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**THE DISTRIBUTIONAL IMPACTS OF A CARBON TAX**

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# THE DISTRIBUTIONAL IMPACTS OF A CARBON TAX<sup>1</sup>

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Two economic models of the U.S. economy — DRI's macroeconomic model and Jorgenson/Wilcoxon's computable general equilibrium model — have been used to examine the consequences of mitigating carbon dioxide (CO<sub>2</sub>) emissions by imposing a carbon tax and directing the tax revenues to alternative uses — e.g., debt reduction or reduction in other forms of taxation. The results of the economic models were then used as inputs into three distributional models: (1) DRI's *CES/DECO* model, (2) the Jorgenson/Slesnick/Wilcoxon (*J/S/W*) model, and (3) the Urban Institute's *TRIM2* model. The results indicate that a carbon tax at the levels analyzed would have a small, slightly regressive impact. However, the analysis indicates that the slight regressivity of a carbon tax can be offset by various tax recycling mechanisms or changes in transfer programs.

## I. INTRODUCTION

The Energy Policy Branch of the U.S. Environmental Protection Agency is engaged in ongoing analyses of greenhouse gas mitigation options. Within the Energy Policy Branch, other domestic and international government agencies, and private organizations, considerable analytic effort has focused on the use of a carbon tax as the least-cost mitigation option. Much of this research has focused on the size of a carbon tax needed to achieve a given level of CO<sub>2</sub> emissions reductions from baseline levels, and on the aggregate economic effect of such a tax. To date, there has not been a thorough examination of the distributional impacts of a carbon tax: its effect on income and consumption levels, on relative purchasing power for different classes of

households, and impact on employment by region and industry.<sup>2</sup> This paper seeks to fill that gap by examining the likely distributional impacts of a carbon tax and the alternative means available to mitigate any potential adverse welfare effects.

In the absence of analysis, a widely held perception is that a carbon tax is regressive. Lower income families spend a greater share of their incomes on energy (i.e., the income elasticity of demand for energy is less than one). In addition, price elasticities of demand for energy are less than one. As the price of energy increases, energy's share of a household's budget will increase, disproportionately reducing lower income household's welfare.

Policy makers need to be aware of the incidence of a carbon tax, the associated losses in welfare, and the alternative methods available to mitigate or even out the unintended adverse effects. Both the efficiency and equity effects of a carbon tax can be strongly influenced by the way in which the revenues are used or recycled back into the economy. The design of a tax revenue recycling scheme may ameliorate a carbon tax's adverse effect on aggregate economic activity and "make whole" each income group. Two caveats are in order. First, the system must be designed carefully to avoid eliminating the price incentives which a carbon tax is intended to produce: CO<sub>2</sub> emissions should be lower with than without the tax. Second, although policies can be designed to transfer income or tax liability from one income group to another, a carbon tax will necessarily create structural changes that alter employment patterns and lifestyles.

To help answer some of the questions associated with the distributional impacts of a carbon tax, the EPA's Energy Policy Branch has funded studies using the DRI's *CES/DECO* model, the Jorgenson/Slesnick/Wilcoxon (*J/S/W*) distributional model, and the Urban Institute's *TRIM2* model.

## II. METHODOLOGICAL ISSUES

A carbon tax as analyzed here would be applied at the point of initial sale to coal, oil, and natural gas. The imposition of a carbon tax and various recycling mechanisms would have three broad distributional effects:

- (1) Prices. The imposition of a carbon tax would make it more expensive to produce goods; the aggregate price level would be higher with the tax than without. Moreover, relative prices would change such that prices for products and services which embody a larger-than-average carbon-input content would rise disproportionately. Changes in relative prices brought about by the carbon tax have different impacts on different groups in society, depending upon their patterns of consumption and the ease of substitution.
- (2) Incomes. The carbon tax and the use of its revenues have broad economic implications that affect the economy's rate and pattern of growth. These, in turn, affect the amounts and shares of income received in the form of wages, profits, dividends, interest, rental income, and transfer payments (both indexed and non-indexed). Individuals or income groups will be differentially affected depending upon their sources of income.
- (3) Taxes. Recycling carbon taxes through a reduction of other tax rates, such as the personal income tax, has obvious distributional effects; all income tax-paying households will see their nominal (and, most probably, real) after-tax income rise. Changes to corporate and capital tax rates may also have subtle, but significant, effects; an investment tax credit or a lowering of the marginal corporate tax rate will spur additional investment and raise aggregate GNP over time. Such a rise in aggregate GNP will likely increase most other sources of income.

The overall distributional effects of carbon taxes clearly depend on how these three effects impact different groups in society.

The question a distributional analysis attempts to answer is: On whom, ultimately, does the effect of a tax fall, and how hard? The *incidence* of a tax refers to some measure of the eventual distribution of the burden of the tax, after all (or while all) economy-wide adjustments are made. Changes to income or changes to lifetime wealth are among the possible alternatives that may be used to measure the incidence or burden of a tax.<sup>3</sup>

In addition, once the incidence is measured, policy makers usually wish to know if the tax is *progressive* or *regressive*. Typically, a progressive tax refers to a situation in which the proportion of income taken in tax rises with income or spending power.<sup>4</sup> As with almost any subject of analysis, however, the choice of metric can affect the story told. As an example, in terms of a carbon tax, the disparity of shares of income between high and low income families spent for direct energy sources (e.g., electricity, natural gas, gasoline) is much larger than the disparity of shares of expenditure between high and low expenditure families. Thus, for any given level of carbon tax, an analysis relying on an income ranking will likely tell a different story than an analysis using expenditure ranking. The question of how best to measure the distributional impacts of a tax program remains a matter of controversy in the modeling community.

Proponents of using an expenditure ranking to determine the progressiveness or regressiveness of a tax argue that households experience numerous transitory shocks to, and lifetime variations in, income. Spells of unemployment, illness, and schooling, as well as retirement will disguise the true long run economic status of a household. Most households make spending decisions looking at both past and future income, so their expenditure is smoother than income. Expenditure analysis proponents believe regressivity should be a long term concern; all else being equal, the aim of individuals is to maximize discretionary income over time. Thus, regressivity studies should look at lifetime income, and lifetime income is better proxied by current expenditures than by current income; income is a noisier indicator of well-being than expenditures.

Those who favor an income analysis, however, argue that while regressivity is a long-term concern, economic hardship is also a short-term, immediate concern. The poor are less able to smooth their expenditures over time, for they tend to have more difficulty borrowing. To the extent that the poor should be the focus of equity concerns, a tax's potential for significant regressivity with respect to annual income is highly relevant.

In addition to concerns regarding the appropriate metric for progressivity or regressivity, there is a larger policy-related methodological question: Is a summary statistic of the aggregate effect sufficient, or is the concern for distributional effects inherently more complex and detailed?<sup>5</sup> Are regional and industry-specific details inadequately captured by broad measures of economic welfare?

The analyses reported here use a variety of methodological approaches. Each has its own unique perspective and strengths, and each emphasizes different policy details. *J/S/W* use a social welfare function (based, in part, on lifetime expenditures) to examine the very long run distributional consequences of a carbon tax. *DRI/CES/DECO* conducts an expenditure-based analysis through the year 2010. The Urban Institute/*TRIM2* analysis focuses on the income effects in the near term, and in the next phase will attempt to analyze more specific sectoral and regional impacts.

### III. MODELING RESULTS

For this exercise, the distributional impact of a carbon tax and alternative recycling schemes was analyzed using three complementary models. Two analyses — DRI's *CES/DECO* model and Urban Institute's *TRIM2* model — use the basic economic output of DRI's aggregate macroeconomics model of the U.S. economy, which excels in its realistic simulation of the constrained adjustment process in the short- and medium-term to policy changes such as a carbon

tax. The *J/S/W* analysis uses a detailed computable general equilibrium (CGE) model of the U.S. economy to generate the basic economic output. The CGE model includes product- and factor-specific supply and demand equations that embody neoclassical general equilibrium theoretical assumptions about individuals' preferences and constraints, and about producers' profit maximizing behavior. This approach allows one to capture unique characteristics of specific sectors of the economy as they adjust over the long term to the imposition of a carbon tax.

The DRI macro model and the *J/S/W* CGE model were used to generate simulations of three alternative means to recycle the carbon tax revenues:

- (1) a revenue neutral lump sum rebate;
- (2) a reduction in the personal income tax rate; and
- (3) (a) for DRI, a blending of an investment tax credit (ITC) and a reduction in the personal income tax rate in proportions such that GNP is maintained at baseline levels; and (b) for *J/S/W*, a blending of a reduction in the marginal rate of taxation on capital and labor.<sup>6</sup>

DRI's *CES/DECO* distributional model was then used to examine the relative effect of changes to prices, incomes, and taxes on income quintiles based on the output from the DRI macro model. The overall effect is obtained by summing the price, income, and tax effects. Results are also reported by age of head of household and size of household.

The *J/S/W* CGE simulation extended through the year 2020. The *J/S/W* distributional analysis focused on changes in expenditures. Proportional changes in lifetime welfare among different household types (called "dynasties") are reported, as is a measure of aggregate social welfare divided into an efficiency and equity component.

The Urban Institute's *TRIM2* microsimulation model was also used to examine the short-term effects of a carbon tax in more detail.<sup>7</sup> Using the microsimulation model, the Urban

Institute focused on the effects in 1994 of a carbon tax that was implemented beginning in 1990.

Two tax scenarios were examined:

- (1) a reduction in the personal income tax rate; and
- (2) the tax revenues were used to lower the federal deficit.

The strength of the *TRIM2* model is its ability to simulate the impacts of policies on a wide set of households with different demographic characteristics with a detailed, realistic representation of the U.S. tax code and government transfer programs.

The results from all three models of the distributional impacts a carbon tax are broadly consistent:

The distributional impacts (as measured by broad income or expenditure groups) are small. Tax recycling mechanisms and adjustments to transfer programs can be used to offset much, if not all, of the adverse distributional impacts, and may even have progressive distributional impacts.

