DISCUSSION PAPER

The Initial Incidence of a Carbon Tax across Income Groups

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Abstract

Carbon taxes efficiently reduce greenhouse gas emissions but are criticized as regressive. This paper links dynamic overlapping-generation and microsimulation models of the United States to estimate the initial incidence. We find that while carbon taxes are regressive, the incidence depends much more on how carbon tax revenue is used. Recycling revenues to cut capital taxes is efficient but exacerbates regressivity. Lump-sum rebates are less efficient but much more progressive, benefiting the three lower income quintiles even when ignoring environmental benefits. A labor tax swap represents an intermediate option, more progressive than a capital tax swap and more efficient than a rebate.

Key Words: carbon tax, distribution, incidence, tax swap, income quintiles, climate change

JEL Classification Numbers: H22, H23, Q52

Contents

The Initial Incidence of a Carbon Tax across Income Groups

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1. Introduction

Many economists suggest that the introduction of a price on carbon is the most efficient way to achieve reductions in greenhouse gas emissions. This could be achieved in various ways: through cap and trade, emissions taxes, or intensity-based performance standards. A wide variety of factors influence the relative attractiveness of these different options. Among the most important of those factors is that emissions taxes or auctioned tradable permits can generate substantial revenue. Both the efficiency and distributional consequences of carbon pricing depend crucially on how that revenue is used.

A common attribute of both the efficiency and distributional aspects of climate policy is that these aspects unfold and change over time. For example, the effect of inefficient policies that reduce economic growth is magnified in the future when lost investment is compounded and manifest in lower economic output. Distributional effects also may change over time (Mathur and Morris 2012) or be experienced differently by younger and older households because of different patterns of consumption, savings, and sources of income (Carbone et al. 2013; Blonz et al. 2012). A central challenge of addressing climate change is that the benefits of doing so also unfold in the future. Within this historical dynamic, the decisionmaker shaping climate policy is always the current generation. Hence, the incidence of climate policy on current generations has disproportionate effects on the decisions of voters and policymakers in the present political process.

This paper addresses the near-term effects of climate policy design within a general equilibrium framework. A substantial literature has employed partial equilibrium methods to examine distributional outcomes, and this approach may bring a high level of resolution to the question. However, a partial equilibrium approach does not account for all the linkages in the economy that can be important, especially with respect to changes in income. The introduction of

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a price on carbon leads to adjustments in energy, product, and factor markets, with implied changes in income. Recycling revenue from carbon policy can also dramatically affect incomes, and in a way that is not necessarily obvious ex ante (e.g., the incidence of using carbon revenue to cut labor taxes is not just on labor).

To simultaneously achieve dynamic and general equilibrium consistency with detailed resolution including a measure of incidence before the new equilibrium is achieved, we link two new models of the US economy. One is a dynamic overlapping generation (OLG) general equilibrium model that solves over a long time horizon. The second is a microsimulation model of incidence that refracts changes in national income onto households according to income groups based on idiosyncratic patterns in expenditure and income.

This model linkage provides key advantages in this context. Because the OLG model is a dynamic general equilibrium model, it can estimate changes in incomes resulting from a carbon pricing (and from recycling the resulting carbon tax revenue) and can pick up interactions between the policy changes and preexisting tax distortions. And the OLG structure represents effects on capital more realistically than other commonly used approaches (such as infinitely lived agents). Linking to the detailed incidence model provides a tight connection to the underlying data on income and expenditure patterns across income groups and allows us to see distributional effects across income groups. To our knowledge, our work is the first to link an OLG model to a separate incidence model in order to examine the distributional effects of environmental taxation.

We use this framework to compare three policy approaches to the use of revenue that would be raised with a carbon tax. One approach uses the revenue to reduce the tax on capital income, a second approach would reduce the tax on labor income, and the third would deliver rebates lump-sum across the economy. These policies achieve quite similar outcomes with respect to emissions, but they vary somewhat into the future because of the different growth paths that emerge over time because of changes in savings and investment.

We evaluate the outcome in the first year of the climate policy, and we find the policies have disparate effects on households. Directing revenue to reduce the capital income tax has the least effect on economic well-being, but it is a regressive approach that yields a wide distribution of outcomes across income quintiles. The lump-sum rebate is a progressive approach that benefits a majority of households; however, it is the most expensive policy from the perspective of overall cost. Using revenue to reduce labor taxes lies in the middle with respect to preferences, usually the second pick when viewed from the impact across the income spectrum.

2. Literature

Government analysis of carbon pricing during the debate for H.R. 2454 (Waxman-Markey) studied many features of the policy, such as directing some allowance value directly to households or local distribution companies, allocation to trade exposed industries, and funding for various specific projects. The Congressional Budget Office (CBO 2009) found the cost per household would vary greatly, with lowest-income households seeing a net benefit and highest-income households a net cost. Middle-income households would have incurred the most significant cost as a percentage of income. In contrast, the Environmental Protection Agency (EPA 2009) and Energy Information Administration (EIA 2009) did not look at distribution but did illustrate how the change in cost of various goods and services hinges on how allowance value is allocated.

