of Carbon."

39. Duty drawbacks are refunds on duties, taxes, and fees paid on goods that are imported and subsequently exported, either unused or after processing. Taking our example, where country A imports from country B, this would amount to an intermediary country C importing from country B and reexporting the good to A. As a result, country A would carbon tax the imported good as if it were coming from C, but it would in fact be produced in B and pay no fees or taxes in C due to drawbacks.

40. A businessman, for example, was found guilty in 2020 of a $1 billion biodiesel tax fraud scheme that worked by creating fake paperwork for biodiesel production to collect IRS tax credits. See "Jury Finds Los Angeles Businessman Guilty in $1 Billion Biodiesel Tax Fraud Scheme," *Justice News*, March 16, 2020.

41. See, for example, Michael Greenstone and Ishan Nath, "Do Renewable Portfolio Standards Deliver Cost-Effective Carbon Abatement?," University of Chicago, Becker Friedman Institute for Economics Working Paper no. 2019-62 (2020). The paper finds that renewable portfolio standards (i.e., mandating renewable sources to produce a specified share of electricity) caused electricity prices to be 11 percent higher after seven years of being enacted.

42. Soren T. Anderson, Ioana Marinescu, and Boris Shor, "Can Pigou at the Polls Stop Us Melting the Poles?," NBER Working Paper no. 26146, August 2019.

43. David Roberts, "Washington Votes No on a Carbon Tax—Again," *Vox*, November 6, 2018.

44. Lucas W. Davis, "The Environmental Cost of Global Fuel Subsidies," *Energy Journal* 38, KAPSARC Special Issue (2017): 7–27.

45. Gary M. Lucas Jr., "Voter Psychology and the Carbon Tax," *Temple Law Review* 90 (2017): 1.