#### *DRI/CES/DECO* MODEL

Macro Model Results: Three simulations are examined in DRI's analysis. All three scenarios start with the imposition of a \$15 per ton carbon tax which is allowed to grow by 5% in real dollars to approximately \$40 per ton in 2010. In all three scenarios, sufficient revenues are recycled in order to hold the full-employment federal deficit at baseline levels. However, the methods by which revenues are recycled differ among the three simulations which has a significant impact both on the distribution and macroeconomic implications of these policies.

In the personal income tax rebate scenario, revenues are recycled through a proportional cut in the personal income tax. This change is intended to be distributionally neutral in itself. All tax rates are reduced by the same percentage, so that the reduction in taxes should amount

to the same fraction of the tax bill for different households over the income spectrum. Higher inflation leads to higher interest rates which reduces investment's share of GNP. However, personal tax cuts boost consumption spending as a share of GNP. A weaker economy leads to a lower exchange rate which modestly boosts exports and reduces imports. This policy leaves real GNP 0.8% below base case levels over most of the next two decades.

In the lump sum tax rebate scenario, revenues are recycled through a per-head tax credit which leaves marginal tax rates constant. This change is clearly progressive with the largest benefits accruing to larger households and the largest proportional benefits accruing to the poorest households. Its macroeconomic effects are similar to those of the personal income tax cut scenario.

In the mixed ITC/personal income tax reduction scenario, investment tax credits are introduced in the 1990s along with proportional reductions in the personal income tax. In this simulation, these two forms of tax cuts are mixed in order to achieve both the same full employment deficit as in the base case, and the roughly the same level of real GNP as in the base case. This required mixing the use of an ITC and personal income tax reduction in the 1990s with revenue recycling through the personal income tax alone after the year 2000. The increase in the capital stock generated in the 1990s by more generous investment tax credits allows the economy to achieve close to baseline economic growth after 2000, even with more consumption-oriented personal tax cut recycling after that date.

Table 1 shows percentage changes in carbon emissions and gross national product in the years 2000 and 2010 under each scenario.

*DECO* and The Reporting Framework for *CES/DECO*: DRI's *CES/DECO* model makes extensive use of the 1989 Consumer Expenditure Survey (CES), published by the Bureau of Labor Statistics, U.S. Department of Labor, as well as demographic projections

from DRI's Demographic-Economic (*DECO*) model. In this model, consumer spending data on 40 separate CES categories are translated into the 15 national income and product account (NIPA) categories forecast in DRI's macroeconomic model of the U.S. economy. This provides information about the share of total spending on a NIPA consumption category attributed to each of five income quintiles, six age groups, and five household size groups.

**Table 1. Overall Effects On The Economy**

(Percentage Change from Base Case)

Rebate Scheme	Carbon Emissions		GNP	
	2000	2010	2000	2010
Lump Sum	-4.0%	-6.5%	-0.8%	-0.9%
Personal Income Tax	-4.0%	-6.5%	-0.7%	-0.8%
ITC/Personal Income Tax	-3.8%	-6.1%	+0.4	+0.0%

Tables 2a and 2b present consumer spending on the 15 major NIPA consumption categories; Table 2a shows for each of the 15 NIPA consumption categories the proportional consumption by each of the income quintile, and Table 2b shows for each quintile the proportion of its total consumption spent on each of the 15 NIPA consumption categories. The five consumption categories most directly affected by a carbon tax (gasoline and oil, fuel oil and coal, transportation services, electricity, and natural gas) are shown at the top of each table. These five consumption categories account for approximately 9.4% of total consumer spending. As seen in Table 2a, upper income quintiles spend proportionately more than lower income quintiles for all consumption categories (i.e., lower quintiles consume more of their income, upper quintiles save and invest more). For four of the five most directly affected consumption categories proportional spending among the quintiles is slightly

smoother than for total consumer spending (i.e., the difference between lower income quintiles share of consumption and upper income quintiles share is smaller than average).

Table 2b indicates that proportional spending on the five most affected consumption categories falls as income rises. The lowest income quintile spends 10.5% of its income on the five most affected consumption categories, quintile 2 spends 10.3%, quintile 3 spends 10.1%, quintile 4 spends 9.4%, and the top quintile spends 8.6%. Only spending on transportation services rises as a proportion of income through the quintiles.

**Table 2a: Spending on Major NIPA Consumption Categories, 1989**  
(By Income Quintile)

Consumption Category	Total Billion \$	Lowest 20%	2nd 20%	3rd 20%	4th 20%	Top 20%	All
Gasoline & Oil	\$84	9.4%	14.2%	20.2%	24.7%	31.5%	100%
Fuel Oil & Coal	\$18	14.4%	17.5%	19.0%	20.4%	29.1%	100%
Transportation Services	\$126	7.5%	11.7%	17.2%	24.7%	38.8%	100%
Electricity	\$69	12.8%	16.8%	19.5%	21.9%	29.0%	100%
Natural Gas	\$29	13.6%	17.2%	19.0%	22.4%	27.6%	100%
Motor Vehicles & Parts	\$216	7.2%	11.8%	16.2%	29.4%	35.3%	100%
Furniture & Appliances	\$171	7.6%	11.9%	16.6%	24.5%	39.4%	100%
Other Durables	\$88	7.9%	10.4%	19.0%	23.7%	38.9%	100%
Food & Beverages	\$595	10.4%	14.0%	18.7%	23.7%	32.4%	100%
Clothing & Shoes	\$205	7.6%	11.7%	17.7%	25.7%	37.3%	100%
Other Nondurables	\$229	9.2%	13.9%	18.2%	22.8%	35.9%	100%
Housing Services	\$534	9.8%	12.8%	16.7%	22.7%	37.9%	100%
Medical Services	\$434	12.2%	18.9%	19.5%	20.4%	28.9%	100%
Other Household Oper.	\$109	10.7%	14.3%	18.8%	23.5%	32.7%	100%
Other Services	\$545	4.7%	7.4%	14.4%	25.2%	48.2%	100%
<b>Total Consumer Spending</b>	<b>\$3,454</b>	<b>9.0%</b>	<b>13.1%</b>	<b>17.5%</b>	<b>23.8%</b>	<b>36.6%</b>	<b>100%</b>

**Table 2b: Spending By Income Quintile, 1989**  
(By Major NIPA Consumption Categories)

Consumption Category	Lowest 20%	2nd 20%	3rd 20%	4th 20%	Top 20%
Gasoline & Oil	2.6%	2.6%	2.8%	2.5%	2.1%
Fuel Oil & Coal	0.8%	0.7%	0.6%	0.4%	0.4%
Transportation Services	3.1%	3.3%	3.6%	3.8%	3.9%
Electricity	2.8%	2.6%	2.2%	1.8%	1.6%
Natural Gas	1.3%	1.1%	0.9%	0.8%	0.6%
Motor Vehicles & Parts	5.0%	5.6%	5.8%	7.7%	6.0%
Furniture & Appliances	4.2%	4.5%	4.7%	5.1%	5.3%
Other Durables	2.2%	2.0%	2.8%	2.5%	2.7%
Food & Beverages	20.1%	19.4%	18.5%	17.2%	15.3%
Clothing & Shoes	5.1%	5.3%	6.0%	6.4%	6.0%
Other Nondurables	6.8%	7.1%	6.9%	6.3%	6.5%
Housing Services	17.0%	15.1%	14.8%	14.8%	16.0%
Medical Services	17.1%	18.2%	14.0%	10.8%	9.9%
Other Household Oper.	3.8%	3.4%	3.4%	3.1%	2.8%
Other Services	8.2%	9.0%	13.0%	16.7%	20.8%
<b>Total Consumer Spending</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

To assess the effect of higher prices, DRI assumes, for simplicity, that households make no adjustment in their real consumption habits in response to changed relative prices. The cost of the carbon tax in terms of higher prices are then measured by the rise in nominal spending required to maintain the base case level and pattern of real consumption.<sup>8,9</sup> These costs are then summed over different consumption categories and divided by income.

**Table 3a. Income Shares by Source, 1989**  
(By Income Quintile)

Income Source	Lowest 20%	2nd 20%	3rd 20%	4th 20%	Top 20%	Total
Compensation	1.58%	6.31%	14.84%	26.95%	50.23%	100%
Proprietors Income	-0.36%	4.28%	8.80%	12.54%	74.60%	100%
Transfers	17.56%	26.20%	21.59%	16.36%	18.29%	100%
Dividends, Interest, and Rent	2.87%	6.78%	14.01%	17.83%	58.44%	100%
Total Household Income	3.65%	8.88%	15.24%	23.97%	48.17%	100%

**Table 3b. Income Shares by Quintile, 1989**  
(By Source)

Income Source	Lowest 20%	2nd 20%	3rd 20%	4th 20%	Top 20%
Compensation	23.6%	41.1%	58.1%	70.9%	60.7%
Proprietors Income	-0.8%	4.1%	5.0%	4.8%	13.1%
Transfers	64.5%	41.8%	20.7%	10.5%	5.4%
Dividends, Interest, and Rent	12.7%	13.0%	16.2%	13.8%	20.8%
Total	100%	100%	100%	100%	100%

The distributional implications for changes in nominal income were assessed by allocating income by source from DRI's macro model to demographic subgroups according to their 1989 CES shares of that income source.<sup>10</sup> Tables 3a and 3b present income from four major source categories: (1) compensation (wages, salaries, and other forms of labor compensation including health and pension benefits, less personal contributions to social insurance); (2) proprietors income (both farm and non-farm); (3) transfers; and, (4) dividends, interest, and rents. Table 3a shows for each income source the proportion received by each

of the income quintiles, and Table 3b shows for each quintile the proportion of its total income received from each of the four sources. As shown in Table 3a, the bulk of proprietors income (75%), dividend, interest, and rents (58%), and compensation (50%) are received by the top income quintile. Thus, changes to those forms of income will be felt most strongly by upper income quintiles. Transfer income, however, is more evenly distributed.

Cutting the data a different way reinforces insights regarding the links between particular sources of income and particular income quintiles. Table 3b indicates that the lowest quintile receives the bulk of its income from transfers (65%) with compensation accounting for the lowest proportion of income of any quintile (25%). The upper two quintiles receive the vast majority of their incomes from compensation (80% and 61%, respectively), and dividends, interest, and rent (14% and 21%, respectively).

