CONTEMPORARY ECONOMIC POLICY

DISTRIBUTIONAL IMPACTS OF GREENHOUSE GAS EMISSIONS TRADING: ALTERNATIVE ALLOCATION AND RECYCLING STRATEGIES IN CALIFORNIA

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Cap and trade remains attractive to many state governments because it provides a much-needed source of additional revenue when greenhouse gas emission allowances are auctioned to the highest bidder. We analyze the income distribution impacts of the California Global Warming Solutions Act under alternative policy designs. These include the free allocation of emission allowances versus recycling of auction revenues through proportional income tax relief and a per capita dividend. The analysis is undertaken under conditions where significant economic gains, rather than losses, are projected for the policy, and in the context of the new electricity pricing regulatory environment in which passing along the opportunity costs of using free allowances may not be approved. We adapt and enhance the Regional Economic Models, Inc. Policy Insight Plus Model and apply it for the first time to estimate the income distribution impacts of cap and trade. The analysis illustrates the importance of considering macroeconomic impacts and identifies important efficiency-equity tradeoffs. The method and results are generalizable to the dozens of states and regions still formulating or revising climate action plans in the United States and to many regions and nations around the world. (*JEL* D31, R11, Q54)

I. INTRODUCTION

Thirty U.S. states have completed or are in the process of drafting climate action plans. Emissions trading, or "cap and trade," features are integrated into most of these plans, including collaboration among states in regional greenhouse gas (GHG) trading consortia (Regional Greenhouse Gas Initiative—RGGI 2007). Forward movement has been slowed by the current recession, but cap and trade remains attractive to many state governments because it provides a much-needed source of additional revenue when GHG emission allowances are auctioned to the highest bidder. Revenues can be used for a variety of purposes such as cutting state budget deficits, offsetting existing distorting or burdensome taxes, investment in research and development of clean technologies, and

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ABBREVIATIONS

CARB: California Air Resources Board
CGE: Computable General Equilibrium
EAAC: Economic and Allocation Advisory Committee
FTB: Franchise Tax Board
GHG: Greenhouse Gas
I-O: Input-Output
IRS: Internal Revenue Service
MSIDM: Multisector Income Distribution Matrix
REMI: Regional Economic Models, Inc.
RGGI: Regional Greenhouse Gas Initiative

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compensating key groups adversely affected by the policy.

The distributional impacts of policy alternatives are important for two reasons. First is the normative goal of equity, or fairness. Of special concern is the impact of GHG mitigation on low-income households because they tend to be more vulnerable to economic losses. Lower income groups spend a higher proportion of their income on necessities, such as electricity and gasoline, and these goods are among those most likely to have their prices affected by climate policy (Parry and Williams 2010). Revenue recycling can help overcome negative income impacts. Second, distributional impacts are important for reasons of positive economics of predicting the outcome of the policy-making process (Parry and Williams 2010; Rose, Stevens, and Davis 1988). This perspective typically shifts many policy makers' attention to powerful special interest groups. It has led to greater willingness to consider the free granting of GHG emission allowances to emitters, mostly businesses. A fairness aspect arises here as well in that many emitters see free granting as a way of compensating them for potential economic losses from undertaking GHG mitigation.

The distributional impacts are complicated by the workings of climate action plans. GHG mitigation polices will have a major effect at the site of their implementation. Some of the options, such as energy efficiency, can result in cost savings directly to businesses, households, non-profit institutions, and government operations that implement them, and they can also provide gains to business and household customers if the savings are passed on in the form of lower prices. It is likely that other options will incur costs to businesses or households, thereby affecting their competitiveness or purchasing power. Many entities will try to recoup these cost increases by raising their prices and passing the burden on to their customers. Net impacts will be affected by various types of indirect effects stemming from economic interdependence. Increases in demand ripple through the economy generating a set of successive rounds of positive multiplier effects on suppliers. Cost savings are passed along to several rounds of customers to add further to the stimulus. Cost increases and decreases in demand in other sectors will have their own ripple effects on different sets of suppliers and customers. The interactive sum of all of these price and quantity effects for the entire economy represents a set of macroeconomic effects whose outcome cannot easily be predicted a priori.

In this study, we analyze four GHG emission allowance allocation/recycling alternatives for the California Global Warming Solutions Act for the target Year 2020. We adapt the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI^+) model (REMI 2010), and supplement it with a Multisector Income Distribution Matrix (MSIDM) to update and heighten the resolution of income distribution considerations. First, we examine the recycling of revenues through proportional income tax relief and a per capita dividend (lump sum transfer). Then we examine the distributional impacts of free allocation under conditions where the opportunity costs of free allowances can and cannot be passed on to purchasers of products generating the emissions. While we do not consider all possible recycling alternatives, the article makes several important contributions to the literature. It provides insights into the relative merits of four major distributional alternatives. Moreover, the analysis is performed in a new context where there are significant economic gains, rather than losses, projected from a cap and trade system, and under conditions of the new electricity pricing regulatory environment in which passing along the opportunity costs of using free allowances may not be approved. It also illustrates how the REMI model can be used to evaluate these polices in a macroeconomic context. The model is the most widely used state-level macroeconometric modeling software package in the United States, and has been used extensively to examine aggregate impacts of climate action plans, but our analysis shows how it can be used to address important distributional impacts. The analysis illustrates the importance of considering macroeconomic impacts and identifies some important efficiency-equity tradeoffs. The results are generalizable to the dozens of states and regions still formulating or revising climate action plans in the United States and to many regions and nations around the world.[1]

This article is divided into seven sections. Section II describes the major assumptions of the policy case simulated in this study. Section III summarizes the REMI PI^+ model we use to estimate the macroeconomic impacts, as well as an overview of the input data. Section IV

1. The REMI Model is typically thought of being specific to U.S. regions, but it has been constructed for Canada and several European countries. Moreover, plans are underway to develop the model for use in Chinese provinces.

presents a summary of the MSIDM methodology. Section V presents and interprets the aggregate and sectoral simulation results. Section VI presents and interprets the impacts on the size distribution of personal income. Section VII provides a summary and some policy implications.