Academic studies also generally find the distributional impact of energy and environmental taxes and regulations is regressive when analyzed on the basis of annual household income because poor households spend a greater fraction of their income on energy than do wealthy households.[1] This result still holds but is reduced when models account for the effects of a carbon tax on prices of nonenergy goods (Hassett et al. 2009; Grainger and Kolstad 2010).

Most studies of the incidence of carbon pricing do not account for changes in income caused by carbon pricing. Computable general equilibrium (CGE) modeling addresses that problem, picking up effects on income and interactions between markets. For example, Rausch et al. (2011) use a CGE model to show that a portion of costs is borne by the owners of resources and capital, which lessens the regressivity of the policy. The interaction between climate policy and preexisting distortionary taxes is particularly important and tends to increase overall costs (Parry et al. 1999). Many of these CGE models are static and thus can model only a long-run equilibrium, not the transition to that equilibrium.

Dynamic CGE models can look at that transition and generally provide a more realistic treatment of effects on capital. But because of computational complexity, dynamic CGE models nearly always model only a single representative agent and thus cannot examine distributional effects. A handful of dynamic models include multiple agents (e.g., Jorgenson et al. 2012) and thus can examine distributional effects, but this typically requires strong assumptions about agents' preferences in order to make the problem computationally tractable.

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[1] Parry et al. (2007) and Morris and Munnings (2013) provide reviews of the literature.

The literature also shows the impact is affected by the use of the revenues (Burtraw et al. 2009). For example, giving the carbon asset value to industry, based on output, emissions, or some other measure, is generally inefficient and regressive, as the value flows to shareholders who are predominantly in higher-income households. Using the asset value to cut income taxes can improve the overall efficiency but also is regressive, although reducing payroll taxes would be less so. Lump-sum, per capita redistribution of asset value has a progressive effect, benefiting low-income households relatively more than higher-income households (Boyce and Riddle 2007). However, this forgoes the efficiency advantage of using revenue to reduce preexisting taxes (Dinan and Rogers 2002; Metcalf 2009; Parry and Williams 2010).

3. Policies

This paper looks at three different policy cases built around a carbon tax of $30 per ton of CO_2 (in 2012$), beginning in 2015 (and not anticipated prior to that date) and held constant (in real terms) thereafter. The tax applies to all fossil fuel–related CO_2 emissions.[2]

The difference across the three policy cases is how the carbon tax revenue is used. Each of the first two cases uses the revenue to finance cuts in preexisting distortionary taxes, with one case focusing on capital tax cuts and the other on labor tax cuts. In each case, the cuts are assumed to be structured so that the percentage-point cut in the effective marginal tax rate (on all capital income in the capital tax recycling case, and on all labor income in the labor tax recycling case) is constant across income levels (which implies that all income groups get the same percentage-point cut in both marginal and average tax rates).[3] In each case, this is a onetime, permanent, unanticipated cut in the relevant tax, starting at the same time as the carbon tax.

In the third case, revenue from the carbon tax is used to provide a tax-free, lump-sum annual "rebate" payment to households, with each individual (regardless of age) receiving the same dollar amount. This rebate begins at the same time as the carbon tax, and the rebate amount remains constant (in real terms) over time and is not taxable income.

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[2] 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.

[3] The easiest way to implement such an across-the-board tax cut for labor income would be to cut the payroll tax rate (and more specifically, the Medicare portion of the payroll tax, which applies to nearly all workers and has no income cap) 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).

In each case, we keep the long-term level of government debt (i.e., the real value of government debt over 100 years) and the cumulative net present value of real government services and real government transfers (other than the policy rebate, if any) the same as in the benchmark (i.e., no policy change) case. Note that this means the time paths of real deficits, transfers, and services may change slightly from the benchmark case, but that the present value of those changes must net out to zero.[4] In the two tax-swap cases, we set the size of the tax cuts for capital or labor income to achieve that 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 that level of long-run debt.

By holding the carbon tax rate constant over time, these simulations differ from most policy proposals for a carbon tax, which typically involve a tax rate that rises over time (at a rate faster than inflation). We do this for simplicity: it is easier to understand and to explain the effects of a constant carbon tax rate than the effects of a carbon tax rate that changes over time. Similarly, many proposals would announce the carbon tax before it is imposed, so that the economy has some time to adjust before the policy takes effect.[5] Again, for simplicity, we assume that the entire policy change is implemented immediately, without any preannouncement.

4. Model

The modeling framework involves the calculation of an intertemporal general equilibrium with overlapping generations and perfect foresight. Results from this equilibrium are refracted onto state-level and income-level subgroups of the population using a microsimulation model.

4.1. General Equilibrium Modeling

The general equilibrium modeling uses a dynamic overlapping generation (OLG) model of the US economy. That model was first developed in Carbone et al. (2013). For full detail on the model, see that paper. We provide a brief overview here.