Distributional Results: *CES/DECO* reports the price, income, and tax effects of a carbon tax by income quintile, age of head of household, and size of family. The sum of the three effects gives the overall distributional effect of a carbon tax. The narrative below describes the three separable effects in greater detail. In the lump sum and personal income tax rebate scenarios, changes to nominal prices are positive compared with base case levels and distributionally regressive; changes to nominal income are positive compared with base case levels and distributionally progressive, but only offset part of the regressive price impacts. In the ITC/personal income tax rebate scenario, nominal price changes are positive, small, and slightly regressive in 2000, but negative, significant, and distributionally progressive in 2010; nominal income changes are negative and progressive in 2000 and neutral in 2010, almost exactly offsetting the slightly regressive price impacts in 2000 and allowing the progressive price impacts to dominate in 2010. The tax effect is progressive in the lump sum rebate

scenario and neutral in the other two scenarios. Differences in overall effect are due to the magnitude and direction of the individual effects in the three simulations.

Price Effects: Implementation of a carbon tax clearly raises some prices by more than others. For example, in the case of a carbon tax with revenues recycled through a proportional cut in the personal income tax, prices for electricity are 14% above base case levels by the year 2010, whereas the price of medical services is less than 1% above its base case level. Figures 1a and 1b show the changes in nominal prices for the most directly affected commodity categories and total consumer spending.

In the lump sum and personal income tax rebate scenarios, price changes induced by the carbon tax are positive compared with base case levels, and regressive, in large measure because the lowest income quintile pays proportionately more of its income on consumption than does the highest quintile. The imposition of the carbon tax increases nominal prices for all commodity categories in all years for the lump sum and the personal income tax rebate scenarios, and this is felt disproportionately by the lower income quintiles. (E.g., In 2010, in the personal income tax rebate scenario, the nominal price rise for its typical market basket of goods is equivalent to 3.80% of pre-tax income for the lowest quintile and 0.95% for the highest quintile.)

The exception to the regressive price effects is found in the later years of the ITC/personal income tax rebate scenario, when, by 2010, nominal prices are significantly lower than in the base case, and the resulting benefits are felt more strongly by lower income consumers. (E.g., In 2010, in the ITC/personal income tax rebate scenario, nominal prices *drop* 4.61% for the lowest quintile and only 1.60% for the highest quintile.) Generally, the price effects hit younger households harder than older households, and larger households are

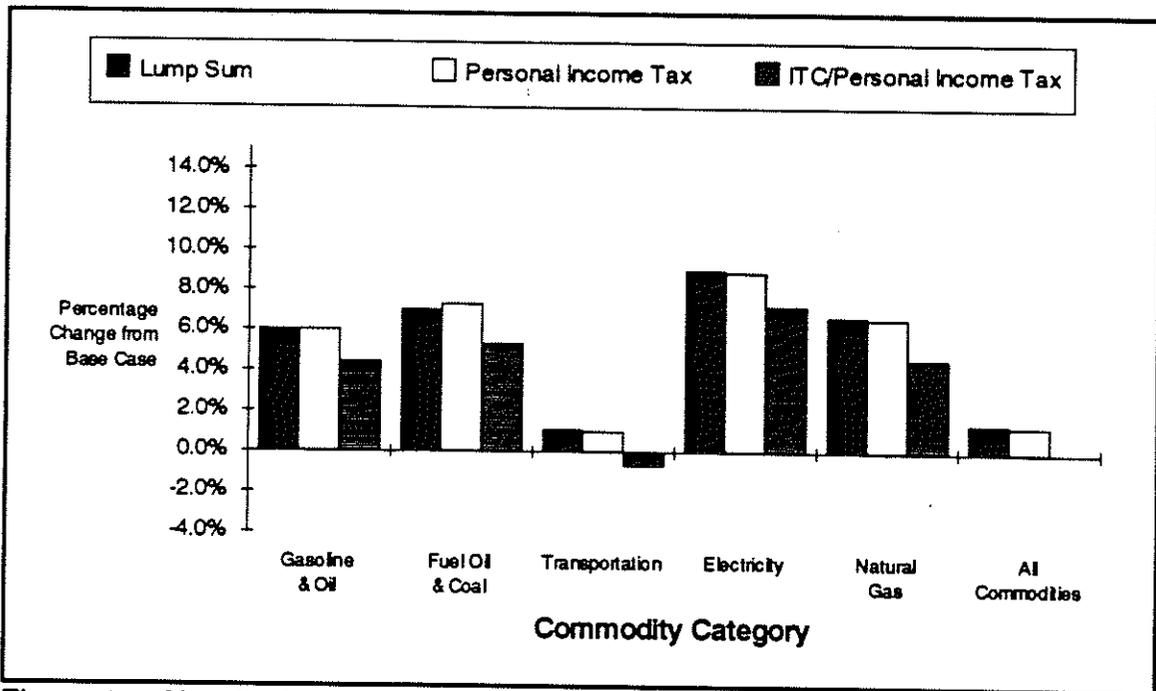


Figure 1a. Nominal Price Changes For 3 Scenarios In 2000.

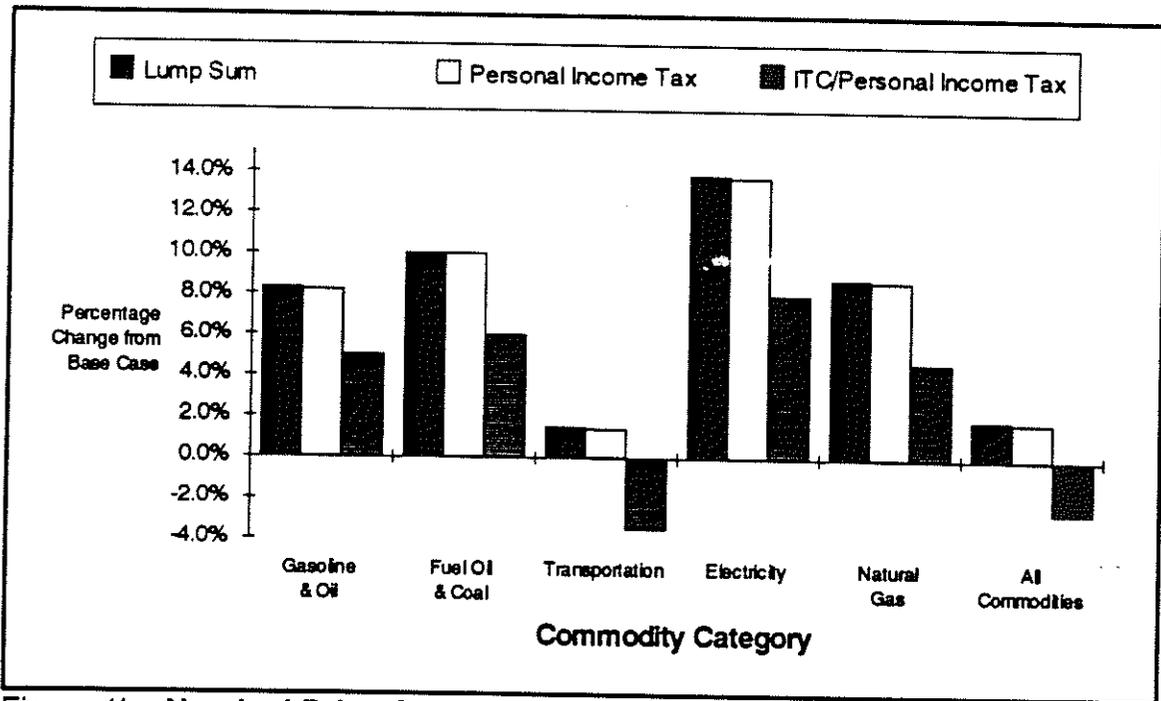


Figure 1b. Nominal Price Changes For 3 Scenarios In 2010.

slightly harder hit than smaller households, with the exception again being the later years of the ITC/personal income tax rebate scenario.

Income Effects: In the lump sum and personal income tax rebate scenarios, nominal income changes induced by the carbon tax tend to be positive and progressive for each of the income quintiles. For the most part, carbon tax and the revenue recycling options examined tend to increase interest, transfer, and wage income, and reduce proprietor, dividend, and rental income.

The exception is again the later years of the ITC/personal income tax rebate scenario when nominal income changes are negative and almost exactly neutral. This singular distributional result obtains because of unique changes to interest and compensation income in the ITC/personal income tax rebate scenario. By 2010, interest and compensation income in the ITC/personal income tax rebate scenario are below base case levels. The highest quintile receives a disproportionate share of the economy's dividends, interest, and rent (58%), and compensation (50%). In addition, the two income sources account for the bulk of the highest quintiles' income sources (61% and 21%, respectively). Thus, a drop in these forms of income will disproportionately affect the upper quintile. The income effects tend to favor older and smaller households except in the ITC/personal income tax rebate scenario where the large decline in non-wage income places a significant burden on Americans over the age of 65 and those living alone.

Tax Cut Effects: By construction, the effects of the simulated tax cuts are exactly neutral across all three demographic dimensions in the cases where revenues are recycled through a proportional reduction in the personal income tax on its own and in combination with an ITC. The lump sum tax cut, as it represents a fixed nominal amount per head, clearly benefits the poor more than the rich. It tends to benefit older and younger households at the

expense of those headed by an individual aged 35 to 64. It is also, for obvious reasons, highly beneficial for larger households.

Overall Effects: Figures 2a and 2b summarize the overall effect for the three tax recycling scenarios by income quintile in the years 2000 and 2010. The overall distributional effect of the lump sum and the personal income tax rebate scenarios are marginally regressive in both the year 2000 and 2010 (i.e., the lowest income quintile suffers a comparatively negative effect relative to base case pre-tax income levels, the negative effect grows smaller for the second through fourth quintile, and then becomes slightly positive for the highest quintile).

