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California Industry Impacts of a Statewide Carbon Pricing Policy

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California Industry Impacts of a Statewide Carbon Pricing Policy with Output-Based Rebates

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ABSTRACT

Pricing greenhouse gas emissions via a comprehensive statewide cap-and-trade system, as mandated by the California Air Resources Board's Scoping Plan, is a highly efficient means of reducing emissions. At the same time, without specific measures to limit adverse impacts, such a system would burden California electricity and primary fossil energy producers, as well as energy-intensive industries sensitive to interstate and/or international trade. This study estimates the impacts on a disaggregated set of California industries of introducing a carbon pricing policy within the state, assumed to be $15/ton of CO_2. Two time horizons are considered, the "very short run" and the "short run", neither of which allow firms to alter their input mix or invest in new technologies. To reflect the potential vulnerability of some California industries to imports from outside the state, alternative assumptions about demand elasticities, i.e., the sensitivity of California-produced goods to local price increases, are considered in the analysis.

To limit adverse impacts on the state's energy-intensive and trade-exposed (EITE) industries, we develop illustrative policy options involving free allowance allocations of emissions permits to particular industries and limited border adjustments on coal, natural gas, crude oil, and refined petroleum product imports, as well as on electricity. Two allocation schemes are considered based on the American Clean Energy and Security Act of 2009 (H.R. 2454): allocations to electricity and natural gas local distribution companies (LDCs) only, and the addition of output based rebates for EITE industries.

Overall, we find relatively small impacts on energy-intensive industries, especially with the rebates in place. The average post rebate EITE output reduction is 0.43 percent, rising to 0.55 percent with our worst case assumption about California demand elasticities. There is, however, considerable variation among the EITE industries. The most heavily impacted industry is fertilizers, where the short run output loss is 3.2 percent with the rebates in place, down from 4.7 percent without the rebates. For our worst case elasticity assumption, the post rebate output loss for fertilizers is 4.0 percent. We also find that the ability to pass on costs, as assumed in the short run case, reduces adverse profit impacts to less than 1.5 percent in most cases, regardless of the rebate scenario. Based on national-level modeling done outside of this study, we estimate that over the long term, the average EITE output losses would be expected to decline by an additional one fifth below the lowest levels reported here.

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I. Introduction

Pricing greenhouse gas (GHG) emissions, via an economy-wide cap-and-trade system, as mandated by the California Air Resources Board's Scoping Plan issued pursuant to Assembly Bill (A.B.) 32, is a highly efficient means of reducing emissions. At the same time, such a system, particularly if adopted without specific measures to limit adverse impacts, would place some burdens on California electricity and primary fossil energy producers, as well as energy-intensive industries sensitive to interstate or international trade. Beyond the economic losses to California industries, there is also concern about emissions leakage if increases in the cost of doing business in California cause economic activity and the corresponding emissions to move to locales with weaker GHG mitigation policies, or none at all, thereby undermining the environmental goals of the program.

Industry-level impacts of an emissions trading system depend on the carbon intensity of the energy-consuming industries; the degree to which they can pass on costs to consumers of their products, often other industries; and the ability to substitute away from high-carbon energy sources. The strength of competition from producers outside California and consumers' ability to substitute other, less carbon-intensive alternatives for a given product are important in determining the impacts on production in the state.

The most effective approach to reduce both emissions leakage and the disproportionate competitiveness impacts on California industries is to ensure comparable carbon pricing policies by other states and nations engaged in substantial trade with the Golden State. In the absence of such policies, however, the state could impose border adjustments on imported carbon-intensive products. Alternatively, or in parallel with some form of border adjustments, California could freely allocate emissions allowances via an output based rebating scheme to the most affected sectors to reduce the adverse impacts of the program..

This study estimates the impacts on a disaggregated set of California industries of introducing a cap and trade scheme in the state based on an assumed allowance price of \$15/ton of CO_2 , which is broadly consistent with short term projections of allowance prices under AB 32. To limit adverse impacts on the state's energy-intensive and trade-exposed (EITE) industries, we develop illustrative policy options involving free allowance allocations of emissions permits to particular industries and border adjustments on coal, natural gas, crude oil, and refined petroleum product imports, as well as on electricity. The allocation provisions modeled in this study are the same as those contained in the proposed national cap and trade system, American Clean Energy and Security Act, as adopted by U.S. House of Representatives in June 2009 (H.R. 2454). Specifically, this includes emissions rebate programs covering electricity local distribution companies (LDCs) and natural gas distribution companies (NGDCs) and also energy intensive trade exposed (EITE) manufacturing industries and petroleum refineries, as defined in H.R. 2454.

The manufacturing rebate programs are designed to cover a certain proportion of carbon emissions within an EITE sector for the subset of industries deemed most likely to be hurt by a U.S. carbon pricing policy. If these free allowances or rebates are updated on the basis of recent output levels, as prescribed in H.R. 2454, firms would be encouraged to maintain production levels in the face of policy-induced cost increases, while sustaining incentives created by the emissions cap to reduce the carbon intensity of production. Importantly, the per-unit allowance allocation is not based on the firm's emissions but on a sector-based average intensity standard, thus creating incentives for within-sector market shares to shift toward firms with low emissions intensities.

As a reference case, an alternative rebate scheme is also examined. This alternative would return the full allowance value directly to households instead of directing a portion of the revenues to the industrial sector via LDC and EITE rebates as proscribed in H.R. 2454.

Estimating the industry-level impacts of carbon pricing policies is complex and the results inherently uncertain. The uncertainty depends on the modeling approach employed, the reliability of the available data, the timeframe considered, and other factors. This study is based on an input-output (I-O) analysis, which depicts the inter-industry relations in the economy. The I-O framework reflects how the output of one industry serves as input to another. Thus, if a price is placed on carbon emissions, the costs of making plastics, steel, or other energy intensive products will rise, as will the costs of the automobile manufacturing or other downstream industries that use these materials as inputs to their production.

While the I-O methodology is relatively straightforward, the data requirements to carry out the analysis are substantial. Credible analysis of the industry-level impacts depends on the availability of a) detailed state-level, industry-specific information, including data on the physical quantities of different fuels used by individual energy-intensive industries and (b) interstate trade data for energy-intensive commodities produced in the state. Such data are commonly well developed at the national level which, in turn, facilitates the analysis of national competitiveness impacts. Unfortunately, the state-level information is more limited, even for a large, sophisticated state like California, thereby introducing further uncertainty in the resulting estimates.

A common method for estimating impacts from national as opposed to state-level studies is to use computable general equilibrium (CGE) models, which allow for the estimation of long-run industry-level and consumer welfare impacts of carbon pricing policies after firms have adjusted by using new technologies and after new import patterns have been established. Such analyses often use a mobile factor framework in which workers and capital are assumed to seamlessly shift from the more heavily burdened sectors to the less heavily burdened ones. Such long-run analyses, however, fail to capture the short-run impacts of a carbon pricing regime. Even with the phase-in of coverage and the ability to anticipate the new carbon pricing policy, a chemical or fertilizer plant faced with higher energy costs cannot immediately and costlessly convert to more energy-efficient methods. If it leaves its output price unchanged, the higher input costs will reduce the firms' profits. If it tries to raise prices to cover the higher costs, it will face lower sales. A carbon control policy that does not address these impacts in a fair manner might be opposed by many stakeholders.

In this study we consider two relatively short time frames:

- the very short run, where it is assumed that output prices cannot be changed but input prices rise and profits fall accordingly, and
- the short run, where output prices can rise to reflect the higher energy costs, with a corresponding decline in sales as a result of product and/or import substitution.

The very short run can be thought of as a worst case analysis, since it is highly unlikely that the affected firms would be unable to pass along any of the additional costs they experience under the cap and trade program. The energy intensive industries protected by border adjustments, such as electricity production, would likely be able to pass along virtually all the added costs. Industries not protected by border adjustments would clearly face some decline in sales if they tried to pass along the added costs, an issue explicitly addressed in the short run model which incorporates industry-specific demand elasticities.[1] The modeling approach used for both the very short run and the short run is based on a *fixed coefficient* analysis, in which the structure of intermediate and energy inputs that characterize the production of a given industry is fixed in the year represented by the underlying data, in this case 2006. Neither the very short-run nor the short-run analysis allows for post-2006 changes in the mix of capital and other inputs used in production or for the adoption of more energy-efficient technologies in response to the newly introduced carbon prices. That is, the analysis forces all emission reductions in both the very short run and the short run to come from output reductions, with no opportunity for either technology shifting or even input shifting. As such, both analyses are likely overestimates of the true impacts. In the final section of this study, we reference results from national-level analyses which involve the use of computable general equilibrium models. Such analyses provide a basis for considering the likely cost reductions that could be achieved when the more restrictive short-run assumptions are relaxed.

Within the context of the I-O framework used in this study, the focus of this paper is on a sequence of relatively transparent steps designed to estimate the impacts of carbon pricing *cum* rebate policies over both the very short-run and the short-run time horizons. Impacts are measured in terms of marginal cost-of-production effects and reduced output and profits. Following this introduction, Section II presents background information on key aspects of the national allocation schemes for EITE industries, as embodied in H.R. 2454 as well as the two illustrative California-specific rebate schemes developed for

[1] This worst case, very short run analysis is used to estimate the maximum possible impact on industry profits arising from the emissions trading scheme. Since no one knows exactly the degree to which firms may be able to pass on higher costs, this scenario is included to illustrate the worst possibility.

this analysis. Section III presents an overview of industrial output, energy use, and carbon intensity in the state, and a comparison with national industrial energy use patterns. Section IV describes the principal results across both time horizons, including the no-rebate case and the two illustrative rebate policies. Section V discusses various aspects of the results. Section VI offers some overall conclusions and recommends a series of possible steps for future analysis.

II. Federal Legislation for Dealing with Energy-Intensive and Trade-Exposed Industries

Although some early national emissions trading proposals did not contain provisions to address leakage and competitiveness impacts, the most recently considered legislative initiatives do contain such provisions. Under H.R. 2454, special treatment is given to four industrial groups: electric utilities, natural gas distribution companies, petroleum refineries, and EITE industries. Understanding the operation of the H.R. 2454 rebates is essential for designing the illustrative systems in California. At the same time, failing to recognize the generally lower CO_2 intensity of California industries and simply applying the H.R. 2454 rebates without adjustment would lead to overcompensation in most cases.

For EITE industries, emissions rebates in H.R. 2454 are given according to historical direct energy and electricity consumption. In order to be deemed an EITE industry, a six-digit North American Industrial Classification System (NAICS) manufacturing industry must have at least a 5 percent energy or GHG intensity *and* a 15 percent trade intensity. Additionally, sectors that have an energy- or GHG-intensity greater than 20 percent are also deemed presumptively eligible. Energy (or carbon) intensity is measured by the value of energy costs as a share of the total value of shipments in that sector.[2] Trade intensity is calculated as the value of imports and exports as a share of the value of total production plus imports. At the national level, EPA has developed a list of presumptively eligible industries that meet these criteria (2009). This nationally based list is adopted for the present analysis of A.B. 32. The presumptively eligible sectors receive rebates based on their average emissions, a calculation that is periodically updated. We have developed estimates of the national-level rebates to be granted under H.R. 2454, as well as the rebates that would be granted in a California-based system operating under comparable rules.

Refineries are not eligible for production rebates in H.R. 2454, although they are freely granted 2 percent of total allowances plus an additional 0.25 percent for those refineries defined as small businesses, without regard to current output levels (i.e., via grandfathering). For modeling purposes, we treat these as output-based rebates for both the national analysis and for California.

Beyond the rebates targeted directly at energy-intensive manufacturing industries, H.R. 2454 would allocate about 30 percent of the allowances gratis to electricity LDCs and about 9 percent to NGDCs, reflecting roughly 75 percent and 50 percent of their contribution to national emissions, respectively. The legislation mandates that these allowances be used for the ratepayers' benefit, which is widely interpreted to include industrial customers. In fact, it is possible that some EITE industries that

[2] In H.R. 2454 GHG intensity is calculated at an assumed price of \$20 per ton of CO_2.

rely heavily on electricity would receive dual benefits, one from the suppression of electricity price increases by the LDC allocation and the other from the gratis allocation of emissions permits that depend on historical electricity consumption. In order to prevent this form of double dipping, H.R. 2454 stipulates that the permit allocation for EITE industries will be "adjusted" so that they do not receive permits for cost increases not incurred as a result of the LDC allocation, which is designed to suppress electricity price increases.[3] Because indirect emissions from electricity consumption are an important component of total emissions of the eligible sectors, the LDC provisions are expected to mitigate a significant portion of the policy-induced costs to the eligible sectors. The allocations to NGDCs will have a smaller impact because this allocation only covers the relatively small number of EITE firms that receive their gas from LDCs (as opposed to the gas mining sector) *and* whose emissions are not directly regulated under H.R. 2454. Unsurprisingly, because the primary energy source for producing electricity in California is natural gas, in contrast to coal for the United States at large, the electricity price increases induced by the A.B. 32 cap-and-trade system are smaller than those at the national level.

III. Methods

This section provides an overview of the data and methods used in this analysis. More detailed information is available in Appendix A and in Adkins et al. (2010).

Both the very short-run and the short-run cases rely on an I–O model of the California economy, disaggregated to the 50-sector level based on the NAICS. This aggregation choice is designed to present reasonable detail on EITE industries in California *and* to provide a basis of comparison with national analyses, where more in-depth information on the national energy use patterns of the individual industries is available.[4] To represent the very short run, where output prices cannot be changed but input prices rise and profits fall, the effect of a carbon tax is computed using a modification of a well-known formula known as the Leontief inverse.

The I–O value data used here are based on the I–O accounts developed by the Minnesota IMPLAN Group Inc. (IMPLAN 2010)[5]. Although not collected via original surveys, the IMPLAN state-level I–O accounts represent imputed information based on available national I–O tables and other relevant state data. In comparing the national- and state-level data, we find them to be broadly consistent. At the same time, in a number of industries we observe substantial differences that cannot be readily explained.[6]

In national competitiveness studies carried out by the present authors and others, the I–O value data are supplemented by the Energy Information Administration's Manufacturing Energy Consumption

[3] See subparagraph D of Sec. 764 of H.R. 2454.
[4] National analyses that we have conducted contain a total of 52 industries. The two additional industries disaggregated in the national analysis vs. California are in the refining and paper sectors.
[5] Minnesota IMPLAN Group Inc. (http://implan.com/v3/) provides documentation of Version 3 of the data that are used here.
[6] For example, the construction industry's use of petroleum products as a share of all intermediate inputs is higher for California than at the national level.

Survey (MECS), which collects information on the physical quantities of different fuels consumed by most manufacturing industries (EIA 2006a). We use this information to estimate industry-specific carbon emissions. Unfortunately, there are no publicly available California data on the physical quantities of different fuels used by industry that are comparable to the MECS. Thus, in the present analysis, industry-specific estimates of carbon emissions are inferred from the IMPLAN value data and available information on average fuel prices in the state.[7] Because the average fuel price data cannot capture the considerable variation in fuel prices paid by different industries, this procedure introduces uncertainties in the resulting estimates of industry-specific carbon emissions not present in the national-level studies based on the MECS data. In developing the underlying I–O accounts for this analysis, we do have physical quantity estimates of aggregate fuel inputs for the state as a whole, as well as for the electric utility industry, the largest energy consuming industry in the state. Thus, we do have reasonable confidence in the overall estimates. Because estimates of state-level process emissions—most significant in the production of cement and lime—are not readily available, in this study they are estimated based on the national ratio of process emissions to CO_2 emissions, by industry. Process emissions used in the national analyses are from Energy Information Administration's (EIA) *Emissions of Greenhouse Gases in the United States 2008* (2009).

For the short run, where output prices can rise to reflect higher energy costs, with corresponding declines in sales as a result of product and/or import substitution, the I–O model is supplemented with an elasticity of demand for industry output, which characterizes consumers' response to changing prices. Indeed, one of the challenges of assessing industry impacts at a highly disaggregated level is to develop credible estimates of the industry-specific demand elasticities. In national-level competitiveness studies, we are able to draw on a substantial database of international trade and industry-specific flows among nations as well as industry-specific elasticity estimates drawn from the literature.[8]

Key limitations of state-level analyses are the absence of a both a database on interstate trade flows and a literature on industry-specific elasticity estimates. Thus, when the costs of producing fertilizers or chemicals in California rise as a result of the state's new carbon pricing policy, one needs to address possible competition not only from non-U.S. producers, but from producers in the other 49 states as well. Yet, in the absence of an official record of existing interstate trade flows, one cannot readily estimate the likely vulnerability of California producers to interstate imports in the face of cost increases in the state. The limited literature that does exist is based on *gravity models* that do not include a price term to explain interstate trade.[9] In one of the few published studies actually estimating

[7] The California's Air and Resources Board does produce a GHG emissions inventory. In principle, further work could be done to integrate our estimates with emissions figures found therein. However, such integration is somewhat problematic since the CARB database incorporates an end use transportation sector in its calculations. Emissions from trucks and other vehicles owned by manufacturing industries would be captured under this end use category, as opposed, to being directly attributed to the specific industry in the inventory tables.

[8] This information is embodied in the Global Trade Analysis Project (GTAP) database and the Adkins et al. (2010) analysis which, in turn, are used to derive the elasticities used in the present analysis.

[9] An example is the ADAGE model (Ross 2008), which also uses the IMPLAN data for interstate trade flows.

price elasticities at the state level, Ha et al. (2008) report estimates for Illinois that are larger than the national estimates for some commodities and smaller for others.

Given the size of the California market and the generally excellent transportation links, it is certainly plausible that industry-specific demand elasticities in California are generally larger than the national ones. However, with the exception of the electric utility industry, where we do have California-specific estimates, we are not aware of any consistent elasticity estimates for a broad range of individual industries in the state. Even the California electricity demand elasticities are not ideally suited to our purpose, as they are specific to commercial and residential end uses (Bernstein and Griffin (2005)).[10]

Our approach to this dilemma is to rely on national elasticity estimates at the industry level combined with a sensitivity analysis. Specifically, we conduct simulations on a large-scale, international CGE model, developed by Adkins et al. (2010), to estimate changes in demand for the 50 different industries. This model identifies 8 regions and 29 NAICS sectors, including 15 manufacturing industries. The elasticities are estimated with the assumption that all fossil fuels, including refined products and electricity, are taxed at the border on the same basis as the domestically produced products, similar to the AB 32 approach. It is assumed that other manufactured goods are not similarly taxed. We develop three alternative scenarios reflecting different assumptions about the industry-specific demand elasticities. The first scenario simply uses the national elasticities as estimated via the CGE model, except for the electric sector, where the California-specific estimate is applied. The second scenario assumes that the nonelectric utility elasticities in California are 10 percent larger, i.e., *more elastic* than the corresponding national figures. The third scenario assumes that the nonelectric utility elasticities are 25 percent *more elastic* than the national figures. [11]

IV. Energy Production and Use in California

In this section, we present a brief overview of energy production and use in California. We also present estimates of the industry-specific EITE subsidies for California based on the H.R. 2454 design. Comparable information for the United States as a whole is also displayed.

