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The Initial Incidence of a Carbon Tax across US States

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Abstract

Carbon taxes introduce potentially uneven cost burdens across the population. The distribution of these costs is especially important in affecting political outcomes. This paper links dynamic overlapping-generations and microsimulation models of the United States to estimate the initial incidence of a carbon tax across states. Geographic differences in incidence are driven primarily by differences in sources of income. Differing patterns of energy use also matter but are relatively less important. The use of the carbon tax revenue plays an important role, particularly in determining how different income sources are affected, as: (1) using carbon tax revenue to cut capital taxes disproportionately benefits states with large shares of capital income; (2) returning the revenue via lump-sum transfers favors relatively low-income states; and (3) returning the revenue via cuts in labor taxes provides a relatively even distribution of cost across states. In general, geographic differences in incidence are substantially smaller than the differences across income groups.

Key Words: carbon tax, distribution, incidence, tax swap, states, geography, climate change

JEL Classification Numbers: H22, H23, Q52

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I. Introduction

Imposing a price on carbon is very likely the most efficient way to reduce greenhouse gas emissions. But carbon pricing appears to be politically difficult, particularly at the federal level in the United States. The distribution—or perceived distribution—across states of the costs and benefits plays a key role in determining the political feasibility of carbon pricing. Thus understanding the distribution across geographic divisions is important.

Many studies have examined the aggregate costs of carbon pricing or the distribution across income groups; however, few have studied the geographic distribution. Most of those have looked at regions that are larger than individual states.¹ In addition, most of these studies are partial-equilibrium: they assume that the full cost of carbon pricing is passed forward, appearing in the form of higher consumer good prices, with no effect on household incomes.²

This paper looks at the distribution of costs of carbon pricing across states, within a general equilibrium framework. We link two models of the US economy: a dynamic overlapping-generations (OLG) general equilibrium model and a detailed model of state-level

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¹ Studies of the regional distribution of the cost of carbon pricing include Burraw, Sweeney, and Walls (2009), Hassett, Mathur, and Metcalf (2009), Paul, Beasley, and Palmer (2013), and Blonz, Burraw, and Walls (2012). These studies look at incidence over geographic regions that are substantially larger than individual states. Two studies that look at finer geographic divisions are by Boyce and Riddle (2009), who examine state-level incidence of a carbon cap-and-dividend policy, and Pizer, Sanchirico, and Batz (2010), who use spatial kernel regression applied to confidential data to look at household energy use across the country (independent of political jurisdictions).

² A few general equilibrium studies look at regional incidence, including Rausch, Metcalf, and Reilly, 2011, and Rausch 2010b).

incidence.³ The OLG model provides a general equilibrium estimate of how consumer prices, wages, returns to capital, and government transfers change in response to the carbon pricing policy, and the incidence model shows how those changes affect households in each state. This linkage makes it possible to look at the full range of effects on consumer good prices and household incomes in a general equilibrium setting and disaggregate the costs to the state level.⁴

We evaluate three different policy cases. All three are based on the same \$30-ton carbon tax but return the revenues in different ways: one devotes the revenue to cutting taxes on capital income, the second uses the revenue to cut taxes on labor income, and the third returns the revenue via a lump-sum “dividend” to households. The three policies produce similar reductions in emissions but differ substantially in their overall costs and in the distribution of those costs.

In this paper, we look only at the initial effects of the policy; that is, we include near-term responses to the policy, such as shifts in consumption and production in response to the carbon price and use of revenue, but not longer-term responses, such as adjustment of the capital stock. We look only at policy costs, and do not include any estimate of the environmental benefits.

We find that differences in sources of income are more important in driving differences in incidence across states than are consumption differences. Not surprisingly, states with large shares of capital income do well under capital tax recycling, those with large shares of labor income do well under labor tax recycling, and lower-income states do well under lump-sum rebates. Different patterns of energy use also matter, but they are less important than differences in income sources. Regional differences with respect to the carbon intensity of economic activity tend to be offsetting; for example, regions with greater home heating may use less air-conditioning. In general, incidence varies less across geography than across income groups.

³ The OLG model used here was introduced in Carbone, Morgenstern, and Williams (2013). The incidence model is similar to the model used by Williams et al. (forthcoming), who looked at incidence across income groups, but differs in that the model in this paper is adapted to look at state-level incidence.

⁴ An alternative approach would be to build a range of heterogeneous households into a computable general equilibrium model. This would yield perfectly internally consistent results (which is not guaranteed when linking two models). However, it is computationally difficult (though the algorithm proposed in Rausch and Rutherford (2010) shows promise), and data limitations make it challenging to parameterize.

II. Policies

This paper considers three policy cases, all of which introduce a carbon tax of \$30 per ton of CO₂ (in 2012 dollars), beginning in 2015 (and not anticipated prior to that date) and held constant in real terms thereafter.⁵ The tax applies to all fossil-fuel-related CO₂ emissions.⁶

The three policy cases differ in how the carbon tax revenue is used. The first two “tax swap” cases use the revenue to finance permanent cuts in preexisting distortionary taxes introduced at the same time as the carbon tax, with one focusing on capital income tax cuts and the other on labor income tax cuts. These cuts are structured so that the percentage point cut in the effective marginal tax rate (on all capital income or all labor income, respectively) is constant across income levels, which implies that all income groups get the same percentage point cut in both marginal and average tax rates.⁷ In the third case, revenue from the carbon tax is used to provide a tax-free, lump-sum annual rebate to every individual (regardless of age). This rebate begins at the same time as the carbon tax, and the rebate remains constant in real terms over time.

In each case, we keep the long-term level of government debt (i.e., the real value of debt over 100 years) and the cumulative net present value of real government services and real government transfers (other than the rebate policy, if any) the same as in the benchmark (i.e., no policy change) case. This means the time paths of real deficits, transfers, and services may change slightly from the benchmark case, but the present value of those changes net out to zero.⁸ In the two tax-swap cases, we set the size of the tax cuts for capital or labor income to achieve the constant level of long-run debt, taking the carbon tax revenue into account. In the rebate case, we return the entire gross revenue from the tax via the rebate and proportionally adjust other taxes in the model to achieve the constant level of long-run debt.

⁵ These same three cases are also considered in Williams et al. (forthcoming).

⁶ This would be most easily implemented via an upstream tax on the carbon content of all fossil fuels. It could also be implemented as a downstream tax, which would be equivalent in our model as long as the downstream tax covers all emitters.

⁷ The easiest way to implement such an across-the-board tax cut for labor income would be to cut the payroll tax rate and replace the lost payroll tax revenue with revenue from the carbon tax. Implementing an across-the-board cut for capital income would be more difficult, because not all capital income recipients file income tax returns (and there is no analogue to the payroll tax for capital income).

⁸ Indexing transfers for inflation would imply holding real transfers constant in each period, not just in net present value. Several papers have shown that indexing of existing transfer programs substantially reduces the regressivity of carbon pricing (Parry and Williams, 2010; Blonz, Burraw, and Walls, 2012; Dinan, 2012; Fullerton, Heutel, and Metcalf, 2012).

