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DISCUSSION PAPER

Climate Policy's Uncertain Outcomes for Households

The Role of Complex Allocation Schemes in Cap and Trade

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RESOURCES FOR THE FUTURE

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Abstract

Uncertainty is a fundamental characteristic of climate change. This paper focuses on uncertainty in the implementation of climate policy, especially as it affects the level and distribution of the burden on households that results from the allocation of emissions allowances. We examine the Waxman–Markey bill (H.R. 2454), introduced in the U.S. House of Representatives in 2009, with bookend scenarios labeled optimistic and pessimistic. The scenarios illustrate varied outcomes associated with allocations to electricity local distribution companies, investments in energy efficiency, and technology development. We introduce a third scenario for comparison, which allocates a substantial portion of allowance value directly to households as lump-sum payments. We find the average net household burden in 2016 in the optimistic scenario to be $133 with a CO_2 allowance price of $13.19. In the pessimistic scenario, the net household burden rises to $418, with an allowance price of $23.41. While the burden varies by income group, the relative impacts stay roughly the same in the optimistic and pessimistic cases, thus the uncertainty in average burdens does not carry over to uncertainty in the distribution of those burdens. Both scenarios impose the greatest burden as a percentage of income on middle-income households. Allocation of allowance value directly back to households as a lump-sum payment imposes an average net household burden of $206 with much less uncertainty in outcome; the distributional impacts are highly progressive.

Key Words: cap and trade, allocation, distributional effects, cost burden, equity, regulation, local distribution companies

JEL Classification Numbers: H22, H23, Q52, Q54

Contents

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Introduction

As the U.S. draws nearer to adopting a national climate policy, the allocation of emissions allowances in a cap-and-trade program has become a front and center issue in the policy debate. With estimates of allowance value at approximately $100 billion per year initially, rising to $230 billion according to the Energy Information Agency (EIA) (2009a) and even higher according to other studies, the stakes are high. Many vested interests have lobbied for a dedicated slice of the allowance pie, and this has led to detailed and complex allocation schemes in current bills in Congress. The front-runners—H.R. 2454, the Waxman–Markey bill, which came out of the House of Representatives in June 2009; S. 1733, the Kerry–Boxer bill, introduced in the Senate in September 2009; and S. 2877, the Cantwell–Collins bill introduced in the Senate in December 2009—have many provisions for allocating allowances among various programs, industry groups, and consumers.

Studies by economists have shown that the allocation of allowances can be a key determinant of both the welfare costs of a cap-and-trade program and the distribution of impacts across households. A number of studies have emphasized, for example, that using the revenues generated from an allowance auction (or a carbon tax) to reduce pre-existing distortionary taxes in the economy, such as income and payroll taxes, can improve the overall efficiency of the program (Parry, Williams, and Goulder 1999; Goulder et al. 1999). On the other hand, several studies have shown that reducing payroll or income taxes in combination with a carbon price is likely to be regressive, benefiting high-income households more than low-income households (Burtraw, Sweeney, and Walls 2009). Giving allowances away for free to existing emitters, so-called "grandfathering" of allowances, has also been shown to be regressive because the benefit flows to shareholders who are predominantly in higher income groups (Parry, 2004; Dinan and Rogers 2002; Burtraw, Sweeney, and Walls 2009). In a recent paper (Burtraw, Walls, and Blonz 2009), we highlighted the impacts of giving allowances away for free to electricity local distribution companies

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(LDCs), the regulated entities that provide electricity to end users. This approach is a feature of H.R. 2454, accounting for 30 percent of allowances, with another 9 percent allocated to natural gas LDCs; S. 1733 has similar features. Our results, suggest this approach has implications for both the welfare costs of the policy and the distribution of impacts across households.[1]

This extensive cap-and-trade literature is instructive in understanding the implications of various allocation provisions. However, the current bills in the U.S. Congress are far more complicated than the arrangements analyzed by existing studies. H.R. 2454 has over 20 provisions for allocating allowances. The bill has money flowing directly to industry, such as to domestic refineries and so-called "energy-intensive, trade-exposed industries". Money goes to consumers, via direct rebates for low-income households and via electricity and natural gas LDCs. Money is also targeted to support a variety of funds to address adaptation to climate change, including extensive technology development, renewable energy, energy efficiency measures, and some international programs. It is unclear how all this money will eventually make its way to households. Language in the bill is vague, for one thing, and even for those less ambiguous provisions, the degree of uncertainty in implementation and in market outcomes is substantial.

In this paper, we analyze the allocation provisions of H.R. 2454 and attempt to determine how the various allocation schemes will flow through to households. We focus on 2016 as the year when all of the main provisions of the bill come into effect, and construct an optimistic and a pessimistic scenario for the LDC provisions and for the various energy efficiency and technology development provisions in the bill. These three sets of provisions account for approximately 43 percent of allowances in 2016, introducing a wide range of possible outcomes for the burden that households will face. Some of this uncertainty stems from the familiar uncertainty associated with technology development, but most of it arises from questions about how the policy would be implemented.

Additionally, we assume that government's own energy costs will increase, although no revenue is set aside in H.R. 2454 to pay for it. Without such an allocation, this increase in government costs would constitute a hidden tax, which we assume to be 14 percent of total allowance

[1] In a recent paper, Hahn and Stavins (2010) enumerate conditions under which the initial allocation of allowances is independent of the efficiency properties of a cap-and-trade system. These conditions center on general issues such as transaction costs, market power, uncertainty, and the like. We show a specific case in which the initial allocation, through its effect on energy prices, is not independent of efficiency.

revenue based on estimates from the Congressional Budget Office (2009a). The magnitude of government costs changes with the allowance price, which varies across scenarios.

Our optimistic and pessimistic scenarios are distinguished in the degree to which they affect allowance prices and the efficiency of the program. In the optimistic scenario, we assume LDC allocations end up reducing fixed charges on monthly electricity bills for some customers. In contrast, in the pessimistic scenario, the LDC allocations reduce variable charges for all customers. The efficiency consequences under these scenarios depend on the degree to which the policy results in a weaker price signal to consumers. If consumers receive a weak price signal, there will be less of a behavioral change by end users of energy. This will lead to more emissions in this sector and will require greater emissions reductions from other sectors of the economy, which raises the allowance price and the overall cost of the program. This is the sense in which the efficiency implications of the policy may depend on the allocation of allowances. Reducing fixed charges, as in our optimistic scenario, preserves the incentive features of pricing carbon and is thus more efficient.

Our pessimistic scenario also assumes the money spent on energy efficiency and technology development provisions is simply wasted, i.e., that no additional emissions reductions are obtained with the money dedicated to these efforts. In our optimistic case, we accept the opinion of some experts that society can benefit more from government investments in various energy efficiency and clean technology development programs than from the efforts of the private market (McKinsey and Company 2007). Among the expected benefits would be additional reductions in CO_2 emissions, a diminished burden on other sectors of the economy, and lowered allowance prices. Again, the allocation of allowances can affect overall efficiency of the policy. In addition, household electricity bills would be reduced as electricity consumption fell.

These two sets of extreme assumptions make a big difference in the costs of climate policy. We find that the net household burden – the consumer surplus loss net of the value of allowances – for an average household in 2016 is three times higher in our pessimistic scenario than in our optimistic one. Under the pessimistic assumptions, the average household incurs a net loss of $418; under optimistic assumptions, the loss is only $133. The CO_2 allowance price in the optimistic scenario is only $13.19/ton, while it is more than $10 higher, $23.43/ton, in the pessimistic scenario. The difference between these two cases is demonstrated by calculating Shapley values to show which of the optimistic assumptions are responsible for what portion of the cost savings to households (Roth 1988).