Energy Consumption and Carbon Intensity

As shown in Tables 1–3, California accounted for a 12.9 percent share of U.S. gross domestic product (GDP) in 2006, but considerably smaller shares of energy use and CO_2 emissions. Electricity production in the state is only about 45 percent as carbon intensive as that in the United States as a

[10] In order to have a single elasticity that incorporates all changes across different end uses, we use a weighted average of the short-run elasticities in this report. The weights used are the shares of consumption of electricity and natural gas that are attributed to residential and nonresidential use in the underlying California energy use data.

[11] In reality, the California elasticities are unlikely to vary from the national estimates by a constant percentage across the board. For goods like apparel and computer equipment, the demand elasticities for California-made products are likely quite elastic in relation to the demand for the same things anywhere within the nation. However, for a good like cement, that is generally produced in close proximity to where it is used, there is probably little difference between the California-specific and the national demand elasticities. Unfortunately, the absence of state level information prevents us from developing such industry-specific scenarios.

whole. Coal consumption in California is 2.7 million short tons versus 1.1 billion short tons at the national level, approximately 0.25 percent of total U.S. consumption. In contrast, state-level consumption of hydroelectric power is approximately 48 billion kilowatt-hours (kWh), representing approximately 16.6 percent of the total U.S. hydroelectric energy consumption (~289 billion kWh). Consumption of natural gas in 2006 was 2.3 trillion cubic feet, compared to total U.S. consumption of 21.6 trillion cubic feet, or 10.7 percent of total U.S. consumption. The consumption of petroleum products and nuclear electric power in the state are less than the state's share of U.S. GDP, with consumption of these energy sources representing approximately 9.5 percent and 4.1 percent, respectively.

Natural gas plays a predominant role in the state's electricity production. Table 2 highlights California vs. U.S. electricity production, along with the associated emissions. In 2006, net-generation of electricity in California was 216.8 thousand gigawatt-hours (GWh) versus U.S. production of 4.1 million GWh. The emissions intensity of electricity in California is significantly lower than the U.S. overall, where coal is the largest single fuel source. An average of 273.94 metric tons of CO_2 is emitted per million kWh of production in the state versus the U.S. average of 605.16 metric tons of CO_2 per million kWh. Overall, California has the 15th least carbon-intensive electricity production in the United States. However, such a figure is somewhat misleading. While approximately 73 percent of California's electricity comes from in-state production, the emissions attributable to imported electricity represent nearly half of the overall emissions from electricity consumption in the state.[12]

Figure 1 displays the composition of California's emissions in 2006 by source catgory, including electricity generation, natural gas consumption, EITE energy consumption (less electricity and natural gas), refining industry emissions, and other sources (mostly transportation). Figure 2 displays comparable information for the United States. As shown, electricity generation is a far smaller share of California emissions than nationally, reflecting the heavy reliance on natural gas and hydropower, and the very limited use of coal in the state. Electricity generation accounts for approximately 15 percent of total state-level emissions versus the 40 percent contribution it makes at the national level. In contrast, natural gas consumption (excluding electricity generation) and the "other" category dominated by transportation are relatively higher shares than at the U.S. level. Approximately 16 percent of California's emissions come from natural gas consumption (excluding natural gas used by electric utilities and the refining industry) versus 13 percent at the national level. California's EITE emissions are a somewhat lower share than nationally, representing 6.7 percent of total state-level emissions versus 8.4 percent at the national level without considering natural gas or electricity emissions. Refinery emissions represent a somewhat higher share of the total than nationally, with approximately 8.7 percent of California emissions attributable to refineries, compared with 5.8 percent nationally.

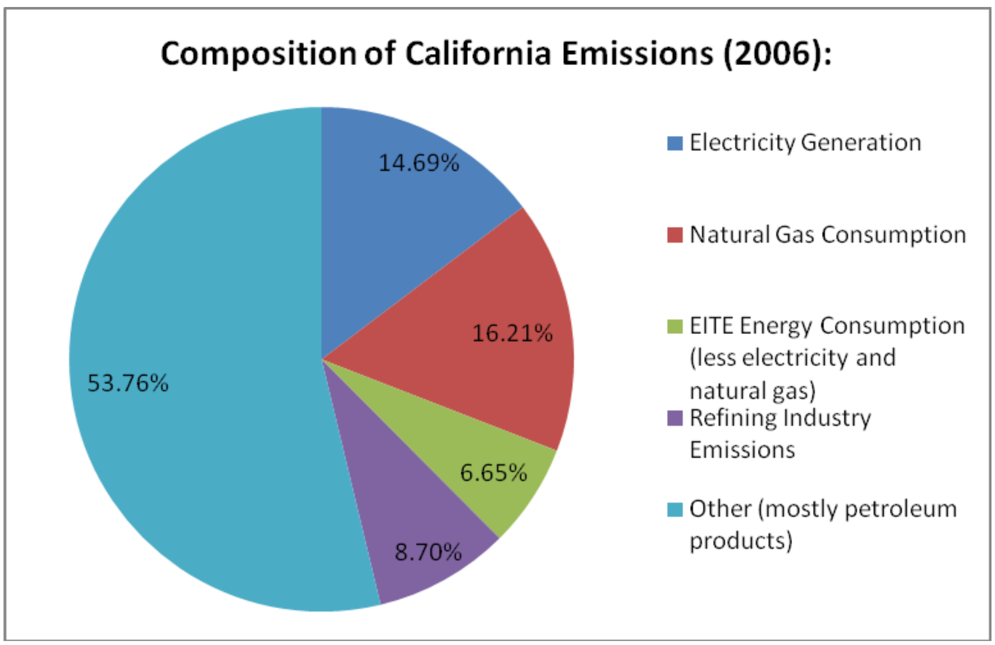
[12] For electricity consumption composition see: http://energyalmanac.ca.gov/overview/energy_sources.html

For emissions composition see: http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_scopingplan_00-08_2010-05-12.pdf

We now turn to a description of the energy consumption patterns and carbon content of the 50 industries considered in the detailed analysis. Tables 4, 5, and 6 present the summary energy consumption information in California for these industries that we have analyzed based on IMPLAN data and other sources as described above and in Appendix A. Table 4 displays energy costs as a share of total costs for electricity, fossil fuel (combusted portion only), and total energy, including noncombustion use of fossil fuels for California industries. Comparable information for the United States as a whole is displayed in Appendix Tables B1, B2, and B3, although here we have slightly greater disaggregation, extending to 52 industries.

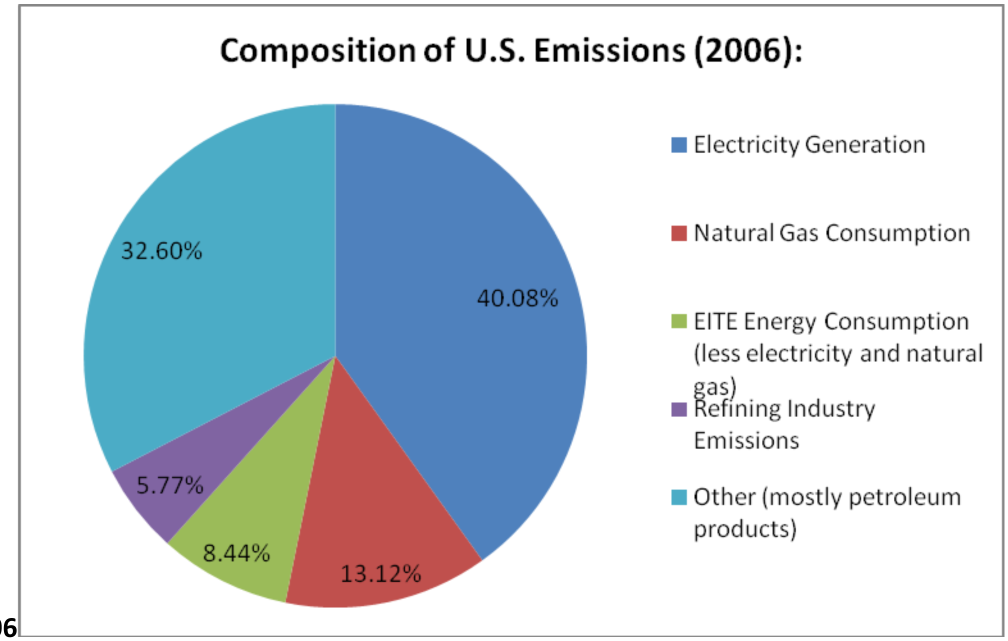
Total costs are defined as the total value of all inputs for industry *j*, including capital input. This equals the value of industry output (at the seller's price before taxes on production). Table 5 presents our estimates of fuel use by the different industries expressed in short tons of coal, barrels of crude oil, and other common fuel measurements. Table 6 presents the data on CO_2 emissions and CO_2 intensity for California, expressed in thousand metric tons and metric tons of CO_2 per dollar of output, respectively.[13],

Figure 1. Composition of Sources of California CO_2 Emissions in 2006



[13] The information in Table 6 is derived from the fuel use by industry in Table 5 and national feedstock ratios underlying Adkins et al. (2010).

Figure 2. Composition of Sources of U.S. CO_2 Emissions in 2006



As shown in column 3 of Table 4, the relative importance of energy in California production as a contributor to total costs, including feedstock uses of fuels, varies widely across the different manufacturing industries, ranging from almost 49 percent for petrochemicals and 43 percent in the petroleum industry to 1 percent in other industries. Outside of manufacturing, a similarly wide range exists, with a high of almost 65 percent in gas utilities. Even when energy costs are restricted to the combusted portion, as shown in column 2 of Table 4, the cost shares range as high as 48 percent to less than one percent. Fifteen of the 33 manufacturing industries identified here have energy costs exceeding 6 percent of total costs. Seven of the 19 nonmanufacturing industries—including electric and gas utilities—have energy costs exceeding 6 percent of total costs.

Within the manufacturing sector, the contributors to energy costs also vary greatly. In some industries, such as cement and inorganic chemicals, a relatively large portion of energy costs are associated with electricity use. In others, such as fertilizers and organic chemicals, direct fuel combustion is more important. When compared to the comparable data for the entire United States (Appendix Table B1), energy costs as a share of total costs are generally lower, with a few notable exceptions: apparel, petrochemicals, inorganic chemicals, fertilizers, and cement. The difference for apparel is quite small. For petrochemicals and cement, however, the differences could be the result of imprecise estimates of total energy use and/or industry output.

Table 5 displays the value of industry output for the 50 industries, along with the energy consumption information expressed in physical quantity terms for the five fuels included in the

California analysis.[14] Not surprisingly, natural gas use by electric utilities in California swamps consumption of that fuel by even the large manufacturing sectors in the state. Electric utilities' use of coal, low by national standards, is still more than twice as great as that of the next largest consumer, cement. The computer and electronic equipment industry is the largest electricity consumer among manufacturers in the state, and is almost twice as large as the number two consumer, the food industry. Outside of manufacturing, the real estate and rentals industry is the biggest electricity user, followed by other services.

Compared to the national situation, California's carbon metrics differ in a number of categories. Of particular interest is the summary measure CO_2 intensity. For most of the listed industries, California is below the national average—much lower in the case of the electric utilities. The three cases where California exceeds the national average are petrochemical manufacturing, fertilizers, and cement. There is, as noted, some uncertainty about the cause of the high numbers in petrochemical manufacturing and cement. It is possible that the California product mix differs significantly from the national average. Alternatively, the differences could be a result of using national average pricing information to derive the fuel quantity estimates or, possibly they could they could be related to the imprecise state-level I–O estimates by IMPLAN. Industry experts could probably explain the remaining disparities. The difference in CO_2 intensities between the state and national estimates for fertilizers is relatively small.

Table 6 displays the CO_2 emissions (expressed in thousand metric tons) from direct combustion, electricity consumption, and process emissions, as well as total CO_2 content per million dollars of output—in other words, total CO_2 intensity. Note the large variation in CO_2 intensity across industries, from 35 metric tons per million dollars of output in miscellaneous manufacturing to 5,600 metric tons per million dollars of output for cement and 1,936 metric tons per million dollars of output for electric utilities. Note also that for both California and the U.S. as a whole, cement ranks number one overall in CO_2 intensity. As noted, we assume that the ratio of process emissions to CO_2 emissions is the same for California as it is at the national level.

H.R. 2454-Style Output-Based Rebates

Table 7 displays the value of the output-based allocations estimated under the modified H.R. 2454 proposal for the California EITE industries based on our 50-industry disaggregation. Recall that in the current analysis, we consider two alternative schemes for free allocation of allowances beyond the reference case which simply returns the revenues to households: LDC/NGDC allocations alone, and a modified H.R. 2454 proposal that includes EITE rebates in addition to LDC/NGDC allocations. For the LDC/NGDC scenario only, the rebates are displayed at the bottom of Table 7; the full rebate scenario includes everything in Table 7. Recall that although the list of eligible industries is identical to the national list, the size of the allocation is based on the application of the H.R. 2454 formulae to the

[14] An additional fuel, liquefied petroleum gas is broken out in the national analysis, shown in Appendix table B2. Note also that the national data are displayed in units that are three orders of magnitude smaller than those for California.

California energy use patterns.[15] Similar to the national system, it is assumed that all fuels, including electricity and refined products, are subject to border tax adjustments. The last column of Table 7 gives the share of industry output that is presumptively eligible for rebates under H.R. 2454 for our list of industries. Of the 31 manufacturing industries examined, 19 are eligible for at least some rebates, totaling about $320 million. Approximately two-thirds of the rebates accrue to the refining industry. Firms within these industries are allocated free allowances based on their output. The subsidy rate is calculated as the ratio of the value of the industry rebate (with a permit price of $15 per ton) to the industry output. These subsidy rates are quite different among the various sectors, ranging from a low of 0.11 percent for aluminum to a high of 3.07 and 3.04 percent for petrochemicals and cement, respectively, among the industries with a 100 percent qualifying share. The industries with a qualifying share of less than 20 percent have essentially zero subsidies. For all manufacturing industries except petrochemicals and cement, the subsidy rates represent less than one percent of output value.

Also displayed in Table 7 are the allocations for electric and gas utilities under the H.R. 2454 rules. Note that these figures are for total rebates for all customers, not just for EITE industries; that is, they include the rebates to the residential and commercial sectors. As shown, the total rebates are $1.40 billion, divided approximately 50–50 between LDCs and NGDCs.

Appendix Table B4 displays comparable information on the H.R. 2454 rebates for the national analysis based on the 52-industry disaggregation. Naturally, 21 of the 33 manufacturing industries examined are eligible for rebates. With a few exceptions in the chemicals industry, the calculated national subsidy rates are somewhat higher nationally than in California. In the case of cement, the industry with the highest subsidy rates, the rate is 4.47 percent nationally versus 3.04 percent in California. For electric utilities, the national subsidy rate is 7.2 percent compared to 2.30 for California.[16] At the national level, the allocation to NGDCs represents an effective subsidy of approximately 7 percent of output, based on our calculations. The comparable subsidy rate for California's NGDCs is 6.03 percent.

V. Effects on Industry Costs, Output, and Profits

This section presents the results of our very short-run and short-run modeling horizons. To illustrate the effects of an economy-wide carbon pricing policy in California, we simulate the effects of a carbon tax of $15 per ton CO_2 (2006$), both with and without the accompanying rebates given in Table 7. In addition to the reference scenario where the revenues are fully returned to households, we consider two illustrative rebate policies, one where only the electric and gas utilities are compensated, and one modifying the provisions in H.R. 2454 that also include subsidies for EITE industries.[17] For the

[15] In practice, determination of the industry-specific allocations would involve the periodic updating of average emissions intensity to calculate a two-year moving average.

[16] At the national level, we have an effective subsidy for the coal mining industry. Although no provision in H.R. 2454 allocates emissions allowances directly to the coal mining industry, this was done as a method for implementing the allocation given for merchant coal generation of electricity under the legislation. California does not produce coal and, as a result, there is no comparable provision in the current analysis.

[17] In both of the policy cases, the remaining revenues are assumed to be allocated back to households.

short-run analysis, results are also presented for alternative assumptions about demand elasticities to show the sensitivity of the results to this critical factor.

Effects on Industry Costs—Very Short-Run Horizon

Table 8 displays the effects of the $15 per ton price on industry costs in California. Table 8 breaks the total cost effect into the contributions due to higher primary fuel prices, higher electricity costs, and higher prices of all other intermediate inputs. For most manufacturing industries, this last factor is estimated to increase total costs by less than 1 percent even without any rebates, the three exceptions being industries in the chemicals group. The industries with the highest total cost increases are petrochemical manufacturing (4.4 percent); followed by cement (3.8 percent); and plastics, materials, and resins (3.8 percent). Those with the smallest cost increases are computer and electronic equipment, miscellaneous manufacturing, and machinery and transportation equipment—each with an increase of less than 0.5 percent.

Tables 9 and 10 display the comparable results with the two H.R. 2454-based rebate schemes in place. As shown, with the subsidies, the estimated cost increases are smaller, but not uniformly so. For example, for fertilizers, the costs rise by 3.4 percent in the carbon pricing-only case, by 3.2 percent in the LDC subsidies case, and 3.18 percent in the LDC-plus-EITE subsidy case. For pulp mills, the corresponding changes are 1.41, 1.15, and 1.07 percent, respectively. Not surprisingly, the LDC rebates mostly benefit heavy electricity users, whereas the LDC-plus-EITE rebates benefit a broader set of industries. Thus, the LDC rebates reduce the policy-induced cost increases by a very small amount in petrochemical manufacturing because fuel combustion related cost increases represent most of this industry's policy induced cost increases. With the full H.R. 2454 rebates, costs are reduced for a broader set of industries. For example, other basic organic chemicals, plastics and resins, and other nonmetallic minerals all see cost reductions of more than one-third. The effects of the rebates are generally quite small in the nonmanufacturing sector given their comparably smaller electricity costs. The principal beneficiaries here are those with the higher electricity bills—real estate (reduced from 0.12 to 0.08 percent) and trade (reduced from 0.2 to 0.17 percent).

Effects on Output—Short-Run Horizon

In contrast to the very short-run, in the short-run horizon we assume that producers raise prices to cover the higher unit costs, with resulting reductions in sales and output as customers switch to alternative goods or imports. As discussed in Section III, to determine the sales response, we estimated the elasticity of demand for each industry by simulating a multi-region global CGE model. These elasticities, displayed in appendix A involve two specific assumptions: (a) that fuels, including refined products, are taxed at the border on the same basis as domestically produced products and (b) that other manufactured goods are not similarly taxed. For the electric utilities industry, we rely on the California-specific elasticity estimates rather than the CGE model-derived estimates.