The model, which describes how the US economy evolves over time, combines two key components: overlapping generations (important for modeling the dynamics of growth and

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[4] 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 (e.g., Parry and Williams 2010; Blonz et al. 2012; Dinan 2012; Fullerton et al. 2012).

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

decision-making over time) and multisector production (important for modeling trade-offs across different industries). Following the standard overlapping-generations approach, the model introduces a new generation in each 5-year model period, which makes life-cycle consumption and savings decisions for its 55-year economic lifetime,[6] and then exits the model. Thus, at any point in time, there are 11 active generations at different stages of the life cycle. Each generation is modeled as a single representative household. Those representative households are scaled such that each generation represents a larger number of people than the previous generation, based on a constant exogenous population growth rate of 1 percent.

Each of the representative households derives income from labor, capital, natural resources, and government transfers. Each household makes savings, consumption, and labor-supply decisions in order to maximize the discounted sum of utility over its lifespan, subject to its budget constraint. Household utility in any given period is a constant-elasticity-of-substitution (CES) function of consumption (c_{gt}) and leisure (l_{gt}).

Aggregate household choices determine the levels of national income, consumption, saving, and investment in the economy, which, in turn, determine how the aggregate capital stock and the economy grow over time.

Production occurs in 19 competitive, constant-returns-to-scale industries (listed in Table 1). Of these, 16 are intermediate goods: 15 energy and energy-intensive industries (those most directly affected by a carbon tax) that are taken directly from the disaggregated Global Trade Analysis Project (GTAP) 7.1 dataset, and a 16th that is a composite of all other intermediate goods. The remaining 3 industries produce government services, an investment good, and a household consumption good.[7]

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[6] This 55-year period is meant to approximate the typical time from first entry into the labor force until death.

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

Table 1. Model Sectors in the GEOLG Model (with three-letter GTAP code)

Energy	Coal (COA); Crude oil (CRU); Natural gas (GAS); Refined petroleum and coal (OIL); Electricity (ELE)
Energy- and trade-intensive	Paper, pulp, print (PPP); Chemical, rubber, plastic products (CRP); Iron and steel (I_S); Non-ferrous metal (NFM); Non-metallic mineral (NMM); Machinery and equipment (OME); Plant-based fibers (PFB); Water transport (WTP); Air transport (ATP); Other transport (OTP)
Rest of industry and services	(Y)

Firms in each industry combine basic factors of production (physical capital, labor, and natural resources) with intermediate inputs. Each industry has a nested CES production function, with the nesting implying 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 in every industry. Goods can also be imported or exported. We assume international prices are fixed (i.e., a small open economy assumption) and that domestic and international varieties of each good are imperfect substitutes for each other.

The model also includes a representation of government taxes, spending, and transfers. This government sector represents an aggregate of federal, state, and local governments. The government has taxes on labor income (representing federal and state income taxes on labor income, plus social security payroll taxes), capital income (federal and state corporate income taxes and personal income taxes on capital income), consumption spending (primarily state sales taxes), and carbon emissions (with the carbon tax initially set to zero).

Tax revenue finances government services and transfer payments to households. In the benchmark case (i.e., the case without any policy changes), spending on government services and on transfer payments grows over time at the same rate as GDP. Each policy case we consider keeps the levels of government services and transfer payments constant in total real net present value over the 100-year period, by making the same nominal percentage adjustment in every year. This implies small year-to-year changes in real government services and transfers, but those changes net out to zero over the 100-year period.

The government may run a deficit or surplus in any given time period. In the benchmark case, the government runs a persistent budget deficit of approximately 3 percent of GDP forever (based on long-term budget projections from the Congressional Budget Office (2012)). This implies an ever-increasing level of national debt. Each policy case we consider may have

changes in budget deficits in the short run but keeps that long-run path of national debt the same as in the benchmark case.

4.2. Decomposition of Incidence by Commodity and Income Source

The OLG model estimates the aggregate price and quantity changes caused by a policy and the welfare effects on different generations. The incidence model refracts that national result onto the distribution of households across income groups. Changes to welfare due to the policy can be decomposed according to changes in welfare stemming from changes in the price and quantity of commodities (which we approximate using consumer surplus) and welfare changes stemming from changes in income (which we approximate using producer surplus).[8] 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.

2. In each policy case, the percent change 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.

The equilibrium representation of changes to consumer surplus for a given commodity i is illustrated in the first panel in Figure 1. Assuming the demand curve is linear in the relevant range of changes in price and quantity, the change in consumer surplus in Figure 1, $\varDelta$ADE − $\varDelta$ABC, would be calculated as

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

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 would omit the welfare implications of 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 results. 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.

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[8] These represent very close approximations: in each policy case, summing producer and consumer surplus changes 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.