The ITC/personal income tax rebate scenario tells a different distributional story; nominal prices and incomes fall, moving in the opposite direction of the lump sum and personal income tax rebate scenarios. The overall distributional effect of the mixed ITC/personal income tax rebate scenario is neutral in 2000 and progressive in 2010. (I.e., In 2000, each quintile is economically better off by approximately 0.2% of base case pre-tax income levels, ranging from \$29 for the average household in the lowest quintile to \$435 for the average household in the highest quintile. In 2010, the lowest income quintile enjoys a positive effect equivalent to 2.2% of base case pre-tax income levels or \$527, the positive effect is smaller for the second quintile, and becomes progressively negative for the third through fifth quintile, equivalent to a loss of \$2421 per household for the highest quintile.) Older households fare better than younger households in general, but this result is reversed in the ITC/personal income tax rebate scenario. Finally, smaller households tend to fare better than larger households except in the later years of the ITC/personal income tax rebate scenario.

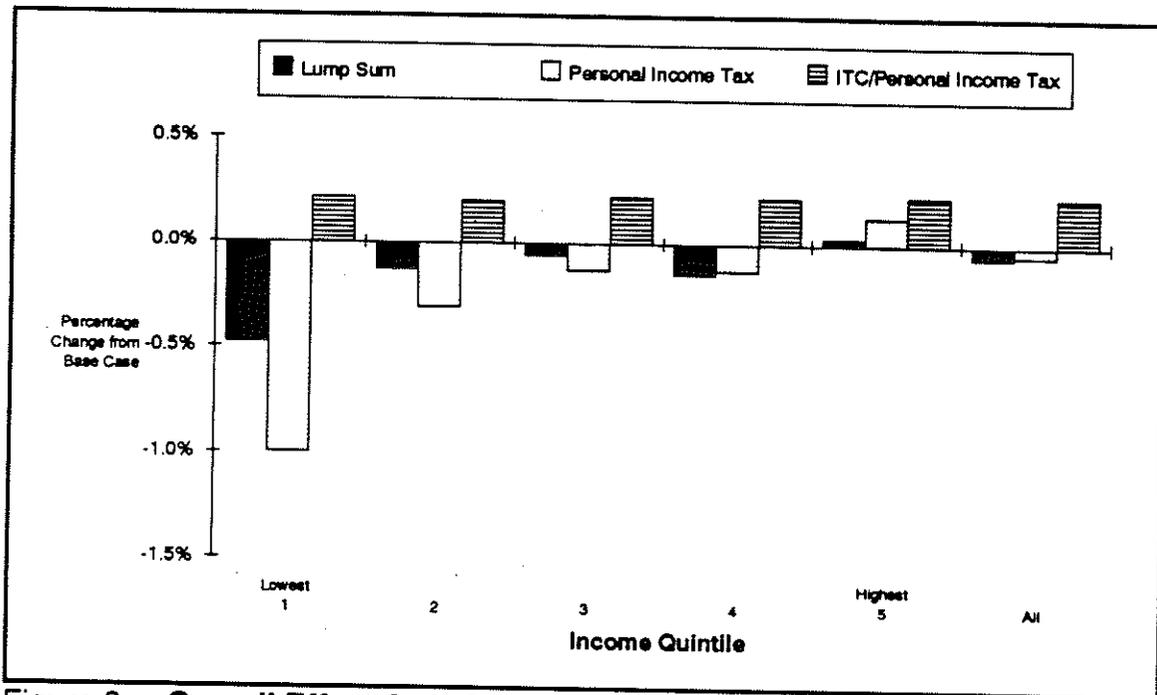


Figure 2a. Overall Effect As A Percentage of Pre-Tax Income For 3 Scenarios In 2000.

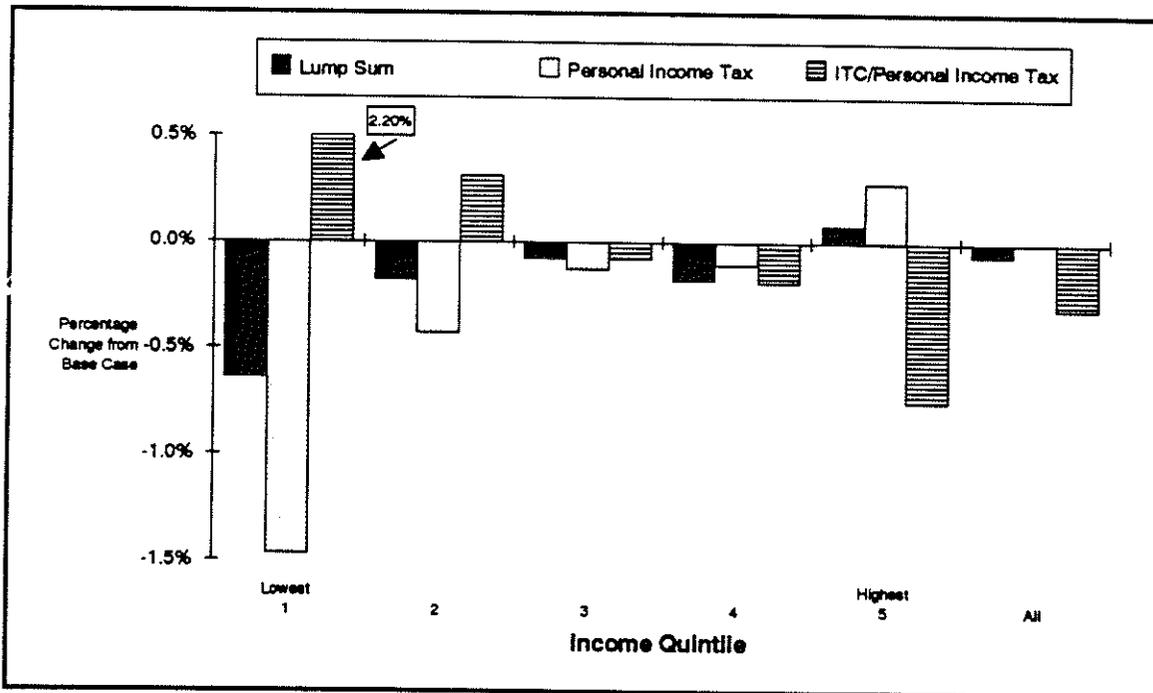


Figure 2b. Overall Effect As A Percentage of Pre-Tax Income For 3 Scenarios In 2010.

## JORGENSON/SLESNICK/WILCOXEN

Macro Model Results: *J/S/W* conducted four simulations, each beginning with the same carbon tax considered by DRI: a charge of \$15 per ton in 1990 rising at a real rate of 5% annually to approximately \$40 per ton in 2010, and remaining at that level thereafter. The analysis was extended through the year 2020. Government spending and the budget deficit were both held at their base case levels in every simulation. The four experiments differed in the treatment of revenues raised by the tax. In the first simulation, the extra revenue was returned to households by increasing the zero tax bracket in the personal income tax schedule. Because this change gave households more income without changing any decisions at the margin, *J/S/W* refer to it as a lump sum rebate. In the second simulation, all the revenues were recycled by lowering the marginal tax rate on labor income. In the third simulation, two-thirds of the revenues were rebated through a reduction in the marginal tax rate on labor and one-third was rebated through a reduction in the marginal tax rate on capital, keeping baseline GNP approximately constant. *J/S/W* refer to the second and third options as the labor tax rebate and the blended capital/labor rebate, respectively. In addition, *J/S/W* simulated a pure capital tax rebate in which all revenues were rebated by lowering the marginal tax rate on capital.

In each simulation carbon emissions fall substantially. By the year 2020 emissions were 32% below the base case for every policy. However, the four policies differ in their effects on the rest of the economy. Table 4 shows percentage changes in carbon emissions, the capital stock, and gross national product in 2020 under each scenario. GNP loss is largest under the lump sum rebate and is substantially less under the labor tax and blended capital/labor tax policies. The capital tax rebate actually increases GNP above its base case level.

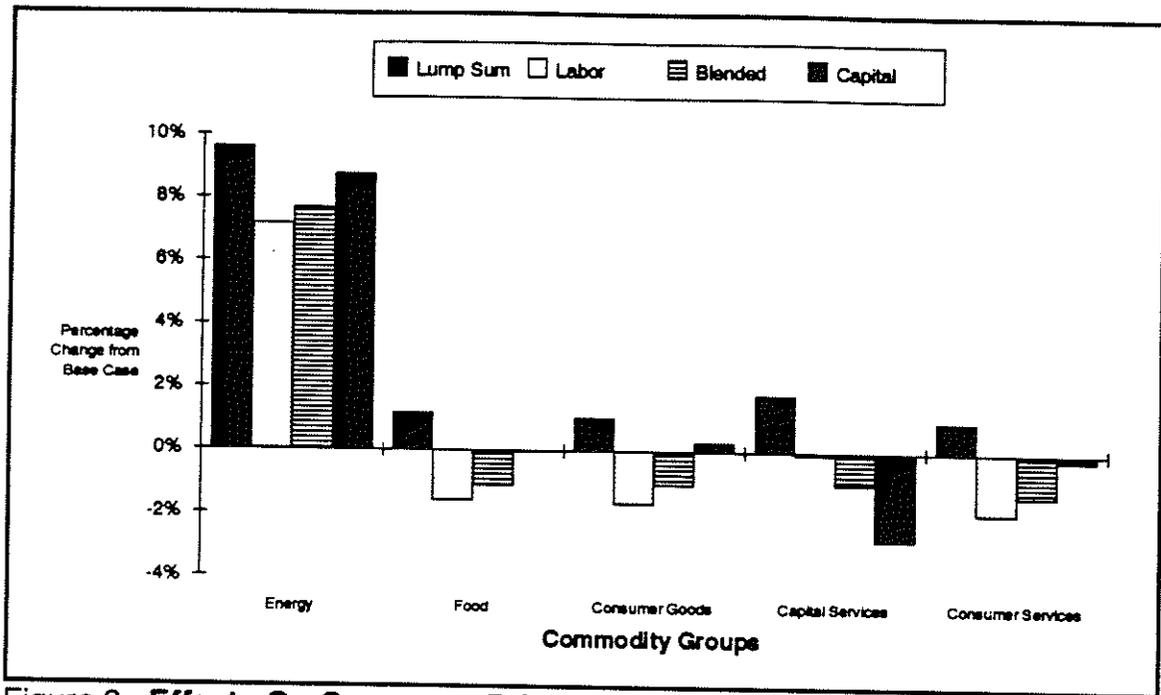


Figure 3. Effects On Consumer Prices In 2020.