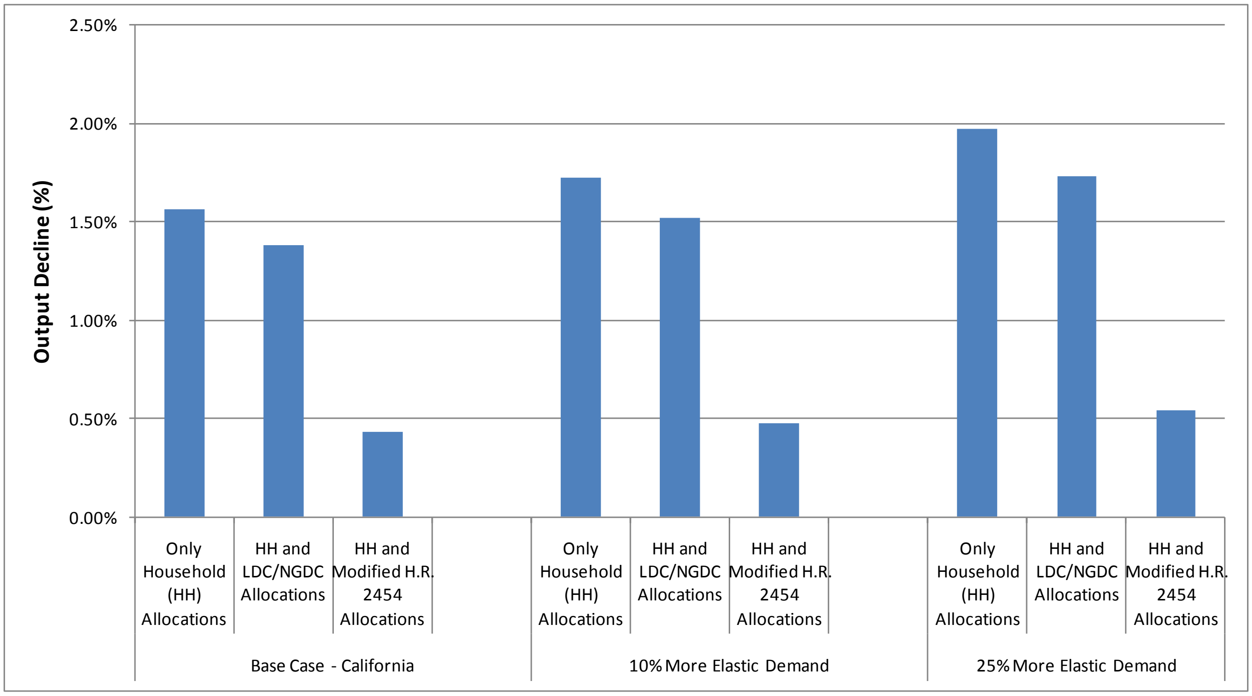
As noted, to reflect the likelihood that the true California elasticities are larger than the national ones derived from the CGE model, we consider three alternative scenarios reflecting different assumptions about the industry-specific demand elasticities: the unmodified national elasticities plus the California-specific electricity sector estimate; an assumed 10 percent increase for all sectors except the electric utilities industry; and an assumed 25 percent increase for all industries except the electric utilities industry. We display the results in two ways, for the 50 individual industries analyzed in this study and in summary form for the EITE industries alone, where the results for the individual industries are weighted by the output levels of the underlying industries.

We first display the average results for the EITE industries across the three policy cases and the three elasticity assumptions considered in this study. Not surprisingly, the impacts decrease with the presence and extent of the rebates and they increase with the alternative (higher) elasticity estimates. As shown in Figure 3, the average EITE output losses associated with a charge of $15 per ton of CO_2 when the base elasticities are used are about 1.6 percent with no allocations, falling to about 1.4 percent with LDC allocations only, and falling to about 0.4 percent with both the LDC and the EITE allocations in place. With elasticities that are 10 percent higher than those in the base case, the corresponding output reductions for the three policy cases are about 1.7, 1.5, and 0.5 percent, respectively. With elasticities that are 25 percent higher than the base case, the output reductions are about 2.0, 1.7, and 0.6 percent, respectively.

Although the output losses for the EITE industries as a group are relatively small, the average obscures considerable inter-industry variation. Table 12a displays the industry-specific results using the base case elasticities. For the most adversely impacted industry, petrochemical manufacturing, we see output declines of 6.1 percent without any allocations, declining slightly to 5.9 percent with the LDC/NDGC allocations, and falling substantially to 1.3 percent with both the LDC and the EITE allocations. The next largest output decline is in the plastics and material resins industry, with output declines of 5.1 percent without any allocations, 5.1 percent with LDC/NGDC allocations, and 2.7 percent with both the LDC/NGDC and EITE allocations. Again, given the underlying uncertainty about the accuracy of the CO_2 intensity for petrochemicals, the output decline for this industry should be considered with a grain of salt. At the national level, the CO_2 intensity for this industry is much smaller and, as a result, if there are errors in the underlying I–O accounts, the estimated output declines could be larger than actual declines. Similar patterns of large reductions in output losses in the presence of both the LDC and the EITE allocations are seen in most other EITE industries. Note that the full rebate scheme reduces the losses in the cement industry from 2.75 to 0.04 percent, a decline of more than 98 percent. At the other end of the scale, the glass containers industry has an estimated output loss of only 0.49 percent without any rebates, and a tiny 0.06 percent with the full rebates. Outside of the manufacturing sector, the initial losses from introducing a $15 per ton CO_2 price are relatively small, as are gains from the rebates, with the exception of gas utilities, where output losses decrease from 4.7 percent with no rebates to 1.52 percent with the full rebates—a reduction in losses of almost 70 percent.

Of particular interest are the gains in output for a number of industries in the reference case with full revenue recycling to households as opposed to the emphasis on rebates to the LDCs and EITE industries. These gains occur in the trade, information, finance and insurance, real estate, business services, and other services industries. The gains are driven by the increases in household demand arising from the full revenue recycling.[18]

Figure 3. Average California EITE Output Declines under Each Policy Scenario (2006)



Tables 12b and 12c display the comparable results for the sensitivity analyses involving the higher elasticity assumptions. As expected, the output losses are proportionally higher with the assumptions underlying the modeling framework, but the pattern of substantial reductions in the output losses in the presence of the output-based rebates remains the same. For example, in the petrochemical industry, we see losses of 6.7 and 7.6 percent, respectively, for the assumed 10 percent and 25 percent increases in elasticities. At the same time, in the presence of the full rebates (LDC plus EITE), these losses decline to 1.5 and 1.7 percent, respectively. Similar patterns apply to the other EITE industries as well as to electric and gas utilities that benefit from the LDC rebates.

Effects on Profits—Comparison of Very Short-Run and Short-Run Horizons

We now turn to a discussion of the effect on profits of carbon pricing policies, both with and without the H.R. 2454-based rebates. Recall that we define profits as the gross return to capital, that is, sales revenue plus rebates (if applicable) less intermediate costs, employee compensation, and taxes. Table 13 displays the results for the very short-run and the short run cases without rebates. Tables 14

[18] An unresolved issue is the amount of time it would take for these gains to become manifest. It is possible they would occur in the short term, as we have assumed in our calculations. It is also possible, however, that they would only appear over the longer term. Thus, we do not emphasize them in our analysis.

and 15 display comparable results for the two illustrative rebate schemes considered. Note that we focus here on the case involving the base elasticity assumptions.[19]

Overall, declines in profits, which are quite large in the hypothetical very short-run case, rebound dramatically when firms are able to raise prices to pass along some of the higher costs. As expected, the rebound is even greater with the LDC and EITE rebates in place. For example, consider the most adversely affected manufacturing industry, other basic organic chemicals, which is estimated to experience profit declines of almost 59 percent in the hypothetical very short-run case. In the short run, when firms are able to raise prices to pass along some of the higher costs, losses are cut by more than 90 percent, to a level of –4.9 percent. With the full LDC and EITE allocations, losses are cut further. Similar results are observed for the plastics and material resin, artificial fibers, and fertilizer industries. Outside of manufacturing, the impacts are generally smaller, except for the air transportation industry. In the very short-run case, profit declines are estimated at approximately 160 percent, depending on the policy case. In the short run, however, the profit declines are minimal. In the case of air transportation, the short-run time horizon more accurately describes the potential impacts because it is relatively easy for airlines to change prices to adjust to a new carbon pricing policy.

Overall, the short run profit impacts tend to be fairly small. This is encouraging, given the estimated profit impacts do not take into consideration the endogeneity that exists between rebates, output effects, and profit impacts. If such relationships were incorporated, the profit impacts would likely be smaller, as the household rebates have the effect of increasing final demand, thus mitigating part of the initial profit losses.

VI. Discussion

Although the data and methodological issues discussed throughout this paper are critical to interpreting the results, the focus in this section is on the specific policy assumptions adopted herein; even small differences in the assumptions might produce different results. We consider three issues: NAs regards the CO_2 pricing assumptions, the calculations for both the very short run and the short run are strictly based on linear models assuming a \$15 per ton of CO_2 price. Thus, if one is willing to maintain the linearity assumption, the estimated effects may be scaled up or down for different CO_2 prices: an assumed \$30 per ton CO_2 price would have twice the impact on industry costs and output losses as a \$15 per ton price.

As regards border tax adjustments, we have assumed that all fuels, including coal, natural gas, crude oil, gasoline, other refined products, and electricity, are taxed at the California border at the same rate as those fuels produced in the state. Effectively, we have assumed the existence of both legal and implementation mechanisms to impose such taxes. For electricity this assumption is straightforward.

[19] Note that correct treatment of industry profit effects would account for the endogeneity that exists between household rebate, output changes, and profits. However, in our analysis we have aimed for a transparent approach. Such endogeneity would significantly detract from any simple, straightforward modeling approach. As a result, our profit calculations do not incorporate the second order effects that demand changes, which result from household rebates, have on industry profits.

For fossil fuels, it is also fairly straightforward, although it's difficult to imagine a foolproof implementation mechanism that didn't have some unintended consequences. Pipelines or tanker trucks carrying gasoline could likely be monitored without great difficulty. At the same time, individual vehicles or small fleets could probably gas up in bordering states without detection, resulting in some emissions leakage and some revenue losses to the state. A similar story might apply to aviation and bunker fuels.

As regards the EITE rebates, we have adopted the list of presumptively eligible industries estimated by EPA (2009) under H.R. 2454 based on national information and we have used California data to calculate the rebates based on the updating scheme embodied in H.R. 2454. An alternative approach, not adopted here, would prepare a list of presumptively eligible industries based strictly on California data on energy and trade intensity. Although such an approach would certainly be hampered by the paucity of publicly available information on the flow of goods among states on an industry-specific basis, it would likely provide a stronger basis for identifying the most adversely impacted industries in the state. For an industry defined as presumptively eligible, determining the size of the rebate to be offered is also a critical issue. In this study, we have adopted the same criteria used in H.R. 2454. Effectively, H.R. 2454 subsidizes 100 percent of the industry's average cost increases for directly combusted fuels and average electricity cost increases, while not compensating for any of the cost increases of intermediate inputs. However, other options are also possible. One could, for example, offer a smaller subsidy for directly combusted fuels, a higher one for electricity, or any other combination.

VII. Conclusions and Policy Implications

In pulling together the diverse parts of this analysis, a number of summary observations can be made. First, it is clear that, on average, most California industries at our level of aggregation have a lower carbon intensity than the same industries in other states. This is due, in large part, to the limited use of coal in the electricity sector, and the relatively heavy reliance on natural gas and renewables throughout the state. Thus, by its very nature, a statewide California cap-and-trade program with a given price on CO_2 emissions would impose relatively smaller additional burdens on the state's industries than a comparable program for the nation as a whole.

Second, in reviewing the modeling results for the assumed $15 per ton CO_2 price, we see relatively small impacts on industry output of energy-intensive industries when viewed as a whole. . The average post rebate EITE output reduction is 0.43 percent, rising to 0.55 percent with our worst case assumption about California demand elasticities. There is, however, considerable variation among the EITE industries. The most heavily impacted industry is fertilizers, where the short run output loss is 3.2 percent with the rebates in place, down from 4.7 percent without the rebates. For our worst case elasticity assumption, the post rebate output loss for fertilizers is 4.0 percent.

Third, our modeling suggests that, even with the sales drop, reductions in industry profits are substantially reduced as firms pass along their higher costs to customers. In most cases, the losses are less than 2 percent even without the rebates. With the LDC/NGDC rebates, and especially with the combined LDC and EITE rebates, the declines in profits are less than 1.5 percent in most industries.

All of these observations apply to the short-run time horizon of our modeling analysis, when capital, labor, energy, and material inputs are fixed and the only step a firm can take in response to the carbon pricing scheme is to try to pass along higher costs to its customers. Over the longer term, however, the situation could be quite different. Invariably, firms in most industries have options to change their input mix and adopt new technologies, which will tend to lower their long-run production costs. At the same time, in the long run, customers will have greater opportunities to alter their purchasing patterns, potentially reducing the adverse impacts in some industries and magnifying them in others. The Adkins et al. (2010) analysis at the national level suggests that both tendencies are at work, with some industries seeing their output losses reduced over time and others seeing further losses. On average, the long run analyses at the national level suggest that output losses are expected to decline by an additional one fifth when compared to the short run results presented here.

Tables

Table 1. 2006 California Gross State Product and U.S. Gross Domestic Product

Region	GSP/GDP (billion $)	Share of U.S.
California	1,727.6	12.9%
United States	13,398.9	—

Source: BEA National Income and Product Accounts Tables and regional economic accounts.

Table 2. Electricity Production and Carbon Intensity (2006)

Region	Primary fuel source	Net-generation (MWh)	CO_2 emissions from electricity production (1,000 metric tons)	Metric tons of CO_2 per million kWh	Electricity generation CO_2 emissions state rank
California	Gas	216,798,688	59,389	273.94	15
United States	Coal	4,064,702,227	2,459,800	605.16	—

Source: EIA 2006 State Electricity Profile report.

Table 3. Energy Consumption Summary (2006)

Energy commodity	California consumption	U.S. consumption	Share of U.S.
Coal (1,000 short tons)	2,771	1,112,000	0.25%
Natural gas (billion ft^3)	2,316	21,685	10.7%
Petroleum (1,000 bbls)	714,117	7,551,000	9.5%
Nuclear electric power (million kWh)	31,959	787,000	4.1%
Hydroelectric power (million kWh)	48,047	289,000	16.6%

Source: EIA 2006 State Energy Data System.

Table 4. California Energy Costs, Intermediate Inputs and Imports, 2006 (% share)

		% Share of Total Costs			
		Electricity	Fuel Combustion	Total Energy (incl non-combustion)	Intermediate Inputs
Manufacturing Industries	Food	1.34	1.15	2.48	73.62
	Textile	2.09	2.15	4.24	66.39
	Apparel	1.04	0.76	1.81	59.99
	Wood & Furniture	1.03	0.70	1.74	47.02
	Pulp Mills	3.45	8.74	12.19	79.65
	Paper and Paperboard Mills	3.72	7.32	11.04	70.42
	Other Papers	0.79	1.09	2.02	49.78
	Petroleum	0.51	4.75	42.85	79.17
	Petrochemical Manufacturing	1.20	47.67	48.98	84.09
	Basic Inorganic Chemical Mfg	8.00	6.16	15.42	68.35
	Other Basic Organic Chemical Mfg	1.23	13.37	17.79	85.11
	Plastics and Material Resins	1.03	3.74	5.15	87.15
	Artificial & Synthetic Fibers, Filaments	2.59	3.76	7.41	83.65
	Fertilizers	2.36	24.16	28.51	77.74
	Other Chemical & Plastics	1.40	0.96	4.38	60.84
	Glass Containers	4.40	5.56	9.96	55.25
	Cement	18.82	10.65	29.47	61.12
	Lime and Gypsum	2.30	5.89	8.19	66.97
	Mineral Wool	4.62	4.21	8.83	56.80
	Other Nonmetallic Mineral	1.31	1.49	2.93	57.29
	Iron and Steel Mills and Ferroalloy	4.18	5.99	10.33	67.90
	Alumina Refining, Primary and Secondary Aluminum	5.75	0.94	7.92	60.10
	Ferrous Metal Foundries	3.96	1.96	6.07	58.00
	Non-Ferrous Metal Foundries	1.81	1.28	3.09	65.17
	Other Primary Metals	1.92	0.67	3.94	67.91
	Fabricated Metals	1.40	1.13	2.58	54.81
	Machinery	0.83	0.64	1.47	63.66
	Computer & Electrical Equipment	1.08	0.16	1.39	69.95
	Motor Vehicles	0.72	0.87	1.61	74.64
	Other Transportation Equipment	0.79	1.85	2.71	62.29
	Miscellaneous Manufacturing	0.73	0.30	1.03	46.59
Non-Manufacturing Industries	Farms	1.03	5.38	7.61	47.16
	Forestry, Fishing, etc	0.19	1.08	1.51	28.43
	Oil Mining	0.58	0.70	1.43	26.23
	Gas Mining	0.55	0.67	1.37	26.18
	Coal Mining	-	-	-	-
	Other Mining Activities	1.22	8.49	11.52	41.15
	Electric Utilities (inc govt enterprises)	0.00	21.71	21.71	35.01
	Gas Utilities	0.05	0.50	64.93	75.20
	Construction	0.26	2.90	3.81	50.98
	Trade	1.04	1.35	2.66	37.20
	Air Transportation	0.41	21.27	26.51	66.03
	Truck Transportation	0.21	13.34	16.56	49.99
	Other Transportation	0.77	6.76	8.99	29.64
	Information	0.45	0.21	0.70	37.29
	Finance and Insurance	0.36	0.16	0.55	22.02
	Real Estate and Rental	1.30	0.43	1.78	23.34
	Business Services	0.64	0.92	1.74	28.29
	Other Services	0.86	0.67	1.64	39.95
	Govt exc. Electricity	0.30	1.29	1.83	7.16

Source: Authors' calculations

Table 5. California Output, Energy Consumption (combustion only) and CO_2 Intensity, 2006