While uncertainty characterizes the difference between the magnitudes of the costs in the Waxman-Markey scenarios, the shape of the distribution is similar across the two H.R. 2454 scenarios. The allocation scheme in the H.R. 2454 bill is progressive over the bottom four-fifths of the income distribution under either set of assumptions. The average household in the lowest income quintile enjoys a net gain (negative burden) in both scenarios and households in the higher quintiles incur relatively more of the burden of the policy through the fourth quintile. The fifth quintile incurs a slightly smaller burden than the fourth as a percentage of income because of how some of the provisions pass through to shareholders, which are predominantly in the highest income quintile. Additional analysis was conducted using consumption quintiles, which are often used as proxies for lifetime income quintiles. The results were similar to those with annual income quintiles, but with all three policies being progressive across the entire consumption distribution. This finding highlights some of the complicated ways in which the provisions impact households.

For comparison purposes, we also assess a simple allocation scheme in which 75 percent of allowances are auctioned and returned to households as a lump-sum payment per person, i.e., a so-called cap-and-dividend approach.[2] The average net household burden in this case is $206 and the allowance price is $17.37/ton, so the results lie in between our optimistic and pessimistic scenarios for H.R. 2454. With no LDC allocation, there is no distortion in electricity markets in the cap-and-dividend scenario and this helps to reduce costs and the allowance price. On the other hand, with no allocation to energy efficiency and technology programs, there is no possibility of reaping those benefits that we obtained in our optimistic scenario. This is balanced against the possibility that the energy efficiency and technology programs might not benefit households, and the revenue might essentially be lost. The cap-and-dividend approach is progressive across the entire income distribution—the lump-sum return of revenue on a per capita basis benefits low and middle-income households relatively more.

Our results are not meant to be precise representations of the outcomes under proposed climate legislation. Rather, they are illustrative of the range of possibilities in a cap-and-trade program that has a complex, multi-faceted allocation scheme. Because of the uncertainty in how the separate provisions affect energy use, emissions, and household welfare, it is difficult to say exactly what the impacts of the legislation will be. Complex allocations and uncertain outcomes also make it difficult to protect certain vulnerable groups because allowance value and initial welfare losses remain undetermined. In contrast, a simple scheme such as embodied in the cap-and-dividend

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[2] The optimistic and pessimistic scenarios are designed around specific provisions of H.R. 2454, but bear some similarity to provisions of S. 1733 because of the similarity of the allocations in the legislation. In contrast, the cap with 75 percent dividend explored in our third scenario bears some resemblance to S. 2877, the Cantwell–Collins bill.

approach has more predictable and straightforward impacts on average burden and the distribution of that burden across income groups.

In the next section, we provide a review of the literature on the economic impacts of climate policy on households. We then describe our data and methodology, lay out the specific provisions of the Waxman–Markey bill, explain how we account for these provisions in our model, and present our results for both average net household burdens and the distribution across quintiles.

Literature Review

Several studies have evaluated the impacts of alternative allocation schemes in a carbon cap-and-trade program. Dinan and Rogers (2002) find that distributional effects hinge crucially on whether allowances are initially distributed free of charge to incumbent emitters (grandfathered) or auctioned and whether revenues from allowance auctions, or from indirect taxation of allowance rents, are used to cut payroll or corporate taxes or to provide lump-sum transfers to households. They find grandfathering to be very regressive, as a result of the value flowing through to shareholders who are primarily in the upper-income groups. Parry (2004) also obtained this result in a calibrated analytical model. In contrast, Dinan and Rogers (2002) find that if allowances are auctioned, with revenues returned in equal lump-sum rebates for all households, then the regressivity finding is reversed. Using auction revenues to cut payroll or corporate taxes is found to be regressive, though less so than grandfathering.

Metcalf (2009) also analyzes reductions in payroll taxes. Specifically, he looks at a policy where revenues from a CO_2 tax are used to give each worker in a household a tax credit equal to the first $560 of payroll taxes; this would be equivalent to exempting from the payroll tax the first $3,660 of wages per worker. He finds that this option leads to approximately equal net impacts, as a percentage of income, across income quintiles. An option that couples this rebate with an adjustment to Social Security payments that benefits the lowest-income households makes the CO_2 policy more progressive. Finally, Metcalf compares these options to a lump-sum redistribution of the CO_2 tax revenues and finds that this last option is the most progressive of all.

Burtraw, Sweeney, and Walls (2009) assess the effects of a cap-and-trade program. They examine two cap-and dividend scenarios, one in which dividends are taxed and one in which they are not taxed. They also explore three other scenarios: reducing the payroll tax, reducing the personal income tax, and expanding the Earned Income Tax Credit (EITC), which is available for low-income households. The authors find that the cap-and-dividend options and the EITC alternative reverse the regressivity of carbon pricing. Reducing payroll or income taxes, however, exacerbates the regressivity.[3]

Most of these studies use data from the Bureau of Labor Statistics Consumer Expenditure Survey (CES), including direct energy expenditures as well as indirect expenditures through the purchase of goods and services. Most take a partial equilibrium approach, and focus on expenditures as a fraction of income. Some of the studies compare results using a measure of lifetime income, in addition to current income. The measure used in most studies as a proxy for lifetime income is consumption expenditures. Most consumption taxes, including CO_2 taxes or a cap-and-trade program, look more regressive on the basis of annual income than on the basis of consumption.[4] We focus primarily on annual income in this analysis, but also conduct sensitivity analysis using a consumption measure. Rausch et al. (2009) use a regionally disaggregated general equilibrium model to trace through the impacts of carbon pricing to changes in wages and returns on capital, issues that are ignored in the partial equilibrium studies.[5] The authors estimate the distributional impacts of a carbon pricing policy with seven alternatives for return of revenue to households: a lump-sum payment per household; uniform reductions in personal income tax rates, capital income taxes, or payroll taxes; a return in proportion to capital income; and two electricity scenarios, one in which revenue is returned in proportion to electricity consumption and one that provides a lump-sum payment. Results are generally similar to the partial equilibrium findings: lump-sum payments make for a progressive policy while reduction in personal income taxes, capital income taxes, or payroll taxes is regressive, with payroll tax reductions the least regressive of the three. A large literature in environmental economics has argued the efficiency merits of reductions in these kinds of taxes (Parry, Williams, and Goulder 1999; Goulder et al. 1999), but Rausch et al. (2009) find the efficiency gains to be relatively modest. The authors argue that this is likely a result of the revenue neutrality requirement in their model. They fix government revenue relative to GDP at the same level as in the

[3] This study also focused on regional impacts, finding that whereas net impacts for average households in each region are quite similar for any given allocation alternative, differences for low-income households are more pronounced. Other studies that look at regional incidence of various cap-and-trade schemes (though not by income group and region together) are Boyce and Riddle (2009), Hassett et al. (2009), and Pizer et al. (2009). We ignore regional issues in the results we present in this paper, but regional variation is an underlying characteristic of the model, as we will explain below.

[4] Grainger and Kolstad (2009) discuss income measures in more detail and calculate the incidence of carbon pricing using alternative measures. However, this study does not deal with allocation of allowances or use of allowance revenue.

[5] The model is a regional version of the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev et al. 2005). For more discussion of the various key parameters and relationships in a general equilibrium framework that determine the ultimate burden of a tax on a pollutant, see Fullerton and Heutel (2007).

no-policy scenario, which means that not all carbon pricing revenue is available for recycling purposes. In some cases, only about one-half of the revenue is available.