By holding the real carbon tax rate constant over time, these simulations differ from most carbon tax proposals, which typically have the real carbon tax rate rise over time. We do this for simplicity, as it is easier to understand the effects of a constant real carbon tax rate than a rate that changes over time. Similarly, many proposals would announce the carbon tax prior to when it is imposed so that the economy has time to adjust before the policy takes effect.⁹ Again, for simplicity, we assume the policy change is implemented immediately, without preannouncement, and focus on the near-term effects of the policy (i.e., before long-term responses, such as adjustment of the capital stock, have had time to occur).

III. Model

The modeling framework calculates an intertemporal general equilibrium with overlapping generations and perfect foresight, combined with a microsimulation model of household income and expenditure, as described in Williams et al. (forthcoming). In this paper, equilibrium results for the initial introduction of the carbon policy are distributed across state-level subgroups of the population.

A. General Equilibrium Modeling

The general equilibrium modeling uses the dynamic overlapping generation (OLG) model of the US economy described in detail in Carbone, Morgenstern, and Williams (2013) which we now summarize. The model characterizes how the economy evolves over time in response to changes in policy. In each 5-year model period, a new generation enters the model and then makes life cycle consumption and savings decisions for its 55-year economic (adult) lifetime. Thus in any given model period, there are 11 active generations. Each generation is modeled as a single representative household, with each succeeding generation scaled up to reflect a constant exogenous population growth rate of 1 percent per year.

Households derive income from labor, capital, natural resources, and government transfers and make decisions about savings, consumption, and labor supply. Households maximize the discounted sum of utility over their life spans, with utility represented by a constant elasticity of substitution (CES) function of consumption and leisure. These decisions collectively determine the levels of national income, consumption, saving, and investment in the economy, which in turn determine the aggregate capital stock and economy activity.

⁹ However, Williams (2012) suggests that it is more efficient not to preannounce environmental policy.

The model also incorporates multisector production, which is important for modeling trade-offs across different industries and changes in sources of income. Production occurs in 19 competitive industries, including 15 energy and energy-intensive industries (those most directly affected by a carbon tax) taken directly from the disaggregated Global Trade Analysis Project (GTAP) 7.1 dataset and one composite of all other intermediate goods. The remaining industries produce government services, investment, and a household consumption good.¹⁰ Production combines basic factors (physical capital, labor, and natural resources) with intermediate inputs, using a nested CES production function. The nesting structure implies that substitution among energy goods is easier than substitution between energy and other inputs. We assume a constant, exogenous 2 percent rate of labor-augmenting technological change. Imports and exports are traded at fixed international prices (i.e., we assume a small open economy), and domestic and international varieties of each good are imperfect substitutes.

The government sector includes taxes on carbon emissions (set to zero in the benchmark), labor income, capital income, and consumption. In the benchmark, tax revenue finances government services and transfer payments to households that grow over time at the same rate as GDP, and the government runs a persistent budget deficit of approximately 3 percent of GDP based on long-term projections from the Congressional Budget Office (CBO, 2011). This implies an ever-increasing level of national debt. Each policy analyzed may have changes in budget deficits in the short run but keeps the long-run path of national debt the same as in the benchmark case.

B. Decomposition of Incidence by Commodity and Income Source

The microsimulation model is similar to that used in Williams et al. (forthcoming) to study incidence across income groups. This paper differs in that it looks at incidence across the US states. The fundamental structure of the model is as follows.

The OLG model estimates the aggregate price and quantity changes caused by a policy and the welfare effects on different generations. The incidence model distributes that national result across households and geographic locations. Changes to welfare due to the policy can be decomposed according to changes in welfare stemming from changes in the price and quantity of

¹⁰ Note that this is equivalent to having government and households directly purchase the “intermediate” goods (and indeed, when we decompose incidence by geography, we take account of different patterns of consumption good purchases across states).

commodities (which we approximate using consumer surplus) and welfare changes stemming from changes in income (which we approximate using producer surplus).¹¹ The general equilibrium results from the OLG model provide the following: (1) in the benchmark (no policy) case, expenditures (x_i) for 17 commodity goods (i) and incomes (y_j) from 8 income sources (j), for each time period; and (2) in each policy case, the percentage changes in price and quantity for each of these commodities and income sources. For government transfers and the potential rebate under a carbon tax, the model provides the absolute change in income.

Assuming the demand curve is linear in the relevant range of changes in price and quantity, the equilibrium representation of changes to consumer surplus for a given commodity i is the change in consumer surplus, calculated as

$$(1) \quad \Delta cs_i = -\left(1 + \frac{\Delta q_i}{q_i} \times \frac{1}{2}\right) \times \frac{\Delta p_i}{p_i} \times x_i .$$

A partial equilibrium demand curve holds the prices of other goods and sources of income constant. Thus, a consumer surplus calculation based on such a demand curve will omit the interactions between price changes for different goods or between price changes and income changes. However, we take the quantity changes from the OLG model equilibrium. Thus the consumer surplus calculation for good i implicitly accounts for all of the interactions between the effects of the price change for good i and changes in income and in the prices of other goods.

Analogously, assuming the supply curve is linear in the relevant range of changes in price and quantity, the equilibrium representation of changes to producer surplus for a given income source j is the change in producer surplus, calculated as

$$(2) \quad \Delta ps_j = \left(1 + \frac{\Delta q_j}{q_j} \times \frac{1}{2}\right) \times \frac{\Delta p_j}{p_j} \times y_j .$$

The producer surplus calculations also take quantity changes from the OLG model equilibrium and thus implicitly account for interactions between prices. The quantity of natural resources is exogenously fixed. For government transfers and potential rebates from a carbon tax we simply use the change in income from these sources (there is no “price change”).

¹¹ These represent very close approximations, as for each policy studied, summing the changes in producer and consumer surplus for the whole economy yields a result that is nearly identical to the sum of equivalent variations across the representative households in the OLG model. This is not surprising, as West and Williams (2004) find that consumer surplus provides a good approximation to equivalent variation when calculating incidence.

Incidence is calculated as the sum of the changes in consumer and producer surplus

$$(3) \quad \Delta W = \sum \Delta cs_i + \sum \Delta ps_j.$$

C. Calculating Welfare Effects Caused by Changes in Consumer Good Prices

We index the changes in welfare, ΔW^k , where k indexes US states, assuming that policy-induced percentage changes in prices and quantities for each good (except electricity, which is described below) are the same across states.¹² However, the initial level of expenditures for each commodity and income by source is different (x_i^k and y_j^k). Using the changes to consumer and producer surplus, we predict the welfare changes across states as

$$(4) \quad \Delta cs_i^k = \Delta cs_i \times \frac{x_i^k}{x_i} \text{ and } \Delta ps_j^k = \Delta ps_j \times \frac{y_j^k}{y_j}.$$

Incidence is written as

$$(5) \quad \Delta W^k = \sum_i \Delta cs_i^k + \sum_j \Delta ps_j^k$$

Data needed from outside the OLG model are the percentage of expenditures and income by state (x_i^k / x_i and y_j^k / y_j).¹³

1. Geographic Variation in the Carbon Intensity of Electricity

Because the carbon intensity of electricity generation varies widely across the country, the change in electricity price stemming from the introduction of a carbon price will also vary. To calculate a change in consumer surplus associated with electricity consumption by state (Δcs_e^k), we use output from the Haiku electricity market model, which identifies equilibria in electricity, fuel, and environmental markets in 22 linked regions over a 25-year time horizon (Paul, Burtraw, and Palmer, 2009). The Haiku model results (denoted by a single bar) provide

¹² This is equivalent to assuming a single national market for each good (except electricity), and that for any particular good, all states have the same elasticity of demand.