Figure 1. Changes in Consumer and Producer Surplus
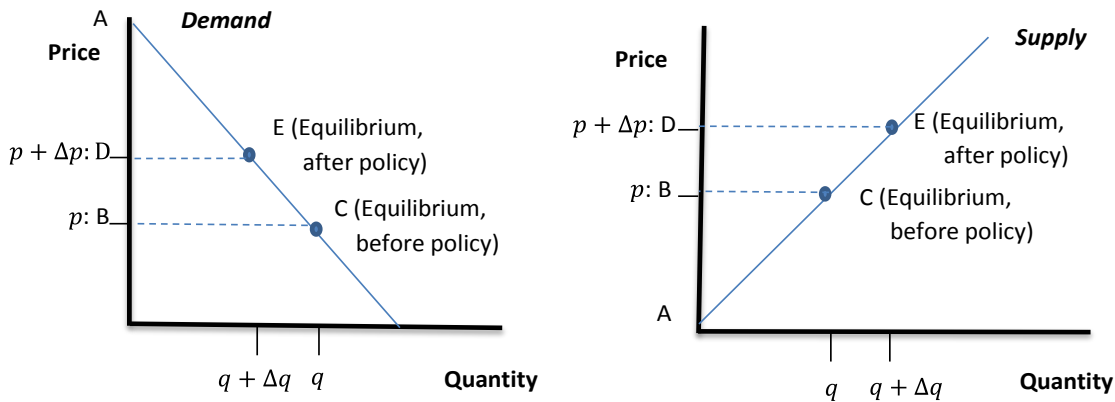
Analogously, the equilibrium representation of changes to producer surplus for a given income source j is illustrated in the second panel in Figure 1. Assuming the supply curve is linear in the relevant range of changes in price and quantity, the change in producer surplus for each income source, $\Delta ADE - \Delta ABC$, would be calculated as

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

As with the consumer surplus calculation, the producer surplus calculation takes quantity changes from the OLG model equilibrium and thus implicitly accounts for interactions between different prices.

The quantity of natural resources is exogenously fixed in the model, and thus there is no quantity change for natural resource income. Two sources of income, government transfers and potential rebates from a carbon tax, have no marginal cost schedule and no change in price, and thus the change in "producer surplus" for that income source is simply equal to the change in income from that source.

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

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

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

We index changes in welfare, ΔW^k, where k is an index of income quintiles. For all goods, we assume that changes to prices and quantities due to the policy are constant across income quintiles. However, the initial level of expenditures of each commodity and income by source is different (x_i^k and y_j^k). Using the changes to consumer and producer surplus indicated previously, we apply the following equations to predict welfare changes across income groups:

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

Incidence is written:

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

Data needed from outside the OLG model are the percentage of expenditures and income by quintile ($\frac{x_i^k}{x_i}$ and $\frac{y_j^k}{y_j}$).

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's (BEA) personal consumption expenditures (PCE) categories. For example, ferrous metal is a commodity that corresponds to the consumption goods furnishings, appliances, and autos.

To represent expenditure across income quintiles, we use the Consumer Expenditure Survey (CEX) conducted by the Bureau of Labor Statistics (BLS), which is a quarterly survey of randomly sampled households from 91 geographically contiguous primary sampling areas across the United States. The CEX also includes data on household income, and income quintiles are determined by calculating individual income as household income divided by the square root of the number of members of the household, and then creating five groups with an equal number of individuals. Goods are organized by Universal Classification Code (UCC) in the CEX data, which are transformed into PCE categories to be comparable to the data from the OLG model data that have also been transformed into PCE categories. We describe the proportion of spending across UCC consumption goods u and income quintiles k as $\frac{\tilde{x}_u^k}{\tilde{x}_u}$.

4.4. 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 that 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 three 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 quintile, we rely on CBO, which provides annual estimates in *The Distribution of Household Income and Federal Taxes.* These estimates are built on one administrative record, the Internal Revenue Service's Statistics of Income (SOI), and one survey, the Census Bureau's Current Population Survey (CPS). The SOI does not record information from low-income households (who do not pay federal income taxes), and the CPS underreports income from capital (which is often the case in self-reported surveys) and lacks information on high-income households, so the CBO estimates attempt to correct for these factors. CBO provides before-tax income estimates by quintile (calculated in the same way we calculate quintiles in the CEX data) for labor and transfer income. We sum CBO estimates for 2010 of capital gains, business income, capital income, and other income (which is mostly retirement income) by quintile to create our capital income estimates. The change in producer surplus across quintiles is calculated that $\Delta ps_j^k = \Delta ps_j \times \frac{\bar{\bar{y}}_j^k}{\bar{\bar{y}}_j}$, where $\bar{\bar{y}}_j = \sum_j \bar{\bar{y}}_j^k$.

5. Results across Income Groups

The results from the OLG model describe an intertemporal equilibrium affecting overlapping generations. But the focus here is on the short-run effect of the policy—that is, how households are affected by the immediate, short-term effects of the policy on prices, wages, and returns to capital. 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.

Results are reported as the change in welfare measured in dollars per household. Table 2 provides an overview of effects on the mean household at the national level in the first year of the climate policy. In the case that recycles tax revenue to reduce the capital income tax, the cost is $291, reducing the labor income tax yields a cost of $407, and rebating the revenue in equal

(lump-sum) payments yields a cost of $866, more than twice as much as labor tax recycling. This order is expected and generally agrees with what we know about tax efficiency. There is no policy that yields a "double dividend" for the mean household. In other words, ignoring the benefits from reduced carbon emissions, no policy is preferable to the status quo.