II. POLICY DESCRIPTION AND ASSUMPTIONS

The California Global Warming Solutions Act of 2006 (Assembly Bill [AB] 32) established a state GHG emissions cap for Year 2020 and other target years. AB32 directed the California Air Resources Board (CARB) to develop a Scoping Plan to identify technically feasible and cost-effective GHG reduction options. The Plan includes both a number of "complementary policies" and a cap and trade program. The complementary policies include Pavley II Vehicle Standards, Low-Carbon Fuel Standard, Vehicle Miles Traveled Reduction, 33% Renewable Portfolio Standard, Energy Efficiency, and Combined Heat and Power. Appendix A presents brief descriptions of these policies.

CARB defined five policy cases for implementing AB32. Each of the cases represents a combination of the cap and trade program and six complementary policies under different assumptions regarding scope and effectiveness. For example, Policy Cases 1 and 2 both assume that 100% of the reduction goals of the complementary options can be achieved, but Case 1 allows the use of offsets for compliance.[2] In this study, we analyze only Case 1, with different assumptions about the distribution of GHG allowances.

We analyze the attainment of the CARB goal of reducing emissions of six major categories of GHGs by 15% below 2005 levels by the Year 2020. This calls for a phase-in of sectors covered by the cap, such that all sectors other than Agriculture, Forestry, and Solid Waste are covered by the target year. Covered sectors include electricity and large industrial, as well as transportation/commercial/residential fuels and small industrial emitters. The policy case allows for the use of offsets and banking. Autonomous energy efficiency improvement, that is, technology development that would have occurred anyway without the policy, is assumed to average 1.5% per year for the economy as a whole.

2. Other cases are described in CARB (2010) and Rose, Wei, and Prager (2010).

TABLE 1
Allowance Allocation and Income Distribution Scenarios

S1. CARB Case 1 with 100% auction of GHG emission allowances
- a. Revenue recycled as proportional personal income tax reduction
- b. Revenue recycled as per capita dividend

S2. CARB Case 1 with 100% free allocation of GHG emission allowances
- a. 0% pass through of opportunity costs of allowances
- b. 100% pass through of opportunity costs of allowances

In this study, we will examine four alternative allowance allocation and revenue recycling scenarios (defined in Table 1) relating to the distributional impacts of CARB Case 1. These scenarios follow the recommendations of the CARB Economic and Allocation Advisory Committee (EAAC 2010). Note that revenue recycling options are much more limited at the state and regional level than at the federal level (e.g., payroll and social security taxes are only the purview of the latter).

III. REMI MODEL ANALYSIS

A. REMI PI$^+$ Model

Several modeling approaches can be used to estimate the regional aggregate and distributional economic impacts of environmental policies, including both direct (on-site) effects and various types of indirect (off-site) effects. These include: input-output (I-O), computable general equilibrium (CGE), mathematical programming, and macroeconometric models. Each has its own strengths and weaknesses (Partridge and Rickman 2010; Rickman and Schwer 1995).

The choice of which model to use depends on the purpose of the analysis and various considerations that can be considered as performance criteria, such as accuracy, transparency, manageability, and costs. After careful consideration of these criteria, we chose to use the REMI Policy Insight Plus (PI$^+$) model (REMI 2010). The REMI PI$^+$ model is superior to the others reviewed in terms of its forecasting ability and is comparable to CGE models in terms of analytical power and accuracy. Moreover, the research team has developed a methodology for applying the model successfully in aggregate analyses in the states of Florida, Pennsylvania, Michigan, and New Mexico (Rose and Wei forthcoming;

Rose, Wei, and Dormady 2011; Miller, Wei, and Rose 2010; Rose, Wei, and Miller 2010).

The REMI model has evolved over the course of 30 years of refinement (Treyz 1993). It is a packaged program, but is built with a combination of national and region-specific data. Government agencies in practically every state in the United States have used a REMI model for a variety of purposes, including evaluating the impacts of the change in tax rates, the exit or entry of major businesses in particular or economic programs in general, and, more recently, the impacts of energy and/or environmental policy actions.

A detailed discussion of the major features of the REMI model is available online at www.remi.com or from the authors. We simply provide a summary for general readers here. A macroeconometric forecasting model covers the entire economy, typically in a "top-down" manner, based on macroeconomic aggregate relationships such as consumption and investment. REMI differs somewhat in that it includes some key relationships, such as input substitution, in a bottom-up approach. In fact, it builds on the finely grained detail of a 169-sector I-O model, thereby capturing important structural distinctions. This is especially important in a context of analyzing the impacts of GHG mitigation actions, where various options were fine-tuned to a given sector or where they directly affect several sectors somewhat differently. The model is able to analyze the quantity interactions between sectors (ordinary multiplier effects), as well as the responses of producers and consumers to price signals. The REMI model also brings into play features of labor and capital markets, as well as trade with other states or countries, including changes in competitiveness.

B. Input Data

The direct costs or savings of individual mitigation policy options we utilize stem from the analysis in CARB (2010), which is based on the ENERGY 2020 model (ICF 2010) simulations. These results are translated to model inputs that can be utilized in the REMI model, which is carried out by linking them to appropriate variables, parameters, and policy levers to simulate policy impacts.

Major ENERGY 2020 outputs include the following:

- GHG emission reductions by sector.
- Electricity generation by fuel type.
- Electricity purchases by sector.
- Utility generating cost.
- Fuel prices by sector.
- Fuel expenditures by sector.
- Equipment investment by sector.
- Self-generation investment by sector.
- Process investment by sector.
- Vehicle fuel efficiency.

The basic data represent two sets of GHG mitigation policy options: complementary policies implemented via regulation and the policy options implemented under the cap and trade program (implemented primarily through individual emitter choice in response to price signals). The reader is reminded of the uncertainty revolving around mitigation cost estimates (Golub, Markandya, and Marcellino 2006). However, the data were vetted extensively by the CARB.