¹³ The national sum of income or expenditures in any category from sources outside the OLG model need not match the level given by the OLG model, as we are using only proportions of national activity occurring in each state.

absolute and percent changes in the price and quantity of electricity, denoted e , by state (k) and time period (t), $(\frac{\Delta p_e^{k,t}}{p_e^{k,t}}, \frac{\Delta q_e^{k,t}}{q_e^{k,t}})$.

The Haiku model results describe a carbon tax that increases over time to improve the equilibrium calculation in that model but averages \$30/ton between 2015 and 2035. Dependent variables are time-dependent and anticipate the path of compliance with other environmental regulations and changing market conditions. Because electricity price effects are sensitive to these time-dependent factors, we average these price changes by state from 2015 through 2035. We use administrative data from the Energy Information Administration's State Energy Data System (SEDS) for baseline state-level residential electricity consumption and scale this over time as reflected by the projected changes in expenditures in the Haiku model baseline. The changes in consumer surplus are calculated using SEDS estimates for the initial level of expenditures and Haiku estimates for changes in price and quantity, averaged across the 20-year time horizon; the sum of consumer surplus changes in Haiku is scaled to match the outcome from the OLG model¹⁴

$$(6) \quad \Delta cs_e^k = \Delta cs_e \times \frac{\Delta \bar{cs}_e^k}{\Delta \bar{cs}_e}$$

2. Expenditure Data

The OLG model provides price and quantity changes (from which consumer surplus changes are calculated) for 17 commodities (i), which are higher-level categorizations of the 57 commodity sectors in the GTAP database and do not represent final consumption goods. We use a transformation matrix (Elliott and Fullerton, 2014) to match consumption goods to the commodity goods in the Bureau of Economic Analysis (BEA) Personal Consumption Expenditures (PCE) categories.

No source of data provides a perfect profile of expenditures at the state level, so we combine multiple sources in order to take advantage of the best features of each data set. The Consumer Expenditure Survey (CEX) is a quarterly survey of randomly sampled households from 91 geographically contiguous primary sampling areas across the United States. CEX data offer a high level of detail, but have some limitations because they are taken from a survey. The already mentioned PCE data are considered to be more accurate at the aggregate level than CEX

¹⁴ Because Alaska and Hawaii are not included in Haiku, national price and quantity changes are used instead.

data; however, PCE data are not broken out by states or income quintiles. For those goods that can be directly compared, CEX data often appears to underestimate actual expenditure. This does not necessarily bias the proportion of expenditures that occurs under each index as long as people across states underreport expenditures of each good at similar rates (which we assume).

Goods in the CEX data are organized by Universal Classification Codes (UCC), which are mapped into PCE categories to be comparable to data from the OLG model. We describe the proportion of spending across UCC consumption goods u and states k as $\tilde{x}_u^k / \tilde{x}_u$.

The expenditure categories that are most affected by introducing a price on carbon are direct energy consumption including gasoline, electricity, natural gas, and other fuel oils for home heating, which we refer to collectively as direct energy goods. We use 2011 data from SEDS, which are highly accurate and provide statewide estimates of residential expenditures on retail electricity, natural gas, and other fuels (e.g., fuel oil, kerosene, and liquefied petroleum gas (LPG)) and gasoline. SEDS does not distinguish uses of gasoline, so we assume that the proportion of all motor gasoline purchased by households is the same in each state.

The CEX also has geographical limitations.¹⁵ We introduce several additional adjustments to reduce the geographic bias for each good. Because states are over- or undersampled in the CEX, there are too many or few households (and thus aggregate state-level expenditures are too high or low). To correct this, we use data from the 2010 census on number of households per state to scale up or down expenditures.

As noted previously, 82.7 percent of the 2011 top-coded observations did not live in a metropolitan area, while 88.7 percent of all observations that did not live in a metropolitan area were top coded. We assume all state-attributable data represent only the metropolitan areas of each state, while the top-coded data are exclusively representative of regional nonmetropolitan areas.¹⁶ We apply these assumptions at the regional level to states that are missing entirely from

¹⁵ The CEX is not meant to be geographically representative below the regional level. Some areas are never sampled and seven states (Iowa, New Mexico, North Dakota, Mississippi, Oklahoma, Rhode Island, and Vermont) are not included in any sampling area. Weights are applied to achieve accurate expenditure levels at regional and national levels. Also, geographic top coding, or veiling of data, is used to guard against the potential identification of survey respondents. Of the sample, 14.7 percent is top coded, including some entire states (Arkansas, Mississippi, Montana, North Carolina, and South Dakota). Of the top coded responses, 82.7 percent do not live in a metropolitan area. Conversely, of the 13.7 percent of the sample that do not live in a metropolitan area, 88.7 percent are top coded. Hence top coding also adds geographically correlated bias.

¹⁶ Regional top-coded totals are calculated by subtracting the microdata from statistics on the Bureau of Labor Statistics (BLS) website, <http://www.bls.gov/cex/tables.htm>

the data, in proportion to the state's metropolitan and nonmetropolitan population. For states that are not completely missing, we combine state expenditures (which we assume are representative of only metropolitan areas) with regional top-coded data in a way that is proportional to the urban-rural makeup of each state, to create a less biased estimate. In other words, we assume the nonmetropolitan population throughout a region has similar characteristics.

As a check on how well our approach improves expenditure estimates from the CEX, we compared them with state-level income data from the National Income and Product Accounts (NIPA) produced by the BEA. Even after adjusting the estimates, many states have implausibly high or low consumption in our constructed data compared with income estimates in the NIPA, which we attribute to the systematic bias in which areas are selected for inclusion in the CEX. To correct for this, we assume the savings rate is similar across all states, and scale up or down savings and expenditures so that the proportion of consumption occurring in each state in our constructed data matches NIPA estimates of the proportion of income earned in each state. This allows us to calculate the consumption side of (4).

D. Calculating Effects on Household Income

There are seven income goods in the OLG model: five sources of asset income (including capital and multiple types of natural resources) plus transfers and labor. We assume the mix of the five sources of asset income is constant across households, as most of these assets are held as securities in diverse portfolios. Consequently, we use estimates of the proportion of income by 3 sources: capital, transfers, and labor. The price changes for income sources from the OLG model are tax-inclusive (e.g., the price change for labor is the change in the after-tax wage from the OLG model equilibrium), but we allocate this across households based on pretax income shares (thus implicitly assuming that any tax rate change is an equal percentage point tax rate change at all income levels).