All of the above studies, with the exception of Rausch et al. (2009), separate the distributional impacts from the efficiency costs of the cap-and-trade or carbon tax policy. Thus in each case, the price of carbon is the same across alternative allocation schemes.[6] The resource cost of the policy and the amount of allowance value created are also the same, and all that changes is the distribution of that value across sectors of the economy and households. Some allocation schemes affect the allowance price, however. The LDC allocation in H.R. 2454 is a case in point. If it leads to lower electricity prices than the prices in a full auction scenario, then it alters the costs of the program and the size of the allowance pie. Our earlier paper focused on this issue, arguing that reductions in variable electricity prices are a likely outcome. We then assessed the additional burden on society, and the distribution of that burden across income deciles and regions, compared with a full auction coupled with a per capita dividend of allowance value (Burtraw, Walls, and Blonz 2009). We calculated that the annual net household burden for an average household would be $157 higher under this approach than under cap-and-dividend.[7] However, we did not evaluate the full impacts of the LDC approach in the context of the entire H.R. 2454 allocation scheme—the exercise that is the focus of this paper.[8]

Three government studies have analyzed the costs of H.R. 2454 to the U.S. economy, the U.S. Department of Energy's Energy Information Administration (EIA 2009a), the U.S. Congressional Budget Office (CBO 2009b), and the U.S. Environmental Protection Agency (EPA 2009). These analyses differ from the aforementioned academic studies in that they analyze only the specific provisions detailed in the legislation.

CBO (2009b) estimates the loss of purchasing power that households will experience in 2020 to be $160, or 0.2 percent of income, at projected 2010 income levels. The cost, however, varies

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[6] Rausch et al. (2009) do not change the allowance price across scenarios; essentially, their policy is more like a carbon tax with changes in emissions and the size of the allowance pie as a result, but no change in the tax rate or carbon price.

[7] This assumes that allowance value outside the electricity sector is not returned to and does not benefit households. Under the other extreme assumption that it all goes to the benefit of households, the difference in net burden for an average houshold was estimated to be $36.

[8] Rausch et al. (2009) assess two versions of the LDC allocation scheme, one of which is a subsidy to electricity consumption. However, the ultimate impact of the extra electricity consumption in their framework is simply higher electricity costs, not additional abatement from other sectors and a concomitant increase in the allowance price as in our model.

greatly over household income levels. They estimate an average household in the lowest income quintile will see a net benefit of $125, or 0.7 percent of income, while an average household in the highest quintile will experience a cost of $165, or 0.1 percent of income. The middle-income quintile will incur the most significant cost of this policy, with an average cost of $310, or 0.6 percent of income, per household.

The CBO analysis allocates 31 percent of the total value of allowances to households, while businesses receive 44 percent of the value. The federal government and state and local governments receive 18 percent of allowance value, and the remaining 7 percent of allowance value is sent overseas to fund projects, such as reducing deforestation and adapting to climate change. Of the 31 percent allocated to households, 15 percent is given directly to households for low-income energy cost assistance, while the other 16 percent is given to electricity and natural gas local distribution companies to pass on to their residential customers. Of the 44 percent given to businesses, 29 percent is allocated to the same local distribution companies to pass on to their commercial and industrial customers, and it is then passed on to households in proportion to their holdings of equities. The remaining 15 percent given to businesses is directed to energy-intensive, trade-exposed industries and passed on to consumers in the form of price decreases to offset the price increases in these industries induced by the cap-and-trade policy (CBO 2009b).

EPA (2009) also estimates the cost of H.R.2454 to households. Rather than purchasing power, however, they estimate the average loss of consumption under the policy. Using their ADAGE computable general equilibrium model, they find an average household will incur a cost of $105 in 2020 (2005$).[9] This cost is equivalent to 0.11 percent of total household consumption in 2020. This analysis corresponds to the ADAGE model's allowance price in 2020 of $16 per metric ton CO_2. EPA does not look at the distribution of costs across different income groups.

The EPA analysis allocates allowances in similar proportions to CBO, but the way in which they are distributed is different, because of their use of the ADAGE computable general equilibrium model. Allowances given to local distribution companies and trade-exposed industries, as well as many other recipients, are allocated within the general equilibrium model, so their distributional effects are subject to the equilibrium found within the model. For example, allowances allocated to electricity LDCs result in lower electricity prices for consumers, as opposed to a transfer to households as in the CBO analysis. Overall, 77.5 percent of the allowances are allocated in this way.

[9] For more information on ADAGE see Ross (2008).

The remaining 22.5 percent of allowance value, however, is allocated outside of the ADAGE model, and this value is given directly to households as a lump-sum transfer on a per-capita basis. These allocations to households incorporate allowance value given to programs such as low-income energy cost assistance and merchant coal generators.

EIA (2009) estimates the cost of H.R. 2454 as the average loss of consumption per household. Based on the results of their National Energy Modeling System (NEMS) energy–economy model, the cost of the policy will be $134 (2007 $) for an average household in 2020. Like EPA, the EIA also does not calculate how this cost would be distributed among households of different income levels. The cost estimate corresponds to the NEMS allowance price in 2020 of $32 per metric ton CO_2. The EIA also allocates allowances in the proportions specified by H.R. 2454, such as those given to LDCs and trade-exposed industries. They do not specify how this allowance value is then passed on to households and shareholders, either within the NEMS model or outside of the modeling framework.

Academic and governmental analyses provide various measures of the household burden of climate policy using different data and types of models and slightly different welfare measures. Each study has its strengths and weaknesses, but together they add to the continually growing body of literature on the incidence of climate policy. Our analysis seeks to further the literature by analyzing detailed and specific allowance allocation mechanisms such as exist in proposed legislation. Unlike other studies, we provide a range of estimates that are intended to capture the uncertainty associated with these complex allocation schemes. The simple cap-and-dividend approach is provided as a point of comparison.

Data and Methodology

We base our analysis on CES data from 2004 through 2008. The population sampled in the CES includes 133,421 observations for 51,694 households; an observation equals one household in one quarter. We use these observations to construct national after-tax income quintiles. Our sample for examining regional effects includes 112,306 observations for 42,828 households in 43 states plus the District of Columbia.[10] We aggregate the observations into 11 regions. Although we do not use observations with missing state identifiers in our regional-level calculations, we do include them in our calculations at the national level.

[10] Five states (Iowa, New Mexico, North Dakota, Vermont, and Wyoming) are dropped because of missing information.

We account for direct energy expenditures and indirect expenditures through the purchase of goods and services.[11] We focus the analysis on 2016, assuming that the distribution of consumption across regions and income groups would be the same as in our data period (2004-2008) in the absence of climate policy. The consumption data is combined with the average carbon contents of goods from Hassett et al. (2009) to estimate the CO_2 content of every household's consumption bundle. The average CO_2 content of household goods is scaled to reflect changes in production and consumption that are predicted by EIA baseline forecast for 2016 outside the electricity sector and the forecast of RFF's Haiku electricity market model in the electricity sector. This procedure ensures that our baseline emissions estimates for 2016 match those of EIA and the Haiku model.

We use Haiku to model the electricity sector more accurately. The model solves for electricity market equilibria in 21 regions of the country that are mapped into the 11 regions we use for the distributional analysis. The electricity model accounts for price-sensitive demand, electricity transmission between regions, system operation for three seasons of the year (spring and fall are combined) and four times of day, and changes in demand and supply-side investment and retirement over a 25-year horizon (Paul et al. 2009). The Haiku model also captures differences in the regulatory environment across regions and allows us to model different behavioral assumptions corresponding to fixed and variable charges for residential, commercial, and industrial customers, as we explained in the introduction. Table 1 illustrates the electricity sector results for the 11 regions of the country that we model, with an indication of how we aggregate states into these regions.[12] The model calculates a national baseline emissions rate of 0.602 tons of CO_2 per megawatt-hour (MWh) for 2016 in the absence of any climate policy. In this example, the introduction of an emissions cap (and scenario characteristics that correspond to the "pessimistic case" described below) lead to an emissions allowance price of \$20.86/metric ton CO_2 ($mtCO_2$) (2006 dollars). Emissions fall to 0.516 tons/MWh. Table 1 also reports the percentage change in electricity price on a regional basis and the percentage change in consumption that is expected to result from the introduction of the price on CO_2 emissions.

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[11] Indirect consumption accounts for approximately 49 percent of an average household's carbon emissions.

