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CARBON PRICING AND REGULATIONS COMPARED

An Economic Explainer

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Key Takeaways

- Carbon pricing, either in the form of a carbon tax or a cap-and-trade system, has the potential to limit pollution to an economically optimal level.
- Carbon pricing allows various pollution sources with differing marginal abatement costs to achieve emissions reduction efficiently whereas regulations tend to treat all pollution sources alike.
- Carbon pricing has greater efficiency advantages over regulations when technology changes over time than when it is fixed.
- A carbon tax combined with revenue recycling would be a less costly policy to reduce emissions than regulations of comparable effectiveness.
- It is difficult to compare the distributional impact of carbon taxes to that of regulations, as there is substantial analysis of the distributional effects of a carbon tax but very limited information on how environmental regulations would impact various demographic groups.

The Niskanen Center is a 501(c)3 issue advocacy organization that works to change public policy through direct engagement in the policymaking process.
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1. Introduction

There is a broad consensus that the world faces a serious threat from climate change, and that reduction of greenhouse gas emissions, eventually to net zero, is essential to mitigating that threat. There is less consensus, however, on how to go about it.

The two leading options for reducing greenhouse gas emissions (or carbon emissions, for short) are carbon pricing and command-and-control regulations. The former relies on markets to achieve emission reductions while the latter relies on regulations, such as performance standards and technology mandates. Carbon pricing and command-and-control regulations both remain in contention, either as alternatives or as complementary policies.

This paper is intended to serve as an economic explainer comparing carbon pricing policies to regulatory policies. It introduces the economic basics of carbon pricing, provides a detailed comparison of carbon pricing and regulations, and discusses the potential impact of the interaction of the two types of policies.

2. Economic basics of carbon pricing

Carbon pricing, as used in this paper, is a generic term for market-based climate policies. One form of carbon pricing is a tax per unit of carbon dioxide or equivalent that is released into the atmosphere. Another form, known as *emissions trading* or *cap-and-trade*, sets a maximum amount for total emissions and issues an appropriate number of emissions permits that firms can buy or sell at a price determined by supply and demand.

For many purposes, the two forms of carbon pricing can be considered interchangeable, but there are some important differences. One difference is the amount of revenue raised by the policy. A carbon tax automatically generates revenue that can be used to fund other climate mitigation or adaptation policies, or to compensate groups affected by the policy. A cap-and-trade system could also raise revenue if the emissions permits are initially sold to businesses through auctions, but it would not raise any revenue if the emissions permits were given away to businesses by the government.[1] Another difference is that carbon taxes make the *price* of emissions more predictable while cap-and-trade makes the total *output* of emissions more predictable.

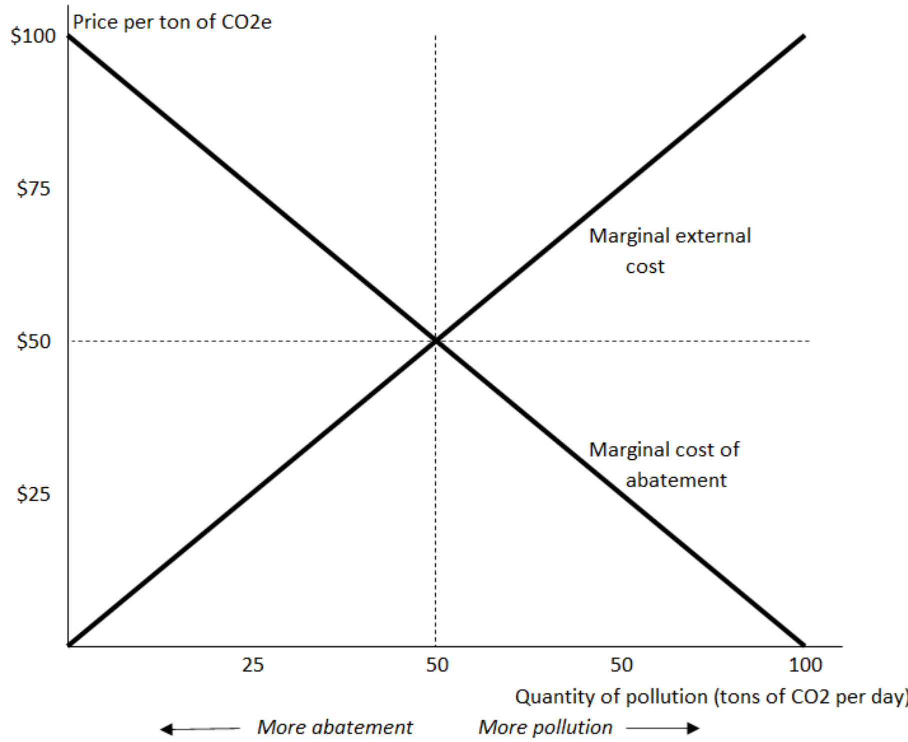
The idea of using the price system to control harmful side effects of production or consumption activities is far from new. More than a century ago, the British economist Arthur Cecil Pigou introduced the term *negative externality* to refer to such harmful side effects, and proposed controlling them by imposing appropriate taxes — known today as "Pigouvian taxes" — to discourage the activities from which the externalities arose.[2] His proposal was motivated by the idea that it would be efficient to reduce pollution whenever the cost of doing so was less than the harm done by the pollution itself, but not if the harm done was less than the cost of pollution abatement.