		Output (million $)	Coal (1000 sh tons)	Crude Oil (million bbls)	Petroleum (1000 bbls)	Gas (million cu ft)	Electricity (GWh)	Total CO2 Intensity (ton CO_2 /mil$)
Manufacturing Industries	Food	71,796.1	194.8	0.0	3,453.7	48,192.2	7,229.7	99
	Textile	4,412.0	25.4	0.0	381.0	6,012.4	713.8	181
	Apparel	12,978.1	0.0	0.0	605.7	4,194.9	1,047.2	67
	Wood & Furniture	15,491.1	17.3	0.0	721.9	3,925.5	1,233.9	65
	Pulp Mills	145.5	2.0	0.0	82.1	472.9	38.7	536
	Paper and Paperboard Mills	1,593.7	43.4	0.0	718.6	4,575.6	459.4	503
	Other Papers	15,195.1	4.8	0.0	1,347.7	3,220.7	928.6	71
	Petroleum	95,314.6	93.2	47.7	0.0	308,975.2	3,735.1	409
	Petrochemical Manufacturing	12.6	0.0	0.0	54.6	70.9	1.2	2,140
	Basic Inorganic Chemical Mfg	1,352.5	11.2	0.0	679.9	1,793.0	840.8	537
	Other Basic Organic Chemical Mfg	1,417.3	9.6	0.0	1,611.0	3,646.4	135.0	664
	Plastics and Material Resins	3,693.0	5.0	0.0	622.8	10,752.0	294.7	264
	Artificial & Synthetic Fibers, Filaments	128.4	1.4	0.0	27.0	252.0	25.8	290
	Fertilizers	1,595.4	2.7	0.0	627.9	48,463.9	292.3	1,897
	Other Chemical & Plastics	64,403.1	96.9	0.0	3,927.6	26,913.1	6,974.4	91
	Glass Containers	878.1	0.0	0.0	188.3	3,268.0	298.3	417
	Cement	1,105.8	954.4	0.0	364.0	2,780.0	1,607.5	5,651
	Lime and Gypsum	1,197.2	103.1	0.0	238.4	4,418.6	212.5	1,054
	Mineral Wool	765.7	3.4	0.0	120.9	2,169.5	273.6	360
	Other Nonmetallic Mineral	9,035.0	6.6	0.0	498.4	9,159.6	911.1	117
	Iron and Steel Mills and Ferroalloy	2,407.3	126.7	0.0	990.1	4,030.2	777.6	483
	Alumina Refining, Primary and Secondary Aluminum	2,488.2	0.0	0.0	35.1	2,137.6	1,094.9	214
	Ferrous Metal Foundries	1,124.4	11.5	0.0	125.9	947.8	344.4	225
	Non-Ferrous Metal Foundries	763.5	0.0	0.0	61.6	393.7	106.8	113
	Other Primary Metals	3,062.2	4.9	0.0	82.0	1,296.3	453.3	92
	Fabricated Metals	28,415.1	0.2	0.0	2,076.3	12,361.9	3,087.9	94
	Machinery	27,154.1	0.9	0.0	1,329.3	4,365.9	1,743.9	53
	Computer & Electrical Equipment	160,980.1	0.0	0.0	302.0	24,998.5	13,475.7	40
	Motor Vehicles	12,790.1	1.2	0.0	867.5	2,644.5	711.8	60
	Other Transportation Equipment	29,245.1	2.2	0.0	5,042.4	3,974.0	1,798.9	102
	Miscellaneous Manufacturing	22,620.1	0.0	0.0	398.1	3,135.1	1,273.9	36
Non-Manufacturing Industries	Farms	33,484.1	9.0	0.0	18,849.9	2,488.0	2,640.1	267
	Forestry, Fishing, etc	7,783.1	0.0	0.0	892.5	35.9	112.7	53
	Oil Mining	15,941.5	11.8	0.0	1,104.4	78.6	664.8	46
	Gas Mining	2,382.0	1.7	0.0	157.4	11.2	94.7	44
	Coal Mining	-	-	-	-	-	-	-
	Other Mining Activities	4,968.1	23.6	0.0	4,116.2	3,317.3	456.7	423
	Electric Utilities (inc govt enterprises)	30,420.0	1,710.9	0.0	7,880.0	946,601.3	0.0	1,936
	Gas Utilities	11,723.4	0.0	0.0	579.2	0.0	42.2	22
	Construction	187,150.1	0.0	0.0	57,357.9	9,773.2	3,817.4	137
	Trade	312,449.9	0.0	0.0	34,093.0	47,914.8	21,717.2	79
	Air Transportation	11,270.1	0.0	0.0	24,790.1	158.1	346.5	924
	Truck Transportation	21,569.1	0.0	0.0	30,601.5	1,327.8	348.3	598
	Other Transportation	42,171.1	0.0	0.0	28,147.5	16,042.7	2,405.1	319
	Information	160,069.9	0.0	0.0	2,575.0	9,738.9	5,447.7	22
	Finance and Insurance	160,609.9	0.0	0.0	2,325.7	3,315.4	4,305.6	17
	Real Estate and Rental	336,909.9	0.0	0.0	7,253.4	64,386.2	30,182.3	52
	Business Services	311,739.9	0.0	0.0	26,353.9	43,646.8	15,445.2	61
	Other Services	368,019.9	0.0	0.0	19,142.2	67,161.3	23,807.2	55
	Govt exc. Electricity	202,449.9	0.0	0.0	23,326.1	69,357.3	4,743.4	75

Source: Authors' calculations

Table 6. California CO_2 Emissions Summary and Emissions Intensities

		Total CO_2 Emissions (thousand metric tons) from:			Total CO_2 Intensity (metric tons CO_2 per million $ output)
		Fossil Fuel Consumption	Electricity Consumption	Process Emissions	
Manufacturing Industries	Food	4,446.7	2,652.5	0.0	98.9
	Textile	536.3	261.9	0.0	180.9
	Apparel	480.7	384.2	0.0	66.6
	Wood & Furniture	547.8	452.7	0.0	64.6
	Pulp Mills	63.8	14.2	0.0	536.0
	Paper and Paperboard Mills	632.6	168.5	0.0	502.7
	Other Papers	744.4	340.7	0.0	71.4
	Petroleum	37,588.6	1,370.4	0.0	408.7
	Petrochemical Manufacturing	26.6	0.4	0.0	2,139.6
	Basic Inorganic Chemical Mfg	417.4	308.5	0.0	536.7
	Other Basic Organic Chemical Mfg	891.8	49.5	0.0	664.2
	Plastics and Material Resins	868.2	108.1	0.0	264.4
	Artificial & Synthetic Fibers, Filaments	27.8	9.5	0.0	290.4
	Fertilizers	2,919.3	107.3	0.0	1,897.0
	Other Chemical & Plastics	3,289.3	2,558.9	0.0	90.8
	Glass Containers	256.8	109.5	0.0	417.1
	Cement	2,156.2	589.8	3,502.9	5,651.1
	Lime and Gypsum	540.7	78.0	643.2	1,054.0
	Mineral Wool	175.3	100.4	0.0	360.1
	Other Nonmetallic Mineral	720.6	334.3	0.0	116.8
	Iron and Steel Mills and Ferroalloy	877.1	285.3	0.0	482.9
	Alumina Refining, Primary and Secondary Aluminum	131.5	401.7	0.0	214.3
	Ferrous Metal Foundries	126.4	126.3	0.0	224.8
	Non-Ferrous Metal Foundries	47.1	39.2	0.0	113.0
	Other Primary Metals	114.4	166.3	0.0	91.7
	Fabricated Metals	1,537.7	1,132.9	0.0	94.0
	Machinery	791.8	639.8	0.0	52.7
	Computer & Electrical Equipment	1,492.7	4,944.2	0.0	40.0
	Motor Vehicles	506.8	261.2	0.0	60.0
	Other Transportation Equipment	2,313.0	660.0	0.0	101.7
	Miscellaneous Manufacturing	336.6	467.4	0.0	35.5
Non-Manufacturing Industries	Farms	7,971.3	968.6	0.0	267.0
	Forestry, Fishing, etc	372.2	41.3	0.0	53.1
	Oil Mining	485.2	243.9	0.0	45.7
	Gas Mining	69.1	34.8	0.0	43.6
	Coal Mining	-	-	-	-
	Other Mining Activities	1,934.5	167.6	0.0	423.1
	Electric Utilities (inc govt enterprises)	58,893.8	0.0	0.0	1,936.0
	Gas Utilities	240.2	15.5	0.0	21.8
	Construction	24,323.1	1,400.6	0.0	137.4
	Trade	16,760.6	7,967.9	0.0	79.1
	Air Transportation	10,290.0	127.1	0.0	924.3
	Truck Transportation	12,764.2	127.8	0.0	597.7
	Other Transportation	12,551.4	882.4	0.0	318.6
	Information	1,600.6	1,998.7	0.0	22.5
	Finance and Insurance	1,145.9	1,579.7	0.0	17.0
	Real Estate and Rental	6,530.2	11,073.7	0.0	52.3
	Business Services	13,317.4	5,666.8	0.0	60.9
	Other Services	11,612.7	8,734.7	0.0	55.3
	Govt exc. Electricity	13,468.0	1,740.3	0.0	75.1

Source: Authors' calculations

Table 7. California Total Permit Allocations to EITE Industries (2006)

		Amount (mil $)	Subsidy Rate (% of Output)	Qualifying Share of Industry Output
	EITE Allocations for Direct Carbon Factor (53% of emissions from NG) + 25% of Indirect Carbon Factor			
Manufacturing Industries	Food	0.6	0.001%	1.0%
	Textile	0.1	0.00%	2.0%
	Apparel	0.0	-	0.0%
	Wood & Furniture	0.3	0.00%	4.0%
	Pulp Mills	0.8	0.57%	100.0%
	Paper and Paperboard Mills	5.8	0.36%	69.0%
	Other Papers	0.0	-	0.0%
	Petroleum	216.0	-	0.0%
	Petrochemical Manufacturing	0.4	3.07%	100.0%
	Basic Inorganic Chemical Mfg	7.3	0.54%	100.0%
	Other Basic Organic Chemical Mfg	13.1	0.92%	100.0%
	Plastics and Material Resins	0.0	-	0.0%
	Artificial & Synthetic Fibers, Filaments	0.4	0.31%	100.0%
	Fertilizers	13.6	0.85%	32.0%
	Other Chemical & Plastics	6.3	0.01%	12.0%
	Glass Containers	3.1	0.35%	100.0%
	Cement	33.6	3.04%	100.0%
	Lime and Gypsum	1.3	0.11%	19.0%
	Mineral Wool	2.2	0.29%	100.0%
	Other Nonmetallic Mineral	1.6	0.02%	19.0%
	Iron and Steel Mills and Ferroalloy	12.7	0.53%	100.0%
	Alumina Refining, Primary and Secondary Aluminum	2.7	0.11%	100.0%
	Ferrous Metal Foundries	0.0	-	0.0%
	Non-Ferrous Metal Foundries	0.0	-	0.0%
	Other Primary Metals	0.4	0.01%	20.0%
	Fabricated Metals	0.0	-	0.0%
	Machinery	0.0	-	0.0%
	Computer & Electrical Equipment	0.0	-	0.0%
	Motor Vehicles	0.0	-	0.0%
	Other Transportation Equipment	0.0	-	0.0%
	Miscellaneous Manufacturing	0.0	-	0.0%
	Allocations for Electric and Gas Utilities			
	Electric Utilities (inc govt enterprises)	699.0	2.30%	-
	Gas Utilities	707.0	6.03%	-
	Total	1,728.3		

Source: Authors' calculations

Table 8. Very Short Run Time Horizon (California): Percent Increase in Costs due to a $15/ton price of CO_2; no Allocations Scenario

		Total cost	Fuel cost	Purchased electricity	Indirect cost
Manufacturing Industries	Food	0.50%	0.11%	0.04%	0.35%
	Textile	0.93%	0.21%	0.06%	0.66%
	Apparel	0.61%	0.07%	0.03%	0.52%
	Wood & Furniture	0.39%	0.06%	0.03%	0.30%
	Pulp Mills	1.41%	0.77%	0.11%	0.53%
	Paper and Paperboard Mills	1.32%	0.69%	0.11%	0.52%
	Other Papers	0.54%	0.09%	0.02%	0.43%
	Petroleum	0.93%	0.66%	0.02%	0.25%
	Petrochemical Manufacturing	4.38%	4.01%	0.05%	0.32%
	Basic Inorganic Chemical Mfg	1.09%	0.55%	0.24%	0.29%
	Other Basic Organic Chemical Mfg	3.42%	1.14%	0.04%	2.25%
	Plastics and Material Resins	3.76%	0.40%	0.03%	3.33%
	Artificial & Synthetic Fibers, Filaments	1.93%	0.38%	0.08%	1.48%
	Fertilizers	3.42%	3.05%	0.07%	0.30%
	Other Chemical & Plastics	0.76%	0.09%	0.04%	0.63%
	Glass Containers	0.96%	0.50%	0.13%	0.32%
	Cement	3.82%	3.03%	0.57%	0.21%
	Lime and Gypsum	1.45%	0.74%	0.07%	0.64%
	Mineral Wool	1.02%	0.39%	0.14%	0.49%
	Other Nonmetallic Mineral	0.88%	0.14%	0.04%	0.71%
	Iron and Steel Mills and Ferroalloy	1.10%	0.62%	0.13%	0.35%
	Alumina Refining, Primary and Secondary Aluminum	0.56%	0.09%	0.17%	0.30%
	Ferrous Metal Foundries	0.70%	0.19%	0.12%	0.39%
	Non-Ferrous Metal Foundries	0.52%	0.11%	0.05%	0.36%
	Other Primary Metals	0.83%	0.06%	0.06%	0.71%
	Fabricated Metals	0.60%	0.10%	0.04%	0.46%
	Machinery	0.46%	0.05%	0.03%	0.38%
	Computer & Electrical Equipment	0.31%	0.02%	0.03%	0.26%
	Motor Vehicles	0.57%	0.07%	0.02%	0.48%
	Other Transportation Equipment	0.46%	0.15%	0.02%	0.29%
	Miscellaneous Manufacturing	0.38%	0.03%	0.02%	0.33%
Non-Manufacturing Industries	Farms	0.72%	0.44%	0.03%	0.25%
	Forestry, Fishing, etc	0.43%	0.09%	0.01%	0.33%
	Oil Mining	0.27%	0.06%	0.02%	0.20%
	Gas Mining	0.27%	0.05%	0.02%	0.20%
	Coal Mining	0.00%	0.00%	0.00%	0.00%
	Other Mining Activities	0.90%	0.72%	0.04%	0.15%
	Electric Utilities (inc govt enterprises)	3.06%	3.01%	0.00%	0.06%
	Gas Utilities	0.09%	0.04%	0.00%	0.05%
	Construction	0.54%	0.24%	0.01%	0.29%
	Trade	0.20%	0.10%	0.03%	0.08%
	Air Transportation	1.84%	1.71%	0.01%	0.12%
	Truck Transportation	1.23%	1.10%	0.01%	0.12%
	Other Transportation	0.64%	0.55%	0.02%	0.07%
	Information	0.14%	0.02%	0.01%	0.11%
	Finance and Insurance	0.08%	0.01%	0.01%	0.05%
	Real Estate and Rental	0.12%	0.03%	0.04%	0.05%
	Business Services	0.19%	0.08%	0.02%	0.09%
	Other Services	0.23%	0.06%	0.03%	0.15%
	Govt exc. Electricity	0.16%	0.12%	0.01%	0.03%

Source: Authors' calculations

Table 9. Very Short Run Time Horizon (California): Percent Increase in Costs due to a $15/ton price of CO2; LDC and NGDC Allocations Scenario

		Total cost	Fuel cost	Purchased electricity	Indirect cost
Manufacturing Industries	Food	0.43%	0.07%	0.01%	0.35%
	Textile	0.81%	0.13%	0.02%	0.66%
	Apparel	0.57%	0.05%	0.01%	0.52%
	Wood & Furniture	0.35%	0.05%	0.01%	0.30%
	Pulp Mills	1.15%	0.59%	0.03%	0.53%
	Paper and Paperboard Mills	1.08%	0.53%	0.03%	0.52%
	Other Papers	0.51%	0.08%	0.01%	0.43%
	Petroleum	0.89%	0.64%	0.00%	0.25%
	Petrochemical Manufacturing	4.24%	3.91%	0.01%	0.32%
	Basic Inorganic Chemical Mfg	0.89%	0.53%	0.06%	0.29%
	Other Basic Organic Chemical Mfg	3.34%	1.09%	0.01%	2.25%
	Plastics and Material Resins	3.71%	0.37%	0.01%	3.33%
	Artificial & Synthetic Fibers, Filaments	1.81%	0.31%	0.02%	1.48%
	Fertilizers	3.20%	2.89%	0.02%	0.30%
	Other Chemical & Plastics	0.72%	0.08%	0.01%	0.63%
	Glass Containers	0.66%	0.30%	0.03%	0.32%
	Cement	3.26%	2.90%	0.14%	0.21%
	Lime and Gypsum	1.20%	0.54%	0.02%	0.64%
	Mineral Wool	0.76%	0.24%	0.04%	0.49%
	Other Nonmetallic Mineral	0.80%	0.08%	0.01%	0.71%
	Iron and Steel Mills and Ferroalloy	0.91%	0.53%	0.03%	0.35%
	Alumina Refining, Primary and Secondary Aluminum	0.38%	0.04%	0.04%	0.30%
	Ferrous Metal Foundries	0.57%	0.15%	0.03%	0.39%
	Non-Ferrous Metal Foundries	0.45%	0.08%	0.01%	0.36%
	Other Primary Metals	0.76%	0.04%	0.01%	0.71%
	Fabricated Metals	0.54%	0.07%	0.01%	0.46%
	Machinery	0.43%	0.04%	0.01%	0.38%
	Computer & Electrical Equipment	0.28%	0.01%	0.01%	0.26%
	Motor Vehicles	0.55%	0.06%	0.01%	0.48%
	Other Transportation Equipment	0.43%	0.14%	0.01%	0.29%
	Miscellaneous Manufacturing	0.36%	0.02%	0.01%	0.33%
Non-Manufacturing Industries	Farms	0.69%	0.44%	0.01%	0.25%
	Forestry, Fishing, etc	0.42%	0.09%	0.00%	0.33%
	Oil Mining	0.26%	0.06%	0.00%	0.20%
	Gas Mining	0.26%	0.05%	0.00%	0.20%
	Coal Mining	0.00%	0.00%	0.00%	0.00%
	Other Mining Activities	0.86%	0.71%	0.01%	0.15%
	Electric Utilities (inc govt enterprises)	3.06%	3.01%	0.00%	0.06%
	Gas Utilities	0.09%	0.04%	0.00%	0.05%
	Construction	0.53%	0.24%	0.00%	0.29%
	Trade	0.18%	0.09%	0.01%	0.08%
	Air Transportation	1.83%	1.70%	0.00%	0.12%
	Truck Transportation	1.22%	1.10%	0.00%	0.12%
	Other Transportation	0.62%	0.54%	0.01%	0.07%
	Information	0.13%	0.01%	0.00%	0.11%
	Finance and Insurance	0.07%	0.01%	0.00%	0.05%
	Real Estate and Rental	0.08%	0.02%	0.01%	0.05%
	Business Services	0.17%	0.07%	0.00%	0.09%
	Other Services	0.20%	0.05%	0.01%	0.15%
	Govt exc. Electricity	0.15%	0.12%	0.00%	0.03%

Source: Authors' calculations

Table 10. Very Short Run Time Horizon (California): Percent Increase in Costs due to a $15/ton price of CO_2, with modified H.R. 2454 Allocations