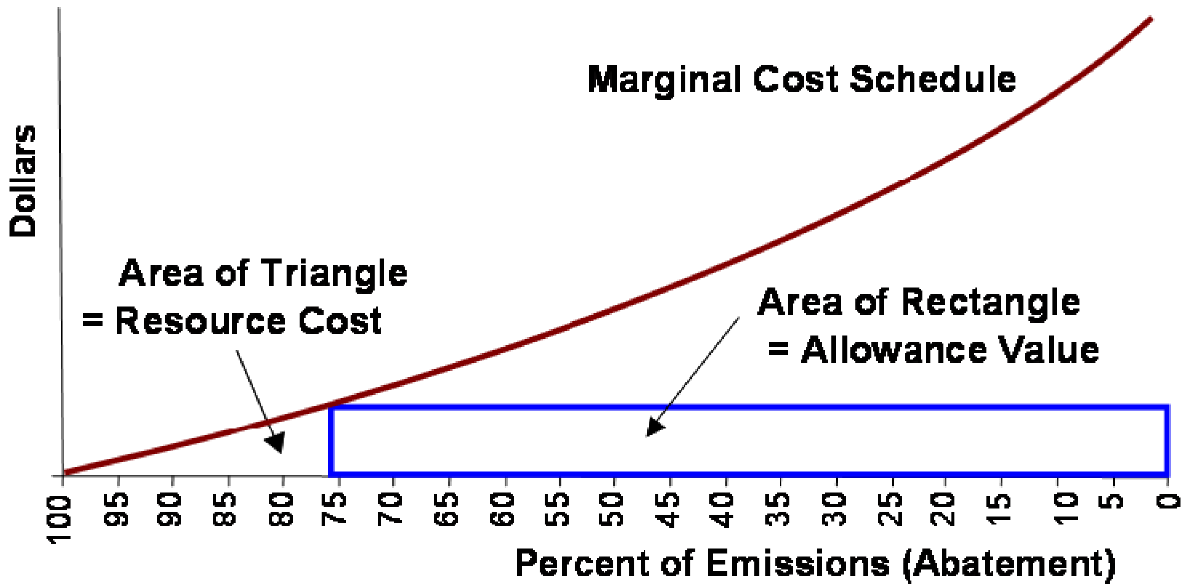
[12] The 48 contiguous states and the District of Columbia are included in the electricity modeling, but as noted, five states (Iowa, New Mexico, North Dakota, Vermont, and Wyoming) are dropped when calculating effects on households at the regional level. However, national estimates always include these five states.

Table 1. Illustrative Results for the Haiku Electricity Sector Model

Haiku Modeling Results - Waxman Markey Basic Case					
Region	**States**	**Baseline CO2 Emissions Per MWh of Generation**	**Post-Cap CO2 Emissions Per MWh of Generation**	**Price Change**	**Change in Consumption**
Southeast	AL, AR, DC, GA, LA, MS, NC, SC, TN, VA	0.602	0.516	3%	-1%
California	CA	0.190	0.215	3%	-1%
Texas	TX	0.619	0.514	5%	-1%
Florida	FL	0.557	0.493	3%	0%
Ohio Valley	IL, IN, KY, MI, MO, OH, WV, WI	0.782	0.660	7%	-3%
Mid-Atlantic	DE, MD, NJ, PA	0.573	0.500	8%	-1%
Northeast	CT, ME, MA, NH, RI	0.371	0.336	6%	-2%
Northwest	ID, MT, OR, UT, WA	0.406	0.234	1%	0%
New York	NY	0.318	0.293	8%	-1%
Plains	KS, MN, NE, OK, SD	0.844	0.809	9%	-4%
Mountains	AZ, CO, NV	0.628	0.609	4%	-2%
National		0.608	0.523	5%	-2%

Figure 1 illustrates the mechanism of placing a price on CO_2 emissions through the introduction of a cap-and-trade policy. The horizontal axis in the graph represents the reduction in emissions (moving to the right implies lower emissions), and the upward-sloping curve is the incremental resource cost of a schedule of measures to reduce emissions; thus, it sketches out the marginal abatement cost (MAC) curve. The electricity sector MAC is generated from the Haiku model, whereas abatement behavior for the rest of the economy, excluding the electricity sector, is taken from the Energy Information Administration (2009) analysis of Waxman–Markey (H.R. 2454). The EIA MAC curve is combined with the Haiku electricity MAC curve to model economy-wide abatement behavior. Using this economy-wide curve, an endogenous allowance price (represented by the height of the rectangle) is calculated such that emissions in our incidence model match capped 2016 EIA levels (17 mtCO2 equivalent).[13]

Figure 1. Resource Cost and Allowance Value



The triangular area under the marginal cost curve up to the emissions target is the cost of resources used to achieve emission reductions. The rectangle represents the value of emissions allowances generated (number of allowances times price per allowance) by the trading program. EIA's analysis of H.R. 2454 provides an estimate of the aggregate burden, i.e., these two areas shown on the graph, along with a breakdown of this burden among sectors. We treat the electricity sector separately, using the Haiku model to obtain changes in emissions due to the CO_2 price. All other sectors' reductions and costs are assumed to match EIA.

To calculate the distribution of losses across regions and households, we use baseline emissions intensities and own-price elasticities along with consumption expenditure and price increases. These data provide a first-order indication of the relative change in burden across various consumption categories resulting from the introduction of a price on CO_2. This distribution of losses is then scaled proportionately across categories of consumption to match

[13] http://www.eia.doe.gov/oiaf/servicerpt/hr2454/excel/hr2454cap.xls

the changes predicted by EIA and Haiku to generate an initial household burden. This explicitly assumes the initial change in household welfare in our model equals the sum of the resource cost and the allowance value estimated by EIA and Haiku. This approach rests on the implicit assumption that producers pass all costs through to consumers and bear none of the costs themselves, which is approximately true in the short run, when demand is relatively inelastic. As a result, our estimate of the initial household burden outside the electricity sector for the average household matches EIA's estimate of abatement cost (including allowance cost).[14]

After initial household burdens are calculated, allowance value is distributed based on scenario dependent allocation schemes. This refunded allowance value is subtracted from the initial household burden to calculate a net household burden.

As mentioned above, for electricity we use the Haiku electricity market model in place of EIA's forecast for the sector. The Haiku model reports price changes that are somewhat different across regions and slightly lower on average than EIA. Using Haiku in place of the EIA electricity model preserves substantial detail with respect to regions and customer classes and allows for the various treatments of customer classes and allocation scenarios that we discuss below.

We use the cost estimate that is predicted by EIA outside the electricity sector and by Haiku within the electricity sector to estimate the total burden on households to achieve an emissions reduction target for 2016. EIA's 2016 emissions level provides our emissions target, and we hold it constant across scenarios.[15] Across regions and income groups, these effects are distributed according to the expenditure patterns revealed in the Haiku model and the CES data.

Description of H.R. 2454 Cap-and-Trade Program

Title III of H.R. 2454 sets an annual cap on greenhouse gas emissions covering approximately 85 percent of all emissions in the U.S. including, among many others, those from oil refineries, natural gas suppliers, electricity generators, and industries such as cement, paper, iron,

[14] This exercise does not affect our distributional findings. It does, however, provide estimates of the overall level of houehold burden.

[15] Both the EIA and Haiku models solve for aggregate intertemporal emissions targets and an intertemporal equilibrium that include potential changes in banking and the purchase of offsets. The models vary to a small degree with respect to emissions obtained in 2016. To hold constant the emissions in that year, we scale the results across scenarios. This introduces a small inconsistency in the aggregate intertemporal emissions reductions achieved over the modeling horizon, but that does not affect the distributional issues that are our focus in this paper.

steel, and chemicals. The cap becomes gradually more stringent over time. In 2012, the first year the law would go into effect, covered emissions are required to be 3 percent below 2005 levels; by 2020, 2030, and 2050, this figure rises to 17, 42, and 83 percent, respectively. The cap is met by allocating emissions allowances among the regulated entities; those allowances can then be traded. The bill has approximately 22 separate provisions dealing with allowance allocation. Table 2 shows the breakdown for 2016, the year of our analysis.