1. "Guidelines for Preparing Economic Analysis," National Center for Environmental Economics, Office of Policy, U.S. Environmental Protection Agency (December 2010).

2. *The Economics of Welfare* (4th ed.) (London: Macmillan, 1932).

Figure 1 shows in stylized form how a tax on carbon emissions would work. The horizontal axis measures the amount of CO_2 emitted per unit of time. To keep the numbers simple, we assume that pollution can range from 0 to 100 tons per day, but the principle would be the same if the units were gigatons per year or any other set of measures. The vertical axis, indicating the tax rate, runs from 0 to $100 per ton. Again, the principles would be the same regardless of the units chosen

Figure 1: The Basics of Carbon Pricing



The negatively sloped curve in Figure 1 shows the cost of eliminating an additional ton of pollution, known as the *marginal cost of pollution abatement*. The point where the marginal cost of abatement curve intersects the horizontal axis shows that 100 tons of CO_2 would be emitted if there were no cost of pollution. Moving up along the curve from right to left, the cost of eliminating one more ton of emissions (the marginal cost of abatement) is low at first, but becomes higher and higher as emissions approach zero. The point where the same curve intersects the vertical axis shows it would cost $100 to eliminate the very last ton of pollution to reach zero emissions.

The positively sloped curve shows the harm done by each additional unit of pollution, known as the *marginal external cost of pollution*. The cost is assumed to rise as emissions increase, reflecting the notion that a tiny bit of pollution is hardly noticeable, but that the damage from each additional ton emitted increases as pollution increases, reaching $100 per ton when the quantity reaches 100 tons.[3]

Pigou's goal of limiting pollution to the efficient level would be attained at a pollution rate of 50 tons per day, the point where the curves intersect, as shown in Figure 1. Anywhere to the right of that point, the cost of eliminating a ton of emissions is less than the harm done. Anywhere to the left of the intersection, it would cost more to eliminate a ton of emissions than the harm that additional ton would cause. According to Pigou's idea to limit pollution to an optimal level, any greater or smaller degree of abatement than 50 tons per day would be inefficient. In that limited sense, then, the point of intersection can be said to be the economically optimal amount of pollution.

The policy that Pigou proposed to ensure that pollution was limited to no more than the efficient level was to impose a tax equal to the height of the point where the curves cross, or $50 in this case. He reasoned that a profit-maximizing polluter would have an incentive to apply additional abatement measures whenever the cost of eliminating a ton of emissions was less than the tax, but not if the cost of abatement were more than the tax. The profit-maximizing level of emissions for the polluter would then exactly coincide with the economically optimal quantity of pollution.[4]

As explained earlier, emissions trading, also known as cap-and-trade, is an alternative way of implementing a price for pollution. The same figure can be used to show how under that approach, instead of imposing a tax, the government issues a fixed number of permits that add up to a total emissions cap of 50 tons. Polluters would have an incentive to buy permits from another firm if their price were less than the marginal cost of abatement. Alternatively, if the price were greater than the marginal cost of abatement, a firm would have an incentive to reduce emissions and sell to someone else whatever permits they had been allocated. The result would be an equilibrium market price for permits of $50, leading to the same, efficient result as the tax.

Hybrid carbon pricing schemes are possible that combine pollution taxes with emissions trading. One such approach, sometimes called emissions trading with a "collar," sets an initial quantity of permits at 50 tons but imposes a price ceiling somewhat above $50 and a price floor somewhat below $50. If changing market conditions shift the curves so that the price hits the cap, additional permits are issued; if the price hits the floor, some permits are withdrawn from the market. A tax with a quantity constraint is another possibility for a hybrid system. Under that approach, authorities would initially set the tax at $50. If the curves shift in a way that makes that too low to reach the desired pollution level, the tax is automatically increased to encourage more abatement.

3. The marginal external cost of pollution should be measured in a way that assumes the application of cost-effective adaptation measures, if any are available. See Ed Dolan, "A Coasean Rationale for a Carbon Tax," Niskanen Center (October 2018).

4. In the case of climate change, the optimal level of carbon emissions, in the long run, may be zero. For details on how a carbon tax or a cap-and-trade can be modified to meet a net-zero emissions goal, see Ed Dolan, "The Role of Carbon Pricing in Deep Decarbonization," Niskanen Center (August 2021).