IV. INCOME DISTRIBUTION METHODOLOGY

A. Background

Distributional impacts of climate policy have received increased attention in recent years (Burtraw and Palmer 2008; Hassett, Mathur, and Metcalf 2009; Metcalf 2009; Parry and Williams 2010; Parry et al. 2006; Rausch et al. 2010). Households can be impacted by climate policies through numerous avenues. They are affected by the level and composition of changes in economic activity in individual sectors, such as changes in wages, profits, and job opportunities. Households are also impacted if the prices of GHG-intensive products increase in response to the policy. The degree to which such production cost increases are passed onto consumers depends on the competitiveness of the market and the extent of government regulation. Moreover, all these changes vary across sectors, socioeconomic groups, and geographic areas (Burtraw and Palmer 2008; Fullerton 2008; Oladosu and Rose 2007; Rose and Oladosu 2002).

These impacts clearly have normative implications in terms of equity, such as the size distribution of personal income across all households or in terms of the lowest income groups more specifically. The differentiated allocation of allowances across sectors has equity implications as well. Poorer households tend to earn higher proportions of income in negatively impacted sectors, as well as spending greater proportions of incomes on carbon-intensive products. Hence, climate policies without any redistributive component have often been found to be regressive (Parry 2004; Parry and Williams 2010).[3]

The issue of income distribution arises prominently in the context of emission allowance trading. The Coase Theorem (1960) states that the manner in which property rights are allocated will not undercut efficiency objectives, as long as transaction costs are low and there are no significant income effects. This provides policy makers with considerable leeway in deciding how to distribute allowances in the first place, whether by free allocation or by auction to the highest bidder. However, real world complications, especially surrounding the distribution of proceeds of the auctioning approach, reveal the potential for efficiency-equity tradeoffs.

Numerous recent studies of emissions trading have examined the impact of recycling auction-generated revenues, with the general consensus being that redistribution can enable a previously regressive policy to become progressive (Burtraw, Sweeney, and Walls 2009; Oladosu and Rose 2007; Parry and Williams 2010). However, Parry and Williams (2010) show that such redistribution can result in reduced efficiency. These authors also show that this efficiency-equity tradeoff is particularly pronounced for some revenue-recycling mechanisms. Using revenues to cut income taxes appears to be the least costly approach, yet it is regressive. Lump sum dividends on the other hand are progressive, yet appear to be the most costly. Burtraw, Sweeney, and Walls (2009) obtain different results when examining a range of possible revenue recycling alternatives for compensation, including reductions in payroll tax and income tax, lump sum payments, and expansions in the Earned Income Tax Credit program, where the latter two are found to be the least regressive (Burtraw and Palmer 2008; Metcalf et al. 2008). Other options for revenue recycling, such as investment in research and development for alternative energy technologies, have been found to be less regressive, especially in the short term (Burtraw, Sweeney, and Walls 2009).

Although revenue recycling offers the opportunity for more equitable outcomes, it is important to note that revenue generating auctions have rarely been implemented as a component of emissions trading systems. Of the major emissions trading systems worldwide, only the RGGI in North America has a substantial proportion of allowance auctioning (as opposed to free granting).[4] This encourages further assessment of the distributional impacts of free allocation approaches, including conditions of the new electricity pricing regulatory environment, which may not approve passing along the opportunity costs of using free allowances.

B. Basic Modeling Considerations

Pre-policy household income distribution data for California is unavailable, so a combination of U.S. Internal Revenue Service (IRS 2010), California Department of Finance (2010), California Employment Development Division (2010), and California Franchise Tax Board (FTB 2010) data is used to develop it (see the first two columns of Table 4 for the results). This is justified on the basis that IRS income distributions are similar for California and the United States, and that California median income of $55,450 (U.S. Census 2010) is similar to the U.S. median income of $50,233 (U.S. Census 2010). With respect to the generality of our results, this indicates that California is a fairly representative state.

The REMI model is disaggregated for only a coarse grouping of five income brackets, and its income distribution data have not been updated to match the rest of the model. We supplement the REMI model with our development of a MSIDM for California, which consists of the distribution of income payments by sector for each of the ten income brackets. Following the method of Rose, Stevens, and Davis (1988) and Li, Rose, and Eduardo (1997), the MSIDM is constructed directly using or adapting data from the U.S. Bureau of Labor Statistics Occupational Employment Statistics Division (2010), the U.S. Census Bureau (2010), IRS (2010), California FTB (2010), and IMPLAN (MIG 2010).

To capture the dynamic impacts of the models, we focused on the five considerations in

3. However, as Fullerton and Metcalf (1997) argue convincingly, the impact of any form of environmental tax depends on the magnitude of the tax, as well as the current regulations and taxes already imposed in that area. For example, Rausch et al. (2010) suggest that carbon pricing itself (pre-recycling) may be modestly progressive, when considering that lower income households' incomes are largely government transfers, which are likely to grow in real terms while other income sources are dampened by the policy.

4. States participating in RGGI divert most auction-generated revenue to investment in energy efficiency programs. Most of the remaining revenue is assigned to state and RGGI program administration.

TABLE 2
Aggregate Economic Impacts of AB32 Policy Cases for Year 2020 (GSP and Income Figures in Billion 2007$)

	Gross State Product Impacts		Income Impacts		Employment Impacts	
Scenario	**Level**	**Percentage (%)**	**Level**	**Percentage (%)**	**Level**	**Percentage (%)**
Scenario 1a	$6.9	0.3	$5.1	0.4	110,855	0.5
Scenario 1b	$7.3	0.3	$5.4	0.4	113,094	0.5
Scenario 2a	$11.5	0.5	$8.9	0.6	136,805	0.6
Scenario 2b	$5.4	0.2	$4.0	0.3	87,244	0.4

a macroeconomic model that have the greatest effect on the income distribution impacts:

1. Relative output price changes.
2. Factor substitution.
3. Occupational substitution.
4. Relative factor price changes.
5. Sectoral mix changes.

The REMI model calculates relative price changes for commodity outputs, as well as changes in relative factor prices. It also allows for factor substitution between capital, labor, and energy. While REMI does not readily produce occupation changes within a sector, it does capture occupational differences across sectors (e.g., electric utilities vs. gas utilities). In addition, REMI calculates the changes in the mix of sectoral outputs.