**Table 4. Overall Effects On The Economy In 2020**  
(Percentage Change from Base Case)

Rebate Scheme	Carbon Emissions	Capital Stock	GNP
Lump Sum	-32.24%	-2.14%	-1.70%
Labor Tax	-32.10%	-1.38	-0.71%
Blended Capital/Labor	-31.95%	-0.29%	-0.12%
Capital	-31.65	+1.88%	+1.10%

Distributional Model Analytic Framework: Changes to GNP can be a poor measure of the true impact of a policy on household welfare. To obtain more accurate results *J/S/W* use a detailed model of household utility maximization. In their model, household consumption is determined by a three-stage intertemporal optimization. At the first stage, each household allocates *full wealth* (the sum of financial wealth, discounted future labor earnings, and an imputed value of leisure time) across different time periods according to its rate of time preference and its intertemporal elasticity of substitution. At the second stage, households decide on the mix of leisure and goods to consume in each period. Finally, at the third stage households allocate consumption expenditures in each period to capital, labor, and 35 commodities.

To examine the welfare effects of a carbon tax, *J/S/W* use a concept called a *dynasty*. A dynasty is an infinitely-lived household of particular demographic characteristics which maximizes an intertemporal utility function. *J/S/W* use the term "dynasties" rather than just "households" to emphasize that the households are infinitely-lived. Altogether there are 1344 dynasties distinguished by family size, age of household head, region of residence, race, type of residence (farm or nonfarm), and sex of household head. *J/S/W* assume that dynasties allocate total expenditure across five broad commodity groups: energy, food, consumer goods, capital

services and consumer services. Each dynasty allocates a different share of its budget to each commodity group. Hence, changes in the relative prices of commodities will have different effects on different dynasties.

The four rebate policies produce very different changes in relative prices and, thus, have quite different effects on individual households. Figure 3 shows the percentage change in consumer prices for the five broad commodity groups relative to the base case in the year 2020. Under the lump sum rebate, the price of all five commodity groups rises. Under the labor tax, energy prices rise, but there are negligible to modest reductions in the other four commodity categories. The blended capital/labor tax rebate also sees a rise in energy prices, but the price of all other commodity categories are lower than base case levels, including the price of capital services. Finally, under the capital tax rebate energy prices rise and there is a very small rise in consumer goods prices, but the price of capital services drops 2.8%.

To measure the full effects (i.e., changes in lifetime wealth — including leisure — due to changes in prices, incomes, and taxes) of a carbon tax on dynasties, *J/S/W* use the concept of *equivalent variation*. The equivalent variation of a particular policy is the amount of wealth that would have to be given to or taken away from a dynasty under the base case scenario to leave the dynasty exactly as well off as it is under the policy scenario.<sup>11</sup>

Distributional Results: *J/S/W* use a different approach than DRI to examine the distributional issues associated with the imposition of a carbon tax and the choice of alternative recycling mechanisms. *DRI/CES/DECO* report a snapshot of income and expenditure patterns in a given year. *J/S/W*, however, use several different approaches to report on the effect of each tax and recycling policy on a particular group's or society's lifetime wealth, welfare, and equity. In effect, summing the differential impacts over time. *J/S/W* begin by examining the distributional impacts of alternative policies along several

demographic dimensions: household size, region of residence, and wealth. *J/S/W* then examine two alternative measures of aggregate social equity.

Demographic Dimensions: The four policies have significantly different effects on individual dynasties. Because the number of dynasties is large, *J/S/W* present results for a single representative dynasty and examine how those results change when the dynasty's demographic or economic characteristics are varied. The reference dynasty is an urban household in the Northeast with four members headed by a white male between the ages of 35 and 44 and having average wealth. Figure 4 presents the equivalent variations in 1990 dollars and as shares of each dynasty's lifetime wealth (to provide a more easily understood relative metric) associated with each tax recycling policy for the reference dynasty and for a selection of similar demographic groups differing only in household size.

The lump sum rebate has a uniformly negative effect across households of different sizes. In fact, the effect is negative for all 1344 dynasties, not just for those shown in Figure 4. As a percent of total wealth, the impact of the lump sum policy increases with household size. In contrast, the effect of the labor tax and the blended capital/labor rebates is positive for all dynasties in the table and, indeed, for all 1344 dynasties. Thus, imposing a carbon tax and using the revenue to lower marginal taxes on labor income, or blending a reduction of marginal labor and capital taxes, will actually improve the welfare of households relative to the base case. Aside from individuals living alone, the effect of the labor tax and the blended capital/labor rebates is essentially uniform across households of different sizes.

This uniformity across household size disappears under the capital tax rebate. For small households the policy has a positive effect, but as household size increases the effect diminishes and eventually turns negative. This occurs because a principal effect of the capital tax rebate is to stimulate capital formation by raising the after tax rate of return. As the

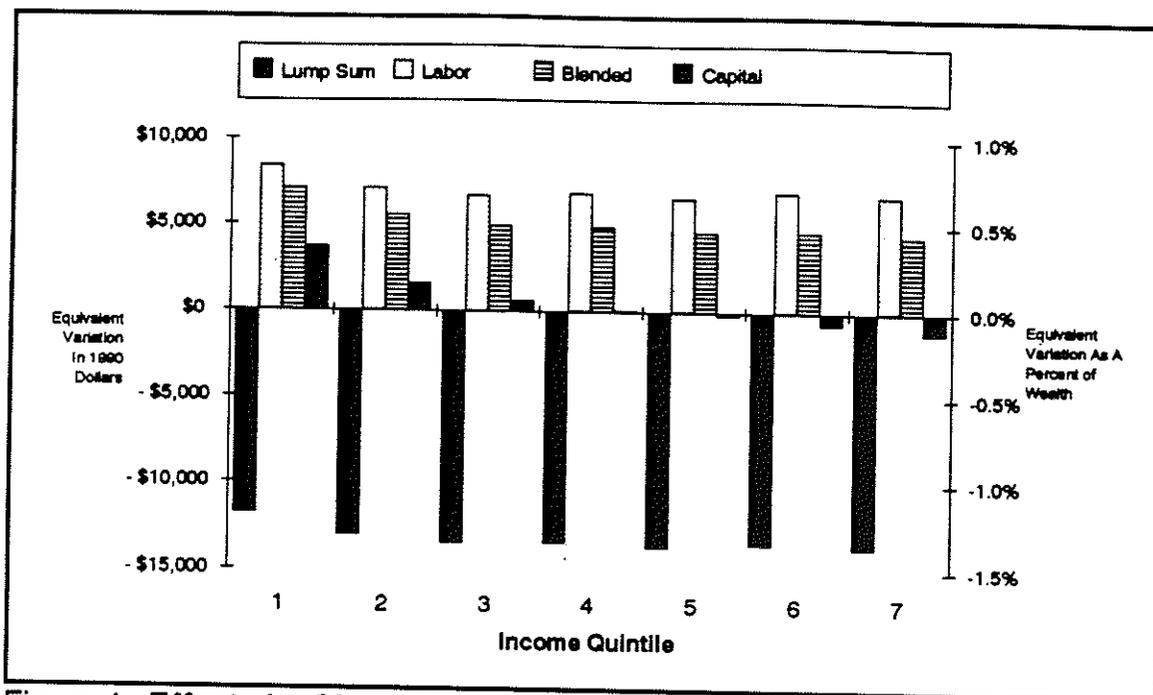


Figure 4. Effects by Size of Household (Equivalent Variation in \$1990 and as a Percent of Lifetime Wealth).

capital stock grows the price of capital services falls (see Figure 3) to the benefit of households with large budget shares devoted to capital services. The share of capital services in a household's consumption profile falls with household size. Thus, small households gain the most from the capital tax rebate. As household size increases, the rebate effect diminishes until the loss due to increased energy prices becomes dominant.

The results in Figure 4 underscore the inappropriateness of GNP as a measure of welfare. The capital rebate produces an increase in GNP in 2020, and the blended capital/labor tax rebate produces a smaller decrease in GNP than the labor rebate (see Table 4). But in terms of welfare, the labor rebate would be preferred. The higher rates of return under the capital rebate and the blended capital/labor rebate cause consumers to increase saving at the expense of current consumption relative to the labor tax rebate. Consumption eventually increases above the labor tax rebate case as the capital stock rises but not until 10 to 15 years after the policy is implemented. Moreover, investment (and hence saving) must be permanently higher to support the increased capital stock. In contrast, under the labor tax rebate consumption increases immediately. Thus, when each dynasty's lifetime equivalent variation is computed, the labor tax policy produces a higher value.