3. Carbon pricing and regulations compared: efficiency and effectiveness

In contrast to carbon pricing, which relies on market-based incentives, command-and-control regulations are specific directives that pollution sources must by law comply with. Some regulations take the form of technology standards that mandate the use of specified technologies or processes, such as carbon capture or fuel-switching, by the regulated entities. Alternatively, regulations can take the form of performance standards, which limit the quantity of emissions per unit of time or per unit of input or output. Performance standards typically allow more flexibility for sources to meet the emissions target than do technology standards.[5]

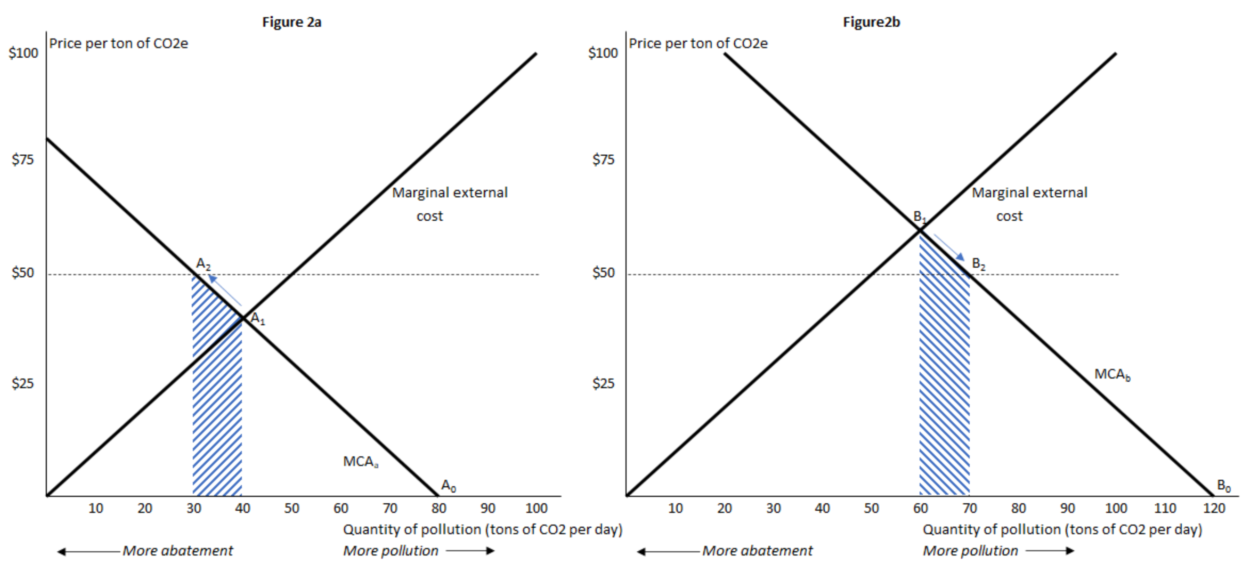
This section compares carbon pricing to regulations in terms of their treatment of multiple pollution sources, responses to technological change, and macroeconomic impacts. The two approaches are evaluated both in terms of their efficiency (reaching goals at the least cost) and their effectiveness (achieving the right goals).

3a. Efficiency with heterogeneous pollution sources

Figure 1 showed how carbon pricing, either in the form of a carbon tax or permit trading, could achieve an efficient level of pollution. If all pollution sources were alike, it would be easy to achieve the same result through regulation. However, when there are multiple emission sources with widely differing technical and economic characteristics, a market-based approach offers distinct advantages.

Figure 2 provides a paradigmatic example. It assumes that pollution comes from two sources that have the same marginal external cost curve, but different costs of abatement. The specific numbers

Figure 2: Efficient Carbon Pricing With Heterogeneous Sources



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5. "Guidelines for Preparing Economic Analysis," EPA.

in Figure 2 are purely for the sake of illustration. The marginal cost of abatement for source *a* is shown by the curve MCA_a, while that for source *b* is MCA_b. Abatement costs might differ for any number of reasons. For example, the preferred abatement technology for both sources might be carbon capture, use, and storage (CCUS), but source *a* is located near existing CO_2 pipelines and CO_2 users, while source *b* is far from pipelines and users.

With no carbon pricing or regulation, source *a* would operate at point A_0, emitting 80 tons of CO_2 per day, and source *b* would emit 120 tons per day, at point B_0. In that case, pollution at both sources would be excessive, in the sense that the marginal external cost would greatly exceed the marginal cost of abatement.

Suppose now that the government issued a regulation that required each source to cut its initial level of emissions in half. In that case, source *a* would move to point A_1 and source *b* would move to B_1. Each source would then be operating at a point where its marginal cost of abatement was equal to the marginal external cost and total emissions would fall to 100 tons. However, although that looks reasonable for each source in isolation, it turns out to be an inefficient way to achieve the intended target of 100 total tons of emissions.

To see why, suppose that starting from 40 tons for source *a* and 60 tons for source *b*, the regulation were replaced by a carbon tax of $50 per ton. In that case, both sources would move, as shown by the arrows, to points where the marginal cost of pollution abatement was equal to the tax. Source *a* would increase its abatement effort and reduce its pollution to 30 tons, moving to point A_2. At the same time, source *b* would move to point B_2, where its emissions would be 70 tons per day.

