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Carbon Tax Revenues Can be Used to Help Those Who Lose

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Climate change is not only causing heat-waves and sea level rise but also increasing the frequency and severity of floods, droughts, and forest wildfires. Illinois is not immune to these climate damages. The impact of climate change depends on the world's total emissions of greenhouse gasses since the industrial revolution began two hundred years ago. Illinois cannot solve these problems by itself, but Illinois cannot ignore the problem, either. To reduce those emissions, many policymakers have proposed energy efficiency standards, subsidies for electric vehicles, renewable electricity generation requirements, a tax on carbon dioxide emissions, or a cap-and-trade permit system. Some of these proposed policies could raise state revenue, but all of them would impose additional costs on those who need to use fossil fuels and on those who might lose their jobs in coal mines or fossil-fuel-fired electric power plants.

Policymakers need estimates of who gains from climate policy, who loses, and what can be done

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to help those who would bear extra costs. If the total benefits of climate policy exceed the total costs by as much as is estimated, then a policy package can be designed to help everybody share in those gains.[2] A state would need revenue to help pay for assistance to low-income families and those who lose jobs. Illinois can discourage emissions by putting a price on carbon and simultaneously raising revenues to help support families during the transition.

This spotlight discusses the pros and cons of a price on emissions—either a carbon tax or a cap-and-trade permit system. Past studies have found that those policies would raise the price of gasoline and electricity, disproportionately impacting low-income families. If this is the case, the policy could be considered "regressive."[3] This spotlight then reviews a new study of the distributional effects of such climate policies that covers more details about more households in different situations.

This new study finds that carbon pricing is slightly progressive—the burden as a fraction of income *rises* with income. It then explains this surprising result. Moreover, it finds larger redistributions between households at the same level of income. The main reasons, as discussed below, are significant differences between households within the same income bracket: some have long commutes, while others can walk to work or ride public transit. Some have poor insulation in their homes, while others live in temperate climates with less need for heat or air conditioning.

This new study finds that carbon pricing is slightly progressive—the burden as a fraction of income rises with income. It then explains this surprising result. Moreover, it finds larger redistributions between households at the same level of income.

The main point of this analysis is to investigate the implications for Illinois. One might think that households would differ less within Illinois than across the country, but the variation within each income bracket in Illinois is still quite substantial. Much of the discussion below is about how Illinois can help ease the transition for displaced workers in fossil-fuel industries and help others who bear the highest burdens from rising energy costs.

BACKGROUND

In 1995, a 95°F heat wave in Chicago caused approximately 750 deaths. By the middle of this century, Illinois will experience temperatures over 95°F on at least ten additional days every year.[4] Illinois households and farmers will be inundated by additional droughts, floods, and other extreme weather events. In addition to the human toll, crop insurance premiums are likely to rise because of crop losses.

Annual negotiations among the world's nations have not yet done nearly enough to prevent the worst effects of these climate changes. To try to deal with climate change, many proposals for a carbon tax or other climate policies have appeared, not only at the federal level but in many states as well. Washington State has just enacted a "cap-and-invest" program to start in 2023, while California's cap-and-trade sale of pollution permits started in 2013 and has raised $14.9 billion to date.[5] Because the price of permits is often at its legal price ceiling, California's policy acts much like a carbon tax. Illinois recently enacted the Climate and Equitable Jobs Act (SB2408).[6] Other laws across the U.S. include energy efficiency standards (for cars and appliances) and subsidies (for electric cars and renewable power generation from wind and solar).

All the new and proposed state and federal climate initiatives might be necessary to save the planet, but they all impose different costs on people in the economy. A carbon pricing policy like a carbon tax or cap-and-trade system would raise the price of carbon-intensive fuels like gasoline, coal, and natural gas. As intended, it would induce electricity generators to shift away from cheap coal toward renewables like wind and solar, and it would induce households to buy low-emission

vehicles or somehow reduce driving distances. But many of the costs would fall on those least able to afford it. Thus, proposals for a "carbon fee and dividend" would return all the carbon revenue to the public via equal annual dividends per capita.[7] If that dividend is the same amount for every person, then it would represent a higher proportion of income for those with less income. In fact, this uniform per capita dividend is estimated to exceed the average increase in energy costs for low-income families but not cover the added cost for high-income families.