Effects on the mean household overall differ substantially from effects on the mean of the middle (third) income quintile (which will approximate the median household overall). The order of preference is completely reversed for the middle quintile, compared with the mean. The effects on the middle-quintile household range from a cost of $534 with a capital tax swap, to a cost of $163 with a labor tax swap, to a gain of $279 with rebates. The rebate policy is the best choice for the middle-quintile household, while it is the worst choice for the mean household. The labor income tax swap is the second choice for both the middle-quintile median and the mean household.

Table 2. Change in Welfare by Household (2012$)

	Middle quintile household ($)			Mean household ($)		
	Capital recycling	Labor recycling	Lump-sum rebate	Capital recycling	Labor recycling	Lump-sum rebate
Energy goods	*-521*	*-534*	*-531*	*-530*	*-543*	*-540*
Electricity	-169	-174	-166	-175	-180	-172
Fuel oil & other	-30	-31	-31	-32	-33	-34
Gasoline	-236	-242	-248	-233	-239	-245
Natural gas	-86	-87	-86	-90	-91	-89
Other goods	*476*	*490*	*481*	*529*	*543*	*539*
Sources of income	*-489*	*-120*	*329*	*-290*	*-406*	*-865*
Capital income	215	-166	-527	556	-429	-1,361
Labor income	-448	-25	-834	-638	-35	-1,188
Rebate	--	--	1,591	--	--	1,603
Transfer income	-257	71	99	-208	58	80
Total	*-534*	*-163*	*279*	*-291*	*-407*	*-866*

The policies do not vary substantially in their effect on welfare loss associated with direct energy goods. For both the middle-quintile and mean households, the spread is $13. The biggest welfare loss among energy goods comes from gasoline consumption. On the other hand, the biggest difference across income groups stems from the effect on sources of income. This difference is in part because of the substantial difference between mean and median income (annual income for the mean household is $127,591 compared with $93,174 for the mean family

in the middle-quintile[9]) and in part because of the difference in income sources (the mean household receives a substantially larger share of income from capital than does the middle-income household).

The welfare loss as a percentage of income across the income distribution is shown in the first panel of Figure 2; it is given in absolute terms (dollars per household) in the second panel. Three quintiles prefer the lump-sum rebate, and these households are strictly winners in this case. The only quintile that prefers the labor tax recycling case is the fourth quintile, although in no case does the fourth quintile strictly benefit (receive a double dividend). In general terms, the labor tax swap would be the second choice of all the quintiles except for the fourth, who prefer it most of all. The labor tax swap is never the least favorite recycling option for any income group. The only quintile that prefers the capital tax swap is the fifth quintile. Except for the difference between the lowest income quintile and the second-lowest quintile under the labor tax swap, the direction of changes in welfare aligns across all quintiles for all the policies. For example, under the capital tax swap, the welfare cost as a percentage of income is strictly decreasing with income and is least for the highest-income households, while for the labor tax swap and the lump-sum rebate, it is strictly increasing with income.

In percentage terms, the first panel of Figure 2 shows that a majority of the quintiles receive a double dividend in the lump-sum rebate case, the first quintile gains more than the fifth quintile loses, and the second quintile gains more than the fourth quintile loses. Nonetheless, the mean household experiences a loss in welfare, because 69.3 percent of income is concentrated in the top two quintiles.

We summarize the results with the observation that a policymaker would pick the lump-sum rebate if she cared most about what the majority would vote for or wanted to reduce inequality. The policymaker would pick the labor tax swap if she wanted to have the most even effect on all income quintiles or to avoid the worst-case scenario for each income quintile. The policymaker would pick the capital income tax swap if she cared most about total welfare.

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[9] Note that these are personal income figures, whereas readers may be more familiar with money income figures, which are substantially lower (e.g., median houshold money income in the American Community Survey in 2012 was $51,371 (Census, 2013)). Personal income is a much more complete measure, including not only money income, but also income that doesn't come in the form of money, such as imputed rent (e.g., the value from living in a house you own, rather than having to pay rent), the value of employer-provided health insurance and retirement contributions, and a range of other non-money income sources (see Ruser et.al., 2004, for more detail). Thus, personal income provides a better measure of how well-off a household actually is.

The components of welfare loss across the income quintiles are evident in Table 3 as a percentage of income. The components are illustrated in Figure 3 for the mean household and the middle quintile (approximate median) household, where red bars represent losses and green bars represent gains to welfare. Similar effects are observed for direct energy goods and other consumer goods over the three policies. The impact as a percentage of income of changes in welfare associated with energy goods is regressive cost across quintiles, largely because expenditure on energy goods is relatively flat across quintiles, but the denominator, income, is not flat. The first five bars of welfare loss do not vary by policy for the mean and middle quintile households in Figure 3.