The effect of relative factor price changes on the distribution of income is calculated via our MSIDM as follows:

a. Utilize the REMI model to obtain the impacts of a policy simulation with respect to wage/salary return changes by sector, along with the economy-wide capital return change. Although REMI only provides a single aggregate rate of return for capital, this is reasonable because of capital mobility of the single capital aggregate in the model.

b. Apply these changes to convert the static (fixed coefficient) MSIDM into a dynamic (flexible factor payments) one. This involves changing the shares of the wage and capital components in each sector of the matrix. REMI then automatically feeds in any changes in income returns by income bracket into corresponding consumption changes.

c. Multiply the changes in sectoral gross output by the revised (dynamic) MSIDM to obtain the revised change in income distribution.

Thus, we are able to trace a circular flow of income generation, income receipt, and consumption stimuli in our model. The method also has the potential to factor in technological change over time. This is a solid conceptual base for a dynamic income distribution analysis.

V. AGGREGATE RESULTS

Our simulation results (Table 2) indicate that the net macroeconomic impacts of AB32 Policy Case 1 on the California economy will be slightly positive in the Year 2020 for all of the four allocation scenarios in terms of gross state product, personal income, and employment. While many mitigation activities incur costs, as when there is a need to purchase new equipment, these activities are more than offset by lower production costs and consumer energy bills stemming from energy savings, by the stimulus to businesses in the state that produce the necessary equipment, and by the stimulus effects of auction revenue recycling.

For Scenarios 1a and 1b, in which allowances are assumed to be 100% auctioned, the recycling of auction revenues is crucial at the aggregate level, because without this feature the aggregate impacts would each be negative. With allowances being fully auctioned, the out-of-pocket expenditures to purchase them will increase the emitters' cost of production, and they will attempt to pass on these cost increases in the form of higher prices to their customers. This in turn increases the cost of production in other businesses, and continues through successive rounds of ripples of cost-push inflation. Moreover, it decreases the purchasing power of household income. In our analysis, returning the revenues back to the households as personal income tax reduction or lump sum transfers to relieve the possible negative impacts on consumers can improve the overall impacts on the state economy and can achieve distributional objectives as well (see the following section).[5]

In Scenarios 2a and 2b, it is assumed that the allowances are 100% freely allocated among the cap-covered sectors. In Scenarios 1a and 1b, the covered sectors need to purchase allowances for all unabated emissions, and the ENERGY 2020 model assumes that all of these allowance costs will be automatically passed on to energy consumers through energy price increase. In the 100% free allocation scenarios, the cap-covered sectors have no additional out-of-pocket cost pressures upon their compliances with the reduction target. However, there have been debates on whether or not the opportunity costs of the free-allocated allowances should be passed through to consumers. To examine the differences in aggregate and distributional impacts of the alternative assumptions on opportunity cost pass through, we analyze both 0% and 100% opportunity cost pass throughs as Scenario 2a and Scenario 2b, respectively.

Following is a brief summary of the aggregate impacts of each scenario analyzed.

Scenario 1a: Under 100% auctioning, the total government revenues from auction are determined by the total amount of unabated emissions from the entities covered by the emissions cap (excluding any offset credits held by the entities) and the allowance price. In CARB Policy Case 1, the allowance price is \$21/tCO_2e, and the total government revenues collected from allowance auction are \$7.9 billion (CARB 2010). Recycling these revenues as personal income tax reduction results in an overall GSP gain of \$6.9 billion, or a 0.3% increase from baseline, and an employment increase of 110,855 jobs in terms of person-year equivalents, or 0.5% above baseline.

5. It may strike the reader that the recycling is simply a transfer and should not affect the aggregate results. However, there are efficiency gains from income tax relief. In the REMI Model, labor force participation is determined by the relative wage rate and employment opportunities. Therefore, the model has a mechanism to show that a higher wage rate will attract more people into the labor force. A decrease in income taxes raises the after-tax wage rate and will thus increase employment. Additionally, the labor force participation rate will respond to an increase in labor demand. We have performed simulations of the marginal cost of public funds using the REMI model and have found that personal income tax relief is expansionary. Finally, all recycled revenues go to residents of California. However, some of the costs are imposed on those outside the state in the form of reductions of profits (a major proportion of ownership of capital is outside the state) and also passed through to purchasers of California exports.

Scenario 1b: This scenario yields the same amount of government revenues from allowance auction as in Scenario 1a. Recycling these revenues as lump sum transfer payments on an equal per household basis results in an overall GSP gain of \$7.3 billion, or a 0.3% increase from baseline. The employment increase is 113,094 jobs, or a 0.5% increase from baseline.

Scenario 2a: Under 100% free allocation, the opportunity costs of the free allowances are assumed not to be passed onto consumers (see further justification below). This results in an overall GSP gain of \$11.5 billion, or a 0.5% increase from baseline, and an employment increase of 136,805 jobs, or a 0.6% increase from baseline. Our approach to simulating this scenario effectively represents an upper bound on possible positive GSP impacts because it stifles all price increases stemming from opportunity costs (although not mitigation cost), where such price increases would mute economic growth.

Scenario 2b: The major difference from Scenario 2a is that 2b allows a 100% pass through of the opportunity costs of the free-allocated allowances. This scenario represents lower-bound impacts, because it allows opportunity cost-induced price increases of the commodities from the cap-covered sectors even if these sectors obtain free-allocated emission allowances. This scenario yields an increase in GDP of \$5.4 billion in Year 2020, or a 0.2% increase from the baseline level, and employment is projected to increase by 87,244, or 0.4% from baseline, because of the greater labor intensity of stimulated sectors. This scenario yields the lowest increases in both GSP and employment.

As to sectoral impacts, the results are generally as expected, with the largest absolute and percentage decreases in sectors such as Electric Power Generation, Oil and Gas Extraction and Petroleum Refining, as well as sectors that are relatively energy intensive, such as Aluminum and Chemical Manufacturing. The largest increases are found in sectors that relate to household spending, such as Real Estate, Retail Trade, and Personal Services and in sectors supporting the implementation of renewable energy, such as Engines, Turbines, and Power Transmission Equipment Manufacturing (Rose, Wei, and Prager 2010). The results presented here regarding the aggregate and sectoral impacts are similar to many other studies about the impacts of AB32 (Roland-Holst 2010; Roland-Holst and Kahrl 2009).