To develop estimates of income by state, we rely on the NIPA estimates (which we denote with a double bar) of personal income by source for each state ($\bar{\bar{y}}_j^k$). NIPA estimates are authoritative because they use administrative records rather than survey data. We use annual before-tax estimates for 2013 to establish a distribution of income from each source across states and use this distribution to calibrate income in the model. These results are used to distribute the estimates in income for the representative household across states, which are indexed by the superscript k

$$(7) \quad \Delta ps_j^k = \Delta ps_j \times \frac{\bar{\bar{y}}_j^k}{\bar{\bar{y}}_j}.$$

IV. Results

The results from the OLG model describe an intertemporal equilibrium affecting overlapping generations. We focus here on the short-run effect of the policy—that is, how households are affected by the immediate effects of the policy on prices, wages, and returns to capital, before long-term adjustments (such as changes in the capital stock) have time to occur. However, note that those immediate effects come from the intertemporal equilibrium (and implicitly anticipate changes that will occur in the future).

All of the results we report omit the environmental benefits from the carbon tax stemming from reduced emissions of greenhouse gases and changes in conventional air pollutants that occur. The reduction in emissions is very similar (though not identical) across the different policy cases, so not accounting for benefits will not significantly affect the relative attractiveness of different policy options (either for the overall mean or for particular subgroups).

The normalization used in the CGE model implies that the price of the average consumer good remains constant. This normalization does not affect the incidence calculation (see Fullerton and Metcalf (2002) for discussion of price normalizations and tax incidence). It allows us to interpret the welfare changes in real terms; that is, all consumption good price changes should be interpreted as real price changes (i.e., price changes relative to the average consumer good), and income changes should be interpreted as changes in real after-tax wages, returns to capital, or government transfers.

A. National Results

We begin by looking at the mean welfare change across households (i.e., the sum of consumer and producer surplus changes, divided by the number of households). When the carbon tax revenue is recycled to reduce the capital income tax, the mean cost is \$291 per household; by comparison, reducing the labor income tax yields a mean cost of \$407 and rebating the revenue in equal (lump-sum) payments yields a mean cost of \$866.¹⁷ This order matches prior results from the literature on environmental taxes and revenue recycling: the

¹⁷ Our related work (Williams et al., forthcoming) shows that these effects differ substantially across income quintiles. For example, while the lump-sum rebate is the costliest policy overall, it produces a welfare gain for the poorest three quintiles. Although data limitations prevent us from making reliable income quintile estimates at a state level, the outcomes within each state probably vary substantially by income, similarly to the way they vary at the national level. Therefore, one should not assume that if a state as a whole gains under a particular policy then most households in that state do also, or the converse.

capital income tax is the most distortionary tax in the model, so cutting it produces a relatively large efficiency gain, whereas lump-sum transfers provide no efficiency gain, and cuts to the labor tax represent an intermediate case. None of these cases yields a “double dividend”; in other words, no case has a negative overall cost (ignoring the benefits from reduced carbon emissions).

Because all three cases have the same carbon tax rate, the changes in energy good prices (which are driven almost entirely by the carbon tax) are similar across the three, and thus the mean welfare loss associated with consumption of direct energy goods is also very similar (between \$530 and \$543). At the same time, the relative price of nonenergy goods falls, implying a gain in welfare from consumption of these goods. Because the normalization means all prices are expressed in real terms, the net change in overall consumer prices is zero, and thus the aggregate welfare gain from nonenergy goods almost exactly offsets the loss from direct energy goods. Consequently, changes in real incomes explain the variation in aggregate outcomes across the three cases.

B. Results Across Geography

Incidence results across geography are reported as the aggregate change in welfare for each state or region, as a percentage of aggregate annual income (or, equivalently, the mean change in welfare divided by mean annual income). We look first at the welfare effects caused by changes in the prices of direct energy goods. These price changes are the most obvious and direct effect of the carbon tax, and show how the geographic variation in burden is affected by geographic variation in energy use. Because they are driven almost entirely by the carbon tax rather than by the recycling method, they are nearly identical across the three recycling options.¹⁸

Table 1 displays welfare changes (as a percentage of income), aggregated from the state level to census division (which we will refer to as regions), and splits out the separate welfare impacts from price changes to the four major energy goods. Figure 1 displays the change in welfare associated with direct energy goods by state.¹⁹ Note that the scale is different for each figure, and to provide context, each figure includes results from Williams et al. (forthcoming) on how each national income quintile is affected.

¹⁸ Note that looking at the effects from price changes of direct energy goods is very different from looking at the effects of a carbon tax without revenue recycling, because the latter would also include substantial welfare effects from nonenergy-good price changes and income changes.

¹⁹ Figure 1 displays the distribution of welfare effects from direct energy good prices for the capital tax recycling case, but this distribution is nearly identical to those under the other two cases.

The heaviest burdens from changes in direct energy good prices fall, generally speaking, in the Deep South, Appalachia, and the Great Lakes (with the exception of Illinois). The lightest burdens are in the Pacific coast and the relatively urban states on the East Coast (from Massachusetts to Washington, DC). Burdens in the Mountain West, most of the Great Plains, Texas, and Florida are close to the national average. For maps that break out this welfare loss by energy good, see the appendix.

The majority of geographic variation is due to price changes for electricity, because per capita electricity consumption and electricity price changes both vary substantially across geography. The variation in price changes is driven by both the carbon intensity of electricity generation and the pricing regimes in regional electricity markets. The per capita welfare loss, in dollars, is heaviest in the South, Appalachia, and Midwest (excluding Illinois). California, the Northwest, and the Northeast are the least affected. With few exceptions (mainly in the Dakotas), states with large per-capita dollar losses from electricity price increases are also poorer, while states with smaller losses (with the exception of some states in the Mountain region) have higher incomes. Expressing welfare loss as a percent of income amplifies this geographic heterogeneity.