Instead of imposing a carbon tax, President Biden's "Build Back Better" plan – if enacted – would provide a half-trillion dollars of tax credits and direct subsidies for electric cars, renewable electricity from solar or wind, and other climate initiatives. That plan would certainly help reduce greenhouse gas emissions, and estimates find that its climate benefits greatly exceed the total cost. But it is not costless: the budget cost of subsidies must be covered by some kind of taxation, and the switch to electric cars and renewable generation will cost more than cheap gasoline and coal-fired electricity. In other words, *all* climate policies place burdens on those with long commutes using gasoline-powered vehicles, those with poorly insulated homes, those who need fossil fuels for heat or electricity, and those who lose jobs in fossil-fuel industries. Short-run burdens are placed not only on those who lose jobs but on entire local economies that have relied on those jobs.

Thus, a disadvantage of carbon pricing is that it would raise the cost of using fossil fuels and raise the price of electricity. However, the advantage is that it provides the most climate benefits per dollar of cost. It induces firms and households to undertake all the lowest cost ways to reduce emissions – both by switching to renewables and by encouraging conservation. Biden's "Build Back Better" plan omits carbon pricing, and it subsidizes the generation of renewable power. In other words, while a carbon tax would increase electricity prices and encourage conservation, the subsidies do not.

The "Climate and Equitable Jobs Act" (SB 2408), signed by Illinois Gov. J.B. Pritzker on September 15, 2021, includes a variety of climate initiatives. It promises 40% renewable energy by 2030, 50% by 2040, and 100% clean energy by 2050. Despite encouraging renewables, however, the act omits carbon pricing and thus makes overall emission reduction more difficult to achieve. Biden's subsidies also reduce electricity prices and discourage energy conservation. However, additional legislation in Illinois can help achieve emission reduction and energy conservation. A carbon pricing program in Illinois can:

- Help Illinois achieve its promise of 100% clean energy by 2050;
- Collect needed additional revenues that could be used for equal per capita dividends, safety net programs, cut other state taxes, or provide the necessary transition assistance for those who lost jobs in fossil-fuel industries;
- Enable Illinois businesses and households to collect even more of the federal subsidies under the Build Back Better plan – to help pay for electric cars and renewable energy; and
- Use the Federal renewable energy subsidies to offset the higher costs of generating electricity under an Illinois carbon tax, potentially canceling out any increase in the state's electricity price.

To be sure, carbon pricing in Illinois would have other pros and cons described below. The biggest opposition to a carbon tax, however, comes from those who then bear extra burdens. Remaining sections below focus on how to estimate who would gain or lose from a carbon tax.

DISTRIBUTIONAL EFFECTS OF CLIMATE POLICY

Most studies on the distributional effects of climate policy are about the "vertical" distribution of burdens up and down the income scale, especially comparing low and high-income households within the U.S. As described more below, Cronin, Fullerton, and Sexton (2019, hereafter CFS) look at costs of a carbon tax reform in the U.S. that has a proportional vertical effect—reducing real incomes by about 1% in all income groups.[8] Revenue rebates can reduce net burdens proportionally to near zero in all deciles (from the poorest ten percent to the richest ten percent). In other words, the net effect of a carbon tax and rebate could be roughly proportional. But legislators have choices about how to use the revenue. A carbon tax and rebate could be regressive if the revenue is used to cut top income tax rates, or it could be progressive if revenue is used strictly for low-income assistance. Moreover, even the same 1% burden on everybody might be deemed too much for low-income households.

In contrast, very few studies measure "horizontal" effects *within* each income group. For example, climate policy will impose greater burdens on families with a greater need for heat and air conditioning, compared to other families at the same income level in locations with less temperature variation. CFS uses detailed data on 322,000 families across the U.S., divided into ten deciles (from the ten percent with the lowest income to the ten percent with the highest income). Within the lowest-income decile, the carbon tax and equal per capita dividend together reduce the real net incomes of some households by 2% and raise the real net incomes of others by 2%. Some poor households live near the western and southern coasts with mild climates that require little spending on heat or air conditioning. Some have no car and buy no gasoline. In those cases, the uniform per capita dividend exceeds their carbon tax burden.