VI. INCOME DISTRIBUTION IMPACTS

A. Allocation and Revenue Recycling Scenarios

Allowance Auction Revenue Recycling.

Government revenue recycling as personal income tax relief. In Scenario 1a, we assume that the auction revenues will be distributed as California Personal Income Tax Relief equally proportional to total income for all brackets. Column 2 in Table 3 shows the total number of households in each of the ten income brackets. Column 3 presents the pre-policy income distribution. Column 4 shows how the total auction revenues are distributed among the ten income brackets under Recycling Scenario 1a based on the pre-policy proportion of total income for each bracket.

Government revenue recycling as an equal per capita dividend to households. In this scenario, we assume that the auction revenues will be distributed as equal Per Capita Dividends (lump sum payments) for all income brackets. The second to last column in Table 3 shows how the total auction revenues are distributed. Note that we assume these dividends are taxable; hence their total is lower than that in the column for income tax relief. The dividend is an equal $556 per household across all the income brackets.

The transfer payments are translated to a vector of final demand changes in the REMI model by distributing them among the 169 sectors based on the consumption coefficient column of each income bracket. The total "Exogenous Final Demand" change to each REMI sector is the sum of consumption changes of all the income groups. The state income tax on these lump sum payments is simulated as an increase in state "Government Spending."

100% Free Allocation of Allowances.

0% pass through of opportunity costs of allowances. Some additional calculations were required to simulate the aggregate and distributional impacts of the 100% free allocation scenario with zero opportunity costs pass through because the ENERGY 2020 simulations of direct effects of this case were not available in the CARB analysis. This required that we apply the device of "rebates" to emitters corresponding to their expenditures on allowances in the ENERGY 2020 auction simulations. The last column of Table 3 shows the value of the allowances from free allocation for each of the income brackets.

The literature on emission allowance trading has traditionally postulated that there is no difference in outcomes with respect to economic efficiency between a system of free-granted allowances and a system of auctioned allowances. The former requires out-of-pocket expenditures, while *opportunity costs* of using free-granted allowances are cited as a justification for an increase in cost to firms receiving them. That is, each time a firm uses an allowance, it foregoes the opportunity to reap revenues from its sale. While the economic basis for this proposition is solid, policy makers are currently not comfortable with its implementation. Most analysts have recently concluded that public utilities commissions are unlikely to grant rate increases to electric utilities on the basis of free-granted permits (Burtraw and Palmer 2008). In fact, the recent EAAC to the CARB on the implementation of AB32, recommended against any such rate increase related to allowance opportunity cost. Even some non-regulated firms in today's business environment are not likely to raise their prices on the basis of the increase in opportunity costs so as to avoid adverse public reactions.

100% pass through of opportunity costs of allowances. To estimate the impacts of Scenario 2b, where the allowances are free granted to the emitting sources, while the total allowance opportunity costs are allowed to be passed on to consumers, we first apply the same device of "rebates" as in Scenario 2a to the emitters to counterbalance their allowance expenditures in the ENERGY 2020 auction simulation. The pass through of the allowance opportunity cost is reflected in price increases of the goods and services produced by the cap-covered sectors. As the ENERGY 2020 model did not provide the direct simulation results of such opportunity cost-induced price increases, in the REMI simulation we increase the "Production Cost" of the emitting sectors equal to the value of the free-granted allowances. The cost pass through is carried out through the internal linkages between the production cost changes and

TABLE 3
Direct Distribution of Allowance Revenues and Values, Year 2020

Income Bracket	Estimated California Households Per Bracket (Millions)	Pre-Policy Income Distribution (Billion 2007$)	Scenario 1a Personal Income Tax Reduction (Billion 2007$)	Scenario 1b Per Capita Dividend After Tax (Billion 2007$)	Scenarios 2a and 2b Allowance Values[a] (Billion 2007$)
<$12.5 k	1.08	7.4	0.004	0.601	0.307
12.5–22.5 k	0.83	16.0	0.018	0.462	0.253
22.5–30 k	2.04	58.9	0.039	1.135	0.649
30–40 k	1.25	48.1	0.094	0.695	0.393
40–52.5 k	0.92	46.8	0.184	0.512	0.297
52.5–62.5 k	1.31	79.8	0.170	0.729	0.452
62.5–80 k	1.56	122.3	0.338	0.868	0.581
80–100 k	0.92	91.1	0.399	0.512	0.425
100–150 k	1.43	196.6	0.900	0.795	0.940
150 k+	1.17	759.9	5.745	0.651	3.594
Total	12.51	1,426.9	7.892	6.958	7.892

[a]The allowance values are the same for Scenarios 2a and 2b.

the commodity price changes in the REMI model.

B. Distributional Impact Results

Tables 4 and 5 present distributional impacts for each of our four distributional scenarios.[6] Again, these distributional alternatives are applied to CARB Policy Case 1, which consists of cap and trade with offsets, plus six complementary policies described in Appendix A.

Scenario 1a results in a $25 million negative impact on the lowest income bracket (see first partition of Table 4), despite revenue recycling. The poorest households are disproportionately impacted because Scenario 1a increases prices for goods on which this group spends a higher relative proportion of income, and because Scenario 1a shifts production toward sectors with greater employment opportunities for higher income groups. The lump sum transfers proposed in Scenario 1a are inadequate in compensating the lowest income bracket, although the next two income brackets (which are also below 150% of the poverty line threshold) have income gains higher than the average for this scenario. Scenario 1b results are very similar to those of Scenario 1a (second partition of Table 4). The impacts are almost identical for the lowest two income groups, although other income groups benefit more from Scenario 1b. This is possible because the overall impact on Personal Income is slightly higher for Scenario 1b than 1a.