*J/S/W* also examine the effects of other demographic characteristics on the equivalent variations of different dynasties. Figure 5 presents results for the reference dynasty and dynasties differing from it by region of residence. As before, the lump sum rebate leads to reductions in welfare across all demographic groups while the labor tax and blended capital/labor rebates produce uniformly positive effects. The capital rebate gives mixed results with the sign of the effect depending on the share of capital services in the dynasty's consumption bundle. In all cases, dynasties living in the West are hurt least (or benefit the most) from each tax recycling policy while those in the Midwest are hurt most. A similar

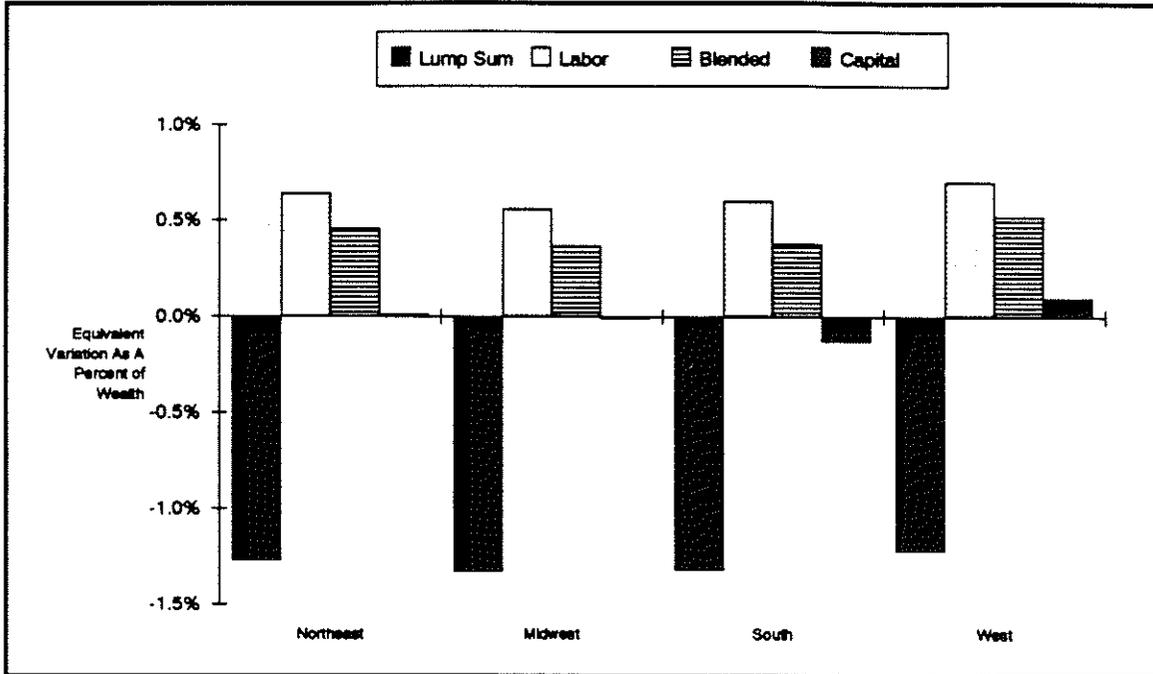


Figure 5. Effects by Regions of Residence (Equivalent Variation as a Percent of Wealth).

analysis shows that urban households are affected more negatively than farm households and that nonwhite dynasties or those headed by males tend to be affected more adversely than their counterparts.

In addition, *J/S/W* examine the effect of differences in lifetime wealth on the reference dynasty's equivalent variation under each policy. Figure 6 gives equivalent variations as shares of wealth for dynasties having average wealth, half of average wealth, and twice average wealth. In all cases, the effect becomes more positive as the dynasty's wealth increases. However, the variation across wealth levels is very small as a share of wealth.

Equity: Given these results on wealth, a natural question to ask is whether the policies are regressive. Because the number of dynasties is large, *J/S/W* constructed two aggregate measures to summarize the overall distributional effects of the tax. The first measure is an index of the *equality of the distribution of wealth*. Before the tax the index takes the value 0.58 on a scale in which 1.0 indicates perfect equality. After the carbon tax is imposed this measure drops by 0.0022 under the lump sum rebate, by 0.0026 under the labor tax rebate, by 0.0024 under the blended capital/labor rebate, and by 0.0020 under the capital tax rebate. Thus, this measure suggests that each of the policies reduces the equality of the distribution of wealth, although only slightly.

An alternative assessment of the welfare effect can be obtained using a *social welfare function*.<sup>12</sup> Furthermore, this approach allows the overall change in welfare to be decomposed into changes in efficiency and changes in equity, providing a second assessment of the distributional effects discussed above. *J/S/W* construct an appropriate social welfare function and use it to evaluate each policy. The function includes a parameter that governs aversion to inequality, so *J/S/W* report values for both maximum and minimum inequality aversion. The results are shown in Table 5.

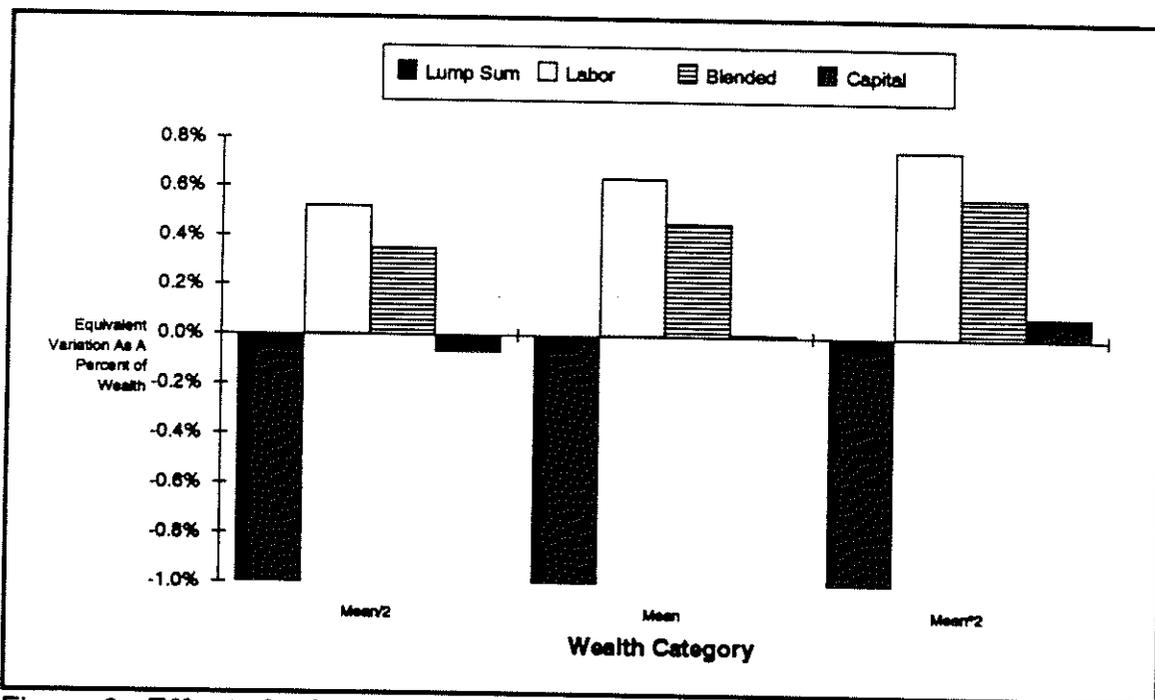


Figure 6. Effects by Level of Household Wealth (Equivalent Variation as a Percent of Wealth).

In general, these figures reiterate the results presented above. Under a carbon tax with a lump sum rebate social welfare drops substantially because the tax has a large negative effect on efficiency. The equity effect varies in sign but is very small for both maximum and minimum inequality aversion. (This effect is discussed in detail in Jorgenson, Slesnick and Wilcoxon, February, 1992). The labor tax and blended capital/labor tax rebate policies reverse the efficiency effect but at the cost of reducing the equality of wealth; the result is a small net increase in social welfare. The capital rebate essentially neutralizes the efficiency loss of the carbon tax at the cost of a slight decrease in equity; the result is a very small decrease in social welfare.

In summary, *J/S/W* find that the welfare effects of a carbon tax are fairly small, but that they can be strongly affected by the use of revenues from the tax. Using the revenue to reduce the marginal tax on labor, or blending a capital and labor marginal tax reduction, would actually leave households better off under the carbon tax than they were without it. A capital tax rebate would ameliorate the adverse impact of the carbon tax to an extent, but it would have uneven distributional effects with some households being made better off relative to the base case while others would be left worse off. Under each of the rebate policies they examine, the overall effect of the tax-plus-rebate scheme is slightly regressive.

#### URBAN INSTITUTE/*TRIM2*

The Urban Institute is engaged in a multi-stage analysis of the demographic impacts of a carbon tax. In this initial stage, the Urban Institute linked output from the DRI macro model to the *TRIM2* microsimulation model to simulate the effects of changes in personal incomes (e.g., changes in wages, inflation-indexed transfer programs, and tax liability) due to the institution of a carbon tax. The current stage of analysis examines changes in income and

taxes within each income decile.<sup>13</sup> Shifts in employment and consumption patterns will be analyzed in a later stage. Because they did not "age" the demographic file, the Urban Institute thought it most appropriate to focus the initial stage of analysis on the effects of a carbon in the near term and, therefore, chose the year 1994.<sup>14</sup>

**Table 5. Effects on Aggregate Welfare**  
(Billions of 1990 Dollars & Percent of Lifetime Wealth)

Rebate Scheme	Inequality Aversion	Social Welfare	Efficiency	Equity
Lump Sum	Max	-\$878 -0.75	-\$1035 -0.8%	+\$157 +0.1%
	Min	-\$1170 -0.9%	-\$1035 -0.8%	-\$135 -0.1%
Labor	Max	+\$408 +0.3%	+\$1260 +1.0%	-\$852 -0.7%
	Min	+\$605 +0.5%	+\$1260 +1.0%	-\$655 -0.5%
Blended Capital/Labor	Max	+\$256 +0.2%	+\$956 +0.8%	-\$700 -0.6%
	Min	+\$403 +0.3%	+\$956 +0.8%	-\$553 -0.4%
Capital	Max	-\$105 -0.1%	+\$241 +0.2%	-\$345 -0.3%
	Min	-\$76 -0.1%	+\$241 +0.2%	-\$317 -0.3%

A microsimulation model differs from other types of models in that it operates on individual units rather than aggregate information. In the social sciences, those units are individual economic units. The database used as input to a microsimulation model contains records describing persons, households, or businesses; in computer programming jargon, the input database is a "microdata file." A computer program applies a set of rules to each

individual record. The result of the computations might be the amount of taxes owed by the unit or the dollar amount of benefits to which the unit is entitled under a government program. Each individual result is multiplied by whatever weight is associated with the unit in the microdata file. The weighted individual results are then added together to obtain the aggregate result.

*TRIM2* is a microsimulation model of tax and transfer programs affecting households and individuals. The input to the model is each year's March Current Population Survey (CPS) — a representative sample of approximately 60,000 households. The March CPS includes detailed information on income, employment, and demographic characteristics, for each person in the sampled households. *TRIM2* adjusts the raw CPS data to add and improve several income categories:

- Interest and dividend incomes are adjusted to compensate for under-reporting.
- Capital gains income is imputed.
- Social Security Income (SSI), Aid to Families with Dependent Children (AFDC), and Food Stamps are simulated with detailed modeling to account for under-reporting.
- Federal tax liability is simulated, including deductions and credits.
- Payroll tax liability is simulated.