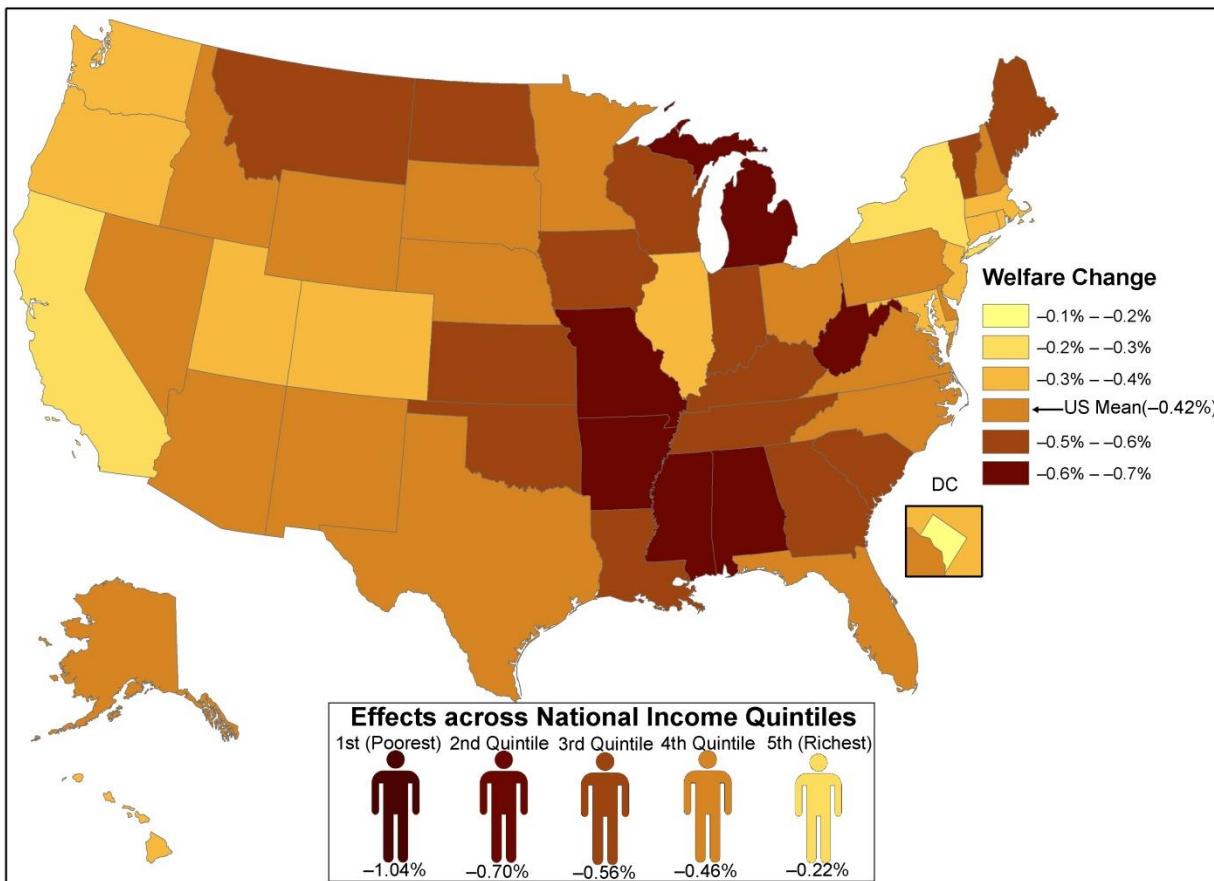
The aggregate welfare loss from gasoline price increases is larger than that for electricity, but varies less across states. On a per capita basis the loss is slightly higher in rural states in the East South Central and West North Central while the population centers in the Northeast are affected slightly less. Many local factors affect gasoline consumption, such as availability of public transport, commute distances, and density, so examining geographic variation at the state level—which groups together urban, suburban, and rural areas—may blur this heterogeneity. Again, this heterogeneity (especially in the South and Northeast) is amplified by expressing welfare loss as a percent of income.

Table 1. Change in Welfare by Census Division (Percent of Income)

	Pacific	Mountain	New England	North Atlantic	East North Central	West North Central	East South Central	South Atlantic	West South Central	USA Total
<i>Capital Recycling</i>	-0.05	-0.23	-0.15	-0.16	-0.36	-0.38	-0.53	-0.18	-0.33	-0.23
Energy goods	-0.28	-0.44	-0.37	-0.33	-0.49	-0.54	-0.60	-0.44	-0.45	-0.42
Electricity	-0.05	-0.15	-0.05	-0.07	-0.16	-0.22	-0.27	-0.19	-0.19	-0.14
Fuel oil and other	-0.01	-0.02	-0.10	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	-0.03
Gasoline	-0.17	-0.19	-0.15	-0.13	-0.19	-0.21	-0.26	-0.20	-0.21	-0.18
Natural gas	-0.06	-0.07	-0.07	-0.09	-0.12	-0.09	-0.05	-0.04	-0.04	-0.07
Other goods	0.41	0.40	0.42	0.43	0.42	0.41	0.41	0.41	0.41	0.41
Sources of income	-0.18	-0.19	-0.20	-0.25	-0.29	-0.24	-0.33	-0.15	-0.29	-0.23
Capital income	0.47	0.46	0.45	0.42	0.39	0.42	0.36	0.49	0.39	0.44
Labor income	-0.50	-0.49	-0.51	-0.51	-0.51	-0.51	-0.48	-0.47	-0.53	-0.50
Rebate										
Transfer income	-0.15	-0.16	-0.15	-0.16	-0.18	-0.16	-0.21	-0.17	-0.16	-0.16
<i>Labor Recycling</i>	-0.23	-0.37	-0.29	-0.22	-0.35	-0.43	-0.42	-0.39	-0.32	-0.32
Energy goods	-0.29	-0.45	-0.38	-0.34	-0.50	-0.55	-0.62	-0.46	-0.47	-0.43
Electricity	-0.05	-0.15	-0.05	-0.07	-0.16	-0.22	-0.28	-0.20	-0.20	-0.14
Fuel oil and other	-0.01	-0.02	-0.10	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	-0.03
Gasoline	-0.17	-0.20	-0.16	-0.13	-0.19	-0.21	-0.26	-0.20	-0.21	-0.19
Natural gas	-0.06	-0.08	-0.07	-0.09	-0.12	-0.09	-0.06	-0.04	-0.04	-0.07
Other Goods	0.41	0.42	0.43	0.42	0.44	0.43	0.44	0.42	0.44	0.43
Sources of income	-0.35	-0.34	-0.34	-0.30	-0.28	-0.31	-0.25	-0.36	-0.29	-0.32
Capital income	-0.36	-0.35	-0.35	-0.32	-0.30	-0.33	-0.28	-0.38	-0.30	-0.34
Labor income	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Rebate										
Transfer income	0.04	0.04	0.04	0.05	0.05	0.04	0.06	0.05	0.04	0.05
<i>Lump-Sum Rebate</i>	-0.66	-0.63	-0.92	-0.69	-0.58	-0.83	-0.44	-0.76	-0.60	-0.68
Energy goods	-0.29	-0.44	-0.38	-0.34	-0.50	-0.55	-0.61	-0.45	-0.46	-0.42
Electricity	-0.05	-0.15	-0.04	-0.07	-0.16	-0.21	-0.27	-0.19	-0.19	-0.14
Fuel oil and other	-0.01	-0.02	-0.11	-0.04	-0.02	-0.03	-0.02	-0.02	-0.01	-0.03
Gasoline	-0.18	-0.20	-0.16	-0.14	-0.20	-0.22	-0.27	-0.21	-0.22	-0.19
Natural gas	-0.05	-0.07	-0.07	-0.09	-0.12	-0.09	-0.05	-0.04	-0.04	-0.07
Other goods	0.45	0.39	0.44	0.48	0.42	0.38	0.37	0.41	0.40	0.42
Sources of income	-0.82	-0.58	-0.97	-0.83	-0.50	-0.66	-0.19	-0.73	-0.54	-0.68
Capital income	-1.14	-1.12	-1.11	-1.02	-0.96	-1.04	-0.89	-1.20	-0.96	-1.07
Labor income	-0.93	-0.92	-0.94	-0.94	-0.94	-0.95	-0.90	-0.88	-0.98	-0.93
Rebate	1.20	1.40	1.02	1.07	1.34	1.26	1.51	1.29	1.34	1.26
Transfer income	0.06	0.06	0.06	0.06	0.07	0.06	0.08	0.06	0.06	0.06

Pacific: AK, CA, HI, OR, WA. Mountain: AZ, CO, ID, MT, NM, NV, UT, WY. New England: CT, MA, ME, NH, RI, VT. North Atlantic: NJ, NY, PA. East North Central: IL, IN, MI, OH, WI. West North Central: IA, KS, MN, MO, NE, ND, SD. East South Central: AL, KY, MS, TN. West South Central: AR, LA, OK, TX. South Atlantic: DC, DE, FL, GA, MD, NC, SC, VA, WV.