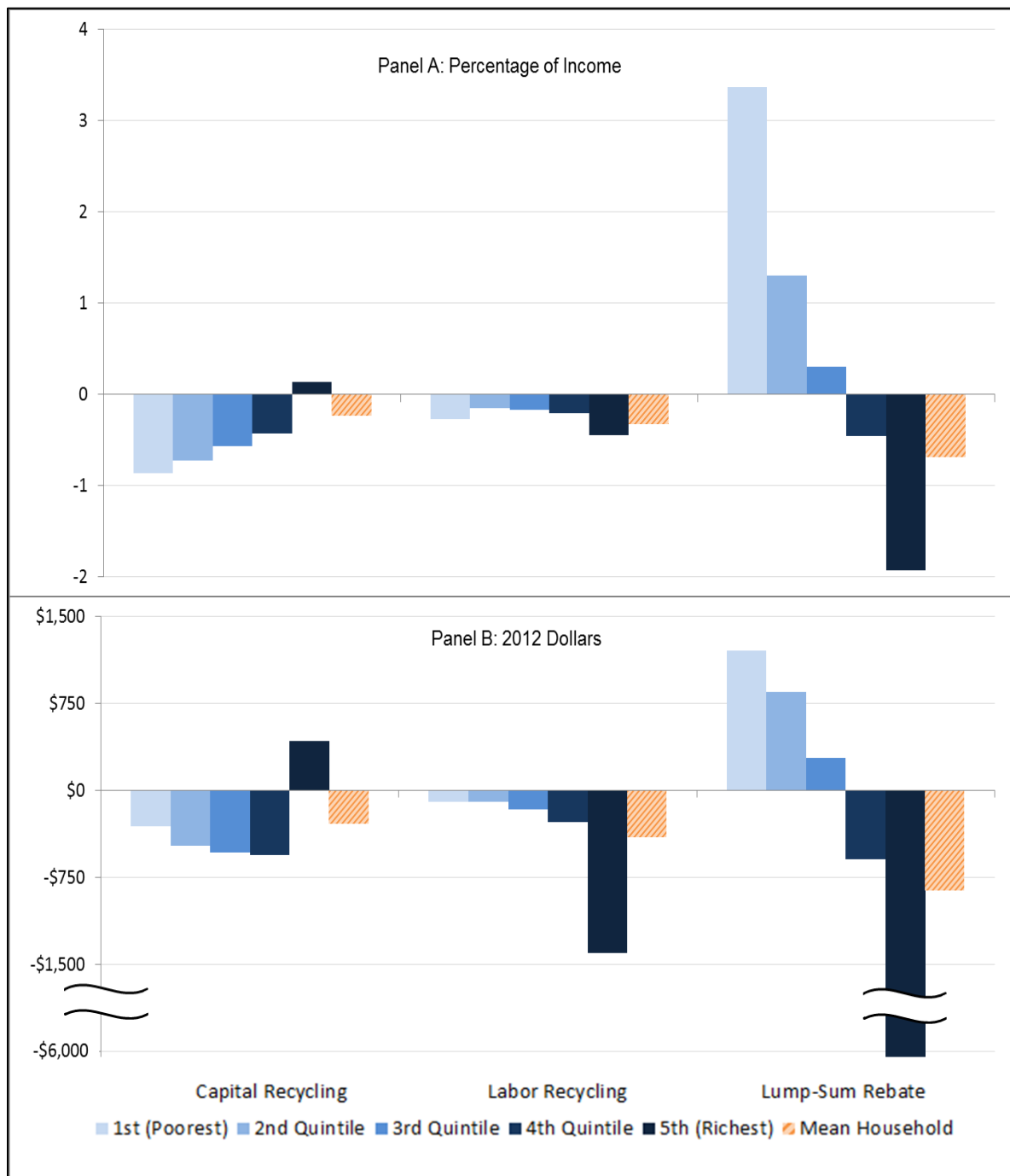**Figure 2. Welfare Change per Household by Quintile**

Table 3. Change in Welfare by Quintile (Percentage of Personal Income)