These horizontal redistributions are not a goal of carbon policy, even if they necessarily accompany any plan to discourage carbon emissions. More strongly, however, one might say that horizontal redistributions ought to be avoided. All else equal, a redistribution that helps one poor person while taking real income away from another equally poor person might be considered unfair. Purely horizontal redistributions reduce some overall measures of social welfare.[9] Policymakers may want to avoid these redistributions, but if so, then they need to know the likely horizontal effects of each proposal. In other words, this issue requires further study.

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The next section will review CFS to discuss various estimation approaches and data needs. They find that the well-studied vertical redistributions between high- and low-income families are small compared to the under-studied horizontal redistributions. They study the costs of a carbon tax, not the distribution of benefits from reduced climate damages—another problem that likely adds more heterogeneous impacts. Households might gain or lose property value from differential exposure to heat, floods, droughts, storms, and wildfires.

Then I will draw on this U.S. study to discuss implications for Illinois. Evidence shown later suggests that heterogeneity within Illinois is likely similar to heterogeneity across the U.S., so any carbon policy in Illinois is also likely to impose extra burdens on those who commute long distances by automobile, on those who have poorly insulated houses that require fossil fuel for heat, and on coal miners who lose their jobs. If so, then a uniform per capita dividend to all Illinois residents will not offset those extra burdens.

THE PROBLEM OF HORIZONTAL REDISTRIBUTIONS

Any policy to reduce greenhouse gas emissions will raise the price of electricity and gasoline and thus raise costs for those who spend the most on energy. Consumer expenditure data from the U.S. and many European countries demonstrate that the average low-income family spends a greater share of income on energy than does the average high-income family. Thus, for vertical distributional effects between high- and low-income families, the conventional view is that carbon policy is regressive. As a consequence, many believe that the additional carbon tax revenue should be used to help cover those extra costs for low-income families.[10]

New research in CFS disputes this conventional view about vertical effects. First, they argue that annual income is not the best way to categorize families from low- to high-incomes. They use a measure of long-run "permanent" income, which makes a carbon tax much less regressive. Second, U.S. law has automatic indexing (cost-of-living adjustments) for Social Security benefits and other public transfers to low-income families. When a climate policy raises energy prices, and those extra energy production costs also raise prices of all other commodities, then many low-income families *automatically* receive higher levels of public transfers. Indexing reduces the net revenue from a carbon tax, and it reduces measured regressivity.[11] Capturing both points—permanent income and indexing of public transfers—CFS find that the net carbon tax burden is a greater share of income for those with more income. In other words, the carbon tax is progressive.

Households receiving public transfers that are indexed to the price level do not need as much "carbon tax dividend" to protect them from harm. Moreover, even if average net burdens are near zero, burdens within each income group are very heterogeneous.

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Heterogeneity of burdens arises both because of different income sources and different expenditure patterns. Within the lowest-income group, for example, burdens are higher for those with a greater share of income from un-indexed wages and those with heavy needs for spending on energy. Other low-income households receive public transfers that are indexed to inflation, where that indexing is based on nationwide average weights for spending categories. They are over-compensated if they spend less than the average share of income on gasoline, heat, and electricity. With no rebate of net revenue, in calculations of CFS, a carbon *tax* can lead to large net *gains* for low-income households whose primary income is from indexed Social Security benefits, whose commutes do not require gasoline, and whose homes are well-insulated. In other words, any package of reforms will create winners and losers within each income group.[12]

HOW TO ESTIMATE HORIZONTAL REDISTRIBUTIONS?

This section describes the data and methodology that underlie the CFS calculations. For a large sample of households, the U.S. Consumer Expenditure Survey (CEX) provides details on purchases of various commodities whose prices are differentially affected by a carbon tax. However, it includes neither verified nor detailed information about income sources, taxes paid, and transfers received. But CFS use the U.S. Treasury Distribution Model (TDM), which includes extensive imputations to construct a dataset with the necessary heterogeneity across a large, representative

sample of families with differing expenditures, sources of income, taxes paid, and transfers received.