**Figure 1. Welfare Change from Direct Energy Good Price Changes by State
(Percent of Income)**



Notes: Each map has a different scale in order to show variation. Welfare change omits environmental benefits of carbon tax.

Natural gas price changes affect welfare much less, as natural gas represents a much smaller proportion of consumption (even for those households in cold states) and has lower carbon intensity than gasoline and electricity. The Midwest and the North Atlantic are most affected, but this variation is dwarfed by electricity variation. Expenditures on fuel oil are fairly insignificant outside of New England.

Welfare effects from changes in the prices of other consumption goods are roughly equal across regions.²⁰ This means that regional variation in welfare changes from consumption goods

²⁰ These changes are welfare gains because of the price normalization—that is, these goods become cheaper relative to the average consumption good.

is almost entirely driven by price changes for direct energy goods. Furthermore, that regional variation is the same for each recycling case, so the variation in outcomes across recycling cases is due to differences in income sources.

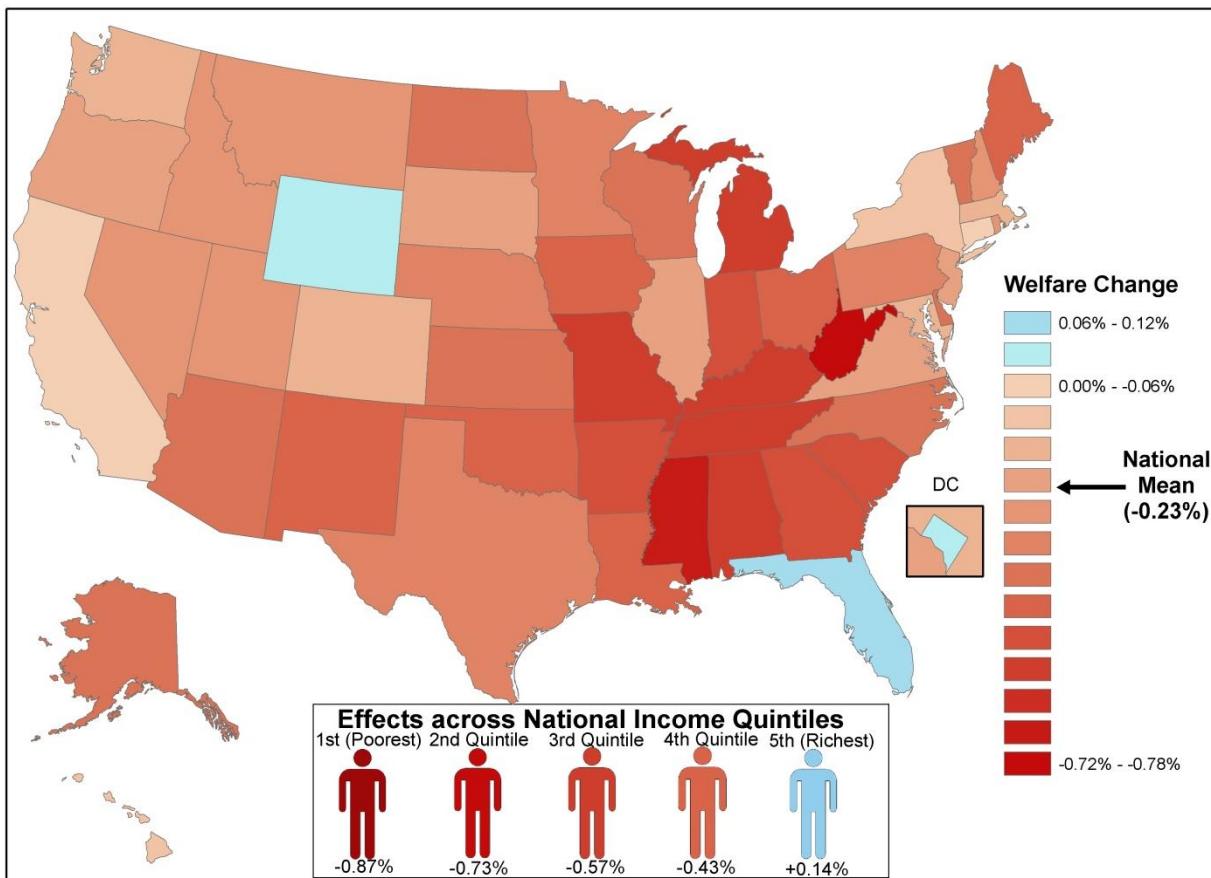
In the capital tax recycling case, regions that receive a relatively high share of income from capital are relatively advantaged. The Pacific region experiences almost no welfare cost due to its large proportion of income from capital (and low carbon content of electricity). New England, the North Atlantic, and the South Atlantic also do relatively well in this case, again reflecting relatively high shares of capital income (with the results for the South Atlantic driven primarily by Florida's very high share of capital income). The regions that do the worst under capital tax recycling are those with low shares of capital income and relatively large increases in direct energy costs, such as the East South Central region.

Figure 2 shows these trends. States with higher proportions of their income from capital (especially Florida and Wyoming) do the best, while states with high incomes in general (the Middle Atlantic and Connecticut) also do well. Low-income states (especially in the South) do significantly worse because these states get a smaller share of income from capital. Capital tax recycling thus reinforces the pattern of observed welfare loss from direct energy goods.

Note that these are estimates of the aggregate effect on welfare in each state, which masks substantial heterogeneity within each state. For example, even though Florida gets a large share of its income from capital (and thus the state as a whole receives a double dividend under capital tax recycling), younger and poorer households in Florida (who have much lower shares of income from capital) will clearly still fare relatively poorly in this case. Also note that the scale varies across the figures.

Labor tax recycling produces the most even distribution across states. This mirrors the outcome with respect to differences across income groups at the national level identified in Williams et al. (forthcoming). The range of welfare losses is narrowest around the mean, and the geographic variation is mostly due to direct energy costs. Examining the effects across states in this case (Figure 3) shows the effects of the substantial drop in real returns to capital. States with large shares of capital income are substantially worse off in this case than in the capital tax recycling case. Florida, Wyoming, Montana, Hawaii, South Dakota, and Connecticut have the highest proportions of capital income (as a share of all income) and also the largest drops in welfare when switching from the capital recycling case to the labor recycling case. The effects on income are relatively even across most of the other states, and thus differences in the overall effect are driven primarily by direct energy costs (compare Figures 1 and Figure 3).