		Total cost	Fuel cost	Purchased electricity	Indirect cost
Manufacturing Industries	Food	0.42%	0.07%	0.01%	0.34%
	Textile	0.76%	0.13%	0.02%	0.61%
	Apparel	0.57%	0.05%	0.01%	0.52%
	Wood & Furniture	0.34%	0.05%	0.01%	0.29%
	Pulp Mills	1.07%	0.58%	0.03%	0.46%
	Paper and Paperboard Mills	0.98%	0.52%	0.03%	0.43%
	Other Papers	0.43%	0.08%	0.01%	0.34%
	Petroleum	0.84%	0.64%	0.00%	0.20%
	Petrochemical Manufacturing	4.07%	3.81%	0.01%	0.25%
	Basic Inorganic Chemical Mfg	0.85%	0.52%	0.06%	0.27%
	Other Basic Organic Chemical Mfg	2.17%	1.06%	0.01%	1.09%
	Plastics and Material Resins	2.02%	0.37%	0.01%	1.65%
	Artificial & Synthetic Fibers, Filaments	1.56%	0.31%	0.02%	1.23%
	Fertilizers	3.18%	2.88%	0.02%	0.28%
	Other Chemical & Plastics	0.63%	0.07%	0.01%	0.55%
	Glass Containers	0.63%	0.30%	0.03%	0.30%
	Cement	3.25%	2.90%	0.14%	0.21%
	Lime and Gypsum	1.10%	0.54%	0.02%	0.54%
	Mineral Wool	0.74%	0.23%	0.04%	0.47%
	Other Nonmetallic Mineral	0.52%	0.08%	0.01%	0.43%
	Iron and Steel Mills and Ferroalloy	0.90%	0.52%	0.03%	0.34%
	Alumina Refining, Primary and Secondary Aluminum	0.37%	0.04%	0.04%	0.29%
	Ferrous Metal Foundries	0.53%	0.15%	0.03%	0.35%
	Non-Ferrous Metal Foundries	0.42%	0.08%	0.01%	0.33%
	Other Primary Metals	0.64%	0.04%	0.01%	0.59%
	Fabricated Metals	0.47%	0.07%	0.01%	0.39%
	Machinery	0.40%	0.04%	0.01%	0.35%
	Computer & Electrical Equipment	0.26%	0.01%	0.01%	0.25%
	Motor Vehicles	0.51%	0.06%	0.01%	0.44%
	Other Transportation Equipment	0.42%	0.13%	0.01%	0.28%
	Miscellaneous Manufacturing	0.34%	0.02%	0.01%	0.32%
Non-Manufacturing Industries	Farms	0.66%	0.43%	0.01%	0.23%
	Forestry, Fishing, etc	0.36%	0.09%	0.00%	0.28%
	Oil Mining	0.20%	0.05%	0.00%	0.14%
	Gas Mining	0.20%	0.05%	0.00%	0.14%
	Coal Mining	0.00%	0.00%	0.00%	0.00%
	Other Mining Activities	0.83%	0.69%	0.01%	0.13%
	Electric Utilities (inc govt enterprises)	3.06%	3.01%	0.00%	0.05%
	Gas Utilities	0.09%	0.04%	0.00%	0.05%
	Construction	0.51%	0.23%	0.00%	0.28%
	Trade	0.17%	0.09%	0.01%	0.08%
	Air Transportation	1.78%	1.66%	0.00%	0.12%
	Truck Transportation	1.19%	1.07%	0.00%	0.11%
	Other Transportation	0.60%	0.53%	0.01%	0.06%
	Information	0.12%	0.01%	0.00%	0.10%
	Finance and Insurance	0.07%	0.01%	0.00%	0.05%
	Real Estate and Rental	0.08%	0.02%	0.01%	0.05%
	Business Services	0.16%	0.07%	0.00%	0.09%
	Other Services	0.19%	0.05%	0.01%	0.13%
	Govt exc. Electricity	0.14%	0.12%	0.00%	0.02%

Source: Authors' calculations

Table 11. Very Short Run Effect of \$15/ton CO_2 Tax on California Industry Prices (% Change in Industry Output Price)

		Price Change (No Subsidy)	Price Change (LDC/NGDC)	Price Change (Modified H.R. 2454)
Manufacturing Industries	Food	0.50%	0.43%	0.42%
	Textile	0.93%	0.81%	0.76%
	Apparel	0.61%	0.57%	0.57%
	Wood & Furniture	0.39%	0.35%	0.34%
	Pulp Mills	1.41%	1.15%	0.50%
	Paper and Paperboard Mills	1.32%	1.08%	0.62%
	Other Papers	0.54%	0.51%	0.43%
	Petroleum	7.27%	7.23%	6.95%
	Petrochemical Manufacturing	4.38%	4.24%	1.00%
	Basic Inorganic Chemical Mfg	1.09%	0.89%	0.32%
	Other Basic Organic Chemical Mfg	3.42%	3.34%	1.24%
	Plastics and Material Resins	3.76%	3.71%	2.02%
	Artificial & Synthetic Fibers, Filaments	1.93%	1.81%	1.25%
	Fertilizers	3.42%	3.20%	2.33%
	Other Chemical & Plastics	0.76%	0.72%	0.62%
	Glass Containers	0.96%	0.66%	0.29%
	Cement	3.82%	3.26%	0.21%
	Lime and Gypsum	1.45%	1.20%	0.99%
	Mineral Wool	1.02%	0.76%	0.45%
	Other Nonmetallic Mineral	0.88%	0.80%	0.50%
	Iron and Steel Mills and Ferroalloy	1.10%	0.91%	0.37%
	Alumina Refining, Primary and Secondary Aluminum	0.56%	0.38%	0.27%
	Ferrous Metal Foundries	0.70%	0.57%	0.53%
	Non-Ferrous Metal Foundries	0.52%	0.45%	0.42%
	Other Primary Metals	0.83%	0.76%	0.63%
	Fabricated Metals	0.60%	0.54%	0.47%
	Machinery	0.46%	0.43%	0.40%
	Computer & Electrical Equipment	0.31%	0.28%	0.26%
	Motor Vehicles	0.57%	0.55%	0.51%
	Other Transportation Equipment	0.46%	0.43%	0.42%
	Miscellaneous Manufacturing	0.38%	0.36%	0.34%
Non-Manufacturing Industries	Farms	0.72%	0.69%	0.66%
	Forestry, Fishing, etc	0.43%	0.42%	0.36%
	Oil Mining	11.50%	11.49%	11.43%
	Gas Mining	13.29%	13.28%	13.22%
	Coal Mining	0.00%	0.00%	0.00%
	Other Mining Activities	0.90%	0.86%	0.83%
	Electric Utilities (inc govt enterprises)	3.06%	0.77%	0.77%
	Gas Utilities	9.13%	3.10%	3.10%
	Construction	0.54%	0.53%	0.51%
	Trade	0.20%	0.18%	0.17%
	Air Transportation	1.84%	1.83%	1.78%
	Truck Transportation	1.23%	1.22%	1.19%
	Other Transportation	0.64%	0.62%	0.60%
	Information	0.14%	0.13%	0.12%
	Finance and Insurance	0.08%	0.07%	0.07%
	Real Estate and Rental	0.12%	0.08%	0.08%
	Business Services	0.19%	0.17%	0.16%
	Other Services	0.23%	0.20%	0.19%
	Govt exc. Electricity	0.16%	0.15%	0.14%

Source: Authors' calculations

Table 12a. Short Run Time Horizon (California): Percent Change in Output due to a 15/ton CO_2 Tax.

		CO_2 Tax w/Household Allocations	CO_2 Tax with LDC/NGDC Allocations	CO_2 Tax with modified H.R. 2454 Allocations
Manufacturing Industries	Food	-0.07%	-0.10%	-0.11%
	Textile	-1.41%	-1.26%	-1.18%
	Apparel	-1.18%	-1.15%	-1.16%
	Wood & Furniture	-0.33%	-0.32%	-0.31%
	Pulp Mills	-0.51%	-0.45%	-0.09%
	Paper and Paperboard Mills	-0.47%	-0.41%	-0.16%
	Other Papers	-0.12%	-0.16%	-0.12%
	Petroleum	-0.36%	-0.40%	-0.39%
	Petrochemical Manufacturing	-6.09%	-5.94%	-1.33%
	Basic Inorganic Chemical Mfg	-1.41%	-1.16%	-0.36%
	Other Basic Organic Chemical Mfg	-4.65%	-4.60%	-1.63%
	Plastics and Material Resins	-5.11%	-5.11%	-2.72%
	Artificial & Synthetic Fibers, Filaments	-2.40%	-2.32%	-1.55%
	Fertilizers	-4.68%	-4.43%	-3.20%
	Other Chemical & Plastics	-0.91%	-0.89%	-0.77%
	Glass Containers	-0.49%	-0.33%	-0.06%
	Cement	-2.75%	-2.37%	-0.04%
	Lime and Gypsum	-0.94%	-0.80%	-0.65%
	Mineral Wool	-0.64%	-0.49%	-0.25%
	Other Nonmetallic Mineral	-0.52%	-0.50%	-0.29%
	Iron and Steel Mills and Ferroalloy	-0.75%	-0.65%	-0.17%
	Alumina Refining, Primary and Secondary Aluminum	-0.81%	-0.55%	-0.35%
	Ferrous Metal Foundries	-0.42%	-0.36%	-0.34%
	Non-Ferrous Metal Foundries	-0.79%	-0.71%	-0.67%
	Other Primary Metals	-1.36%	-1.30%	-1.06%
	Fabricated Metals	-0.25%	-0.26%	-0.22%
	Machinery	-0.70%	-0.69%	-0.63%
	Computer & Electrical Equipment	-0.72%	-0.67%	-0.64%
	Motor Vehicles	-0.76%	-0.79%	-0.74%
	Other Transportation Equipment	-0.72%	-0.71%	-0.69%
	Miscellaneous Manufacturing	-0.83%	-0.82%	-0.80%
Non-Manufacturing Industries	Farms	-0.36%	-0.39%	-0.38%
	Forestry, Fishing, etc	-0.16%	-0.21%	-0.17%
	Oil Mining	-1.12%	-1.16%	-1.17%
	Gas Mining	-2.13%	-2.17%	-2.17%
	Coal Mining	0.00%	0.00%	0.00%
	Other Mining Activities	-0.18%	-0.20%	-0.20%
	Electric Utilities (inc govt enterprises)	-0.56%	-0.06%	-0.07%
	Gas Utilities	-4.66%	-1.51%	-1.52%
	Construction	-0.37%	-0.37%	-0.36%
	Trade	0.09%	0.05%	0.04%
	Air Transportation	-0.83%	-0.87%	-0.86%
	Truck Transportation	-0.50%	-0.54%	-0.54%
	Other Transportation	-0.18%	-0.22%	-0.22%
	Information	0.10%	0.06%	0.05%
	Finance and Insurance	0.15%	0.10%	0.09%
	Real Estate and Rental	0.10%	0.07%	0.06%
	Business Services	0.01%	-0.02%	-0.02%
	Other Services	0.06%	0.02%	0.01%
	Govt exc. Electricity	-0.08%	-0.08%	-0.08%

Source: Authors' calculations

Table 12b. Short Run Time Horizon (California): Percent Change in Output due to a 15/ton CO_2 Tax (10% more elastic demand).

		CO_2 Tax w/Household Allocations	CO_2 Tax with LDC/NGDC Allocations	CO_2 Tax with modified H.R. 2454 Allocations
Manufacturing Industries	Food	-0.09%	-0.11%	-0.12%
	Textile	-1.56%	-1.39%	-1.30%
	Apparel	-1.30%	-1.27%	-1.28%
	Wood & Furniture	-0.36%	-0.35%	-0.34%
	Pulp Mills	-0.58%	-0.50%	-0.11%
	Paper and Paperboard Mills	-0.53%	-0.46%	-0.19%
	Other Papers	-0.14%	-0.18%	-0.14%
	Petroleum	-0.40%	-0.44%	-0.43%
	Petrochemical Manufacturing	-6.71%	-6.54%	-1.47%
	Basic Inorganic Chemical Mfg	-1.55%	-1.28%	-0.39%
	Other Basic Organic Chemical Mfg	-5.13%	-5.07%	-1.80%
	Plastics and Material Resins	-5.63%	-5.62%	-3.00%
	Artificial & Synthetic Fibers, Filaments	-2.65%	-2.56%	-1.71%
	Fertilizers	-5.16%	-4.88%	-3.52%
	Other Chemical & Plastics	-1.00%	-0.99%	-0.85%
	Glass Containers	-0.55%	-0.37%	-0.07%
	Cement	-3.03%	-2.61%	-0.05%
	Lime and Gypsum	-1.04%	-0.88%	-0.72%
	Mineral Wool	-0.71%	-0.54%	-0.28%
	Other Nonmetallic Mineral	-0.58%	-0.55%	-0.32%
	Iron and Steel Mills and Ferroalloy	-0.83%	-0.72%	-0.19%
	Alumina Refining, Primary and Secondary Aluminum	-0.90%	-0.61%	-0.39%
	Ferrous Metal Foundries	-0.47%	-0.40%	-0.38%
	Non-Ferrous Metal Foundries	-0.87%	-0.79%	-0.74%
	Other Primary Metals	-1.50%	-1.43%	-1.17%
	Fabricated Metals	-0.28%	-0.29%	-0.25%
	Machinery	-0.78%	-0.76%	-0.70%
	Computer & Electrical Equipment	-0.80%	-0.74%	-0.70%
	Motor Vehicles	-0.84%	-0.88%	-0.82%
	Other Transportation Equipment	-0.80%	-0.78%	-0.76%
	Miscellaneous Manufacturing	-0.92%	-0.90%	-0.88%
Non-Manufacturing Industries	Farms	-0.40%	-0.44%	-0.42%
	Forestry, Fishing, etc	-0.19%	-0.23%	-0.19%
	Oil Mining	-1.24%	-1.28%	-1.29%
	Gas Mining	-2.35%	-2.39%	-2.39%
	Coal Mining	0.00%	0.00%	0.00%
	Other Mining Activities	-0.20%	-0.23%	-0.22%
	Electric Utilities (inc govt enterprises)	-0.54%	-0.05%	-0.06%
	Gas Utilities	-5.13%	-1.67%	-1.68%
	Construction	-0.41%	-0.41%	-0.39%
	Trade	0.09%	0.05%	0.04%
	Air Transportation	-0.92%	-0.97%	-0.95%
	Truck Transportation	-0.55%	-0.60%	-0.59%
	Other Transportation	-0.21%	-0.24%	-0.25%
	Information	0.11%	0.07%	0.06%
	Finance and Insurance	0.16%	0.11%	0.10%
	Real Estate and Rental	0.10%	0.08%	0.07%
	Business Services	0.00%	-0.02%	-0.03%
	Other Services	0.05%	0.01%	0.01%
	Govt exc. Electricity	-0.08%	-0.09%	-0.09%

Source: Authors' calculations

Table 12c. Short Run Time Horizon (California): Percent Change in Output due to a 15/ton CO_2 Tax (25% more elastic demand).

		CO_2 Tax w/Household Allocations	CO_2 Tax with LDC/NGDC Allocations	CO_2 Tax with modified H.R. 2454 Allocations
Manufacturing Industries	Food	-0.11%	-0.13%	-0.14%
	Textile	-1.78%	-1.59%	-1.49%
	Apparel	-1.49%	-1.45%	-1.45%
	Wood & Furniture	-0.42%	-0.40%	-0.39%
	Pulp Mills	-0.67%	-0.58%	-0.13%
	Paper and Paperboard Mills	-0.61%	-0.53%	-0.22%
	Other Papers	-0.17%	-0.21%	-0.16%
	Petroleum	-0.47%	-0.51%	-0.50%
	Petrochemical Manufacturing	-7.63%	-7.43%	-1.67%
	Basic Inorganic Chemical Mfg	-1.77%	-1.46%	-0.45%
	Other Basic Organic Chemical Mfg	-5.84%	-5.77%	-2.04%
	Plastics and Material Resins	-6.41%	-6.39%	-3.41%
	Artificial & Synthetic Fibers, Filaments	-3.03%	-2.92%	-1.95%
	Fertilizers	-5.87%	-5.55%	-4.00%
	Other Chemical & Plastics	-1.15%	-1.13%	-0.97%
	Glass Containers	-0.64%	-0.42%	-0.09%
	Cement	-3.45%	-2.97%	-0.06%
	Lime and Gypsum	-1.19%	-1.01%	-0.82%
	Mineral Wool	-0.82%	-0.62%	-0.32%
	Other Nonmetallic Mineral	-0.67%	-0.63%	-0.36%
	Iron and Steel Mills and Ferroalloy	-0.96%	-0.83%	-0.22%
	Alumina Refining, Primary and Secondary Aluminum	-1.04%	-0.69%	-0.44%
	Ferrous Metal Foundries	-0.55%	-0.46%	-0.43%
	Non-Ferrous Metal Foundries	-1.00%	-0.90%	-0.84%
	Other Primary Metals	-1.72%	-1.63%	-1.33%
	Fabricated Metals	-0.33%	-0.34%	-0.28%
	Machinery	-0.89%	-0.87%	-0.80%
	Computer & Electrical Equipment	-0.91%	-0.84%	-0.80%
	Motor Vehicles	-0.97%	-1.00%	-0.94%
	Other Transportation Equipment	-0.91%	-0.89%	-0.86%
	Miscellaneous Manufacturing	-1.06%	-1.03%	-1.00%
Non-Manufacturing Industries	Farms	-0.47%	-0.50%	-0.48%
	Forestry, Fishing, etc	-0.22%	-0.27%	-0.22%
	Oil Mining	-1.42%	-1.46%	-1.47%
	Gas Mining	-2.68%	-2.72%	-2.72%
	Coal Mining	0.00%	0.00%	0.00%
	Other Mining Activities	-0.24%	-0.26%	-0.26%
	Electric Utilities (inc govt enterprises)	-0.53%	-0.04%	-0.05%
	Gas Utilities	-5.84%	-1.90%	-1.91%
	Construction	-0.47%	-0.46%	-0.45%
	Trade	0.10%	0.06%	0.04%
	Air Transportation	-1.05%	-1.10%	-1.08%
	Truck Transportation	-0.64%	-0.69%	-0.68%
	Other Transportation	-0.25%	-0.28%	-0.28%
	Information	0.11%	0.07%	0.06%
	Finance and Insurance	0.18%	0.12%	0.11%
	Real Estate and Rental	0.11%	0.08%	0.07%
	Business Services	0.00%	-0.03%	-0.03%
	Other Services	0.05%	0.01%	0.01%
	Govt exc. Electricity	-0.10%	-0.10%	-0.10%

Source: Authors' calculations

Table 13. Very Short Run vs. Short Run (California): Effect on Profits Due to a $15/ton CO_2 Tax (Percent Change - No Allocations)