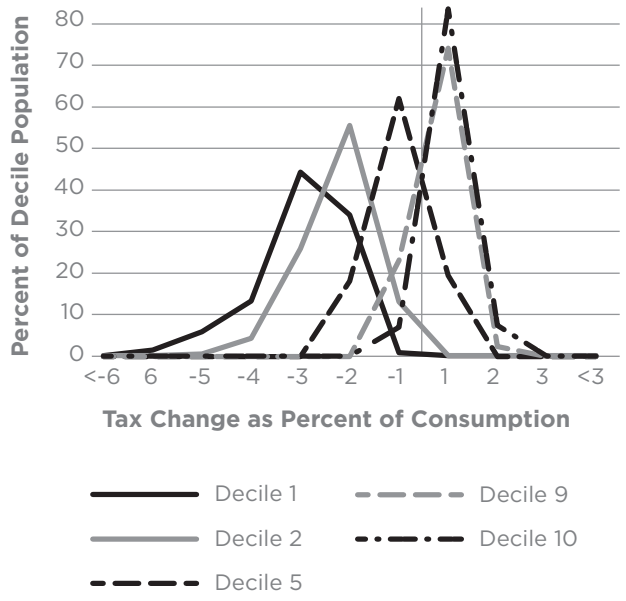
The TDM starts with a merged file of 300,000 U.S. tax returns plus 22,000 non-filer "information returns" to capture a representative number of those whose income is below the tax filing threshold. It uses only non-dependent returns and weights them, so the final weighted dataset represents 172 million U.S. families. It uses an exact match of the Social Security number on each return, to verify details about Social Security benefits received and payroll taxes paid.[13] Each return is also matched to a similar family in the CEX whose expenditure shares for 33 consumption categories are applied to the total expenditures of the tax family. The TDM makes further imputations for participation in each transfer program and receipts from each program such as Temporary Assistance for Needy Families (TANF), Supplemental Nutrition Assistance Program (SNAP), and the Earned Income Tax Credit (EITC).

The Treasury's 322,000 households provide plenty of detail for the U.S. as a whole but do not show taxpayer state of residence (which could be enough information to identify a particular confidential tax return). Therefore, the same study cannot be performed just for Illinois. Nonetheless, CFS use the TDM to calculate U.S. effects of a carbon tax with $100 billion of annual revenue, and they employ several alternative assumptions about the rebate of revenues: (1) no rebate, but 23% of revenue must be used under existing law to index transfers and tax brackets for consumer price increases; (2) all net carbon tax revenue is used to pay a uniform $229 per capita rebate; and (3) net revenue is used for a 5.9% increase in all existing transfers.

Burdens are determined for each family in a way that captures the direct and indirect impacts of this carbon tax on prices for each of 389 consumption goods.[14] Thus, the tax impacts the price of fuels and intermediate goods according to their carbon intensities, and these changes impact the market price of each commodity. The overall consumer price index rises about 1%, but the price increase for electricity is 9.0%, for natural gas is 14.8%, and for gasoline is 14.8%. The price hike for mass transit is 4.6%, and for airline tickets is 5.5%.

This method also has limitations.[15] One limitation is that they have only one year's data, but one year's income is a poor measure of well-being. The low-annual-income group includes not only the perennially poor but also the young who will earn more later, the elderly who did earn more earlier, and those with volatile income observed in a bad year. Instead, CFS use annual spending as the best available measure of well-being, or "permanent income," because it allows for people to spend a bit less in high-income years and a bit more in low-income years (consumption smoothing).[16] Annual consumption is not a perfect measure of permanent income, because of borrowing constraints and information problems, but it is better than annual income as a measure of a family's well-being.

Figure 1: Net Tax Changes by Decile for Carbon Tax with Per Capita Rebate



RESULTS FOR U.S. HOUSEHOLDS

CFS show the sensitivity of results to different assumptions. For example, they compare results that classify households by annual income and by annual consumption, with or without indexing. Like prior studies, the use of annual income with no indexing means the carbon tax is regressive. When they instead use annual consumption to classify families, the carbon tax is roughly proportional. Then, when they account for indexing, they find that the carbon tax is progressive. The burden rises from 0.45% of consumption for the lowest decile to 0.80% of consumption for the highest decile. Also, some families have little need for energy and thus very small carbon tax burden but still receive increased transfers that reflect the nationwide average increase in costs of goods. Within the first decile, even with no dividend, this carbon tax leads to a net gain for 13.6% of families.