The costs incurred or saved by making these adjustments would be equal to the shaded areas under each source's marginal cost of abatement curve. To cut its emissions from 40 to 30 tons would cost source *a* an additional $450 in abatement expenditure, shown by the shaded trapezoid in Figure 2a. Increasing emissions from 60 to 70 tons would reduce source *b's* abatement costs by $550, as shown by the shaded trapezoid in Figure 2b. On balance, then, there would be a net saving in abatement costs of $100 per day, with no change in emissions – a substantial increase in efficiency with no loss in effectiveness.

The result would be much the same if emissions trading were used rather than a tax. If each source were initially given enough permits to reach half its initial level of emissions, source *a* would get 40 permits and source *b* would get 60 permits. Starting from that point, source *b* would be willing to pay anything up to $60, the marginal cost of abatement at point B_1, to buy one of source *a's* permits. Source *a* would accept anything more than $40, the marginal cost of abatement at point A_1. Mutually beneficial permit trades could continue until the marginal abatement costs were equal for the two sources at $50 per ton, which would happen with 30 tons per day of emissions from source *a* and 70 tons from source *b*.

3b. Response to technological change

The preceding example assumes that there is one abatement technology shared by all sources that remains unchanged over time. In reality, however, new technologies are being developed all the time. The reasoning of the preceding section can be extended to show that the efficiency advantages of carbon pricing over regulation are much greater when technology is variable than when it is fixed.

To see the effects of a change in technology, look again at Figure 2. Suppose, as shown, that a $50 carbon tax is in effect and the economy has reached an equilibrium at A_2 and B_2, as shown. Now suppose that a new technology becomes available to source *a* that shifts its abatement cost curve downward from MCA_a, but that the new technology is not available to source *b*. Source *a* would have an incentive to adjust to the new technology by reducing its emissions below 30 tons per day until it reached a point where the marginal cost of abatement was again equal to the tax. Doing so would increase its profits, since it would spend less on pollution abatement, and at the same time, total emissions would fall below 100 tons, to the benefit of the environment.

If, instead, a performance standard were used to hold source *a*'s emissions at 30 tons and source *b*'s at 70 tons, the outcome would be different. Source *a* would still have an incentive to use the new technology, which would make it less costly to meet the required level of emissions, but it would have no incentive to decrease total emissions. The new technology would increase source *a*'s profits, but it would have no environmental benefits.

Supporters of a regulatory approach might point out that the agency in charge could revise its performance standards whenever any new technology became available. In practice, however, that could prove difficult. For one thing, the regulator might not be the first to learn of the new technology, and the people at the pollution source would have little motive to pass the information along if they were the first to learn of it. In fact, if the people at the pollution source anticipated that regulators would react to the new technology by tightening the pollution standard, they would have an incentive to *conceal* the new technology.

It is also possible that the new abatement method might not be an actual advance in science or engineering, but rather, just a better way of applying existing technology to particular local conditions. In that case, regulators would probably never learn of it. Finally, the new technology might not be equally applicable to all emission sources, meaning that regulators would face the complex task of establishing different optimal performance standards for each source. As even our simple example shows, none of these possibilities would hamper adjustment to changes in abatement costs under a carbon tax.

The preceding discussion assumes that pricing is implemented in the form of a carbon tax. If a cap-and-trade approach were used instead, the market would not adapt as smoothly to technological change. Suppose that initially the cap on emissions is 100 tons, as shown in the figure. If a new technology shifts source *a*'s marginal cost of abatement downward, it will no longer have the need for the 30 emission permits to operate at point A_2. It will offer some of its permits for sale, and would be willing to accept somewhat less than $50 per permit. As the permit price dropped, source *b* would buy them and use them to increase pollution up to the point where its marginal cost of abatement was equal to the new permit price. A new equilibrium would be reached in which the permit price was a little lower, with source *a* emitting a bit less CO_2 and source *b* a bit more. Total pollution would remain at 100 tons unless and until regulators became aware of what was going on and tightened the cap. The outcome under cap-and-trade would be more efficient than a simple performance standard, since the total costs of meeting the 100-ton emissions cap would be minimized. However, the cap-and-trade approach would be less effective in reducing total emissions than would a carbon tax.

3c. Economywide effects of carbon pricing and regulation

Before enacting incentives to reduce carbon emissions, it is important to assess the impacts on the economy overall. That is a challenging task to which only partial solutions have been achieved to date. Some of those attempts simplify the problem by considering a single regulation or a single market mechanism, such as a carbon tax. It is difficult enough to gauge the impacts of such individual policies, and harder still to evaluate the impacts of the complex combination of command-and-control regulations, clean energy subsidies, and investment in research and development that are currently used to mitigate GHG emissions in the United States.[6] Despite these problems, it is worth looking at some of the attempts that have been made.