	1st (poorest)	2nd quintile	3rd quintile	4th quintile	5th (richest)	US total
Capital recycling	*-0.87*	*-0.73*	*-0.57*	*-0.43*	*0.14*	*-0.23*
Energy goods	-1.04	-0.70	-0.56	-0.46	-0.22	-0.42
Electricity	-0.41	-0.25	-0.18	-0.14	-0.07	-0.14
Fuel oil & other	-0.06	-0.04	-0.03	-0.03	-0.02	-0.03
Gasoline	-0.40	-0.29	-0.25	-0.22	-0.10	-0.18
Natural gas	-0.17	-0.12	-0.09	-0.07	-0.04	-0.07
Other goods	0.81	0.59	0.51	0.46	0.29	0.41
Sources of income	-0.64	-0.63	-0.53	-0.43	0.08	-0.23
Capital income	0.15	0.16	0.23	0.30	0.64	0.44
Labor income	-0.40	-0.42	-0.48	-0.55	-0.51	-0.50
Rebate	--	--	--	--	--	--
Transfer income	-0.39	-0.37	-0.28	-0.17	-0.06	-0.16
Labor recycling	*-0.28*	*-0.15*	*-0.18*	*-0.21*	*-0.45*	*-0.32*
Energy goods	-1.06	-0.72	-0.57	-0.47	-0.23	-0.43
Electricity	-0.42	-0.25	-0.19	-0.15	-0.07	-0.14
Fuel oil & other	-0.06	-0.04	-0.03	-0.03	-0.02	-0.03
Gasoline	-0.41	-0.30	-0.26	-0.22	-0.10	-0.19
Natural gas	-0.17	-0.12	-0.09	-0.08	-0.04	-0.07
Other goods	0.82	0.61	0.53	0.47	0.29	0.43
Sources of income	-0.03	-0.04	-0.13	-0.21	-0.51	-0.32
Capital income	-0.12	-0.12	-0.18	-0.23	-0.50	-0.34
Labor income	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03
Rebate	--	--	--	--	--	--
Transfer income	0.11	0.10	0.08	0.05	0.02	0.05
Lump-sum rebate	*3.36*	*1.29*	*0.30*	*-0.46*	*-1.93*	*-0.68*
Energy goods	-1.05	-0.71	-0.57	-0.47	-0.23	-0.42
Electricity	-0.40	-0.24	-0.18	-0.14	-0.07	-0.13
Fuel oil & other	-0.06	-0.04	-0.03	-0.03	-0.02	-0.03
Gasoline	-0.42	-0.31	-0.27	-0.23	-0.11	-0.19
Natural gas	-0.17	-0.12	-0.09	-0.07	-0.04	-0.07
Other goods	0.84	0.61	0.52	0.46	0.29	0.42
Sources of income	3.57	1.39	0.35	-0.45	-2.00	-0.68
Capital income	-0.37	-0.39	-0.57	-0.73	-1.58	-1.07
Labor income	-0.75	-0.78	-0.90	-1.03	-0.95	-0.93
Rebate	4.55	2.42	1.71	1.24	0.51	1.26
Transfer income	0.15	0.14	0.11	0.07	0.02	0.06

**Figure 3. Components of Welfare Change per Household
(Percentage of Personal Income)**
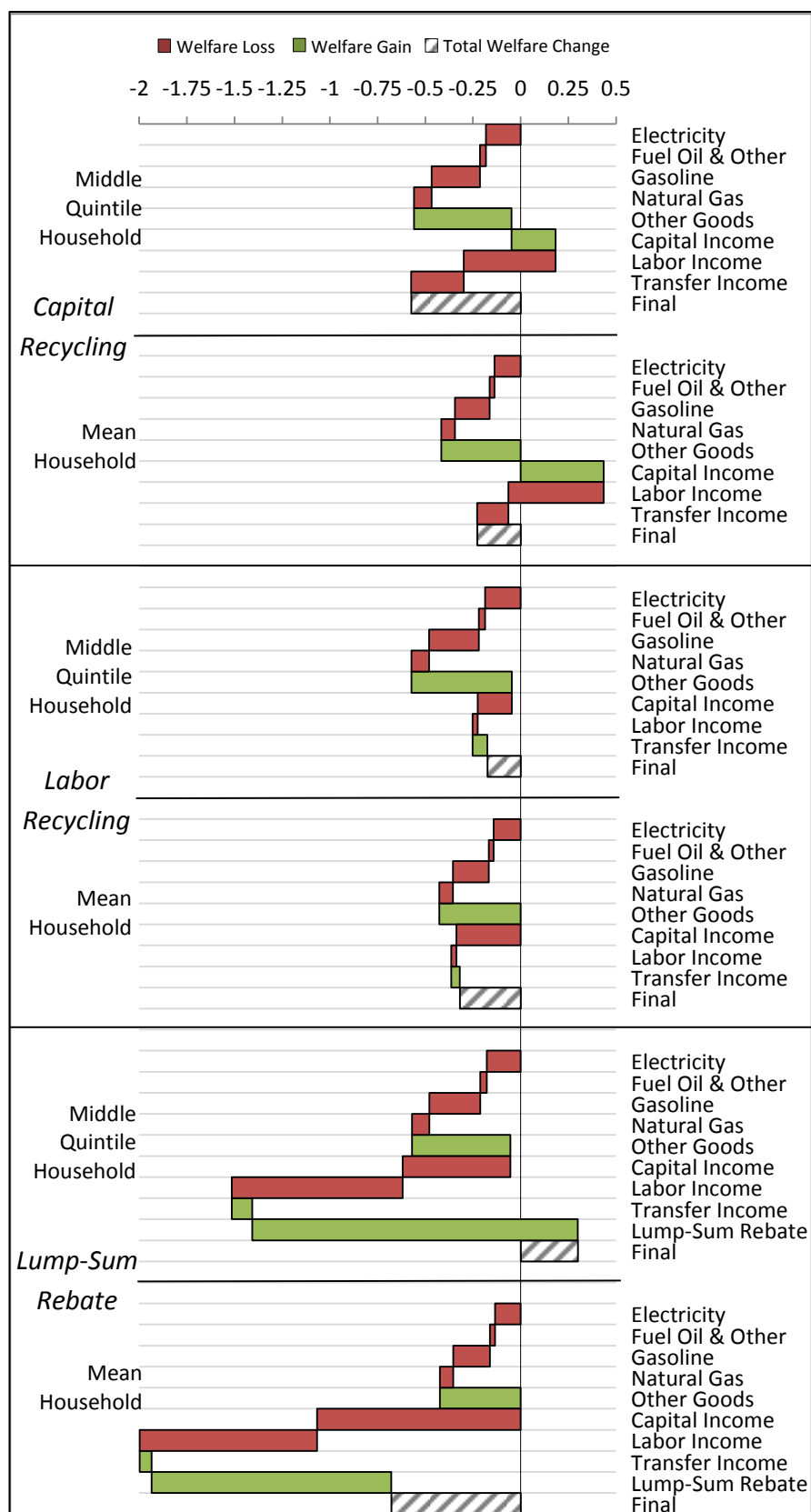
Welfare changes associated with consumption of other (nonenergy) goods consistently deliver increases in welfare. This is a result of the price normalization, which holds the price of the average consumer good constant: the price increase for energy goods means that the relative price of nonenergy goods falls. Other consumption is more evenly spread across quintiles than is income. However, since expenditures on energy goods are more equal across quintiles than expenditures on other goods, the regressive nature of the welfare loss from direct energy goods overwhelms the progressive nature of the welfare gains from other goods. Therefore, before considering welfare changes from income, we observe that poorer quintiles are consistently worse off because energy consumption composes a larger proportion of their total consumption.