When carbon tax revenues are refunded by a uniform per capita dividend, the net additional burden as a percent of consumption is even more progressive. The poorest 10% of families gain 2.6% of consumption on average, and each of the first seven deciles receives a net gain, but the richest decile faces a net tax burden equal to 0.58% of consumption.

The progressive vertical redistribution also appears in Figure 1. This figure shows how burdens range from a negative net burden (*i.e.,* gain) equal to 6% of consumption on the left, and it extends up to a positive burden equal to 3% of consumption on the right. Each curve represents a selected decile (lowest, second, fifth, ninth, and tenth). Each curve's height shows the percent of families in that decile who face the net burden on the horizontal axis (as a percent of consumption).[17] The solid black line shows burdens within the poorest group. Its height is 45 where the horizontal axis is –3, indicating that 45% of this group has a negative burden between 2 and 3 percent of consumption. The dark dashed line for the middle decile has a peak at –1, so 60% receive a net *gain* from zero to 1 percent of consumption. The peak for the richest decile is at +1, so over 85% have a positive net burden between zero and 1 percent of consumption.

The same figure also demonstrates horizontal redistributions within each group. The black line for the poorest group is most spread out: of this poorest group, 12% of families gain 3 to 4% of consumption, and 5% gain 4 to 5% of consumption, while 35% of families gain 1 to 2% of consumption.

Each mechanism to rebate revenue causes larger horizontal redistributions than those imposed by the carbon tax itself. Figure 1 shows the effects of the per capita rebate. Family size varies within each decile, and so per capita rebates vary as a percent of family income. The average family in the poorest decile gains 2.6% of consumption, but some gain more than 4%, while others bear a positive net burden. The average burden in the richest decile is 0.58% of consumption, but 8% face extra burdens up to 2%, and 7% *gain* up to 1% of consumption.

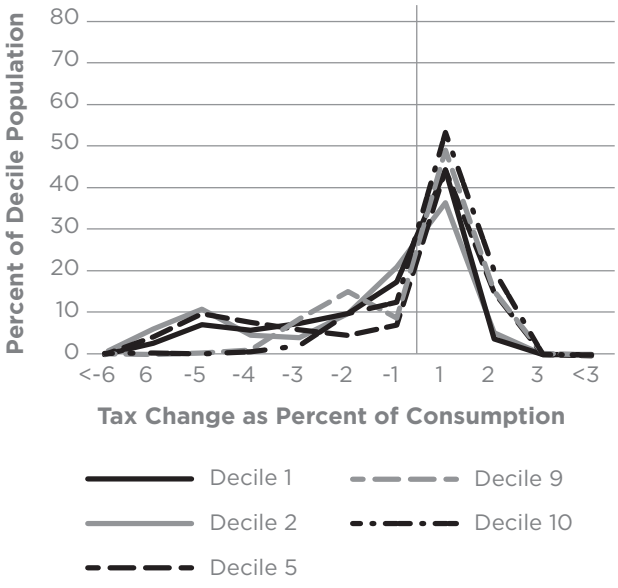
Next, consider the case where all net carbon tax revenue (after automatic indexing of transfers) is returned via uniform 5.9% increases in all public transfers. This reform also results in a progressive distribution of average burdens across the ten deciles (but it is less progressive than with the per capita rebate). The poorest group gains 0.96% of consumption on average, and all of the first eight deciles gain, but the top decile loses 0.50% of consumption.

Again, however, focusing on vertical distributions by looking at the average family in each decile misses the bigger story. Within the poorest decile, the average gain is 0.96% of consumption, but 47% of families get a net tax increase.

Complicated rules for public transfers deny eligibility to some people, and even those who are eligible often do not participate. Only 32% of families in the lowest decile receive EITC benefits, only 19% receive SNAP benefits, and only 16% receive Social Security income. Thus, a proportional increase in such transfers adds more horizontal variation than does the carbon tax itself. Within each of the deciles shown in Figure 2, even where many families gain 1% or 2% of consumption, net losses are experienced by 42% to 66% of families. Some of those losses exceed 2% or 3% of their total consumption. The figure shows more variation in net burden under the transfer expansion than under the per capita rebate.