**Figure 2. Capital Tax Recycling Welfare Change by State
(Percent of Income)**



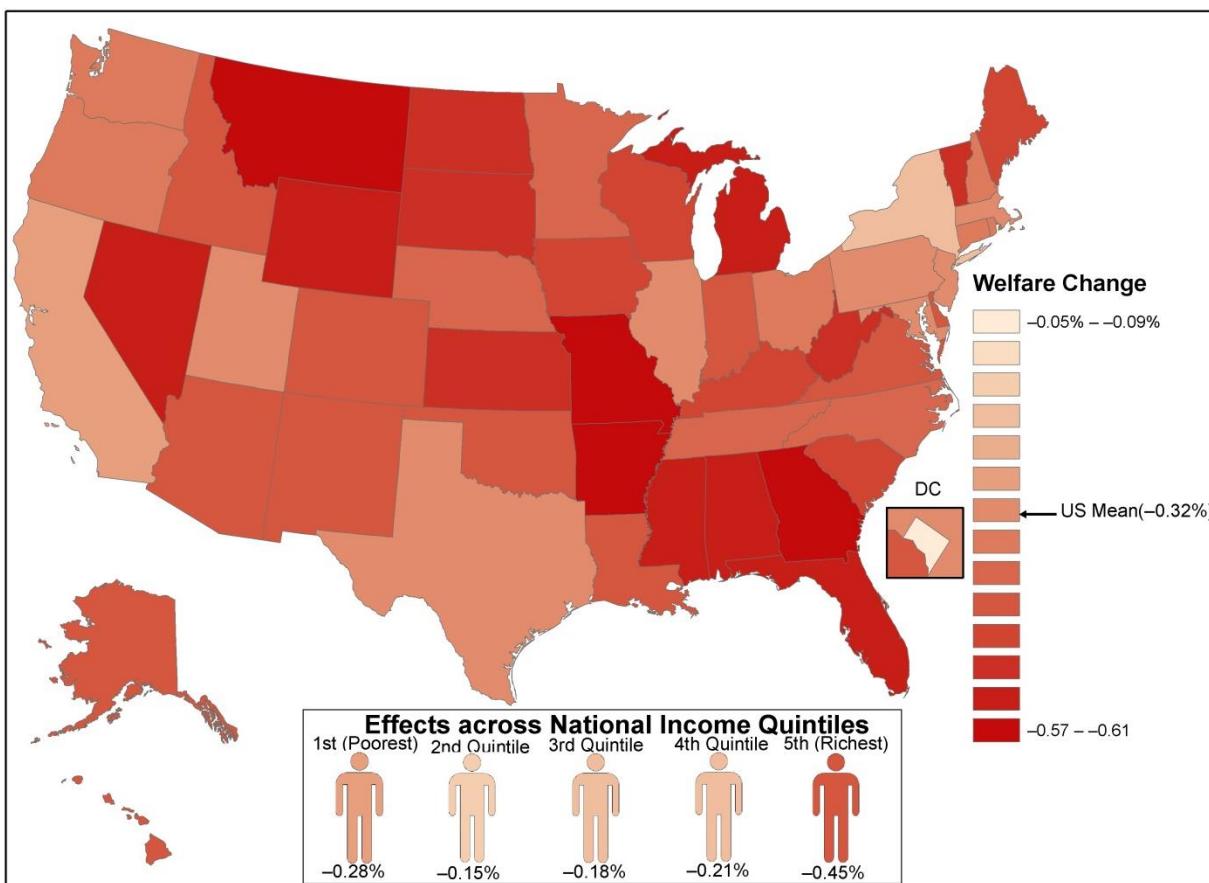
Notes: Each map has a different scale in order to show variation. Welfare change omits environmental benefits of carbon tax.

In the lump-sum rebate case (Figure 4), the poorest states do the best. This is predictable, as the rebate is the largest percentage of income for the lowest-income households. In many ways, the results under the lump-sum rebate are the mirror image of capital tax recycling: the states that do best compared to the rest of the nation under capital tax recycling typically do worst under the lump-sum rebate, and vice versa. A notable exception is the Pacific Coast region, whose direct energy cost increases are low enough that this region still does comparatively well under the lump-sum rebate, despite relatively high incomes and high capital shares.

In general, the distributional effect of the rebate more than outweighs the effect of direct energy expenditures. For example, even though the East South Central region has the largest welfare loss from direct energy expenditures, it gains enough from the rebate to do better than any other region in this case (being a low-income region, it benefits substantially from lump-sum

rebates). Interestingly, this case has the largest variation in welfare effects across states, which results mostly from differences in income shares. Real returns to capital and labor fall in this case (these factors bear much of the burden of a carbon tax, and there are no offsetting cuts in capital or labor taxes). Thus, states with large shares of capital and/or labor income tend to do worse in this case than states with higher shares of income from government transfers.

**Figure 3. Labor Tax Recycling Welfare Change by State
(Percent of Income)**

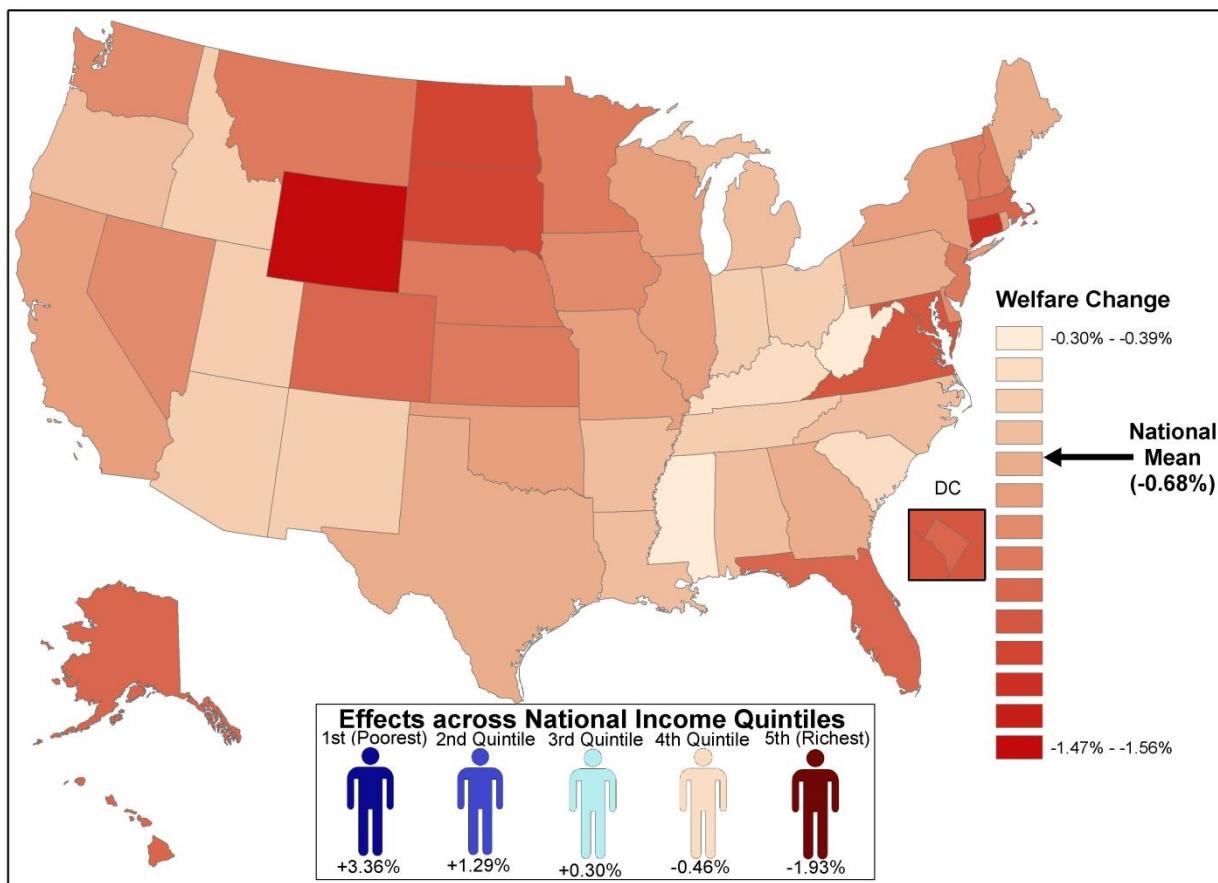


Notes: Each map has a different scale in order to show variation. Welfare change omits environmental benefits of carbon tax.