The results of Scenario 2a (first partition of Table 5) are more favorable to the lowest income group than in Scenarios 1a and 1b. Free allowances (as opposed to income tax reduction or lump sum transfers in Scenarios 1a and 1b) go to owners of firms, who typically have higher incomes than the general population. The percentage increase in the highest bracket incomes is about twice as high in Scenario 2a as in Scenarios 1a and 1b. Scenario 2b, the free allocation scenario with opportunity costs passed through, shows mixed results in terms of income distribution (second partition of Table 5). The lowest income bracket is adversely affected, as in Scenarios 1a and 1b, although to a slightly lesser extent. Overall, the results for Scenario 2b sit

6. We use income as a welfare measure in this analysis. For an excellent discussion of the limitations of this measure and the advantages of alternatives such as consumption and consumers surplus, the reader is referred to Burtraw and Palmer (2008). Lifetime income is conceptually preferable to current income, as it is wealth disparities over the long term that concern policy makers. Following the permanent income hypothesis, current consumption has been used as a proxy in numerous studies (Parry 2004), and results for the same policy scenarios have been found to be less regressive than when using an annual income measure (Parry and Williams 2010). Similarly, Hassett, Mathur, and Metcalf (2009) find a carbon tax to be more regressive for an annual measure when compared with a lifetime income measure. At the same time, the use of consumption as a measure of welfare is problematic also. Bull, Hassett, and Metcalf (1994) observe that household consumption patterns often reflect abrupt changes in income, while Zeldes (1989) observes that imperfections in capital markets may cause young workers' consumption to underestimate lifetime income. Specific to emissions trading, Poterba (1989) highlights that younger and older individuals spend a smaller proportion of their budget on polluting goods when income is annualized rather than current. Also, income may be the superior alternative when considering a short-run perspective, as we do in this paper.

TABLE 4
Total Distributional Impacts of C&T with Offsets Policy, 100% Auction of Allowances (Scenarios 1a and 1b), Year 2020 (2007$)

Income Bracket	Income Tax Relief			Per Capita Dividend		
	Direct Income Transfer (Billion $)	Total Income Change		Direct Income Transfer (Billion $)	Total Income Change	
		(Billion $)	Percentage (%)		(Billion $)	Percentage (%)
<$12.5 k	0.004	−0.025	−0.331	0.601	−0.024	−0.326
12.5–22.5 k	0.018	0.106	0.662	0.462	0.106	0.660
22.5–30 k	0.039	0.340	0.577	1.135	0.346	0.587
30–40 k	0.094	0.214	0.445	0.695	0.222	0.462
40–52.5 k	0.184	0.182	0.389	0.512	0.191	0.408
52.5–62.5 k	0.170	0.277	0.347	0.729	0.298	0.373
62.5–80 k	0.338	0.283	0.231	0.868	0.315	0.258
80–100 k	0.399	0.293	0.321	0.512	0.317	0.348
100–150 k	0.900	0.903	0.459	0.795	0.954	0.485
150 k+	5.745	2.590	0.341	0.651	2.751	0.362
Total	7.892	5.163	0.362	6.958	5.475	0.384

TABLE 5
Total Distributional Impacts of C&T with Offsets Policy, 100% Free Allocation of Allowances (Scenarios 2a and 2b), Year 2020 (2007$)

Income Brackets	Allowance Values (Billion $)	0% Opportunity Cost Pass Through		100% Opportunity Cost Pass Through	
		Total Income Change		Total Income Change	
		(Billion $)	Percentage (%)	(Billion $)	Percentage (%)
<$12.5 k	0.307	0.015	0.198	−0.021	−0.278
12.5–22.5 k	0.253	0.121	0.757	0.077	0.479
22.5–30 k	0.649	0.437	0.742	0.261	0.444
30–40 k	0.393	0.297	0.618	0.156	0.325
40–52.5 k	0.297	0.260	0.556	0.129	0.275
52.5–62.5 k	0.452	0.389	0.488	0.180	0.225
62.5–80 k	0.581	0.476	0.389	0.156	0.128
80–100 k	0.425	0.413	0.453	0.182	0.200
100–150 k	0.940	1.201	0.611	0.636	0.323
150 k+	3.594	5.348	0.704	2.287	0.301
Total	7.892	8.957	0.628	4.044	0.283

between Scenarios 1a and 1b on one side and Scenario 2a on the other. In both Scenarios 1a and 1b, the highest income bracket receives 50% of the total change in income, while in Scenarios 2a and 2b a larger proportion is distributed to the highest income bracket (59% and 56%, respectively). Moreover, the lower half of the income distribution (the brackets between $0 and $52.5 k) receives 15.8% of the total change in income in Scenario 1a and 15.3% in Scenario 1b, while receiving 14.9% in Scenario 2b and 12.6% in Scenario 2a.

Table 6 presents the results in terms of a measure of distributional changes. The Gini coefficient is a one-parameter estimate of the skewness of the distribution, that is, a measure of inequality.[7] On a scale between 0 and 1, smaller Gini coefficients reflect a more equal distribution.

The values in the second numerical row of Table 6—"Change in Income Distribution Before Transfers or Allocations"—are the same

7. The Gini coefficient is the most commonly used inequality metric (Cowell 2000), though there are numerous others. Aside from being widely used and well known, the Gini coefficient approach is appealing because it can be readily visualized in relation to the Lorenz curve. However, the Gini coefficient approach has drawbacks, including that it is not decomposable in terms of income brackets, i.e., the coefficient tells us only the overall distribution, and does not identify the relative shifts between brackets (Cowell 2000). We have rectified this limitation with our discussion of the impacts on the various brackets.

TABLE 6
Gini Coefficient Impacts, Year 2020

		Pre-Policy	Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b
1	Total income distribution before transfers or allocations	0.592411	0.592227	0.592227	0.592227	0.592227
2	Change in income distribution before transfers or allocations	n.a.	−0.000184	−0.000184	−0.000184	−0.000184
3	Direct transfers or allocations	n.a.	0.765602	0.000000	0.430757	0.430757
4	Total income distribution after transfers or allocations	0.592411	0.592312	0.592322	0.592622	0.592438
5	Change in income distribution after transfers or allocations	n.a.	−0.000099	−0.000089	0.000211	0.000027

n.a., not applicable.

for each scenario and show a slight decrease from the Pre-Policy, or baseline, level of 0.5922. This indicates that the income distribution improves from the general effect of Case 1 (i.e., before any revenue transfers).