This disconcerting picture raises the question of whether a carbon tax reform package can be designed to reduce horizontal disparities within each income group. Available data include each family's expenditures and income sources, but not the age or insulation of their dwelling nor the energy efficiency of their appliances and vehicles. It might be hard for any policy package to account for each family's weather, commuting distance, or access to commuter rail. While carbon tax rebates based upon these characteristics could reduce horizontal variation in net burden outcomes, however, the big problem is that such rebates also affect incentives and could reduce future investments in energy efficiency or insulation.

Figure 2: Net Tax Changes by Decile for Carbon Tax with 5.9% More Transfers



WOULD ILLINOIS EXPERIENCE SUCH WIDESPREAD GAINS AND LOSSES?

As discussed above, the wide variation in carbon tax burdens within an income group is related to the wide variation in needs for fossil fuels to generate electricity, heat homes in winter, and air-conditioned homes in the summer. Within the low-income group, some families live in Minnesota and some live on the coast of California. The variation in heat and air conditioning needs are not that great within Illinois, but other variations can still be substantial. Therefore, we turn to the more limited available evidence about the variation of energy needs within Illinois.

Illinois is almost 400 miles long, from north to south. Natural gas needs for heating in the winter vary. Table 1 shows that winter temperatures range from 11-29°F in northern Illinois to 25-43°F in southern Illinois. Needs for air conditioning must also vary, as summer temperatures range from 62-83°F in the north to 69-89°F in the south. Moreover, differences between individual households are obscured by looking only at these averages for the two ends of the state. Some households within northern Illinois have more than average needs for heat, and some households within southern Illinois have more than average needs for AC.

Data for the consumption of fossil fuels is not available for all counties, but Table 2 shows some major differences between the City of Chicago (Cook County) and its neighboring suburban counties. In the first column, per household consumption of electricity is substantially less in Chicago than in the suburbs, most likely due to differences in house size, household income, multi-family structures, and demographic characteristics like family size. Yet household consumption of natural gas is a bit higher in Chicago than in most suburbs, likely because Chicago has an older housing stock that is less well insulated.[18] The third column of Table 2 shows even larger differences in vehicle miles traveled (VMT) per household, because residents of Chicago are more likely to walk to nearby stores or jobs, and they have much better access to mass transit. For this reason, many families in Chicago would have less than average burdens from a carbon tax on gasoline for commuting, compared to those in the suburbs.

Again, however, many diverse households within each county are averaged together to obtain the averages for each county shown in Table 2. For this reason, a carbon tax in Illinois would still impose widely different energy-cost burdens on different households within a county or within any single income group in Illinois.

Finally, despite having significant nuclear power and new wind power, Illinois still has substantial coal mining activity and coal-fired power plants. The *Chicago Tribune* reports that "More than half of the 32 million tons of coal mined in Illinois came from Foresight Energy, which owns Sugar Camp coal mine near Benton in Southern Illinois".[19] The concentration of this activity means that particular areas could be hard hit by a large carbon tax. Those areas could need transition assistance such as relocation and retraining of workers.

Table 1: High and Low Average Temperatures in Illinois (Fahrenheit)

	January		July	
	High	Low	High	Low
Northern Illinois	29	11	83	62
Central Illinois	35	19	86	65
Southern Illinois	43	25	89	69

Note: Data are taken for one city in each row: Freeport, Springfield, and Cairo. See https://perma.cc/PY85-RH9D

Table 2: Residential Energy Use and Vehicle Miles Traveled (VMT) per Household (hh), in Chicago and Suburban Counties

County	Electricity (Kwh per hh)	Natural Gas (therms per hh)	VMT (per hh)
Cook (Chicago)	7,935	1,084	15,632
DuPage	9,124	898	22,036
Lake	11,631	1,180	23,296
Will	11,109	882	26,096
Kane	9,376	913	23,619
McHenry	11,560	971	25,818
Kendall	10,688	1,079	26,240

From https://perma.cc/PV26-DCV9. These data are only available for 2005 and represent only residential energy use. Depending on the county, residential use in each column is either more or less than half of the total (including residential, commercial, and industrial use). Vehicle Miles Travelled (VMT) is estimated using odometer readings taken during emissions testing (provided by the Illinois Department of Motor Vehicles). Thus, the table shows VMT attributed to households in the county (not all miles driven in the county).