To begin with a relatively simple example, economists at the Tax Foundation found that an economywide carbon tax, considered in isolation, would increase the prices of carbon-intensive goods and services, reduce economic output, and lower the level of employment.[7] Specifically, they modeled a $50-per-ton carbon tax and found that the carbon tax itself would reduce long-run GDP by 0.4 percent. It would also lower after-tax wages and negatively impact work incentives, which would reduce employment by 421,000 full-time-equivalent jobs.[8] However, that estimate must be interpreted with caution, since it accounts neither for how the revenue from the tax would be used nor for the environmental benefits.

A complete assessment of the overall macroeconomic and distributional impact of a carbon tax policy would need to consider the effects of revenue recycling.[9] Carbon tax advocates and lawmakers have proposed a variety of ways to use the revenue a carbon tax raises, including returning the revenue to eligible households as dividends, cutting other distortionary taxes, or investing in clean technologies.[10] A dividend would make it possible to compensate lower-income households for higher energy costs. It would also stimulate consumer demand, thereby offsetting some of the impact on GDP. Using some or all of the revenue to reduce other taxes that are characterized as distortionary by organizations like the Tax Foundation would mitigate some of the negative effects on growth.[11] And investing in clean technologies would offset some of the impact on jobs as well as increasing environmental benefits.

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6. For a detailed overview of the current policies in place to address GHG emissions in the United States, see Justin Gundlach et al., "Interactions between A Federal Carbon Tax and Other Climate Policies," Center on Global Energy Policy, Columbia University (March 2019).

7. Kyle Pomerleau and Elke Asen, "Carbon Tax and Revenue Recycling: Revenue, Economic, and Distributional Implications," Tax Foundation (November 2019).

8. Pomerleau and Asen, "Carbon Tax and Revenue Recycling."

9. Shuting Pomerleau, "Revenue Recycling is a Critical Element of a Carbon Tax," Niskanen Center (January 2021).

10. "What You Need to Know About a Federal Carbon Tax in the United States," Center on Global Energy Policy, Columbia University.

11. Pomerleau and Asen, "Carbon Tax and Revenue Recycling."

Furthermore, economists have long recognized that GDP itself is an inadequate measure of human welfare and its changes over time. Environmental considerations, such as biodiversity and security from environmental catastrophes, are completely omitted from GDP. At the same time, expenditures on recovery from those same environmental catastrophes, such as rebuilding after floods and fires, is included in GDP. Many attempts have been made to produce an alternative "Green GDP," but none has won wide acceptance.[12]

Instead of assessing a carbon tax in isolation, it is also possible to compare a hypothetical carbon tax with comparable regulatory policies through modeling studies. Several such studies have found that a carbon tax combined with revenue recycling would be a less costly way to achieve a given reduction in emissions than relying on command-and-control regulations alone.

One of them, a study by the American Action Forum, found that a hypothetical carbon tax would have been more than twice as cost-effective as the command-and-control climate regulations implemented under the Obama administration. The cost advantage of carbon pricing would be even greater if revenue recycling effects were accounted for. The AAF study also found that either command-and-control regulations or a carbon tax would place a significant burden on the economy through increased energy prices. However, the negative impact of a carbon tax could be reduced through a "tax swap" — cutting other distortionary taxes, such as the corporate income tax.[13]

Another study, by Ernst & Young, also found that a carbon tax would be a less costly approach to reducing carbon emissions than existing regulatory policies.[14] Specifically, the EY study estimated that the existing regulatory approach would reduce GDP in the long run by $1,770 per household annually on average. In contrast, an "emissions-equivalent" carbon tax that replaced the existing regulations and used the tax revenue in three alternative ways would increase GDP per household annually between $1,170 and $5,090 on average. Among the three modeled alternatives for using carbon tax revenue, permanently extending certain provisions in the Tax Cuts and Jobs Act of 2017 would have the largest net positive economic impact (a 3.2 percent increase in long-run GDP), whereas sending out household rebates would result in the lowest net positive economic impact (a 0.7 percent increase in long-run GDP).[15]

Finally, a study by NERA Economic Consulting found that the Climate Leadership Council's $40-per-metric-ton carbon tax proposal would be significantly less economically costly than the combination of regulatory policies aimed at achieving equivalent emissions reductions without

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12. This report gives an overview of the issues involved in such an effort: Joseph Stiglitz et al., "Report by the Commission on the Measurement of Economic Performance and Social Progress," Stiglitz-Sen-Fittousi Commission (September 2009).

13. Philip Rossetti et al., "Comparing Effectiveness of Climate Regulations and a Carbon Tax." American Action Forum (July 2018). Note that the study does not account for the environmental benefits from emissions reduction.

14. The EY study modeled the effects of all the following regulations as if they were all fully implemented: Corporate Average Fuel Economy standards, Clean Power Plan, Renewable Fuel Standards, and Appliance and Equipment Efficiency Standards. Ernst & Young, "Carbon Regulations vs. a Carbon Tax: A Comparison of The Macroeconomic Impacts." Prepared for the Alliance for Market Solutions (October 2018).