We have divided the provisions into categories. A significant percentage of total emissions allowances is to go toward relieving the burden of higher energy prices on households. Thus, both electricity and natural gas LDCs receive allowances. For electricity LDCs, which receive 30 percent of total allowances, distribution is based one-half on emissions and one-half on electricity output. Natural gas LDCs receive 9 percent of allowances. LDCs are regulated or publicly owned entities in all 50 states, so they can be expected to act as trustees on behalf of consumers, passing the value of allowances on to customers through lower rates (or equivalently funding investments) rather than retaining it as profits. How exactly they will do this is the subject of much debate and we return to this issue below. Other allocations are designed for a variety of purposes – to reduce the burden on low-income households, to provide money for adaptation to climate change, to fund supplemental international reductions, to lessen the burden on industries that are thought to be particularly hard hit by climate policy, and to enhance energy efficiency, technology development, and the development of renewable energy.

Many of the allocations will be handled by federal and state government to further climate related goals. These allocations, however, do not address the impact of a carbon price on government. Federal, state, and local government account for approximately 14 percent of all CO_2 emissions in the U.S. (CBO 2009b), yet H.R. 2454 does not explicitly set aside allowances to cover those emissions.[16] We return to this issue and explain how we handle it in the next section of the paper.

[16] Bills introduced in the U.S. Senate that have an impact on the federal budget are required to specify how that impact will be addressed, thus S. 1733 and 2877 both explicitly provide for increased government costs, though they do so imprecisely and do not account for changes in state and local costs. No such requirement exists in the House.

Table 2. Allowance Allocation in 2016 as Specified in H.R. 2454 and Distribution of Allowances in Model

	Allocation Section of Bill	Program Description Section of Bill	Description	Percent	Optimistic Case	Pessimistic Case
Household Energy Consumption	782(a)(1)	783(b)	LDCs - Electricity	30.00	Allocated through fixed charge on electricity bills	Allocated through variable charge on electricity bills
	782(b)	784	LDCs - Natural gas	9.00	Captured in MAC curve	
	782(c)	785	Home heating oil, propane	1.50		
Low Income	782(d)	Title IV (C)	Energy refunds for low-income consumers	15.00	Per-capita dividend to low income households	
Industry	782(a)(1)	783(c)(d)	Merchant coal, long-term contracts	5.01	Shareholders	
	782(e)	765	Trade-vulnerable, energy-intensive industries	14.44	Captured in MAC curve	
	782(j)	787	Refineries	2.25	Shareholders	
Adaptation & Adjustment	782(k)	Title IV (B2)	Climate Change Worker Adj. Assistance Fund	0.50	Per-capita dividend to all households	
	782(l)	453, 467	Domestic adaptation, including Climate Change Health Protection and Promotion Fund	1.00		
	782(m)	480(a)(b)	Wildlife and natural resources - to states and natural resource climate change adaptation fund	1.00		
	782(u)	788(b)	Supplemental agriculture	0.14		
International	782(n)	Title IV (E2)	International adaptation	1.00	Lost revenue overseas	
	782(o)	Title IV (D)	International clean technology development	1.00		
	781(a)	Title III (E)	International forestry (REDD)	5.00		
Energy Efficiency, Energy R&D, Technology Development, Renewables	782(i)	124	Investment in clean vehicle technology	3.00	Abatement at $75/ton*	Revenue lost
	782(f)	786	Development of CCS Technology	1.75	Abatement at $50/ton*	Revenue lost
	782(u)	788(c)	Supplemental Renewable Energy	0.14	Abatement at $34/ton*	Revenue lost
	782(g)(1)	132	Investment in energy efficiency and renewable energy	3.25	Abatement at $34/ton*	Revenue lost
				3.25	Electricity consumption reduced at 2.8 cents/kwh*	Revenue lost
	782(a)(2)	783(e)	Efficiency, ratepayer assistance, etc through small electricity LDCs	0.50		Revenue lost
	782(g)(3)	132	State renewables and energy efficiency programs	0.05		Revenue lost
	782(h)	171, 172	Energy innovation hubs, advanced energy research	1.50		Revenue lost
	782(g)(2)	201	Efficiency in building codes	0.50	Captured in MAC curve	Revenue lost
TOTAL				100.78		
Cap in 2016			5,482 MMT CO2e			
			*Affects households through lower allowance price or through lower electricity bills.			

How money will be spent is unclear in many cases. For example, money flows into several funds, such as the Natural Resource Climate Change Adaptation Fund, but no guidance is provided on how those funds are to be spent. The same problem exists for many of the energy efficiency, renewables, and technology development programs. Much of the money is allocated to state administered programs, but with no strict requirements as to how the funds are spent.

Even in those provisions that contain more specifics, outcomes and impacts on households are still highly uncertain. The LDC provisions are a case in point. Because they are regulated, LDCs are required to pass on the allowance value to consumers, but it is not obvious exactly how they will do that. H.R. 2454 has language suggesting that LDCs reduce fixed charges on monthly electricity bills for residential and commercial class customers "to the maximum extent feasible," but such a change is thought to be infeasible in practice and the more likely outcome is a reduction in variable electricity rates (Burtraw 2009). The outcome has serious implications for the cost of the policy. If variable rates are reduced, electricity consumption remains higher than it would be if the price of electricity reflected the price of CO_2 allowances used in generation. Consequently, other sectors of the economy must work harder to reduce emissions in order to meet the economy-wide cap. This increases the allowance price and the overall cost of the program (Burtraw, Walls, and Blonz 2009). How households are affected, on net, is unclear, but we expect on average that households are made worse off for the effort to subsidize their electricity consumption. On the one hand, electricity prices are lower as are electricity expenditures. On the other hand, a higher allowance price results in increased prices for expenditures on goods and services other than electricity. Because the overall value of allowances is greater, how these allowances flow into various categories will also affect the outcome.

The energy efficiency, renewables, and technology development provisions also generate highly uncertain outcomes. Some observers and efficiency advocates have argued that a great deal of "low-hanging fruit" is available for reducing energy use and CO_2 emissions. In fact, an iconic image of the last decade, in energy policy circles, is the *McKinsey efficiency curve* that indicates substantial opportunities to reduce energy use at no cost or significant negative cost (McKinsey and Company 2007). That study and several replicas, for example Sweeney and Weyant (2008), identify marginal abatement cost curves for reducing CO_2 emissions. These curves show engineering cost estimates for achieving the same or a comparable level of energy services through a variety of energy-saving options in production and consumption. From an economic perspective, the technical costs of energy-saving options only address half the problem. There may be significant behavioral, informational or social barriers to realizing these potential technical gains. In any case, the ultimate impact of these provisions on energy use, emissions, and household welfare are unclear; allocating money to energy efficiency programs, technology development, renewable energy, and the like may improve upon private market outcomes or it might simply lead to wasted expenditures.

Modeling Strategy

To illustrate the range of potential impacts on the overall costs of the policy and the distribution of those costs across households, we model two bookend scenarios with respect to the LDC and energy efficiency provisions of the Waxman–Markey bill. One scenario is optimistic and the other pessimistic, distinguished by the possibility that uncertain provisions of the bill lead to efficiency-enhancing outcomes or not.

With respect to the LDC allocations, in the pessimistic scenario, we assume the allowance value flows to all classes of customers—residential, commercial, and industrial—via a reduction in the variable electricity rates on monthly bills. As we explained above, consumption is higher as a consequence of the subsidy to electricity prices, so the allowance price is higher in this case and the overall costs of the policy are higher as a result; this is the sense in which the assumption is pessimistic. In the optimistic scenario, we assume that fixed charges are reduced for industrial and commercial customers. However, we assume this remains infeasible for residential customers. As explained in Burtraw, Walls, and Blonz (2009), a review of current billing practices and state public utility commission behavior suggests that significant hurdles exist to implementing this kind of pricing (a reduction in the fixed portion of the electricity bill) by 2016. One prominent reason for this is that in almost no case does the fixed portion of costs appear as a separate line item on bills for residential class customers, and even when it does appear separately, the cost is recovered almost entirely through volumetric charges. Furthermore, even if it were possible to return allowance value to residential customers through fixed payments it is unclear how residential customers would respond. Many observers have suggested that residential customers are unlikely to understand and respond in an economically rational way to an increase in the variable rate (marginal cost) by reducing consumption if their overall bill were reduced.[17] Industrial and commercial electricity consumers, however, may have a more sophisticated understanding of the difference between the fixed and variable parts of their bill, and thus we evaluate this possibility in our optimistic case with respect to the allocation to LDCs.