		Very Short Run (Output Fixed)	Short Run
Manufacturing Industries	Food	-4.63%	-0.29%
	Textile	-8.98%	-1.64%
	Apparel	-4.50%	-1.39%
	Wood & Furniture	-1.79%	-0.43%
	Pulp Mills	-20.17%	-0.81%
	Paper and Paperboard Mills	-8.33%	-0.76%
	Other Papers	-3.34%	-0.31%
	Petroleum	-7.18%	-0.51%
	Petrochemical Manufacturing	-44.26%	-6.20%
	Basic Inorganic Chemical Mfg	-8.62%	-1.54%
	Other Basic Organic Chemical Mfg	-58.64%	-4.86%
	Plastics and Material Resins	-53.23%	-5.35%
	Artificial & Synthetic Fibers, Filaments	-26.75%	-2.74%
	Fertilizers	-32.00%	-4.85%
	Other Chemical & Plastics	-3.64%	-1.08%
	Glass Containers	-4.37%	-0.73%
	Cement	-14.51%	-2.92%
	Lime and Gypsum	-6.81%	-1.10%
	Mineral Wool	-4.00%	-0.78%
	Other Nonmetallic Mineral	-4.98%	-0.67%
	Iron and Steel Mills and Ferroalloy	-5.51%	-0.99%
	Alumina Refining, Primary and Secondary Aluminum	-2.78%	-1.04%
	Ferrous Metal Foundries	-4.03%	-0.63%
	Non-Ferrous Metal Foundries	-5.51%	-0.97%
	Other Primary Metals	-5.28%	-1.56%
	Fabricated Metals	-3.76%	-0.42%
	Machinery	-5.01%	-0.82%
	Computer & Electrical Equipment	-17.45%	-0.83%
	Motor Vehicles	-13.51%	-1.04%
	Other Transportation Equipment	-8.98%	-0.83%
	Miscellaneous Manufacturing	-1.71%	-0.99%
Non-Manufacturing Industries	Farms	-2.02%	-0.52%
	Forestry, Fishing, etc	-16.80%	-0.32%
	Oil Mining	-0.52%	-1.27%
	Gas Mining	-0.51%	-2.27%
	Coal Mining	0.00%	0.00%
	Other Mining Activities	-2.69%	-0.29%
	Electric Utilities (inc govt enterprises)	-6.91%	-0.73%
	Gas Utilities	-0.62%	-4.84%
	Construction	-3.01%	-0.37%
	Trade	-1.12%	-0.09%
	Air Transportation	-162.96%	-0.94%
	Truck Transportation	-5.27%	-0.63%
	Other Transportation	-3.32%	-0.33%
	Information	-0.48%	-0.06%
	Finance and Insurance	-0.23%	-0.03%
	Real Estate and Rental	-0.19%	-0.08%
	Business Services	-0.91%	-0.12%
	Other Services	-1.38%	-0.15%
	Govt exc. Electricity	-1.72%	-0.10%

Source: Authors' calculations

Table 14. Very Short Run vs. Short Run (California): Effect on Profits Due to a $15/ton CO_2 Tax (Percent Change - LDC/NGDC Allocations)

		Very Short Run (Output Fixed)	Short Run
Manufacturing Industries	Food	-4.03%	-0.25%
	Textile	-7.86%	-1.44%
	Apparel	-4.21%	-1.30%
	Wood & Furniture	-1.62%	-0.39%
	Pulp Mills	-16.66%	-0.67%
	Paper and Paperboard Mills	-6.87%	-0.63%
	Other Papers	-3.17%	-0.30%
	Petroleum	-6.88%	-0.51%
	Petrochemical Manufacturing	-42.94%	-6.02%
	Basic Inorganic Chemical Mfg	-7.10%	-1.27%
	Other Basic Organic Chemical Mfg	-57.36%	-4.75%
	Plastics and Material Resins	-52.51%	-5.27%
	Artificial & Synthetic Fibers, Filaments	-25.13%	-2.57%
	Fertilizers	-30.08%	-4.56%
	Other Chemical & Plastics	-3.43%	-1.02%
	Glass Containers	-3.05%	-0.51%
	Cement	-12.48%	-2.52%
	Lime and Gypsum	-5.67%	-0.92%
	Mineral Wool	-3.03%	-0.59%
	Other Nonmetallic Mineral	-4.52%	-0.61%
	Iron and Steel Mills and Ferroalloy	-4.61%	-0.83%
	Alumina Refining, Primary and Secondary Aluminum	-1.93%	-0.72%
	Ferrous Metal Foundries	-3.28%	-0.51%
	Non-Ferrous Metal Foundries	-4.80%	-0.85%
	Other Primary Metals	-4.87%	-1.44%
	Fabricated Metals	-3.42%	-0.39%
	Machinery	-4.72%	-0.78%
	Computer & Electrical Equipment	-15.64%	-0.75%
	Motor Vehicles	-12.90%	-0.99%
	Other Transportation Equipment	-8.50%	-0.78%
	Miscellaneous Manufacturing	-1.60%	-0.93%
Non-Manufacturing Industries	Farms	-1.94%	-0.50%
	Forestry, Fishing, etc	-16.63%	-0.32%
	Oil Mining	-0.50%	-1.27%
	Gas Mining	-0.49%	-2.27%
	Coal Mining	0.00%	0.00%
	Other Mining Activities	-2.58%	-0.28%
	Electric Utilities (inc govt enterprises)	-1.96%	-0.21%
	Gas Utilities	41.38%	-1.79%
	Construction	-2.96%	-0.37%
	Trade	-0.96%	-0.07%
	Air Transportation	-162.06%	-0.93%
	Truck Transportation	-5.24%	-0.62%
	Other Transportation	-3.20%	-0.32%
	Information	-0.43%	-0.05%
	Finance and Insurance	-0.20%	-0.03%
	Real Estate and Rental	-0.13%	-0.06%
	Business Services	-0.81%	-0.11%
	Other Services	-1.21%	-0.13%
	Govt exc. Electricity	-1.64%	-0.09%

Source: Authors' calculations

Table 15. Very Short Run vs. Short Run (California): Effect on Profits Due to a \$15/ton CO_2 Tax with Modified H.R. 2454 Allocations for EITE Industries + LDC + NGDC (percent change)

		Very Short Run (Output Fixed)	Short Run
Manufacturing Industries	Food	-3.94%	-0.24%
	Textile	-7.34%	-1.34%
	Apparel	-4.19%	-1.30%
	Wood & Furniture	-1.57%	-0.38%
	Pulp Mills	-7.31%	-0.30%
	Paper and Paperboard Mills	-3.98%	-0.37%
	Other Papers	-2.63%	-0.25%
	Petroleum	-4.65%	-0.49%
	Petrochemical Manufacturing	-8.86%	-1.39%
	Basic Inorganic Chemical Mfg	-2.71%	-0.49%
	Other Basic Organic Chemical Mfg	-21.26%	-1.76%
	Plastics and Material Resins	-28.53%	-2.87%
	Artificial & Synthetic Fibers, Filaments	-17.44%	-1.79%
	Fertilizers	-21.88%	-3.31%
	Other Chemical & Plastics	-2.98%	-0.88%
	Glass Containers	-1.40%	-0.23%
	Cement	-1.04%	-0.22%
	Lime and Gypsum	-4.70%	-0.76%
	Mineral Wool	-1.83%	-0.36%
	Other Nonmetallic Mineral	-2.86%	-0.38%
	Iron and Steel Mills and Ferroalloy	-1.92%	-0.35%
	Alumina Refining, Primary and Secondary Aluminum	-1.44%	-0.54%
	Ferrous Metal Foundries	-3.06%	-0.48%
	Non-Ferrous Metal Foundries	-4.50%	-0.79%
	Other Primary Metals	-4.04%	-1.19%
	Fabricated Metals	-2.97%	-0.34%
	Machinery	-4.33%	-0.71%
	Computer & Electrical Equipment	-14.88%	-0.71%
	Motor Vehicles	-11.99%	-0.92%
	Other Transportation Equipment	-8.19%	-0.76%
	Miscellaneous Manufacturing	-1.55%	-0.90%
Non-Manufacturing Industries	Farms	-1.85%	-0.48%
	Forestry, Fishing, etc	-14.28%	-0.27%
	Oil Mining	-0.38%	-1.26%
	Gas Mining	-0.38%	-2.26%
	Coal Mining	0.00%	0.00%
	Other Mining Activities	-2.47%	-0.27%
	Electric Utilities (inc govt enterprises)	-1.96%	-0.21%
	Gas Utilities	41.39%	-1.79%
	Construction	-2.86%	-0.35%
	Trade	-0.95%	-0.07%
	Air Transportation	-157.84%	-0.91%
	Truck Transportation	-5.11%	-0.61%
	Other Transportation	-3.12%	-0.31%
	Information	-0.41%	-0.05%
	Finance and Insurance	-0.20%	-0.03%
	Real Estate and Rental	-0.13%	-0.05%
	Business Services	-0.77%	-0.11%
	Other Services	-1.13%	-0.12%
	Govt exc. Electricity	-1.59%	-0.09%

Source: Authors' calculations

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Appendix A: Data and Methods

The input–output (I–O) accounts for California come from the Minnesota IMPLAN Group. The base year for data used in the analysis is 2006. The underlying IMPLAN data for California contain 509 industries. The modeling framework used in this analysis is based on a regional use matrix, which contains the interindustry transactions in California. The use matrix must account for intermediate input and fuel uses from production within California and from imports. The IMPLAN software only allows for exporting a "regional use matrix" that contained intermediate and fuel inputs that were produced within California. The IMPLAN data do allow the user to go between use matrices based on California-produced inputs and the broader, more common concept with California and non-California inputs. The relationship between these two matrices can be computed based on IMPLAN's regional and gross absorption coefficients. The relationship is explicitly given below

$$U_{i,j} = \frac{Gabsorb_{i,j}}{Rabsorb_{i,j}} U^R_{i,j}$$

Where $U_{i,j}$ is the use of industry *i*'s output used by industry *j*, including the output of industry *i* not produced within California, $Gabsorb_{i,j}$ is the gross absorption coefficient, $Rabsorb_{i,j}$ is the regional absorption coefficient, and $U^R_{i,j}$ is the regional use matrix, which *does not* include the use of intermediate inputs produced outside of California. Because the software exports $U^R_{i,j}$, $Gabsorb_{i,j}$, and $Rabsorb_{i,j}$, we computed the matrix $U_{i,j}$. Our computations were cross-checked with the version within the IMPLAN software itself to ensure that the use matrix was computed correctly. IMPLAN produces documentation that covers these absorption coefficients and the underlying data in more detail.

In addition to the regional use matrix, a full set of I–O accounts for the California economy requires detailed final demand and value added components. The next step in developing California accounts was to include the final demand and value added components based on the IMPLAN data. The final demand component refers to final consumption, investment, government consumption, exports, and imports of each commodity represented in the economy. The value added component includes employee compensation, taxes, and gross operating surplus that comprise a major portion of industry output. The IMPLAN software contains data on "institutional commodity demand," which is the demand for each identified commodity across households, government, investment and inventory changes, and exports. We used these data to append to the use matrix computed above. Because the original institutional demands file did not contain data on imports, we supplemented the institutional demands file with the exports and imports data also in the IMPLAN software. IMPLAN contains data on imports and exports of commodities in two forms. The first is imports from the United States and the other is imports from the United States and international imports. This is similar to the different forms of the regional use matrix that the IMPLAN software generates. After merging the California use matrix with the final demand components, we appended the value added data for each industry within the use matrix.

Preparation and Aggregations (Use)

Some data preparation involving the use and make matrices was needed because the IMPLAN tables contain additional industry classifications not found in the standard I–O tables produced by the Bureau of Economic Analysis (BEA). In developing the use matrix it was necessary to have a matrix free of the following industries.

Industry number	Industry name
500	Noncomparable imports
501	Scrap
502	Used and secondhand goods
507	Rest of world adjustment to final use
508	Inventory valuation adjustment

We decided to drop the "scrap" and "used and secondhand goods" industries from the use matrix. This was implemented by deleting the row and column for each of these industries in the 509 industry use matrix (note that the column sums were zero for both of these industries; this was not the case for the row sums). In the case of the "scrap" and "used and secondhand goods" industries, the only nonzero entries were in the final demand columns of the use matrix. As a result, after removing the original rows and columns, we reallocated the amount of each consumed by the different final demand components according to the shares of total consumption of each commodity by each final demand component. For example, if the final consumption value for "scrap" was 100, the 100 would be reallocated column-wise among the different commodities consumed as final demand, in proportion to the size of each entry. We also removed the row corresponding to the "inventory valuation adjustment." The row sum for this entry was zero. The column was treated separately by reallocating the amount across the "gross operation surplus" row entries in the use matrix. After making these adjustments, we compared the gross state product (GSP) values found in the underlying data based on the final demand and value added calculations. We found that the value-added GSP was approximately $1,749 billion and the final demand calculation of GSP was $1,815 billion. These two figures should be identical in theory, and we scale the final demand components at a later point such that they match exactly.

Before rescaling the final demand components, it was necessary to deal with the "rest of the world adjustment to final uses" entry in the exports column of the use matrix. Here we decided to reallocate the value across all other rows in the exports column in proportion to the size of each entry in the final "consumption" column (we used the "consumption" as opposed to the "exports" column because the next step listed below would have resulted in a few negative values for certain entries in the "consumption" column). This has the effect of adjusting the commodity outputs that were obtained in the IMPLAN data; so we decided that, in order to preserve these totals, we would subtract from the final “consumption” column the same amount that was applied to the exports entry of each row. This ensured that the commodity outputs of each of the industries went unchanged. At this point, we rescaled final demand components so that the value added and final demand GSPs are equal. This was done by applying a share computed to result in the scaling of the final demand columns to exactly match the total value added GSP (the value added GSP was used as the target because it was closer to the BEA GSP value for California in 2006). The resulting use matrix was aggregated to a 49-industry level.

Preparation and Aggregations (Make)

Similar adjustments were made to the California make matrix that was obtained from IMPLAN. The make matrix presented some issues that differed from those of the use matrix, primarily because it included a few industries that are not found in the use matrix. In particular, the make matrix contains commodities made by households, government, and other entries for commodities made corresponding to the Capital and Inventory Additions classifications found in the underlying data. We chose to ignore these entries, rather than making any attempt to reallocate them among the rest of the make matrix. We deleted the “scrap and “secondhand goods” rows of the make matrix because they were comprised entirely of zeros. We also removed the columns in the make matrix corresponding to “scrap” and “secondhand goods” and the row and column corresponding to the “inventory valuation adjustment.” At this point, the make matrix is aggregated to 49 industries. At the 49-industry level we chose, we have an “oil and gas mining” sector. We disaggregated this sector into separate ”oil mining” and “gas mining” sectors based on the ratio of the commodity output of each, as computed in the energy developments file discussed in the next section.

Energy Developments and Updates:

After generating use and make matrices at the 49-industry level, it was necessary to check how well the underlying IMPLAN data captured energy consumption relative to a handful of state-specific data on fuel consumption, production, and emissions. The following industries were used in this process.

IMPLAN industry:
Oil and gas mining
Coal mining
Power generation
Natural gas distribution
Petroleum products

Initial values for commodity output and commodity consumption for each of these industries based on the IMPLAN data are found below, along with Energy Information Administration (EIA 2006b) estimates of energy expenditures in California.

Industry	Commodity output (mil $)	IMPLAN consumption (mil $)	EIA expenditures (mil $)
Oil and gas mining	9,029	91,248.9	
Coal mining	0.3	2,761.7	144.0
Power generation	33,721.5	37,549.0	33,433.0
Natural gas distribution	35,253.5	14,174.9	
Petroleum products	83,635.5	62,351.5	67,763.8

From this it is clear that, for some industries (e.g., petroleum products), the IMPLAN and EIA figures correspond fairly well, and for others (e.g., coal mining), they are very far off. The approach used to reconcile the disparities is discussed in the next section for each industry.

Coal Mining

The initial step in updating the coal mining row of the use matrix was to rescale the entries in the row such that the total consumption of coal in California matched the $144 million figure from EIA. This is done by scaling down each entry based on its share of total commodity consumption in the state. Essentially, the larger values were scaled down more in absolute value than the smaller entries. To impute the coal consumption by industry, we used the national ratio of coal use (in short tons) per unit of output (million $) and multiplied that ratio by the IMPLAN industry output. After this initial imputation, coal consumption for the electric utilities and cement sectors were replaced with data obtained from EIA (2006b) and the U.S. Geological Survey (USGS 2010), respectively. Coal consumption by the cement sector represents one major component of EIA's industrial end-use classification. As a result, we took the residual industrial consumption of coal in California (the total less consumption by the cement industry) and reallocated it across the other sectors classified as industrial. The reallocation was based on the initial imputation of coal use by industry, which was based on the national coal use per million $ of output. We computed a share for each industry in the industrial sector, where the share was the amount of coal consumption divided by the total coal consumption of the industrial sector based on the first imputation. The consumption of coal between the electric utilities and the industrial sectors represents almost all of the coal consumption in California. Below are two tables containing some of the relevant coal-related information obtained from EIA (2006b) and USGS (2010).

End use	Coal consumption (1,000 short tons)	Source
Total	2,771	EIA
Commercial	1	EIA
Industrial	1,870	EIA
Electric power sector	899	EIA

Industry	Coal consumption (1,000 short tons)	Source
Cement	954.4	USGS

After the total coal consumption was aligned with the EIA (2006b) figures, the nominal values of coal consumption were computed by multiplying the physical consumption by the average statewide coal price of $58.2 per short ton. The average statewide coal price was computed based on the heat content of coal (million British thermal units [Btus] per short ton) and the California-specific coal price (in $ per million Btus).

Oil and Gas Mining

The IMPLAN sector aggregation level does not distinguish between the oil and gas mining industries. This is an important distinction for accurately capturing CO_2 emissions across industries. The initial disaggregation of the "oil and gas mining" industry into "oil mining" and "gas mining" industries was based on work underlying Adkins et al. (2010). In particular, at the national level, we have consumption by industry from the disaggregated "oil mining" and "gas mining" industries. We applied the ratio of consumption from each, by industry, to disaggregate the single number corresponding to each industry's consumption of oil and gas from the mining industry. After making the initial disaggregation in this manner, we observed that the IMPLAN value of imports for the oil and gas mining sector deviated from what the existing EIA data would suggest. For instance, after disaggregating the oil and gas mining sectors in this manner, the commodity output for the oil mining sector was negative. Not only is it impossible to have a negative commodity output, California is also a large producer of oil. Fortunately, for the disaggregated oil and gas mining industries, we do not have to rely on the national ratio for the disaggregated import values. EIA and the California Energy Commission (CEC) produce data on the imports and exports of crude oil and natural gas (in barrels and cubic feet, respectively) that were used to accurately replace these values (CEC 2007 and EIA 2008b). For natural gas, we attribute imports of natural gas to the gas mining sector. Exports of natural gas from California are attributed to the natural gas distribution sector. After computing the value of imports and exports of crude oil and natural gas based on the EIA and CEC data, we find that the value of imports across these two sectors totals approximately $37 billion, as opposed to the $83 billion figure that was contained in the IMPLAN data.

We also were able to obtain data on the amount of natural gas consumed by the electric power sector from EIA and the amount of crude oil consumed by refineries from CEC (CEC 2008). We used these values to replace the values computed based on the national oil and gas mining disaggregation. To impute the physical consumption of oil and natural gas based on the nominal dollar consumption values, we used the first purchase price for crude oil in California and the wellhead price for natural gas in California (EIA 2010a and EIA 2010b). We also obtained data on withdrawals of natural gas from inventories in California for 2006 (EIA 2008b). These data were also incorporated into the investment/inventories column of the final demand component of the I–O accounts.