15. Ibid.

carbon pricing.[16] CLC's carbon tax proposal would return the net revenue raised through the tax to households as dividends. Specifically, the study estimated that GDP would be 0.7 percent lower on average ($190 billion annually) under the regulatory policies than under the proposed carbon tax over the studied period of 2021-2036. Household consumption under the regulatory policies would be 0.7 percent lower on average ($840 annually per household) than under the proposed carbon tax.[17]

4. Carbon pricing and regulations compared: distributional impacts

Much of the preceding discussion has focused on the efficiency and effectiveness of carbon pricing and regulations. In practice, however, much of the public discussion of such policies focuses on their distributional effects.

It is even harder to compare the distributional impact of environmental regulations and carbon pricing than to compare their impacts on efficiency or GDP growth. While there are plenty of studies that examine the distributional effects of a carbon tax, much less information is available about the impact of environmental regulations on different demographic groups. Some supporters of regulatory policies see the lack of distributional analysis of command-and-control regulations as a feature, not a bug. Their thinking is that political resistance to command-and-control regulations is less when voters do not understand how regulations would impact them, whereas the more transparent effects of a carbon tax can easily be used by critics to oppose the policy. At the same time, it is easy for proponents of regulation to represent their unknown or hidden distributional effects as neutral or positive.

In particular, opponents of a carbon tax point to its regressivity, which may lead some people to support regulations over a carbon tax. For example, critics frequently call attention to the fact that low-income consumers spend a larger share of their incomes on energy than high-income consumers. However, that argument is incomplete in two ways. For one thing, it compares the easily estimated distributional effects of a carbon tax with the largely unmeasurable effects of specific regulations. Second, while lower-income households would lose a larger share of their money to a carbon tax, high-income households would pay more in the aggregate because they use so much more energy. Households in the top quintile of the income distribution account for 35 percent of all emissions, compared with just 10 percent by households in the lowest quintile. Keeping energy prices low, then, is a very inefficient way to help the poor, as it subsidizes high energy usage by the rich. Using all or part of the revenue generated by carbon taxes or the auctioning of emission permits to compensate low-income consumers for higher energy prices is far more efficient and effective.[18]

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16. The NERA study modeled the effects of these regulations: "a mixture of energy efficiency standards (for both stationary sources and on-road vehicles), a clean energy standard for electricity generation, and a subsidy program to accelerate adoption of battery-electric vehicles." Page 4; NERA Economic Consulting, "Economic Impacts of the Climate Leadership Council's Carbon Dividends Plan Compared to Regulations Achieving Equivalent Emissions Reductions; Volume I: Analysis Insights for Policymakers." Prepared for the Climate Leadership Council (December 2020).

17. "Economic Impacts," NERA Economic Consulting.

18. For more on the distributional effects of carbon taxes, see Ed Dolan, "When Does 'It Will Hurt the Poor' Outweigh 'It Will Help the Environment'?", Niskanen Center (March 2019).

4a. Estimates of the distributional impact of climate regulations

U.S. federal agencies are obligated to evaluate the benefits, costs, and the distributional impact of any major environmental, health, and safety regulation prior to releasing it. Researchers at Harvard University reviewed 12 major regulations (mostly environmental) released between 2009 and 2011 and found that "agencies provide little information on distribution, often simply noting that the regulation will not adversely affect the health of children, minorities, and low-income groups."[19]

Specifically, the Harvard researchers found that agencies hardly ever quantify how the health benefits and compliance costs of a proposed regulation would be distributed across different demographic groups. Even in cases where agencies provided estimates on direct compliance costs, the estimates were typically reported either as an aggregate amount or as the average cost incurred on a per-unit basis (for example, per manufacturing plant or per vehicle). At most, the agencies would provide information on how such compliance costs would be borne by different industries, or by public and private entities. But agencies typically *do not* provide information on how compliance costs would be passed on to consumers in the form of increased prices, or whether high production costs for polluters would lead to lower profits and wages, or how these costs would affect various income groups.[20]

The Harvard researchers concluded that the approach to distributional analysis adopted by federal agencies is "problematic" and that "it provides incomplete information on the trade-offs involved in decision making" and "does not provide the data required if we wish to take distribution seriously." The researchers offered several explanations for why agencies do not provide detailed distributional analysis: They may not want to reveal distributional outcomes for political reasons; they may believe the distributional impact to be insignificant; or they may not have the know-how to conduct comprehensive distributional analysis.[21]

On purely theoretical grounds, there is no reason to believe that the impacts of environmental regulations are any less regressive than those of a carbon tax. Since regulations tend to raise the cost of doing business, they can be expected to raise prices of goods, with a disproportionate impact on the purchasing power of low-income households. Meanwhile, the environmental and health benefits generated by the regulations may be valued more by wealthy households than the disadvantaged households.[22]

In the face of the inadequacy of the distributional analyses produced by federal agencies, some academic studies have attempted to fill the gap. Consider, for example, a study by Gilbert Metcalf that reviews previous distributional studies on fuel economy standards, energy standards for buildings, and state regulations on the pricing of natural gas. Metcalf argued that while the

19. Lisa Robinson et al., "The Role of Distribution in Regulatory Analysis and Decision Making," Harvard Kennedy School, Harvard School of Public Health (February 2014).