Since Illinois already has a climate policy that promises to switch electricity generation away from coal and other fossil fuels toward renewables like solar and wind power, the state could implement a carbon tax to help achieve that switch while raising revenue that can be used to help households who bear large burdens from job losses. Well-targeted assistance could also reduce the highest burdens from rising energy prices in the figures shown above.

HOW TO HELP THOSE WITH HIGHER-THAN-AVERAGE BURDENS

Most workers started their careers years ago, and those who are homeowners bought their houses a long time ago. If they had known that a carbon tax would suddenly raise the price of fossil fuels, then they could have entered a different career or bought a different house with more insulation. With full information about the future, they may have bought a house with a shorter drive to their place of work or one closer to mass transit. Now, however, those individuals have "sunk costs" associated with buying their house or investing in a coal-mining career. A poorly insulated house that requires a long commute has already lost value, even before enactment of strong climate policy, because enough new information has come to light about future damage from climate change and the likely eventual success of efforts to reduce it. Now that everybody knows about future increases in energy costs, houses close to mass transit stops have already risen in value. One set of homeowners has suffered a capital loss, while another set has gained. Those who chose careers in coal mines or coal-fired power plants have already suffered capital losses, while others made more beneficial choices.

State policy cannot simply help support households with rising energy costs, because that would negate the incentive to reduce their energy costs. Indeed, the purpose of a carbon tax that raises energy costs is to provide an incentive to residents to insulate their homes, turn off the lights when they leave the room, buy a bicycle for commuting to work, or even eventually move to a house closer to their place of work. The problem is that those higher energy costs impose burdens, as shown above. Policymakers may wish to offset burdens on a household with a poorly insulated residence, but any continuing aid to families with poorly insulated homes would cancel the incentive for them to reduce their fossil-fuel use by adding insulation.

Perhaps an imperfect but fair plan can be devised to help those who lose the most. For example, the state might allow households to submit past natural gas bills, electricity bills, and evidence of past gasoline expenditures or driving distance to their place of employment. Then, perhaps temporary transition aid for a few years can be based on those *past* energy expenditures. As long as that assistance does not depend on future energy bills, it could leave a powerful incentive for families to use those funds for insulation that could reduce future energy bills.

Moreover, state policy can help support those who lose their jobs in the coal industry or at coal-fired power plants, but it should not encourage them to stay in that profession. Those workers need relocation assistance and training for new jobs in other industries. Moreover, policy can encourage new industries to move into former coal-mining regions of the state. Still, however, those who are already over 55 when they lose their coal industry jobs may not be able to find new jobs, and therefore may need early retirement benefits.

As stated in simple terms above: If the total benefits of climate policy exceed the total costs by as much as is estimated, then a policy package can be designed to help everybody share in those gains.

ENDNOTES

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[2] See Intergovernmental Panel on Climate Change estimates at https://perma.cc/RW6A-VDS6 and U.S. EPA estimates at https://perma.cc/F59E-NFVG. The U.K. published the Stern Review, at https://perma.cc/8243-GCZJ. It finds that costs of action to avoid climate change could be around 1% of GDP, while benefits of reduced climate change are several times higher.

[3] Distributional effects are "proportional" if burdens as a fraction of income are the same for all groups, "regressive" if that fraction is falling with income, and "progressive" if rising with income.

[4] See https://perma.cc/AMV8-WMQF.

[5] See https://perma.cc/FK7G-DBN6 for Washington State, and https://perma.cc/NE2T-HP88 for California.

[6] See https://perma.cc/SD7T-RDBK for Illinois.

[7] See https://perma.cc/858R-T9MF.

[8] Julie-Anne Cronin, Don Fullerton, and Steven Sexton, "Vertical and Horizontal Redistributions from a Carbon Tax and Rebate," *Journal of the Association of Environmental and Resource Economists* 6, no. S1 (2019): S169-S208, https://perma.cc/2REF-2MY4. This study builds on others that use expenditure data to estimate burdens. See Florens Fluens, and Alastair Thomas (2015), "The Distributional Effects of Energy Taxes," OECD Taxation Working Paper, Organization for Economic Cooperation and Development, Paris. Also, see William A. Pizer and Steven Sexton, "The Distributional Impacts of Energy Taxes," *Review of Environmental Economics and Policy* 13, no. 1 (2019): 104–123, https://perma.cc/BZ82-DU6M.