The estimates for Washington, DC, deserve special attention. It is a special case, because it is only a city, whereas all of the states include at least some rural and suburban areas. Thus one can view Washington as a rough indicator of how core urban areas in general might fare (though Washington is somewhat wealthier than the typical US city). Washington does relatively well under all three recycling methods, because it suffers relatively little welfare cost from direct energy good price increases; being an urban area with good public transport, it is relatively

energy-efficient, largely due to very low expenditures on gasoline. Thus it fares better than almost all states in the capital tax and labor tax recycling cases. And despite its relatively high incomes, it does relatively well even in the lump-sum rebate case. Results for other urban areas are likely to be similar—though again, it is important to note that effects on individual households within urban areas vary widely.

**Figure 4. Lump-Sum Rebate Welfare Change by State
(Percent of Income)**



Notes: Each map has a different scale in order to show variation. Welfare change omits environmental benefits of carbon tax.

To this point, we have stressed the regional differences in welfare changes from these policies, but the scale of variation is less than in our previous work on income quintiles (Williams et al., forthcoming). The sample standard deviations of the welfare changes as a percentage of income for the five income quintiles are 0.39, 0.12, and 1.98 percentage points for the capital tax recycling, labor tax recycling, and lump-sum rebate cases, respectively. Across the 50 states and the District of Columbia, the sample standard deviations for the three cases are

0.17, 0.10, and 0.23 percentage points. Expenditure and income shares vary far more across income groups than they do across states and regions. It is therefore no surprise that the variation in welfare loss is smaller across regions and states than across income quintiles.

If the senators from each state were to decide among these three revenue-recycling options based solely on maximizing aggregate welfare in their state, most would pick the capital recycling policy: in 38 states and Washington DC, the aggregate cost is lower in this case than in either of the other two. Nine states (Alabama, Indiana, Louisiana, Michigan, Ohio, Pennsylvania, South Carolina, Tennessee, and Texas) are best off in the labor tax recycling case.²¹ Only three states do best in the lump-sum rebate case (Kentucky, Mississippi, and West Virginia).

However, effects on median households may differ substantially from state aggregate effects. Median income is less than mean income, and the lump-sum rebate is highly progressive (Williams et al., forthcoming). Consequently, the lump-sum rebate is likely to look better for the median household in any given state than the state mean would indicate, so there are likely more states in which the median household would prefer the lump-sum rebate.

A national policy maker looking to build support from different areas of the country may want to avoid a pure lump-sum rebate recycling policy because it results in the greatest geographic heterogeneity. But policy makers don't have to select only one of these recycling options. Indeed, one might expect the most likely outcome would be to divide the carbon tax revenue across two or more recycling options (which would produce an outcome that would be a weighted average of our results for the different cases). Since the lump-sum rebate produces the best comparative results for poorer states, and since poorer states seem to be hit hardest by changes in the price of direct energy goods, devoting part of the revenue to a lump-sum rebate would undo some of the inequality in results from change in the price of energy.

V. Conclusion

Differences in outcomes from a carbon tax on energy prices across states will always be important to Congress, whose members are elected to represent a geographic district or state. These differences could also be important for other carbon reduction policies, including when states develop plans to regulate carbon emissions from stationary sources under the Clean Air

²¹ However, the differences in welfare changes between the capital tax recycling and labor tax recycling cases are often small; among these states, only in Ohio and Tennessee is the difference more than 0.1 percent of income.

Act (and potentially coordinate with other states to achieve regional application of different forms of carbon pricing).

Our results show that the consumer surplus losses associated with consumption of direct energy goods are more heavily concentrated in places where the electricity price is most likely to increase (due to a combination of the carbon intensity of existing electricity generation, the pricing regime of the electricity market, and the potential for renewable generation), that are less urbanized, and where spending on energy represents a higher proportion of total income (often due to extreme weather); these areas include the South, Appalachia, the Midwest, and the Great Plains.

However, the use of revenue from the carbon tax plays a more important role in determining the geographic distribution of welfare changes. The lump-sum rebate is the least efficient policy in the aggregate: at the national level and in many states, aggregate welfare is lower under this recycling option than under labor or capital tax recycling. But the distributional effects of lump-sum recycling are sufficient to reverse the pattern of relative welfare losses across states, causing smaller losses in the Southern and Eastern Midwest states than in affluent states on the East Coast. This policy, however, creates the widest gap in welfare losses across states.

In contrast, the labor tax recycling policy, while preserving the pattern of relative outcomes, narrows the geographic differences and produces a fairly even distribution of outcomes across states. This approach could be appealing if the goal is to have welfare effects that are relatively similar across different states.

Finally, recycling revenue to reduce capital taxes is the most efficient policy, but it makes carbon pricing, which is already regressive, even more so (at least in the short run). In this case, the poorest states in the South and Midwest bear a disproportionate share of welfare loss.

The distribution of costs across states from environmental policy is always of political importance; however, we find that the differences across states are relatively small compared with the variation across income quintiles. As shown in Williams et al. (forthcoming), even though the lump-sum rebate policy produces the least efficient outcome for the nation as a whole, each of the bottom three quintiles receives a net gain from this policy (even when ignoring any environmental benefits). Consequently, policymakers who care about income equality (or who are concerned about how the majority of households would vote if they were to follow only their self-interest) would not concentrate only on geographic distribution.

Moreover, regional and state variation may not be the most important geographic division. If our estimates for Washington, DC, can be taken as a rough proxy for other core urban areas, there appears to be a larger difference between cities and rural and suburban areas than among states because of the high wealth and relative energy efficiency of many urban areas.

Our findings are necessarily limited by the detail available in the OLG model. One important limitation is the assumption of a single national labor market, with no differentiation by skill level or region. Labor in different locations and at different skill levels is likely to be affected by and respond differently to a carbon tax, and our model will miss those differences. Similarly, we assume that all households hold a fully diversified investment portfolio. If portfolio composition differs across households, and different assets are affected differently by policy changes, our model will miss the resulting distributional implications.²²

Finally, this paper looks only at incidence in the short run. In ongoing research, we look at how incidence by quintile and geography changes over a longer time frame, that is, during the transition to a new long-run equilibrium. This may be particularly important for the capital tax recycling case, where the initial benefit of the capital tax cut goes to owners of capital, but over time, as the capital stock grows in response to the capital tax cut, some of that benefit is passed through to workers and consumers in the form of higher wages and lower consumer prices.

²² A particularly important example could be local real estate. Owner-occupied housing represents a significant portion of the capital stock.

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Appendix: Figure A.1. Welfare Change from Direct Energy Goods by State, % of Income