For Scenarios 1a and 1b the Gini coefficient results suggest that macroeconomic impacts of income transfers are less equitable than the pre-revenue recycling results, as shown in the last row of Table 6. Revenue recycling here acts as a net stimulus to the economy, and no sectors are worse off as a result. These benefits are passed on to the highest income brackets at a disproportionate rate for many sectors. The majority of sectors that benefit most from the revenue recycling also have a higher than average proportion of income received by the highest bracket. For example, for Scenario 1a, the highest bracket income proportion of Real Estate (81.1% of all Real Estate income goes to the highest income bracket), Construction (57.5%), and Telecommunications (76.7%) are all above the economy-wide average of 50.2%. Hence for any revenue recycling option, when households spend their transfers, higher income households benefit more overall in comparison to the pre-recycling results.

As the personal income tax reductions of Scenario 1a are skewed toward higher income brackets, it is not surprising that this scenario results in a worsening of the overall income distribution when compared to the pre-recycling results, as exhibited by an increase in the Gini coefficient between rows 1 and 4 of Table 6. Because the transfers for Scenario 1b are lump sum, they have a Gini coefficient of 0.0, or perfectly egalitarian (see row 3), which puts downward pressure on the Gini coefficient of the post-transfer result. However, the Scenario 1b post-transfer Gini coefficient is not reduced but actually increases slightly from 0.592227 to 0.592322 (about 0.02%) as a result of macroeconomic interactions. Again, the impacts on the overall income distribution stem primarily from the changes in the sectoral mix that favor higher income groups.

As shown in Table 6, the free granted allocation values for Scenarios 2a and 2b are more unevenly distributed than in Scenario 1b (compare the Gini coefficient of 0.431 in row 3 with zero of Scenario 1b), although more evenly distributed than Scenario 1a. The overall results of Scenarios 2a and 2b yield the less egalitarian outcome of the scenarios simulated (increases in the Gini of 0.000211 and 0.000027, respectively). This is somewhat counterintuitive because the direct distribution of free allowances, although highly uneven (Gini of 0.431), is still more even than the baseline income distribution (Gini of 0.592). This result stems from the fact that both free allocation scenarios are dominated by the indirect (macroeconomic) effects. For example, in Scenario 2a the outcome is far more favorable to the highest income group than any of the other scenarios we have simulated. Distributional outcomes of Scenario 2a include larger increases in the output of sectors that have more evenly distributed income payouts. Yet these outcomes appear to be offset by the inherent regressivity of higher energy prices. In comparison to Scenario 2a, Scenario 2b is projected to result in a much lower adverse impact on the Gini coefficient because the gains to the highest income bracket are lower and the gains to the lower income brackets are higher in the latter scenario.

The relative values of the Gini coefficient results for Scenarios 1a and 1b are counterintuitive at first glance. Lump sum transfers alone (Scenario 1b) should be more equitable than proportional income tax relief (Scenario 1a); these results suggest the opposite, although the difference in Gini coefficients is only 0.00001. Eight of the ten sectors for which Scenario 1b yields higher gross output impacts than Scenario 1a distribute 57.7% to 82.94% of their income to the highest income bracket; in contrast, on an economy-wide average basis, only 50.2% of total income is distributed to the highest income bracket. Further, sensitivity tests reveal that if we were to decrease pre-policy, economy-wide income for the highest bracket by 7%, while holding the gross output results constant, this would cause the Gini coefficient results for Scenarios 1a and 1b to switch and match theoretical expectations—Scenario 1b would become fairer than Scenario 1a. This suggests that these counterintuitive results are largely driven by the highest income bracket of the MSIDM.

Revenue recycling has a limited potential to affect the overall income distribution. The nearly \$7 billion in allowance revenues (after tax) translate into a direct transfer of \$556 per household or less than \$200 per person in the state. Still the availability of allowance auction revenues or their free allocation does raise some important equity issues. For example, \$556 represents nearly 10% of the income of households in the lowest income bracket. The worst case with respect to the lowest income group, Scenario 1a, yields a loss of income for the entire bracket of \$25 million (Table 4), which translates to a loss of \$23 per household in that bracket, although this is after \$556 per household has been transferred as a dividend. The greatest gain of any scenario goes to the highest income bracket under free allocation Scenario 2a. This \$5.1 billion gain translates into more than \$4,500 per household in that bracket, although it represents only slightly less than 1.0% of the average household income in this bracket.

The results indicate an efficiency-equity tradeoff. Scenario 2a, free allocation, is projected to yield the largest increase in GSP and personal income, but it makes the overall income distribution less equitable. Still, it is the only scenario that benefits the lowest income groups, and it also reaps rewards for the highest income group more than twice as high as Scenarios 1a and 1b. The gains in aggregate economic activity are fairly minor, amounting to no more than 0.5% in GSP for the most effective scenario from an efficiency standpoint. The difference between the highest impact scenario (2a) and the lowest (2b) in terms of GSP is only \$6.1 billion and 49,000 jobs. These are small gains to give up to avoid the greatest worsening in the income distribution of all scenarios. Also, the difference in economic gains between the most progressive scenario (1a) and the most regressive scenario (2a), in terms of the Gini coefficient for income distribution, is only \$4.6 billion in GSP and 25,000 jobs.

Our distributional impact results are similar to those found by other scholars (Burtraw and Palmer 2008; Goulder, Hafstead, and Dworsky 2009; Hassett, Mathur, and Metcalf 2009; Roland-Holst 2010). They find the free allocation approach to be generally more regressive than the auction approach. When considering revenue recycling, these studies find a more equitable outcome associated with per capita dividends than personal income tax reduction; we found them to be essentially the same. Our results therefore stand between the above findings, and those of Parry and Williams (2010), who find income tax reductions to be regressive and lump sum dividends progressive. The major explanation for our results is the strong workings of macroeconomic linkages that cause major changes in the sectoral mix that favor higher income brackets (e.g., Real Estate, Construction, and Telecommunication). Another difference between the present study and these others is in the extent of variation between policy designs. The variation in outcomes is more muted than in the other studies, which were performed at the national or large region level, in part because of the smaller amount of recycled revenues considered here, even after adjusting for the size of the economies modeled.