The big differences between the outcomes of the policies stem from welfare changes to sources of income. Under the capital tax swap, there is a significant welfare gain to capital income and a significant welfare loss to labor income. Because capital income is more significantly concentrated in the top quintile than labor income, this means there is a regressive net effect from these sources. The larger green bar for capital income in the first panel of Figure 3 for the mean household over the middle quintile household illustrates how capital income drives this outcome. The loss in transfer income also is a contributing factor to the regressive outcome. As noted previously, we hold the cumulative real net present value of transfers over a 100-year period constant for all policy changes by making the same percentage adjustment to nominal transfers in every year. Over the longer term, capital tax recycling leads to slightly lower consumer prices, implying lower nominal transfers. But because that effect on consumer prices takes several periods to appear, the reduction in transfers implies a small initial drop in real transfers.

In the labor income tax swap, the large welfare loss to labor income is almost completely erased: the cut in labor tax rates means that real after-tax wages remain roughly constant (remember that the price normalization means that all changes should be interpreted in real terms). But real after-tax returns on capital fall substantially in this case. Because capital income is concentrated in higher-income quintiles, this produces a progressive effect overall. The bars in Figure 3 representing welfare changes from sources of income are the smallest in the labor recycling panel, which nicely illustrates why this policy produces the most even results across quintiles.

Under the lump-sum rebate, there are large reductions in after-tax wages and returns to capital, thus producing substantial welfare losses from those terms. The rebate income is equal across quintiles in dollar terms, but it represents a much larger proportion of income for the poorer quintiles than it does for the top quintile. All of these changes in income have very progressive effects, especially the rebate itself, and as Figure 3 illustrates, the welfare changes

from each source of income are much larger than in other policies, which is why the lump-sum rebate policy is the most uneven in effects and the most progressive.

6. Conclusion

Our results show that the effects of a carbon tax on energy prices are somewhat regressive, consistent with earlier studies. However, we also find that the use of revenue can outweigh that effect. As expected, the mean household does the worst under a lump-sum rebate, but we find that this policy will create a double dividend for the bottom three quintiles of the US population in the first year. This finding should be particularly interesting to policymakers who are interested in internalizing the price of carbon and reducing inequality, and if households vote based on their self-interest, such a policy could be politically quite popular.

In contrast, recycling revenue to reduce capital taxes is the most efficient policy, but we caution that it makes carbon pricing, which is already regressive, even more so (at least in the short run). Meanwhile, using carbon tax revenue to reduce taxes on labor is a clear middle-of-the-road option: while it is less efficient than recycling revenue to cut capital taxes, the efficiency difference is relatively modest, and cutting labor taxes offsets some of the natural regressivity of a carbon tax. The distributional effects are close to even across the income distribution, when measured as a percentage of income, which could have political advantages. In contrast, if the rebate policy is viewed as an attempt to reduce inequality, this might introduce a controversial policy subplot into an already polarized debate.

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. Finally, this paper looks only at incidence across incomes and only at incidence in the short run. In ongoing work, we examine the distributional effects of these three policies by state and region. In related work in progress, we look at the transitional incidence of the three policies by quintile and geography over a longer time frame to trace incidence through 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 growth adjusts, some of that benefit is passed through to workers and consumers in the form of wages and lower consumer prices.

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