With the improved and additional income data, the *TRIM2* provides a more accurate description of the baseline U.S. income distribution, and, thus, a more accurate basis for analysis of the post-carbon tax income distribution than a raw CPS file.

For the carbon tax recycling scenario analyses, DRI's estimates of changes in seven income categories were mapped on to *TRIM2*'s income categories. At this stage of the analysis, all recipients of a particular type of income had the same modifications made to that income. E.g., all wage earners, regardless of income level or industry of employment, had

their wage income reduced by an identical percentage.<sup>15</sup> Taxes were modeled using current tax law.

Distributional Results: The Urban Institute/*TRIM2* analyses examined two scenarios for the recycling of the carbon tax revenues: (1) the revenues were used to lower the federal deficit (i.e., revenue raising scenario); and (2) tax revenues were recycled through a reduction in the personal income tax rate (i.e., personal income tax reduction scenario). The results are reported below by income categories. Figures 7 and 8 summarize the pre-tax and post-tax changes in income for both scenarios.

Earned Income: In the revenue raising scenario, overall average nominal earned income (i.e., wages, self-employment income, farm income) drops by 0.1%; average earned income falls by approximately the same percentage in each decile. In the personal income tax reduction scenario, overall earned income drops by 0.01%; average earnings rise in the first, second, eighth, and ninth deciles, and fall slightly in the third through seventh and the tenth. However, the magnitudes of the changes are sufficiently small that the distribution of earnings across deciles is virtually unchanged in both scenarios.

Unearned Income: In the revenue raising scenario, nominal unearned income (i.e., interest, dividends, net rental income) and transfer payments (i.e., SSI, AFDC, unemployment compensation, workers compensation, and veterans benefits) change slightly; the largest change being a 2.3% drop in net rental income. The overall distribution of these types of income shifts slightly, with the share in the top decile falling from 38.5% to 38.3%. In the personal income tax reduction scenario, interest income increases by 2.0% and net rental income falls dramatically by 43%.<sup>16</sup> The decile most affected is the richest decile, in which 24% of families have rental income. Average unearned income in the top 5% of the income distribution falls by 2.2%, from \$60,633 in the baseline to \$59,320 (in 1994 dollars). The fifth

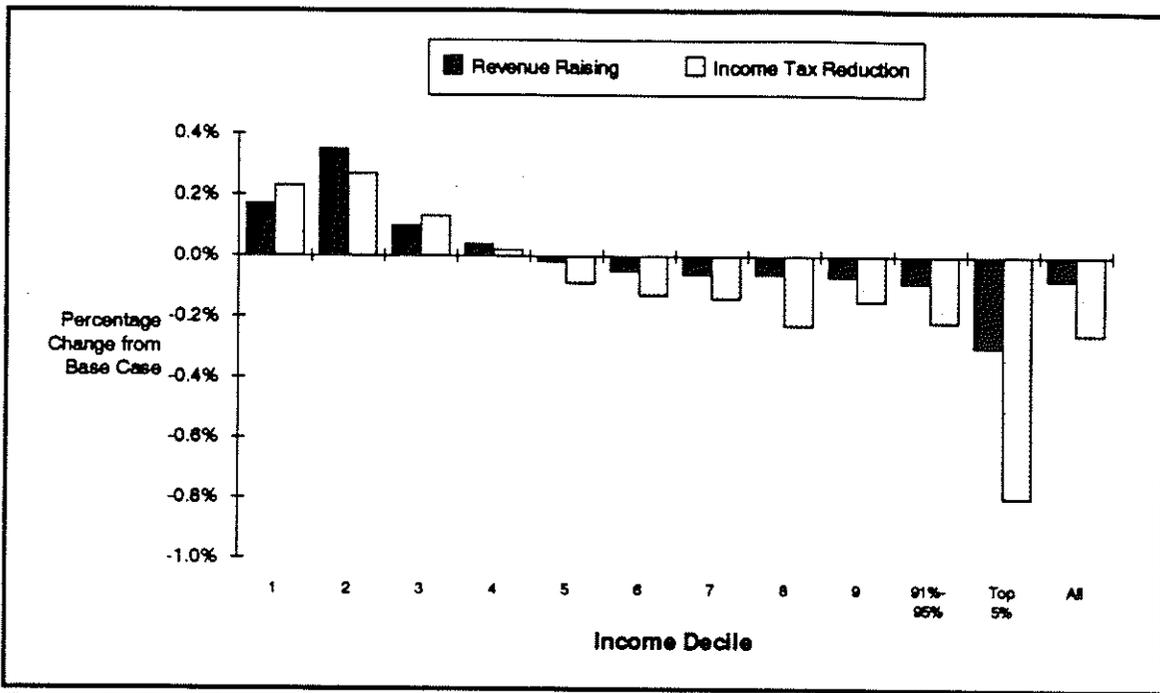


Figure 7. Pre-Tax Nominal Income Effects In 1994.

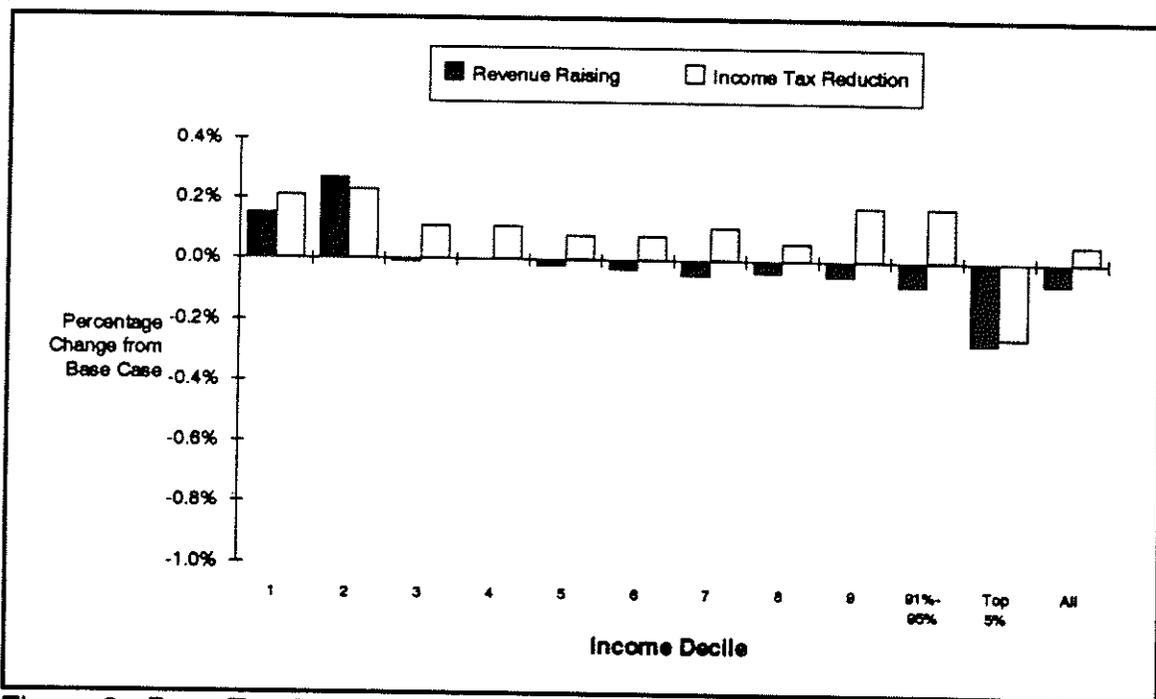


Figure 8. Post-Tax Nominal Income Effects in 1994.

through ninth deciles experience lower average levels of unearned income than in the baseline. The distribution of these types of unearned income thus shifts in favor of the lower 40% of the income distribution.

Secondary Effects On Transfer Programs: In both the revenue raising and the personal income tax reduction scenarios, overall SSI and AFDC benefits are predicted to fall due to the estimated increases in the other forms of income of SSI and AFDC recipients.<sup>17</sup>

Effects of Income Tax Reduction: In the personal income tax reduction scenario, the Urban Institute reduced each of the marginal personal income tax rates by the same percentage in order to achieve the DRI-estimated 2.7% reduction in total federal personal income tax collections relative to the baseline simulation.<sup>18</sup> The taxpaying families in the first three deciles pay higher taxes than in the baseline, despite the rate reduction, due to the estimated increase in their taxable incomes. In all other deciles, however, taxes are lower than in the baseline. The percentage reduction in average taxes is greater in the top deciles, which were hit hardest by the estimated reduction in rental income. As a percentage of all cash income, federal income tax liability falls from 11.86% in the baseline to 11.58% when carbon taxes are recycled through the personal income tax.

Net Effects: Overall pre-tax cash income to families (in nominal terms) is estimated to fall by 0.08% in the revenue raising scenario and by 0.26% in the personal income tax reduction scenario. In both scenarios, the lowest four deciles see increases in pre-tax cash incomes while the upper six deciles see decreased incomes. The pre-tax cash income of the top 5% falls by 0.3% in the revenue raising scenario and by 0.8% in the personal income tax reduction scenario. The effect of recycling of carbon tax revenues through a reduction in personal income taxes shows up in a comparison of post-tax incomes. Overall post-tax income for families is estimated to fall by 0.07% in the revenue raising scenario, but to rise by 0.06%

in the personal income tax reduction scenario. In the revenue raising scenario, post-tax income falls for all deciles except the two lowest and remains unchanged for the fourth decile. In the personal income tax reduction scenario, however, post-tax income rises for all but the top 5%. It is important to note that in both carbon tax scenarios DRI estimated the CPI would be 1.8% higher in 1994 than without a carbon tax. Therefore, nominal increases of less than 0.8% still constitute small losses of real income.

Focusing on income effects alone, and assuming that all recipients of a particular type of income experience the same change in that income, the current *TRIM2* simulations show the greatest negative impact on the top decile of the income distribution. The DRI macro model predicts that a carbon tax of the magnitude being considered in this analysis would reduce certain types of incomes that are held largely by richer families — i.e., rental income, dividend income, and in one scenario, self-employment income. Wage income — the type of income held by the broadest spectrum of families — is projected to be little effected.