[17] Borenstein (2009) illustrates that models of consumer response that have been used in many previous studies of increasing-block pricing are not realistic models of the information consumers have at the time they make consumption decisions.

Another of the significant sources of uncertainty affecting the future development of energy and climate policy is the ability to harvest potential low cost opportunities for improvements in the way producers and consumers use energy. Indeed, how well previous investments of this nature have performed remains controversial (Arimura, Newell, and Palmer 2009). The Waxman–Markey bill would expand the previous programs to a national scale, and how well this approach would perform in the future in regions that have no experience with such programs is even more uncertain. These so-called "opportunity regions" may have substantial undeveloped potential, but they also lack the infrastructure, expertise and regulatory rules such as decoupling of cost recovery from energy sales that have developed over many years in other regions. In addition, these regions historically have lacked the will (perhaps because of historically low prices) to implement such programs. On the other hand, intuition and some evidence indicate that the greatest efficiency improvements at the least cost may be technically possible in these regions. Arimura, Newell, and Palmer (2009) speculate that incremental spending by utilities that had low previous levels of spending could achieve savings at one-half the incremental cost of previous programs.

In the case of allowance value directed to energy efficiency and technology development, our optimistic scenario uses selective estimates in the literature for the cost of reducing electricity consumption through end-use efficiency improvements. We based the optimistic scenario on the premise that these options would not be adopted in response to the price signal introduced from the cap-and-trade program alone. The advocates of spending resources through LDCs on energy efficiency programs argue that this spending can overcome institutional or market barriers and, in effect, accomplish cost-effective investments (of the type illustrated by McKinsey 2007) that households cannot or do not make for themselves (Cowart 2008). Hence, in the optimistic scenario, spending by government or LDCs on energy efficiency provides a net benefit to society.

In a large survey of the energy efficiency literature, Gillingham, Newell, and Palmer (2004) estimate that investments in efficiency have reduced electricity use at a payoff of about 2.8 cents per kWh of electricity saved (2002$). However, subsequent studies characterize this as a very optimistic estimate. Using improved statistical methods, Arimura, Newell, and Palmer (2009) estimate an average cost of 6.2 cents per kWh (2007$) saved in previous programs. Accounting for the possibility of improvement in program design and the expansion to new regions of the country that provide low-cost opportunities, we use the Gillingham, Newell, and Palmer estimate of 2.8 cents per kWh as an optimistic forecast of the cost-effectiveness of future investments in efficiency on average across the nation. We apply an average emissions intensity of electricity generation in the country of 0.000523 tons CO_2 per kWh of generation as forecast by the Haiku model in the baseline to arrive at an optimistic estimate of $53.50 as the cost per ton of avoided emissions resulting from energy efficiency investments.[18]

Compared to other estimates of the cost of emissions reductions and our estimated allowance prices, the cost per ton for reductions that could be achieved through energy efficiency are relatively expensive. However, these investments not only reduce emissions but they also reduce spending on electricity, providing a direct savings and, thus, an additional benefit to households. We also capture this impact in the model.

The optimistic estimates for the technology development provisions—those provisions targeting renewable energy, clean vehicles, and carbon capture and storage (CCS)—come from McKinsey and Company (2007), Kammen et al. (2009), and Al-Juaied and Whitmore (2009). These studies provide estimates of the cost per ton of CO_2 emissions reduced when particular technologies or alternative fuels are used in place of the conventional option. Al-Juaied and Whitmore (2009), for example, estimate the cost of abating CO_2 emissions through CCS, both for a first-of-a-kind plant and a mature technology plant in 2030, using a range of cost estimates from several previous studies. They conclude a first-of-a-kind plant is likely to have an abatement cost of $100–150 per metric ton CO_2 avoided, while a mature technology plant is likely to have an abatement cost of $30–50 per metric ton CO_2 avoided. Kammen et al. (2009) estimate the cost per ton of emissions reduced in a range of scenarios for plug-in hybrid and electric vehicles compared with conventional gasoline vehicles. As mentioned above, McKinsey and Company (2007) has cost and effectiveness estimates for a range of technologies and scenarios.

Based on findings in these studies, we assume in the optimistic case that CCS, renewable energy, and clean vehicle technology provide CO_2 emissions reductions at costs of $50/ton, $34/ton, and $75/ton, respectively.[19] In the pessimistic scenario, we assume that these activities and investments have no benefit and thus all of the allowance value devoted to them is lost.

Using these estimates along with the percentages devoted to these activities as specified in the bill, we calculate the total amount of money available, and then compute total emissions reductions. This means that fewer reductions are needed elsewhere in the economy, thus lowering the

[18] For comparison, EIA (2009b) indicates average emissions intensity in 2010 is 0.000558 tons CO_2 per kWh.

[19] We do not solve with any specific introduction date for any of the technology development provisions, and they may not be deployed by 2016. Instead, we assumed that some of these technologies will work to reduce cumulative emissions targets over the lifetime of the cap-and-trade policy, and consequently 2016 allowance prices, through the banking mechanism.

allowance price and providing a benefit to households. The pessimistic scenario simply assumes that the money going to all of the efficiency and technology provisions is lost.

Table 2 summarizes the assumptions that we use in our two scenarios for the Waxman–Markey bill. About 57 percent of allowances are allocated in the same way across the two scenarios; these are shown in the bottom portion of the table. The first four rows of that section show allocations that are captured in EIA's marginal abatement cost curve and that are taken into account in both the optimistic and pessimistic representation of H.R. 2454.[20] The provision dealing with low-income consumers is for households with annual incomes less than 150 percent of the poverty line. The EIA is directed to estimate loss in purchasing power for this group, and to refund it via direct cash transfers. We assume the allocations to refineries and to merchant (independently owned, unregulated) coal generation plants do not affect the variable costs of production, and hence are earned as industry profits that flow back to shareholders. Assigning the value of the domestic adaptation provisions to households is difficult. This money goes to dedicated trust funds; the money from those funds is to be spent on programs that offset the impacts of climate change. For lack of a better alternative, we simply distribute this money back to households as a lump-sum payment per person. Finally, we assume that all of the value of allowances going to international efforts — adaptation, forestry, and clean technology development — is lost to the U.S. economy.

The remaining allowances, or 43 percent of the total, are examined under the alternative optimistic and pessimistic scenarios. These allowances go to electricity LDCs and the variety of energy efficiency and technology development provisions discussed above.

We emphasize that the optimistic and pessimistic scenarios, particularly in the case of the energy efficiency and technology provisions, are truly bookends, i.e., they reflect the range of plausible outcomes and the truth may lie somewhere in between. Nonetheless, they provide a sense of the uncertainty in the outcomes with such a large and complex climate bill.

For a third and final comparison, we model the impacts of a cap-and-trade program with 100 percent auction of allowances, with 75 percent of the revenue returned as a lump-sum per capita payment, i.e., a cap-and-dividend program. This formulation roughly corresponds to the Cantwell–Collins proposal (S. 2877), which reserves 25 percent of allowance value for a set of unspecified

[20] This includes 3.75 percent of allocation directed to LDCs and home heating that EIA models explicitly as investments in energy efficiency. This is incorporated in the EIA marginal cost curves, and is held constant across our scenarios. Allocation to natural gas LDCs and home heating also is captured in the EIA model and is constant across our scenarios.

spending priorities. To model this, we assume that the funds that are not returned as dividends include money directed to lowering consumer costs for home heating from natural gas and fuel oil (6.75 percent) and expenditures on related energy efficiency programs and building codes (4.25 percent). In addition, we assume the maintenance of allowance cost rebates to energy-intensive, trade-exposed industries (14.44 percent). These priorities are embodied in the marginal cost curves we adopt from the EIA.