20. Ibid.

21. Ibid.

22. Ibid.

distributional implications of regulatory policies are not well understood, it appears that "most regulatory policies and tax subsidies to achieve energy policy goals are regressive."[23]

In a 2012 study, Mark Jacobsen confirmed the widespread belief that corporate average fuel economy (CAFE) standards are progressive when they are first implemented, since CAFE standards increase prices of new cars and thus have a larger impact on wealthy households than low-income households. However, after incorporating the interactions of the CAFE standards with the used-car market, Jacobsen found that the regulations become "sharply regressive" in the long run because CAFE leads to higher prices for used vehicles.[24]

A more recent study by Lucas Davis and Christopher Knittel that also models the distributional impact of CAFE standards largely confirms Jacobsen's findings. They found that the U.S. fuel economy standards are "mildly progressive" accounting for only new vehicles. But after the analysis included used vehicles, the fuel economy standards are "mildly regressive." They also found that because CAFE standards are more regressive than a carbon tax combined with revenue recycling, "it is difficult to argue for fuel economy standards on distributional grounds."[25]

4b. Estimates of the distributional impact of a carbon tax

In contrast to the hit-or-miss analysis of regulations, the distributional impact of carbon taxes has drawn extensive study from economists, tax policy analysts, fiscal policy experts, and federal agencies. Using methods similar to those used to study the impact of other tax policies, researchers have been able to estimate how a carbon tax (with or without revenue recycling) would affect various groups of taxpayers. These estimates use modeling that is quantitative, data-based, and tailored to specific carbon tax policy designs.

For example, the Tax Foundation modeled a $50-per-metric-ton carbon tax that would be implemented in 2020 and grow annually at 5 percent. Such a tax would raise about $1.9 trillion in net revenues between 2020 and 2029. Researchers estimated that the carbon tax on its own would result in a less progressive federal tax code. The carbon tax would reduce after-tax income across all taxpayers, with the bottom quintile seeing the largest drop, 2 percent, whereas the top 1 percent would see a smaller reduction of 1.4 percent.[26]

However, the distributional outcomes of the modeled carbon tax change after accounting for different revenue uses. Specifically, the same tax accompanied by a dividend of $1,057 per tax filer would be progressive — taxpayers in the bottom quintile would receive higher after-tax income and the top 1 percent would take home less after-tax income. Alternatively, if the tax were combined with a cut in the employee-side Old Age, Survivors, and Disability Insurance (OASDI) payroll tax, it would be "slightly more progressive on net" than current law. It would increase the long-run level of economic output, lower the marginal effective tax rate on labor income, and

23. Gilbert Metcalf, "The Distributional Impacts of U.S. Energy Policy," *Energy Policy* 129 (June 2019): 926-929.

24. Mark Jacobsen, "Evaluating U.S. Fuel Economy Standards In a Model with Producer and Household Heterogeneity." University of California (March 2012)

25. Lucas Davis and Christopher Knittel, "Are Fuel Economy Standards Regressive?" *JAERE* Volume 6 (March 2019): Number S1.

26. Pomerleau and Asen, "Carbon Tax and Revenue Recycling."

positively impact work incentives. In contrast, combining the modeled carbon tax with a corporate tax cut would "make the tax code less progressive overall."[27]

In another study, the Treasury's Office of Tax Analysis (OTA) modeled a $49-per-metric-ton carbon tax that would be implemented in 2019 and increase to $70 per metric ton in 2028. Such a tax would generate approximately $2.2 trillion in net revenues over the 10-year period. Consistent with the findings of the Tax Foundation study, OTA estimated that the carbon tax without revenue recycling would reduce after-tax income for all taxpayers. However, OTA found that even without revenue recycling, the distributional impact of the modeled carbon tax would be mostly progressive.[28]

In addition, OTA studied the distributional impact of the modeled carbon tax with four alternative revenue recycling options. For example, the modeled carbon tax combined with a fully refundable per-person tax credit would be "very progressive." It would increase the tax burden on high-income households and reduce the tax burden on low-income households. Combining it with a corporate tax cut would make the tax burdens regressive.[29]

5. Interactions of pricing and regulation in mixed systems

In the real world, market-based and regulatory policies typically exist side by side. For example, California relies on its statewide cap-and-trade program and a mix of regulatory policies such as a renewables portfolio standard to reduce carbon emissions.[30] The two types of policy in some cases generate positive synergies, but sometimes we find that a mixed policy regime has unintended adverse consequences.