The current *TRIM2* simulations also indicate the importance of tax recycling mechanisms. In both scenarios analyzed, the same decile — the top decile — was hardest hit. When there was no change in personal income taxes, the reduction in the top decile's post-tax income was the same as in pre-tax income. With a reduction in personal income tax rates, the negative effects of the carbon tax on this group were mitigated; the reduction in post-tax income was much less than the reduction in pre-tax income. Other tax recycling mechanisms might or might not have this property.

## QUALITATIVE ANALYSIS OF EMPLOYMENT EFFECTS

The extent of welfare losses may not be fully captured by aggregate figures if there are structural changes which lead to prolonged unemployment in certain sectors of the economy.

To help answer some of these questions, the Urban Institute has conducted some preliminary qualitative analysis of the likely employment effects.

In DRI's personal income tax recycling scenario civilian employment is reduced 0.2% below baseline levels and nonagricultural civilian employment is reduced by 0.3%. These reductions are small in aggregate terms; however, one needs to look behind these numbers at the structural change that they imply in order to determine any disproportionately greater impact on lower income families. If low income workers are disproportionately represented in industries most impacted, aggregate data (i.e., analysis based on generic income categories) may not accurately reflect actual losses (or gains) in welfare.

Five industrial sectors are projected by DRI to have employment losses greater than 0.9% in the first five years of the carbon tax in at least one of the scenarios analyzed: (1) lumber and wood products (in 1994, employment loss relative to base line estimates are 0.77% in the revenue raising scenario, and 1.16% in personal income tax reduction scenario); (2) stone, clay, and glass (0.56% and 0.94%); (3) primary metals (0.69% and 0.96%); (4) contract construction (0.76% and 1.5%); and, (5) mining (1.0% in both scenarios). Of those five industrial sectors, only construction has significant employment in the lowest two income deciles; 8% of employed family heads in the lowest decile are employed in construction, and 8% in the second lowest decile. However, within these two lowest deciles, only 38% of the lowest and 51% of the second lowest have wage income. Thus, it appears that employment loss in the lowest deciles will be small.

Moreover, nominal earned income for the lowest two deciles increased slightly for the tax recycling scenario for 1994, the year *TRIM2* was used to simulate the distributional effects of a carbon tax. Increases were about 0.05% for the lowest decile and 0.01% for the second lowest, compared to a 0.01% increase for earned income overall. In the case of the revenue

raising scenario, income for deciles one and two declined by 0.03% and 0.08%, respectively, while earned income declined overall by 0.10%.

Based upon a qualitative assessment, the impacts are small under the current scenarios, both with respect to changes in employment as well as income. Under the circumstances, it appears unlikely that structural changes in employment will create significant undetected changes in welfare. However, if the taxes were larger, causing greater structural changes in the economy, the situation would have to be reevaluated. These results should be verified by a more rigorous analysis.

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## ENDNOTES

1. This is a draft of a paper that has been submitted to the Stanford Energy Modeling Forum Report #12. The views expressed in this paper are those of the authors and do not represent the views of the United States Environmental Protection Agency.
2. Poterba (1990) is a notable exception. In that study, Poterba uses a partial equilibrium approach to assess the regressivity of a carbon tax on households measured in terms of both income and consumption expenditure. He finds that the carbon tax is slightly regressive, but that "the findings based on the expenditure measure of incidence are less dramatic than those based on income rankings."
3. A population of households can be measured across an infinite number of characteristics — income, expenditures, region, size, race, etc. — and it is a matter of judgment and policy interest how best to capture the salient effects of a tax on a population.
4. At a more fundamental level, the distribution of income (or expenditures) *per se* is a significant indicator of equity only if income differences are a true reflection of utility differences.
5. Both expenditure and income analyses may obscure the true incidence of taxes when grouping households by expenditure or income categories. More than one-third of the households in the lowest income class spend nothing on gasoline, and these would likely be made better off by a gasoline tax (or carbon tax), as their indexed incomes would increase more than expenses. The flip side of this is that those who spend more than 10% of their income on gasoline are also concentrated in the poorer households. Nearly one in six households in the lower half of the expense distribution spend more than 10% on gasoline, and this may be one area where traditional regressivity concerns are valid.
6. Previous research using the DRI macro model, the Jorgenson/Wilcoxon computable general equilibrium model, and two other models has examined the GNP effects of alternative carbon tax regimes and revenue recycling options. Despite a variation of predicted outcomes across the models, a general hierarchy of revenue recycling options clearly emerges from the results. Revenue recycling options that encourage capital formation tend to offset the effect of the carbon tax on output (as measured by GNP) better than do options that encourage final consumption, private or public. (See Shackleton, et. al., 1992.)
7. For the final paper, the Urban Institute will examine the three recycling scenarios described in the DRI/CES/DECO analysis (lump sum rebate, personal income tax rebate, and personal income tax rebate blended with an investment tax credit).
8. Of course, consumers will respond to higher price levels and adjust their consumption patterns accordingly. Thus assuming that consumers would continue to consume the same proportions of goods whose relative prices had changed tends to overstate welfare losses. On the other hand, to look only at prices on quantities after the price changes, understates welfare losses. To see this, consider an extreme case in which consumers give up the consumption of the only good

whose price has risen. In this case, measuring welfare losses based on final purchases, gives the result of zero welfare loss. Thus, the aggregate costs of higher prices to consumers will be over-estimated using one method or under-estimated using the other. In this analysis, DRI has taken the former approach.

It should be noted that given the relatively modest levels of carbon tax in the three simulations examined, the error caused by this assumption is quite small. As an example, in the simulation in which revenues are recycled through the proportional reduction in personal income taxes, the consumer cost of higher prices is estimated at \$205.8 billion, using base case real consumption levels. Using post-policy real consumption levels reduces this loss to \$202.6 billion.

9. DRI did, however, adjust for changes in the demographic structure of the population that are forecast to occur over the next two decades using DRI's *DECO* forecast. Thus, although the lowest income quintile is expected to account for the same fraction of U.S. health-care spending over the next 20 years, the fraction spent by the youngest age group and the smallest household size have both been adjusted in accordance with the projected change in their share of total households. Cost per household is then found by dividing the total for each demographic group by the number of households in that group in the year in question.

10. *DECO* is based on the Current Population Survey (CPS) of the United States and uses a definition of income called *Census Money Income*. This definition excludes capital gains, wages-in-kind, income from owner-occupied housing, and other sources of "non-money" income. This results in a significantly different concept of income from that contained in NIPA, but, nonetheless, has the advantage of being consistent with the consumption categories in DRI's macro model. Moreover, given the very different behavior of rental, interest, and proprietors income in these simulations, it was felt that *DECO* could not adequately simulate the effects on income distribution for particular demographic sub-groups of policy-induced changes in these income sources.

An alternative methodology was, therefore, used to estimate income distributions. This involved allocating income by source from DRI's macro model to demographic subgroups according to their share of that income source as reported in the 1989 CES. Although the description of income by source does not precisely match that in the NIPA accounts, it is believed that errors caused in translation are relatively slight. In addition, this method had the advantage of allocating all of NIPA income, thus preventing the under-representation of non-wage income that is characteristic of both the CES and the CPS.

11. The equivalent variation is the wealth required to attain the welfare associated with the carbon tax at prices in the base case less the wealth for the base case. If the equivalent variation is positive, then the carbon taxes induce a gain in lifetime welfare for the dynasty; otherwise, the policy change results in a welfare loss. The equivalent variations in wealth enable one to rank the reference policy and any number of alternative policies in terms of a money metric of the lifetime welfare levels of the dynasty.

In applied welfare economics, two alternative measures of changes in welfare are commonly used: *compensating variation* and *equivalent variation*. Compensating variation is a measure of

the change in an individual's welfare following, for example, a change in prices. The compensating variation is the maximum amount of income that could be taken from someone who gains from a particular change while still leaving him no worse off than before the change. The compensating variation of the loser from some change is the minimum amount he would have to be paid following the change to leave him as well off as he was prior to the change. (I.e., how much income would someone have to be given at the new price level to remain whole.) The equivalent variation is the minimum amount that someone who gains from a particular change would be willing to accept to forgo the change. The equivalent variation of the loser from some change is the maximum they would be willing to pay to prevent the change. (I.e., how much income would someone have to be given at the old price level to remain whole.)

12. A full definition of the social welfare function used may be found in Jorgenson/Slesnick/Wilcoxon (April 1992).

13. The income concept used to define the deciles is post-tax, i.e., cash income minus federal income tax and payroll tax.

14. The Urban Institute's TRIM2 simulations are based on an initial linkage with the DRI macro model and should be viewed as preliminary; more reliable and comprehensive conclusions regarding the distributional impact of a carbon tax should await further analysis. The linkage does not take into account the fact that some earners will lose their jobs entirely, others will have no change in wage, and others will have increased earnings. Furthermore, the price effects of a carbon tax could have important consequences on real purchasing power, and those effects could vary by income decile; price effects are not included in the simulations.

15. An assumption of an identical percentage change in each person's income is perhaps more realistic for the categories of unearned incomes and transfers than in the case of earned income. If overall interest levels increase, all savers will earn more money on their deposits. However, changes in dividend income would vary by the particular industry of investment; these variations are not captured in the current analysis.

16. Although rental income as reported on the CPS is a net figure, net of rental expenses, it is not entirely comparable to the DRI net rental income concept. In further analyses, the Urban Institute may examine other options for estimating changes in the CPS-based net rental income figures.

17. These results are sensitive to the ordering of the changes in various income types, and should not be viewed as a statement that a carbon tax would reduce welfare expenditures.

18. The DRI macro model contains only one average and one marginal federal income tax rate. In DRI's macro simulations the personal income tax cut was implemented by reducing the average tax rate from 12.7% to 12.3%. The Urban Institute TRIM2 model, however, has a more detailed representation of the income tax code. In TRIM2 simulations the marginal tax rates were lowered such that the same percentage reduction in personal income tax liabilities was achieved. The 15% rate was lowered to 14.70%, the 28% rate to 27.44%, and the 31% rate to 30.38%.