In addition to the coal mining sector errors in the IMPLAN data, the oil and gas mining sector appeared to be the other sector in the IMPLAN data with large errors relative to readily available data on total California consumption and production. For instance, after completing the steps discussed above, the commodity output of the gas mining industry was significantly *overstated* compared to EIA data on natural gas production in California (EIA 2008b). This is unlikely to have arisen based on our choice of disaggregating the larger oil and gas mining sector into separate industries based on national ratios. The reason is that the refining industry accounts for almost all of the crude oil consumption in California, and hence, any other industry consumption that was attributed to crude oil was small compared to the level of non-refinery consumption of natural gas. With data on crude oil production in California available and relatively few industries, aside from the refining industry, we set the total amount of oil consumption by the refining industry such that the sum of the oil mining row (i.e., the amount produced in California) equals the existing data on state-level oil production. CEC does produce data on the amount of crude oil consumed by refineries, and the choice made here results in a number that is consistent with the CEC data. The table below lists the commodity output of the natural gas mining industry at this stage in the energy updates and how it compares to available EIA data on natural gas production in California.

Industry	**Implied IMPLAN commodity output (million cubic feet)**	**EIA commodity output (million cubic feet)**
Gas mining	1,760,854.0	315,209.0

To reduce this large discrepancy, we rescaled each of the industry consumption values such that the commodity output was equal to the 315 million cubic feet from the EIA. In this rescaling, we held constant the inventory withdrawals and imports, due to the fact that these numbers are independent EIA data. After doing this rescaling, we find that the total consumption of natural gas from the gas mining sector (which includes natural gas going from the mining to the utilities sector) is consistent with the state-level natural gas consumption value from EIA’s State Energy Data System. After adjusting the physical quantity data to be consistent with available data, we multiplied the physical amount of natural gas from the mining sector by the California-specific wellhead price of $6.47 per thousand cubic feet. The resulting commodity output (in nominal dollars) was $2,335 million compared to the “marketed production value" of $2,039 million as obtained from EIA. To keep the nominal consumption values consistent with the EIA value, we rescaled the nominal consumption values such that these two figures were the same.

For the oil mining sector, we went from consumption in barrels to nominal consumption by multiplying the physical consumption value by the first purchase price of oil in California. The resulting value of oil production in California was $14,006 million which was very close to the production value of $14,309 million obtained by simply multiplying the number of barrels of oil produced in California by the first purchase price of oil. We rescaled the row of nominal consumption values such that these two figures were the same. Notably, the resulting ratio of the nominal value of commodity outputs for these two industries was 87.5 percent. That is, oil production accounted for 87.5 percent of the value of production of the more aggregated oil and gas mining sector. This ratio was used to disaggregate the column of the use matrix and the rows and columns of the make matrix for the aggregated oil and gas mining sector.

Power Generation

The IMPLAN sector corresponding to electricity production is the "power generation" sector, which also includes a few other forms of "power generation" aside from electricity. In the initial aggregation of the IMPLAN 509 sector use and make matrices, we aggregated the state and local electric utilities industries with the "power generation" sector. Unlike the coal mining and oil and gas mining sectors, the initial IMPLAN data on nominal consumption (million $) appears to be reasonably consistent with available EIA data for California. Based on IMPLAN data for the consumption of electricity from the "power generation" sector (in million $) we impute the consumption in gigawatt-hours (GWh) based on end-use specific electricity prices in California. EIA produces data for final residential consumption of electricity and interstate shipments of electricity. We replaced the initial imputations for residential consumption and electricity imports with these values. Also, the USGS data for the cement sector provided data on the amount of electricity consumed by the cement industry in California (2010). We replaced the initial imputation for the cement industry with this value. After the initial imputation and these replacements, the implied net-generation of electricity in California was approximately 185 million kilowatt-hours (kWh). The net-generation of electricity in California based on EIA's *State Electricity Profile* report was 216 thousand GWh (EIA 2008a). The initial net-generation in GWh based on the initial imputation was close to this value, but the values for final consumption and imports were far off, suggesting that it was a distributional issue. We rescaled the electricity consumption values (except for final consumption and imports) so that the net-generation was equal to the EIA figure. To go from electricity consumption in GWh to nominal consumption, we multiplied each by the average electricity price in California.

Natural Gas Distribution

Using the IMPLAN nominal consumption values, we first imputed the consumption of natural gas from the gas distribution industry with end use-specific prices for natural gas from EIA. The prices used in this imputation are found below.

End use	Price ($ per 1,000 cubic feet)
Statewide average	9.17
Commercial	10.63
Residential	12.02
Transportation	8.08
Industrial	9.48

After the initial imputation of physical consumption levels by industry, the commodity output of the natural gas distribution industry corresponds well to the amount of natural gas that was purchased from the gas mining industry by the gas distribution industry. Although the total corresponds well, it is clear that the IMPLAN data contain some inconsistencies. In particular, the IMPLAN data have a value of exports of natural gas from the gas utilities industry of $21,175 million. This value was not consistent with any EIA data we could find on exports of natural gas, exports to their other states or outside of the United States, (see EIA 2008b. As a result, we decided to remove this value. We also replaced the final residential and cement consumption levels with data from EIA and USGS, respectively. After these changes, we rescaled all of the other imputed consumption levels so that the total consumption of natural gas from the gas distribution sector was equal to the amount of natural gas that was purchased from the gas mining sector by the distribution sector.

Petroleum Products

The initial IMPLAN data on the consumption of petroleum products agrees well with EIA's data for total consumption (in million $) of petroleum products in California. The table below contains the initial consumption value of petroleum products from the IMPLAN data and the value obtained from EIA's 2006 State Energy Data System tables (EIA 2006b).

Industry	IMPLAN consumption (million $)	EIA consumption (million $)
Petroleum products	62,351.5	67,763.8

The initial imputation of physical consumption (in barrels) of petroleum products, based on the IMPLAN data, used a price of $99.6 per barrel, which corresponds to the average price across all sectors for petroleum products in 2006. This price was computed based on EIA data for the heat content of petroleum products (million Btus per barrel) and the California average price for petroleum products ($ per million Btus). After the initial imputation, the total consumption across California was estimated to be 624 million barrels, which is somewhat lower than the 714 million barrels that EIA reports for the state (EIA 2006a). We rescaled all of the consumption values in the petroleum products row that correspond to final consumption (all entries except inventories, exports, and imports) such that the total physical consumption was consistent with EIA's 714 million barrels figure.

Emissions and Carbon Intensity Calculations

After updating the energy consumption rows of the use matrix, as discussed above, we then calculated the emissions by fuel type for California to check against state-level emissions data. Before we could do that, though, we had to disaggregate the oil and gas mining column of the use matrix such that it was consistent with the use row corresponding to the oil and gas mining that was disaggregated previously. Here we used the ratio of commodity output of the oil mining sector to the total commodity output of the oil and gas mining sector (after the energy updates were done).

To compute emissions levels, it is necessary to distinguish between feedstock and non-feedstock consumption of energy. Feedstock energy consumption is any consumption of energy (e.g., petroleum products) that is not combusted. Non-feedstock consumption is the consumption of an energy source that is combusted. An example of feedstock consumption of energy is the refining industry's consumption of crude oil. The crude oil is not burned but rather is converted into other products, such as gasoline. Unfortunately, there is no source of feedstock ratios for energy consumption in California. As a result, we used the feedstock ratios that were based on EIA's Manufacturing Energy Consumption Survey (EIA 2006a) at the national level and developed for Adkins et al. (2010). Feedstock ratios are fuel- and industry-specific and represent the proportion of fuel consumption by a particular industry that is not combusted. Multiplying the combustion ratio (one minus the feedstock ratio) by the total consumption of each particular energy source, by industry, results in energy consumption levels for which industries would be responsible under a carbon pricing policy. From this point, we computed emissions to compare to EIA total emissions by fuel type in California.

Emissions calculations are based on the non-feedstock consumption levels and emissions coefficients from EIA. From physical fuel consumption, we computed CO_2 emissions in million metric tons. The table below contains the emissions coefficients and other conversion factors that we used to go from physical fuel consumption levels to metric tons of CO_2.

Conversion	Conversion rate
Million Btus/barrel of crude oil	5.800
Million metric tons of carbon per quad BTU	20.24
Lbs of CO_2 per 1,000 ft^3 of natural gas	120.593
Lbs of CO_2 per short ton	4,280.95

Lbs of CO_2 per gallon of petroleum	21.770
Short tons of carbon per GWh	55.34
Metric tons per short ton	0.91
Metric tons of CO_2 per metric ton of carbon	44/12

In our previous national study, computed national emissions based on the MECS fuel consumption data, and feedstock ratios were not exactly the same as the actual total. This was because some petroleum-based products that are used outside of the manufacturing sector are not combusted. As a result, we applied a feedstock ratio to nonmanufacturing consumption of petroleum products that was approximately 0.21. The same approach was used for California. The feedstock ratio used here was 0.185. This ratio for nonmanufacturing consumption of petroleum products results in the state-level emissions that match the California emissions from EIA. The total emissions from fuel consumption in California in 2006 were 397.1 million metric tons. The emissions estimated after the energy updates are 397.2. Note that this figure does not include process emissions, something we addressed separately. The table below has the total emissions from consumption by fuel type for California in our data and the amount from EIA.

Fuel	Emissions in California data (million metric tons of CO_2)	Target (EIA emissions—million metric tons of CO_2)
Crude oil	17.87	
Natural gas	133.68	124.55
Coal	7.30	6.29
Petroleum	238.33	266.25
Electricity	79.71	
Total	397.18	397.1

Process Emissions

Although detailed process emissions figures are available at the national level, process emissions at the state level are not available. Incorporating process emissions is important for a few sectors, including the cement sector, along with the lime and gypsum industry. Without an estimate of these emissions, one will significantly understate the effects of a carbon pricing policy on these industries. We took the approach of assuming that process emissions represented the same share of all other emissions for the above industries in California as they did at the national level. The table below contains our estimates of emissions in the above industries and our estimate of process emissions that result from the national ratio approach.

Industry	Estimated emissions (from fuel consumption—million metric tons of CO_2)	Process emissions estimate (million metric tons of CO_2)	Total emissions (million metric tons of CO_2)
Cement	2.59	3.308	5.9
Lime and Gypsum	0.598	0.622	1.22

Carbon Intensity

From the emissions estimates by industry, we computed industry-specific carbon intensities. These intensities were computed as the total CO_2 emissions by industry (from primary fuel consumption, indirect emissions from electricity consumption, and process emissions) divided by industry output. The second type of emissions intensities computed were the total CO_2 emissions from fuel combustion divided by the total value of each energy commodity output that was used as combusted fuel. These are the "thetas" in the modeling equations. The estimates are presented below.

Fuel type (industry)	CO_2 emissions from consumption of fuel	Value of combusted fuel consumption	CO_2 emissions per unit of combusted consumption
Coal mining	7.30	218.1	33,452.6
Crude oil	17.87	2,400.2	7,446.8
Gas mining	74.55	8,633.2	8,634.8
Gas utilities	59.13	9,890.6	5,978.7
Petroleum products	238.33	56,378.9	4,227.3

Output Demand Elasticities

The output demand elasticities are drawn from a global CGE model from Adkins et al. (2010). The elasticities were obtained by applying a *marginal tax shock* to each industry's output, respectively, in the fixed capital framework discussed therein. For the energy-producing industries, a similar tax was applied to imports. The two exceptions in the table below are for the electric utilities and the refining industry elasticities. For the electric utilities elasticity, we draw upon the work in Bernstein and Griffin (2005), which reports estimates of California-specific electricity price elasticities for commercial and residential end uses. Our analysis of the output changes of a carbon pricing policy does not make this distinction and, as a result, we compute a weighted average of the two elasticities. The weights used in this calculation are the total electricity consumption attributable to residential and nonresidential uses in the underlying IMPLAN data after we made the updates discussed earlier in this appendix. For the refining industry, we use a national short-run elasticity from Hughes et al. (2006).

Output Demand Elasticities

	Sectors	
1	Farms	-0.765
2	Forestry, fishing, etc	-0.765
3	Oil mining	-0.111
4	Gas mining	-0.171
5	Coal mining	-0.161
6	Other mining activities	-0.348
7	Electric utilities (inc. government electricity)	-0.238
8	Gas utilities	-0.530
9	Construction	-0.715
10	Food	-0.588
11	Textile	-1.775
12	Apparel	-2.288
13	Wood and furniture	-1.124
14	Pulp mills	-0.585
15	Paper and paperboard mills	-0.585
16	Other papers	-0.585
17	Petroleum	-0.071
18	Petrochemical manufacturing	-1.424
19	Basic inorganic chemical mfg	-1.424
20	Other basic organic chemical mfg	-1.424
21	Plastics and material resins	-1.424
22	Artificial and synthetic fibers and filaments	-1.424
23	Fertilizers	-1.424
24	Other chemical and plastics	-1.424
25	Glass containers	-0.767
26	Cement	-0.767
27	Lime and gypsum	-0.767
28	Mineral wool	-0.767
29	Other nonmetallic mineral	-0.767
30	Iron and steel mills and ferroalloy	-0.912
31	Alumina Refining, Primary and Secondary Aluminum	-1.901
32	Ferrous metal foundries	-0.912
33	Nonferrous metal foundries	-1.901
34	Other primary metals	-1.901

35	Fabricated metals	-0.717
36	Machinery	-1.814
37	Computer and electrical equipment	-2.733
38	Motor vehicles	-1.828
39	Other transportation equipment	-1.828
40	Miscellaneous manufacturing	-2.636
41	Trade	-0.438
42	Air transportation	-0.550
43	Truck transportation	-0.550
44	Other transportation	-0.550
45	Information	-0.421
46	Finance and insurance	-0.438
47	Real estate and rental	-0.672
48	Business services	-0.672
49	Other services	-0.672
50	Government (exc. electricity)	-0.672

Source: Elasticities were calculated by simulating a tax on each respective industry's output in the global CGE model from Adkins et al. (2010). For electric utilities, the elasticity was computed as a weighted average of estimates of California-specific commercial and residential price elasticities. For the refining industry, the elasticity came from the literature as discussed in this appendix.

Implementing Output-Based Rebates

The calculation of the allocations in H.R. 2454 begins with the list of "presumptively eligible sectors" classified at the six-digit NAICS level provided by EPA (2009). We use Annual Survey ofManufacturers data (U.S. Census Bureau) on industry total shipments value to compute the rebate-qualifying share. Because some industries at our level of aggregation will include a portion of six-digit NAICS industries that are deemed presumptively eligible under H.R. 2454, we compute the qualifying share of output to determine appropriate levels of rebate compensation for these industries. The computation is

$$\rho_j^{qualify} = \frac{\sum_{k \in eligible(j)} X_k^V}{X_j^V}$$

where X_j^V is the industry output.

H.R. 2454 specifies that 30 percent of the national cap will be allocated to electric utilities. The California-adjusted allocation to the electric utilities industry is approximately 11 percent. As a result, we calculate the allocation to electric utilities as

$R_j = 0.11 * C$ j=electric utilities

Here C is the total California emissions of CO_2 in 2006.

Given this approach to cushion the impact of electricity prices, as modeled under the modified H.R. 2454 approach, approximately 75 percent of emissions from electricity generation will be covered. As a result, we compute the amount of allowances rebated to the EITE industries based on their *direct carbon factor* (emissions of CO_2 from primary fuel consumption) and 25 percent of their *indirect carbon factor* (indirect emissions of CO_2 from electricity consumption). Note that in our model we use only 25 percent of natural gas consumption to determine the direct carbon factor—this is the result of NGDC allocations. In our model, the suppressed electricity price increase benefits all industries and final demand, and the 25 percent derives from the fact that electricity allocation effectively compensates the electric utilities industry for about 75 percent of its emissions. This *direct combustion* allowance is the carbon intensity multiplied by the qualifying share of the industry's output in 2006.

$$R_j^{DC} = \rho_j^{qualify} \theta_j^{DC} X_j^V$$

The value of the rebates is simply the allowance multiplied by the carbon price

$$R_j^{value,DC} = t^C R_j^{DC}$$

where t^C is the permit price (in this analysis \$15 per ton). The rate of subsidy for industry output embodied in this rebate is thus

$$s_{j,DC}^C = \frac{R_j^{value,DC}}{X_j^V}$$

Note that this subsidy rate is zero for most of our industries; it is positive only for the few with a positive value for $\rho_j^{qualify}$.

However, H.R. 2454 recognizes the emissions embodied in electricity consumption and provides rebates to EITE industries based on their indirect carbon factor, which is determined by several components, namely annual output, electricity intensity, and electricity efficiency for each industry. To calculate this, we begin with the electricity efficiency for industry *j*—the kWh of electricity input per dollar (2006\$) of gross output.

The electricity input is the dollar value in our rescaled I–O use table divided by the California-specific average price per kWh. We denote this electricity intensity by

$$e_j^{elec} = \frac{electricity input_j}{X_j^V} \text{ (kWh per million \$)}$$

We further define the carbon intensity for electricity use in industry *j* as the metric tons of CO_2 per million kWh in output

$$\epsilon_j^{elec} = \epsilon^{elec}$$

The allowance rebated for indirect emissions is the industry output multiplied by the tons of carbon embodied in the electricity used

$$R_j^{EL} = \rho_j^{qualify} \epsilon_j^{elec} e_j^{elec} X_j^V$$

$$s_{j,EL}^C = \frac{t^C R_j^{EL}}{X_j^V}$$

As stated earlier, in our analysis, the EITE allocation for an industry's indirect carbon factor is 25 percent of the formula in the legislation (this derives from the fact that provisions in the law prevent these dual benefits to EITE industries). As a result, the EITE allocation for indirect emissions is given below

$$R_j^{*,EL} = 0.25\rho_j^{qualify}$$

The subsidy rate for electricity use is

$$s_{j,EL}^C = \frac{t^C R_j^{*,EL}}{X_j^V}$$

The total carbon price subsidy rate under this alternative policy is

$$s_{j,total}^C = s_{j,DC}^C + s_{j,EL}^C$$

Revenue Recycling and Household Income Effects

Any policy that sets a price on carbon, via the auctioning emission allowances, will generate substantial government revenues. In this analysis, it is assumed that the government allocates part of the revenues to affected industries (energy-intensive, trade-exposed industries along with electricity and natural gas distribution companies) and the remaining amount is recycled back to households. In the reference case, it is assumed that all government revenues are given back to households. Below we briefly discuss how revenue recycling was implemented and how we accounted for household income effects that result under a carbon pricing policy.

First, define the total allowance revenue used for competitiveness allocations (i.e. for the EITE industries, electric utilities, and natural gas distribution companies) as:

$$R^{EITE} = \sum_j (R_j^{value,DC} + R_j^{value,EL} + R_j^{value,NG} + R_j^{value,EU})$$

Where $R_j^{value,EL} = t^C R_j^{*,EL}$ and the latter two terms are the value of the rebates given to the natural gas distribution and electric utilities industries, respectively. Note that each of the terms $R_j^{value,DC}$, $R_j^{value,EL}$, $R_j^{value,NG}$, and $R_j^{value,EU}$ can be zero, depending on the policy case considered. In tax-only policy case, all of these terms are zero and in the case with only allocations for electric and natural gas utilities, only $R_j^{value,DC}$ and $R_j^{value,EL}$ are zero.