[9] See Pizer and Sexton, ibid, and Carolyn Fischer and William A. Pizer, "Horizontal Equity Effects in Energy Regulation," *Journal of the Association of Environmental and Resource Economists* 6, no. S1 (2019): S209-S237, https://perma.cc/KXK9-TUEC.

[10] Many papers find the carbon tax to be regressive and suggest rebates to help low-income families. For examples, see Corbett A. Grainger and Charles D. Kolstad, "Who Pays a Price on Carbon?" *Environmental and Resource Economics* 46, no. 3 (2010): 359-76, https://perma.cc/C3MG-HE68; and Aparna Mathur and Adele C. Morris, "Distributional Effects of a Carbon Tax in Broader U.S. Fiscal Reform," *Energy Policy* 66 (2014): 326-34, https://www.sciencedirect.com/science/article/abs/pii/S0301421513011543. https://perma.cc/3ZNE-BD6X

[11] Indexing in the U.S. includes not only public transfers like Social Security but also income brackets in the tax code. Other papers account for indexing of transfers, including Terry Dinan, "Offsetting a Carbon Tax's Costs on Low-Income Households," CBO Working Paper 2012-16, Congressional Budget Office, Washington, D.C. (2012), https://perma.cc/6M2A-QUH4; and Don Fullerton, Garth Heutel, and Gilbert E. Metcalf, "Does the Indexing of Government Transfers Make Carbon Pricing Progressive?" *American Journal of Agricultural Economics* 94, no. 2 (2012): 347-53, https://perma.cc/DVY4-5A2B. But CFS also account for indexing of income tax brackets.

[12] See James M. Sallee, "Pigou Creates Losers: On the Implausibility of Achieving Pareto Improvements from Efficiency-Enhancing Policies," NBER Working Paper No. 25831 (2019), https://perma.cc/R6CR-5C26.

[13] For each family in the TDM, "total consumption" is computed as taxable income plus fringe benefits minus tax paid and savings.

[14] A carbon tax raises the price of gasoline and electricity, but every industry uses both gasoline and electricity for production. The Treasury model employs an "input-output" matrix that shows how each industry uses the output of every other industry as an input to its own production. Thus, to varying degrees, a carbon tax raises all output prices. Each family's burden is calculated as their observed expenditure on each good times its price increase, so quantities are fixed. Similar methods are employed in Grainger and Kolstad (2010) ibid, or Mathur and Morris (2014) *ibid*.

[15] First, they do not measure efficiency effects of a carbon tax, only detailed distributional effects assuming no changes in behavior. Second, they ignore possible changes in wage rates or other factor prices. They focus only on diverse patterns of spending on energy-intensive goods and of transfers received. Third, they have one year's cross-section of data on consumer spending and transfer receipts, not a panel to construct a long-run measure of well-being. Fourth, the merged dataset excludes information on each family's geographic location, house characteristics, appliance energy efficiency, or commuting distances—all of which affect exposure to carbon tax burdens. It does capture the variation of actual energy spending across households.

[16] A dollar is worth more in a bad year than in a good year. This "declining marginal utility" for consumption within a year means that families want to smooth consumption over time to reflect their permanent income. Thus, carbon tax regressivity is exaggerated when using annual income to classify households. See Milton Friedman, "The Permanent Income Hypothesis?" in Milton Friedman, ed., *A Theory of the Consumption Function*, Princeton University Press (1957). Also see James M. Poterba, "Lifetime Incidence and the Distributional Burden of Excise Taxes," *American Economic Review* 79, no. 2 (1989): 325-330, https://perma.cc/XB5Q-5TH6, Finally, also see Bruce Meyer and James X. Sullivan, "Identifying the Disadvantaged: Official Poverty, Consumption Poverty, and the New Supplemental Poverty Measure," *Journal of Economic Perspectives*, 26, no. 3 (2012): 111-136, https://perma.cc/P8LA-GJ5R.

[17] Figure 1 here is taken from Figure 1A in Cronin et al (2019), while Figure 2 below is taken from Figure 1B.

[18] See page 8 of https://perma.cc/2L2S-N4CY for evidence on the age of housing in Chicago compared to the other counties.

[19] See https://perma.cc/XZP3-8UYY.

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