VII. CONCLUSION

This article analyzes the distributional impacts of the California Global Warming Solutions Act on the state's economy. We adapted a state of the art macroeconometric model known as REMI PI^{+} model, and a MSIDM supplemented by data on California household income from various tax authorities to perform this analysis. The analysis is based on direct implementation data provided by the CARB and ICF International, Inc., used in simulations of direct economic impacts of AB32 policies.

Each of the four alternative allowance allocation/recycling scenarios of the AB32 Main Policy Case we evaluated is projected to yield a small positive impact on the state's economy by Year 2020. The economic gains emanate in part from the ability of mitigation options to lower the cost of production. This stems primarily from their ability to improve energy efficiency and thus lower production costs, thereby increasing consumer purchasing power. The results also emanate from the stimulus of increased investment in energy-saving equipment and the expansionary impacts from auction revenue recycling.

Although providing improvements in the overall income distribution, the auction scenarios combined with either California Personal Income Tax Relief or a Per Capita Dividend are projected to incur small losses to the lowest income group, because of the strong influence of structural shifts in the economy that affect employment opportunities for this group. This suggests that even larger transfers may be needed for the lowest group under these scenarios to avoid an inequitable outcome. However, these transfers can be made with only a minimal sacrifice in economic efficiency.

The economic improvements are projected to be distributed positively across all income brackets and across labor and capital income shares for the free allocation scenario when opportunity cost increases are not allowed to be passed through to price increases, although only small gains accrue to the lowest income group. The impacts of free allocation when the opportunity costs are fully or partially passed through to customers of firms receiving allowances are less unevenly distributed, although the lowest income bracket is projected to incur a slight drop in income as in Scenarios 1a and 1b.

Overall, the findings from this study suggest that implementing the proposed California Global Warming Solutions Act would generate small net positive economic impacts to the state's economy for all four scenarios. Moreover, the impacts on all but the lowest income group are positive under three of the policy designs analyzed in this article. Revenue recycling is a flexible policy instrument and can be further refined to alleviate inequities to any specific income groups. Free allocation does not readily offer this opportunity, and, in fact, favors the highest income groups. It would be very difficult to tailor free allocation to improve distributional equity. The results indicate some important efficiency-equity tradeoffs, including the fact the scenario that offers the greatest net economic gains in GSP and employment (Scenario 2a) is projected to worsen the overall income distribution.

The various factors affecting the results that are operative in California also exist in other states and many advanced nations, so our method, and, to some extent, our findings are representative of impacts in other parts of the United States and many other parts of the world. Our methodology can be applied in cases where REMI models are available for these countries or regions, or can be adapted to other model types. For example, a MSIDM is inherent in most CGE models, income tax data are available from government agencies, and data on mitigation costs for various economic sectors and for households are available from most climate action plans.

I. APPENDIX A: COMPLEMENTARY POLICIES DESCRIPTION

Complementary policies are additional policies that may be pursued whether a cap and trade program is implemented or not. The following description is excerpted from CARB (2010).

A. Pavley II Vehicle Standards

The marginal vehicle efficiency for passenger cars and light trucks is incrementally increased, beginning in 2017, to reach a new vehicle fleet of 42.5 mpg by 2020. Policy impacts include increases in expenditure for vehicles of greater efficiency and decreases in fuel expenditures.

B. Low-Carbon Fuel Standard (LCFS)

The ethanol share of passenger ground transportation fuels is increased to approximately 18% for light vehicles and the biodiesel share of freight ground transportation is increased to approximately 15% to represent a 10% reduction in the carbon intensity of fuels by 2020. For exposition purposes biofuels from the Federal Renewable Fuel Standard are included as part of the LCFS policy. Biofuels have historically been priced above gasoline, although with federal tax credits, a maturing biofuels industry, and projected higher crude prices, the cost of producing biofuels relative to petroleum-based fuels is expected to decline within the next several years. Nevertheless, for this analysis, staff assumes that biofuels will continue to be priced above gasoline. Furthermore, it is assumed that a sufficient amount of the type of biofuels needed to comply with the standard will be available.

C. VMT-Reduction Measure

Vehicle miles traveled per year in California are assumed to be reduced by 4% by 2020. This measure is representative of changes that could occur through the implementation of SB 375—a 2008 state law to reduce GHG emissions from vehicles by redesigning communities. No assumptions are made with regard to exactly how this reduction would be achieved or the cost of achieving it.

D. 33% Renewable Portfolio Standard

The sales share of renewable electricity (not required to be in-state) is increased to 33% by 2020. The type of renewable generation built to meet this mandate was based on resource mix projections by the California Public Utilities commission. The costs for any new transmission needed to comply with a 33% Renewable Portfolio Standard are not accounted for in the ENERGY 2020 model.

E. Residential and Commercial Energy Efficiency

Building and device efficiency standards and programs are assumed to reduce electricity sales by 24,200 GWh and natural gas sales by 800 million therms by 2020. The efficiency is represented in the model as an increase in device and building efficiency standards. The increased costs of actual equipment upgrades associated with these efficiency gains are captured in the model; however, utility program and administration costs are not estimated.

The availability of low-cost energy-efficiency potential is based on market failures that have prevented the penetration of energy-efficient devices among some customers. In this analysis, we assume that this efficiency potential exists without being specific as to what market failures are being corrected by the policy intervention.

F. Combined Heat and Power

This measure sets a target of an additional 4,000 MW of installed combined heat and power (CHP) capacity by 2020, enough to displace approximately 30,000 GWh of demand from other power-generation sources. It is assumed that the heat output of these facilities is used to serve existing or new heating loads. Increasing the deployment of efficient CHP will require addressing these barriers and instituting incentives or mandates where appropriate.

G. Heavy-Duty Vehicle and Marine Efficiency

This measure increases freight endues efficiency in trucks to reflect the SmartWay program of the U.S. Environmental Protection Agency, and it increases the use of on-shore electricity for ships in port.

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