Finally, across all three scenarios we maintain the assumption that government incurs additional costs for its own direct expenditures on energy and other goods and services that are equal to 14 percent of allowance value.[21] It is not known if governments would meet these costs through tax increases or spending decreases, so the incidence of the costs is uncertain. Previous studies have frequently omitted this change in government cost, thereby implicitly introducing a tax that is hidden from their analyses, which will be paid ultimately by households. CBO (2009b) does not account for this cost directly, but nets it out against the 18 percent of allowances to government for spending on projects such as renewable energy and energy efficiency, and thus does not distribute to households these increases in government costs and spending. EPA (2009) predicts that increased prices of goods and services will increase government spending and assumes the increase is made up by adjusting taxes in a lump-sum manner. EIA (2009) analysis of H.R. 2454 does not specify if government costs increase under the policy, or if so, how the NEMS model accounts for the increased costs.

To account for the effect this has on household well being, we assume an increase in government costs equal to 14 percent of allowance value. Although the share is constant across scenarios, the absolute value of government's change in costs differs with the allowance price. We assume budget neutrality in this regard, as does EPA, but we assume this is achieved through an increase in the average personal income tax for each income group. The increase in personal income taxes is accounted for in calculating the net burden per household.

Results

Table 3 shows the average net household burden by income quintile and for all households for the three scenarios: the two H.R. 2454 scenarios and the 75 percent cap-and-dividend scenario. We first discuss the national average household burden and compare the different scenarios; in the following section, we explain the distributional results.

[21] CBO (2009a) predicts this cost to be 14 percent of allowance value; CBO (2009b) predicts it to be 13 percent.

Table 3. Average Net Household Burden of Three Cap-and-Trade Scenarios, by Income Quintile (in 2006$)

Household Income Quintile	Average Income	Waxman-Markey Optimistic Case	Waxman-Markey Pessimistic Case	75 Percent Cap-and-Dividend
1	11,276	-110	-122	-65
2	26,804	21	111	7
3	44,060	181	408	106
4	68,609	314	667	255
5	140,283	258	1,029	725
All	58,207	133	418	206
Allowance Price		\$13.19 mt/CO2	\$23.41 mt/CO2	\$17.37 mt/CO2

Impacts on Average Households

The average net household burden varies widely across the three scenarios, from \$133/household in the optimistic H.R. 2454 scenario to \$418/household in the pessimistic scenario, with the cap-and-dividend option in between, at \$206/household. There are a number of factors driving the differences. We focus first on the comparison of our optimistic and pessimistic scenarios.

Three categories of assumptions distinguish the optimistic and pessimistic scenarios: the assumptions about how LDCs will pass on the value of allowances to customers, in fixed or variable charges, and the assumptions about whether the value of allowances devoted to energy efficiency and technology programs yield benefits or are simply wasted resources. Separating the effects of these three policies on the difference between the optimistic and pessimistic scenarios is not straightforward. Each policy affects the allowance price, which in turn has a direct effect on household expenditures and on the revenue that flows to the other program areas. For example, a change in the LDC allocation from optimistic to pessimistic scenario causes the allowance price to increase, making more allowance revenue available as compensation for low-income families and for both technology and energy efficiency programs.

To understand the effects of these three policies we use the Shapley value, which is an axiomatic approach to sharing of costs or benefits (Roth 1988). The Shapley value is based on the calculation of the marginal contribution of every possible combination of policies that distinguish the optimistic and pessimistic scenarios, resulting in a unique estimate of the share of that difference that can be attributed to each policy. Table 4 shows the results for the pessimistic and optimistic cases, along with the Shapley values that describe the percent of the reduction in cost and allowance price that can be attributed to each of the policies.

Table 4. Shapley Values by Income Quintile per Household for LDC, Technology Provisions and Electricity Energy Efficiency Programs

Household Income Quintile	Waxman-Markey Pessimistic Case	Percentage Reduction in Household Cost Due to			Waxman-Markey Optimistic Case
		LDC Billing Behavior	Technology Programs	Electricity Energy Efficiency Programs	
1*	-122	485%	284%	-669%	-110
2	111	-77%	15%	162%	21
3	408	-23%	34%	89%	181
4	667	-9%	37%	72%	314
5	1,029	40%	21%	39%	258
All	418	6%	25%	69%	133
		Percent Reduction in Allowance Price			
Allowance Price	$23.41 mt/CO2	21%	51%	28%	$13.19 mt/CO2

* The first income quintile experiences net losses under the optimistic assumptions. Consequently negative Shapley values signify gains from a given assumption and postiive Shapley values signify losses

The changes in the average cost and allowance value due to the LDC billing behavior are minimal. This is because the difference between the pessimistic and optimistic LDC assumptions is not as extreme as it is for the other two policies. Changing from pessimistic to optimistic assumptions for LDCs is a reallocation from one method of spending the revenue to a more efficient one. For the other two programs, the switch from pessimistic to optimistic constitutes a shift from an unproductive loss of the revenue to productive investments that benefit households. Although the pessimistic LDC assumptions do have real costs and efficiency losses for households, on average they only account for 6 percent of the loss in household burden.

The savings to households due to changes in LDC assumptions are dwarfed by those of the electricity energy efficiency program, which accounts for 69 percent of the cost savings.[22] Efficiency policies provide savings through two separate mechanisms. Because of improved efficiency, households purchase less electricity than they would otherwise, and the lower quantity of consumption leads to a lower equilibrium price in electricity markets that further benefits

[22] This percentage does not include efficiency measures totaling 4.25 percent that are included in the EIA marginal abatement cost curves and held constant across scenarios.

households. In addition, emissions decline because less electricity is generated, meaning that other sectors of the economy do not need to reduce emissions as much; this lowers the allowance price and reduces overall costs. The efficiency investments account for cost savings of $99 due to avoided electricity expenditures for the average household compared to the pessimistic cases where no such investments exist.[23] This effect, in combination with the 28 percent allowance price reduction caused by the program, yields the full $197 (69 percent) savings due to the optimistic assumptions.

Although the payoff from electricity efficiency initiatives can be, and often is, sharply debated, we feel that the technology development initiatives in H.R. 2454 may be even more speculative. Over 8 percent of allowances are directed to CCS, clean vehicle technology, and renewable energy, and in our optimistic scenario, we assume these three investments provide CO_2 abatement at $50, $75 and $34 per ton respectively. These costs are greater than the value attained for emissions reductions in other components of the model, so they raise program costs at least in the near term (2016). Nonetheless, in the optimistic scenario they provide a total reduction in emissions of 127 million tons. This lessens the burden on other sectors and lowers the allowance price compared to the pessimistic scenario. We hasten to point out that because of their relatively high abatement costs, these initiatives do not lower the allowance price in comparison with an alternative where the money would be returned to households directly or spent on more cost-effective CO_2 reduction options.

Even considering the high abatement costs of the technology programs, they account for 51 percent, or $5.22, of the reduction in the allowance price between the pessimistic and optimistic cases. This large decrease is responsible for 25 percent of the savings ($71 per household). While these savings are significant, it is important to note that they are much smaller than those of the electricity energy efficiency program, although technology programs receive 8.1 percent of allowance value, compared to only 5.3 percent dedicated to the efficiency program.