The CAFE standards provide an important example of positive synergies in which market-based policies make regulatory measures more effective and efficient by controlling the so-called *rebound effects*.[31] The rebound effect of CAFE standards stems from the fact that while they encourage consumers to buy more fuel-efficient cars and trucks, they also encourage them to drive more once they have the new vehicles. With gasoline at $3 a gallon, fuel costs are 15 cents a mile for an older car that gets 20 miles per gallon, but just 7.5 cents a mile for a new one that gets 40 miles a gallon. If doubling fuel efficiency induces a 30 percent increase in driving (a plausible estimate, based on available research), then replacing the country's whole vehicle fleet with new cars will not cut fuel consumption in half, but rather, by only 35 percent.[32] Gasoline taxes offer a reasonable way to control the rebound effect. If, at the same time thriftier cars are sold, a carbon tax raises the price of gasoline by a proportional amount, the fuel cost per mile of driving will not fall and the rebound effect will disappear.

27. Ibid.

28. John Horowitz et al., "Methodology for Analyzing a Carbon Tax," Office of Tax Analysis, Department of the Treasury (January 2017).

29. Ibid.

30. "California Climate Policy Fact Sheets," UC Berkeley School of Law.

31. For a more detailed discussion of CAFE standards and the rebound effect, see Ed Dolan, "The Tough Economics of Fuel Economy Standards," Niskanen Center (August 14, 2018).

32. For a summary of the recent literature on elasticity, see Lutz Kilian and Xiaoqing Zhou, "Gasoline Demand More Responsive to Price Changes Than Economists Once Thought," Federal Reserve Bank of Dallas (June 2020).

Emil Dimanchev and Christopher Knittel of MIT provide a more general assessment of the synergies between carbon pricing and regulation.[33] They note that "a climate policy portfolio that combines both approaches may balance the distinct advantages of each, as well as provide opportunity for consensus between advocates of either option." They then go on to construct a model in which it is possible to vary the mix of the two policies. The model shows that even a small carbon price has a strong favorable effect on the performance of a mixed market-based and regulatory strategy.

However, in some cases, carbon pricing and regulations can interact in ways that produce unfortunate consequences. For example, suppose that a country has a broad cap-and-trade system that covers all, or nearly all, emission sources. Next, suppose that a performance standard is imposed on the power sector only that limits tons of CO_2 per megawatt hour of electricity while sources in other industries continue to be subject only to the cap-and-trade system. Electric utilities, forced to cut back emissions to meet the new performance standard, would no longer have to buy as many permits as before, but the excess permits would remain on the market, depressing the permit price. Pollution sources in the industrial and transportation sectors would buy the cheaper permits and use them to increase their emissions until a new equilibrium was reached in which total emissions would be unchanged at a level equal to the total number of permits, but the price of permits would be lower. The environment would not be any better off for the new regulations; the costs of adaptation would merely be shifted toward one sector. The tendency for add-on regulations under a cap-and-trade scheme to depress permit prices and shift emissions around rather than reducing them is sometimes called the waterbed effect.

The waterbed effect is a particular problem of the cap-and-trade version of carbon pricing which does not apply to carbon taxes. It is one reason why Danny Cullenward and David Victor argue that "cap-and-trade systems can be made more effective when they are designed to behave more like taxes."[34]

Conclusions

Carbon pricing, either in the form of carbon taxes or emissions trading, is the most efficient and effective policy to incentivize carbon reduction. It has the potential to limit pollution to an economically optimal level by imposing a price on each unit of emissions through a tax or an emissions permit.

Carbon pricing has significant advantages compared to command-and-control regulation. It allows various pollution sources with differing marginal abatement costs to achieve emissions reduction efficiently, whereas regulations tend to treat all pollutions sources alike. The efficiency advantages of carbon pricing over regulations are also much greater when technology changes over time than when it is fixed, because the market mechanism does not require regulators to scramble to keep up with technological advances. Economists argue that a carbon tax combined with revenue recycling would be a less costly policy to reduce emissions than command-and-control regula-

33. Emil G. Dimanchev and Christopher R. Knittel, "Trade-offs in Climate Policy: Combining Low-Carbon Standards with Modest Carbon Pricing," MIT Center for Energy and Environmental Policy Research, Working Paper CEEPR WP 2020-020 (Nov. 2020).

34. Danny Cullenward and David Victor, *Making Climate Policy Work* (Wiley, 2020).

tions of comparable effectiveness. Although there are many thorough quantitative studies of the distributional effects of a potential U.S. carbon tax, there is not enough information on how the impact of environmental regulations would be distributed across various demographic groups. Therefore, any claim that a carbon pricing policy would result in worse distributional outcomes than regulations should be viewed with caution.

In short, carbon pricing deserves serious consideration as the central mechanism for mitigating climate change. Without it, progress toward a carbon-free economy will be costlier, slower, and more uncertain.

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