The total revenue the government receives under the carbon pricing policy, before any allocations, is given by:

$$R^{Total} = t^C C$$

Here C is the total carbon emissions covered and t^C is the carbon tax rate. Subtracting the competitiveness allocations from the gross carbon revenue gives the total sum that is recycled to households:

$$R^{HH} = R^{Total} - R^{EITE}$$

Household income effects

Household income effects stem from two sources. First, a carbon pricing policy will raise the price of commodities each household consumes. While households respond by reducing the amount of each commodity they consume, what they do still consume is now more expensive. This has the effect of lowering the households' real income. Second, households receive dividends from their ownership of firms. If a policy that allocates allowance revenues to affected firms, this will mitigate the profit impacts of carbon pricing, indirectly mitigating the profit effects on household incomes. Below we first highlight income effect that arises from consuming more expensive commodities and then highlight the profit effects on household incomes. The net effect of these along with the allowance revenue rebated back to households, R^{HH}, will define what we call the net-income effect.

After a carbon price policy has been implemented, the change in sales of commodity *j* due to the higher price induced by the carbon tax is given by the demand elasticity, η_j. We assume that households reduce their purchases at the same rate, i.e. their demand curve follows the economy wide demand. The change in household expenditures on commodity *j* is the change in price plus the change in quantity. In the case of inelastic goods, this change in positive and leaves the household with less income to spend on other goods. We take this income effect into account in order to generate a complete accounting of the economy wide effects, even in the partial equilibrium framework.

We let the percentage change in personal consumption expenditures on commodity *j* be given by:

$$\hat{Y}_j^{hh} = \hat{p}_j + \hat{c}_j$$

Where $\hat{p}_j$ and $\hat{c}_j$ are the percentage changes in the price and quantity demanded of by households, respectively. The income effect due to the carbon tax, Y^{t^C}, is the sum over all commodities:

$$Y^{\tau^c} = \sum_j (\hat{p}_j + \hat{c}_j) p_j C_j$$

Since most of the elasticities are less than one (the reduction in quantities will be smaller than the increase in prices), the carbon tax will raise expenditures for most commodities, ignoring income effects. That is, we expect Y^{t^C} to be positive, and this means that there is less total effective spending.

In order to develop a true net-income effect, we must account for the fact that industry-level profits will differ under alternative rebating policies. We define $\Delta\pi^{t^C}$ to be the total change in profits, across all industries, under a carbon price of t^C. We assume that net-profit declines will indirectly lower household incomes. Thus, the total net-income effect is defined by the transfers to households less income effects due to higher consumption expenditures, Y^{t^C}, plus any change in economy-wide profits, $\Delta\pi^{t^C}$, given below as:

$$Y^{net} = R^{HH} - Y^{\tau^C} + \Delta\pi^{t^C}$$

When Y^{net} is positive, the effect will be an increase in final demand by households. We assume the total increase in expenditures arising from this effect is split according the base year household final demand allocation in the underlying I-O accounts. For national analyses, the I-O framework is used to compute the additional domestic production that must occur to satisfy this change in demand for each industry's output. At the state-level, imports can represent a very large share of state-level production, in some cases well over 100 percent. This poses complications for the standard I-O framework, simply because a large share of the additional production will be met through an increase in imports. Our analysis takes this into consideration. Specifically, the change in demand for each industry's output is satisfied by California production and imports. The contribution of imports is based on the each industry's import share (defined as imports divided by the sum of California production and imports). Because an increase in imports requires households to give up an equivalent value via exports, we implement this by adjusting the total value of exports down by the same value as the increase in exports. The total export adjustment is applied across industries by the share of exports each industry represents.

Appendix B: Selected National Results

The tables presented here contain national energy consumption and CO_2 intensities for the industries considered in Adkins et al. (2010).

Table B1. U.S. Energy Costs and Intermediate Inputs, 2006 (% share)

	% Share of Total Costs			
	Electricity	Fuel Combustion	Total Energy (incl non-combustion)	Intermediate Inputs
Food	1.36	1.70	3.06	75.10
Textile	4.13	2.51	6.64	70.96
Apparel	0.75	0.33	1.08	43.32
Wood & Furniture	2.10	2.57	4.72	58.06
Pulp Mills	3.97	7.81	11.78	68.80
Paper Mills	5.87	5.31	11.18	61.18
Paperboard Mills	8.85	8.81	17.66	66.61
Other Papers	1.54	1.09	2.63	61.58
Refining-LPG	0.78	9.28	69.02	84.97
Refining-Other	0.78	9.29	69.06	84.95
Petrochemical Manufacturing	0.83	16.99	21.31	72.45
Basic Inorganic Chemical Mfg	8.75	2.97	12.37	66.91
Other Basic Organic Chemical Mfg	2.68	12.19	19.45	83.27
Plastics and Material Resins	2.33	7.19	25.99	83.74
Artificial & Synthetic Fibers, Filaments	5.81	4.98	12.14	81.17
Fertilizers	3.22	23.64	26.96	82.07
Other Chemical & Plastics	2.44	1.93	5.55	53.89
Glass Containers	8.06	12.32	20.39	55.20
Cement	10.97	14.12	25.09	52.05
Lime and Gypsum	3.35	14.33	17.68	59.57
Mineral Wool	5.96	5.99	11.95	56.90
Other Nonmetallic Mineral	2.07	4.03	6.27	56.70
Iron and Steel Mills and Ferroalloy	5.76	5.30	11.50	63.92
Alumina Refining, Primary and Secondary Aluminum	18.17	5.58	25.11	66.33
Ferrous Metal Foundries	5.77	3.39	9.33	51.04
Non-Ferrous Metal Foundries	3.41	3.64	7.05	66.04
Other Primary Metals	3.78	1.96	6.94	66.50
Fabricated Metals	1.39	0.96	2.36	54.99
Machinery	1.04	0.33	1.37	58.01
Computer & Electrical Equipment	0.90	0.23	1.20	50.65
Motor Vehicles	1.08	0.59	1.68	71.03
Other Transportation Equipment	0.87	0.46	1.33	50.39
Miscellaneous Manufacturing	0.62	0.17	0.79	50.39
Farms	1.49	4.05	6.52	55.42
Forestry, Fishing, etc	0.20	1.22	1.74	23.76
Oil Mining	0.31	0.69	1.14	25.68
Gas Mining	0.31	0.69	1.14	25.68
Coal Mining	0.47	4.62	6.12	46.82
Other Mining Activities	0.50	5.62	7.38	44.60
Electric Utilities (inc govt enterprises)	0.00	17.27	17.65	32.86
Gas Utilities	0.08	0.10	48.89	71.12
Construction	0.18	1.74	2.36	47.33
Trade	0.78	0.70	1.65	37.32
Air Transportation	0.09	16.87	21.34	57.23
Truck Transportation	0.68	7.99	10.72	47.17
Other Transportation	0.09	5.16	6.31	35.72
Information	0.34	0.29	0.68	45.74
Finance and Insurance	0.27	0.09	0.38	21.70
Real Estate and Rental	2.00	0.33	2.40	31.29
Business Services	0.58	0.71	1.44	25.74
Other Services	0.86	0.48	1.42	39.59
Govt exc. Electricity	0.77	3.39	4.82	37.80

Source: Authors' calculations

Table B2. U.S. Output, Energy Consumption (combustion only) and CO_2 Intensity, 2006

	Output ($bil)	Coal (million sh tons)	Crude Oil (million bbls)	Petroleum-LPG (million bbls)	Petroleum-Other (million bbls)	Gas (billion cu ft)	Electricity (billion kWh)	Total CO2 Intensity (ton CO2 /mil$)
Food	580.9	8.2	0.0	0.0	27.7	659.6	82	199
Textile	57.1	1.7	0.0	0.0	2.8	107.9	25	445
Apparel	29.2	0.0	0.0	0.0	0.1	7.8	2	59
Wood & Furniture	159.4	0.9	0.0	0.0	44.2	100.8	36	293
Pulp Mills	4.1	0.3	0.0	0.0	2.5	12.6	2	807
Paper Mills	51.4	6.6	0.0	0.0	8.3	176.9	32	875
Paperboard Mills	23.2	3.6	0.0	0.0	5.7	138.0	22	1,277
Other Papers	179.3	0.3	0.0	0.0	0.4	170.7	30	160
Refining-LPG	27.1	0.1	26.5	20.4	0.0	46.6	2	762
Refining-Other	452.0	2.5	442.9	341.4	0.0	778.5	38	763
Petrochemical Manufacturing	52.6	0.0	0.5	0.0	96.5	106.9	5	903
Basic Inorganic Chemical Mfg	25.7	1.1	0.9	0.0	5.2	54.4	24	872
Other Basic Organic Chemical Mfg	74.7	2.6	1.9	0.0	71.0	297.4	21	866
Plastics and Material Resins	76.5	0.5	0.5	1.7	22.9	323.6	19	543
Artificial & Synthetic Fibers, Filaments	8.5	0.5	0.1	0.0	3.1	35.2	5	837
Fertilizers	11.1	0.1	0.0	0.0	0.2	302.9	4	1,742
Other Chemical & Plastics	483.1	3.8	0.0	1.7	15.1	538.1	127	254
Glass Containers	4.4	0.0	0.0	0.0	0.1	48.6	4	1,124
Cement	10.3	11.7	0.0	0.0	14.0	19.4	12	3,600
Lime and Gypsum	8.9	4.0	0.0	0.0	4.7	78.7	3	1,799
Mineral Wool	6.4	0.1	0.0	0.0	0.0	34.0	4	774
Other Nonmetallic Mineral	89.5	0.3	0.0	0.0	9.0	266.3	20	349
Iron and Steel Mills and Ferroalloy	83.3	22.7	0.0	0.0	3.6	316.8	51	1,220
Alumina Refining, Primary and Secondary Aluminum	22.9	0.0	0.0	0.0	0.5	121.5	45	1,702
Ferrous Metal Foundries	20.0	1.1	0.0	0.0	3.8	34.0	12	717
Non-Ferrous Metal Foundries	12.5	0.0	0.0	0.0	0.0	38.6	5	435
Other Primary Metals	46.3	0.4	0.0	0.0	1.6	67.1	19	380
Fabricated Metals	280.0	0.0	0.0	0.0	1.3	233.0	42	144
Machinery	290.4	0.0	0.0	0.0	0.9	81.6	33	90
Computer & Electrical Equipment	418.5	0.0	0.0	0.0	0.5	84.3	40	65
Motor Vehicles	350.6	0.2	0.0	0.0	3.2	172.8	41	121
Other Transportation Equipment	175.2	0.1	0.0	0.0	1.3	69.2	16	82
Miscellaneous Manufacturing	144.5	0.0	0.0	0.0	1.2	15.2	10	48
Farms	220.1	0.3	0.0	0.0	126.4	51.5	37	353
Forestry, Fishing, etc	39.8	0.0	0.0	0.0	6.8	1.4	1	80
Oil Mining	89.9	0.6	0.0	0.0	6.8	8.1	3	72
Gas Mining	122.5	0.9	0.0	0.0	9.3	11.1	4	72
Coal Mining	26.1	0.0	0.0	0.0	14.2	26.6	1	313
Other Mining Activities	158.5	3.9	0.0	0.0	110.8	175.9	8	421
Electric Utilities (inc govt enterprises)	372.3	1,026.6	0.0	0.0	71.4	6,231.2	0	6,346
Gas Utilities	115.4	0.0	0.0	0.0	1.5	0.0	1	10
Construction	1,245.1	0.0	0.0	0.0	310.5	33.4	24	112
Trade	2,432.8	0.1	0.0	0.0	193.5	109.6	176	76
Air Transportation	144.6	0.0	0.0	0.0	342.9	0.5	1	947
Truck Transportation	234.8	0.0	0.0	0.0	268.4	23.8	17	507
Other Transportation	399.7	0.1	0.0	0.0	232.3	858.5	4	355
Information	1,013.6	0.0	0.0	0.0	24.6	100.3	36	34
Finance and Insurance	1,366.2	0.0	0.0	0.0	12.8	31.8	39	21
Real Estate and Rental	2,301.8	0.3	0.0	0.0	73.5	161.2	450	126
Business Services	2,142.8	0.2	0.0	0.0	192.7	152.5	132	75
Other Services	3,014.2	0.1	0.0	0.0	127.2	637.3	273	82
Govt exc. Electricity	2,608.7	1.2	0.0	0.0	809.6	2,867.4	218	235

Source: Authors' calculations

Table B3. U.S. Carbon Emissions Summary and CO_2 Intensities

		Total CO_2 Emissions (thousand metric tons) from:			Total CO_2 Intensity (metric tons CO_2 per $ output)
		Fossil Fuel Consumption	Electricity Consumption	Process Emissions	
Manufacturing Industries	Food	62,952.4	52,575.4	0.0	198.9
	Textile	10,320.7	15,052.4	0.0	444.7
	Apparel	476.9	1,241.3	0.0	58.9
	Wood & Furniture	24,845.9	21,890.0	0.0	293.1
	Pulp Mills	2,253.3	1,093.8	0.0	807.2
	Paper Mills	25,813.1	19,102.9	0.0	874.6
	Paperboard Mills	16,732.8	12,912.7	0.0	1,277.4
	Other Papers	10,047.4	18,716.1	0.0	160.4
	Refining-LPG	19,201.0	1,429.1	0.0	762.3
	Refining-Other	320,879.1	23,883.2	0.0	762.8
	Petrochemical Manufacturing	44,371.2	3,109.1	0.0	902.5
	Basic Inorganic Chemical Mfg	7,572.2	14,806.6	0.0	871.5
	Other Basic Organic Chemical Mfg	50,340.1	14,345.6	0.0	865.9
	Plastics and Material Resins	28,454.9	13,118.8	0.0	543.5
	Artificial & Synthetic Fibers, Filaments	4,078.5	3,041.5	0.0	836.7
	Fertilizers	16,854.7	2,411.7	0.0	1,742.0
	Other Chemical & Plastics	43,185.8	79,324.5	0.0	253.6
	Glass Containers	2,705.8	2,237.9	0.0	1,124.5
	Cement	29,309.7	7,788.1	46,700.0	3,599.5
	Lime and Gypsum	13,913.6	2,184.7	16,500.0	1,799.2
	Mineral Wool	2,144.1	2,832.2	0.0	774.0
	Other Nonmetallic Mineral	18,800.7	12,471.8	0.0	349.2
	Iron and Steel Mills and Ferroalloy	62,887.6	38,809.8	0.0	1,220.4
	Alumina Refining, Primary and Secondary Aluminum	6,850.8	32,167.1	0.0	1,702.4
	Ferrous Metal Foundries	5,445.6	8,927.9	0.0	717.1
	Non-Ferrous Metal Foundries	2,112.5	3,331.9	0.0	434.5
	Other Primary Metals	5,050.5	12,542.8	0.0	379.7
	Fabricated Metals	13,275.4	27,117.9	0.0	144.3
	Machinery	4,910.1	21,337.4	0.0	90.4
	Computer & Electrical Equipment	4,800.5	22,203.6	0.0	64.5
	Motor Vehicles	11,049.9	31,497.0	0.0	121.4
	Other Transportation Equipment	4,422.3	9,974.2	0.0	82.2
	Miscellaneous Manufacturing	1,306.9	5,602.2	0.0	47.8
Non-Manufacturing Industries	Farms	53,599.2	24,050.0	0.0	352.7
	Forestry, Fishing, etc	2,769.4	422.1	0.0	80.2
	Oil Mining	4,411.9	2,013.2	0.0	71.5
	Gas Mining	6,015.3	2,744.8	0.0	71.5
	Coal Mining	7,086.9	1,092.1	0.0	313.0
	Other Mining Activities	61,185.8	5,589.9	0.0	421.4
	Electric Utilities (inc govt enterprises)	2,362,712.2	0.0	0.0	6,346.4
	Gas Utilities	609.3	567.9	26,600.0	10.2
	Construction	125,084.7	14,343.9	0.0	112.0
	Trade	83,082.1	102,921.3	0.0	76.5
	Air Transportation	136,143.8	784.1	0.0	947.0
	Truck Transportation	107,835.8	11,220.5	0.0	507.0
	Other Transportation	139,444.1	2,275.7	0.0	354.6
	Information	15,241.8	19,653.2	0.0	34.4
	Finance and Insurance	6,835.0	21,952.7	0.0	21.1
	Real Estate and Rental	38,506.1	250,394.6	0.0	125.5
	Business Services	85,300.2	76,420.6	0.0	75.5
	Other Services	85,500.2	162,546.1	0.0	82.3
	Govt exc. Electricity	480,472.4	132,616.8	0.0	235.0

Source: Authors' calculations

Table B4. U.S. Total Permit Allocations to EITE Industries (2006)

EITE Allocations for Direct Carbon Factor (53% of emissions from NG) + 25% of Indirect Carbon Factor

		Amount (mil $)	Subsidy rate (% of Output)	Qualifying Share of Industry Output
Manufacturing Industries	Food	8.9	0.002%	1.4%
	Textile	3.5	0.01%	1.6%
	Apparel	0.0	-	0.0%
	Wood & Furniture	16.9	0.01%	4.1%
	Pulp Mills	33.2	0.80%	100.0%
	Paper Mills	396.7	0.77%	100.0%
	Paperboard Mills	0.0	-	0.0%
	Other Papers	0.0	-	0.0%
	Refining-LPG	114.1	0.42%	100.0%
	Refining-Other	1,905.8	0.42%	100.0%
	Petrochemical Manufacturing	648.2	1.23%	100.0%
	Basic Inorganic Chemical Mfg	167.5	0.65%	100.0%
	Other Basic Organic Chemical Mfg	778.8	1.04%	100.0%
	Plastics and Material Resins	0.0	-	0.0%
	Artificial and Synthetic Fibers and Filaments	71.6	0.84%	100.0%
	Fertilizers	63.7	0.58%	32.4%
	Other Chemical & Plastics	87.8	0.02%	12.4%
	Glass Containers	32.6	0.74%	100.0%
	Cement	460.3	4.47%	100.0%
	Lime and Gypsum	35.8	0.40%	18.5%
	Mineral Wool	29.5	0.46%	100.0%
	Other Nonmetallic Mineral	44.3	0.05%	18.9%
	Iron and Steel Mills and Ferroalloy	942.8	1.13%	100.0%
	Alumina Refining, Primary and Secondary Aluminum	168.0	0.73%	100.0%
	Ferrous Metal Foundries	0.0	-	0.0%
	Non-Ferrous Metal Foundries	0.0	-	0.0%
	Other Primary Metals	18.5	0.04%	20.3%
	Fabricated Metals	0.0	-	0.0%
	Machinery	0.0	-	0.0%
	Computer & Electrical Equipment	0.0	-	0.0%
	Motor Vehicles	0.0	-	0.0%
	Other Transportation Equipment	0.0	-	0.0%
	Miscellaneous Manufacturing	0.0	-	0.0%
	Allocations for Electric and Gas Utilities and Coal Mining			
	Electric Utilities (inc govt enterprises)	26,933.0	7.23%	-
	Gas Utilities	8,079.8	7.00%	-
	Coal Mining	4,488.8	17.18%	-
	Total	45,530.3	0.00	0.00%

Source: Authors' calculations