As shown in Table 2, all of the revenue directed at energy efficiency and abatement programs is assumed to be lost in the pessimistic scenario. This money constitutes 13.44 percent of allowance value, approximately $17.4 billion ($134/household) of revenue, which does not find its way back to households. Households would experience a decreased burden of $286 if this money were rebated

[23] The government benefits from the electricity energy efficiency programs in the same way that households realize savings from decreased utility bills. The energy efficiency programs reduce the revenue collected by the government to pay for their increased energy costs under cap-and-trade. The electricity energy efficiency programs save households $16/year in increased tax revenue in the optimistic case.

directly, and they experience even greater savings as it is spent on energy efficiency and direct abatement programs. The cap-and-dividend case does not share the complexities of the H.R. 2454 scenarios and is hence much easier to understand. There is no uncertainty as to the potential effectiveness of energy efficiency and technology development programs or the outcomes of electricity LDC allocations.[24] Instead, 75 percent of auction revenue is directed as a per capita dividend back to households that, as a result, experience a modest burden of $206 per year (last column of Table 3). The allowance price in this scenario is $17.37—substantially lower than in the pessimistic H.R. 2454 case but higher than in the optimistic case.

One reason the price and the net household burden are lower than in the pessimistic case is because of the 7 percent of allowance value going overseas to adaptation and supplemental reduction purposes in H.R. 2454 but not in the cap-and-dividend case. If this program were included in the cap-and-dividend scenario, directing a comparable 7 percent share of allowance value overseas, it would raise the average cost per household from $206 to $257. Furthermore, in the cap-and-dividend case, there is no cost from LDC allocations; but even in our optimistic scenario, we assume that LDC allocation leads to lower electricity prices for residential households, which increases the cost of the policy. However, most importantly, the uncertainty is eliminated. The wide range in our optimistic and pessimistic scenarios costs is a result of the uncertainty in how the LDC allocation will be implemented, as well as how the energy efficiency and technology provisions will work in practice, an uncertainty that does not exist with cap-and-dividend.

Distributional Consequences Across Income Groups

In addition to differences for average households, our scenarios also reveal potential differences by income quintiles. However, the overall distributional consequence appears of secondary importance, compared to the overall changes in the level of the policy, which are reflected in the cost for the average household. The outcomes are reported in Table 3.

The H.R. 2454 optimistic scenario exhibits comparatively low costs for most income quintiles compared to the other scenarios, which is driven by the low allowance price and electricity savings due to energy efficiency programs. In the optimistic H.R. 2454 scenario, we assume that

[24] As in the optimistic and pessimistic Waxman–Markey cases, a small portion of allowance value directed to energy efficiency programs, as well as to subsidize home heating and to support trade-exposed industries is built into EIA modeling of the policy. Concequently, the outcome from these measures does not vary across our scenarios. In the cap-and-dividend case, this constitutes the 25.44 percent of allowance value that is not returned as dividends to households.

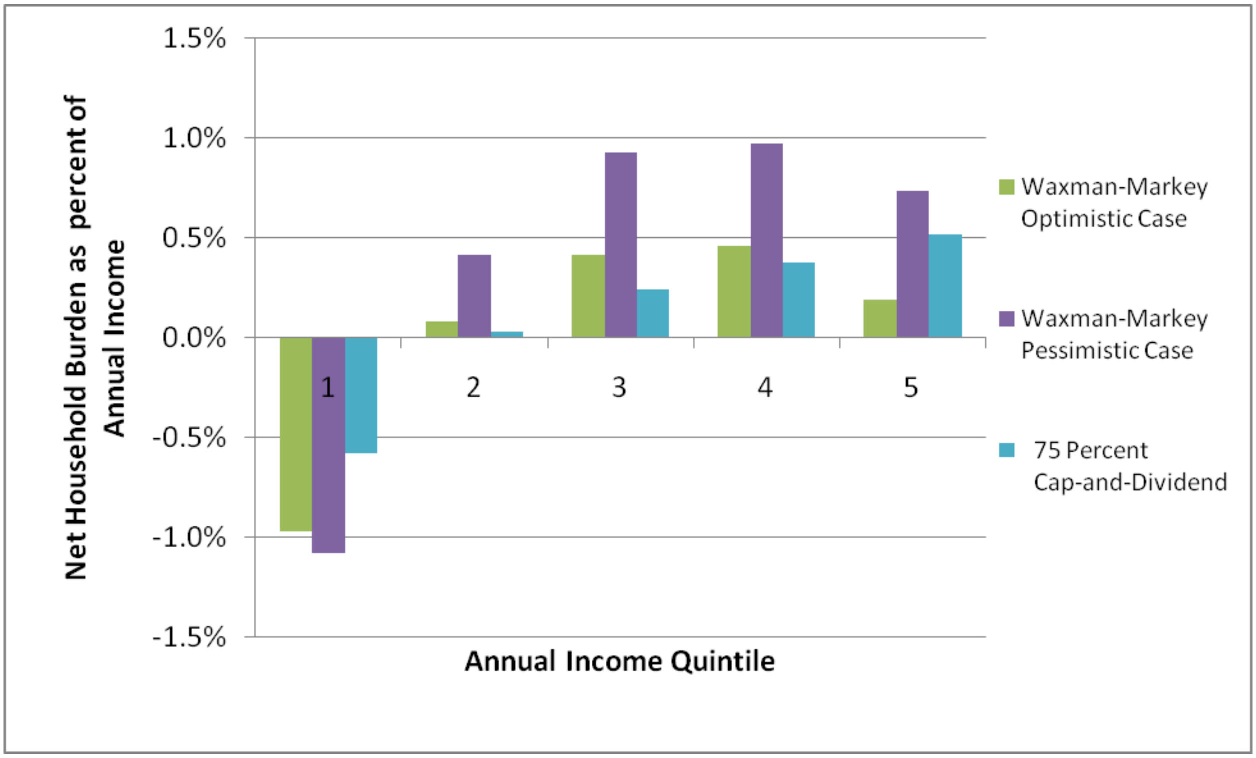
LDCs are able to pass the allowance value through the fixed portion of electricity bills for commercial and industrial customers; in the pessimistic scenario, the value ends up reducing variable electricity prices. These differences have significant distributional consequences. In the optimistic case, the transfer ultimately finds its way to shareholders, the vast majority of which belong to the top income quintile. In the pessimistic case, commercial and industrial customers pass through the reduced electricity price to lower prices of goods and services; this benefits all consumers. Consumption is less concentrated in the upper income quintiles than is the share of share ownership, which explains the fact that the average household in the fourth quintile bears a higher burden than the average household in the top quintile, in the optimistic scenario.

This effect can be seen in the Shapley values in Table 4. The fifth income quintile sees significant benefits from the optimistic LDC assumption due to transfers to shareholders. Forty percent of the reduction in high income household burdens moving from the pessimistic to optimistic case is due to the LDC assumption. The bottom four income quintiles, however, actually see their burdens rise from the LDC assumptions. They lose out because they do not receive the LDC subsidy through lower electricity and goods prices nor through an increase in shareholder value. Households in quintiles 1-4 gain relatively more from the energy efficiency assumptions. While high-income households may receive more absolute savings from the energy efficiency provisions, savings to households in the lower quintiles are a larger share of their overall savings that result from the optimistic scenario.

Households in the lowest income quintile have almost the same net burden in the optimistic and pessimistic cases. This results from the fact that low-income households receive 15 percent of total allowance value in both cases. The lower allowance price in the optimistic case leads to a smaller amount of money going to these households and this offsets some of the gains from the optimistic assumptions.

Figure 2 displays the net household burdens of the three scenarios as a percent of income. Both of the H.R. 2454 scenarios display a similarly shaped distribution in which costs increase as a percent of income for the 1st through 4th income quintile, but decline for the 5th quintile. This is most striking in the optimistic case, where the 5th quintile has a lower burden as a percentage of income than the 3rd quintile. As discussed above, these results are mostly due to LDC allocations ultimately finding their way to shareholders. By contrast, the cap-and-dividend scenario exhibits progressivity across the full income distribution.

Figure 2. Average Net Household Burden as a Percent of Income of Three Cap-and-Trade Scenarios, by Income Quintile

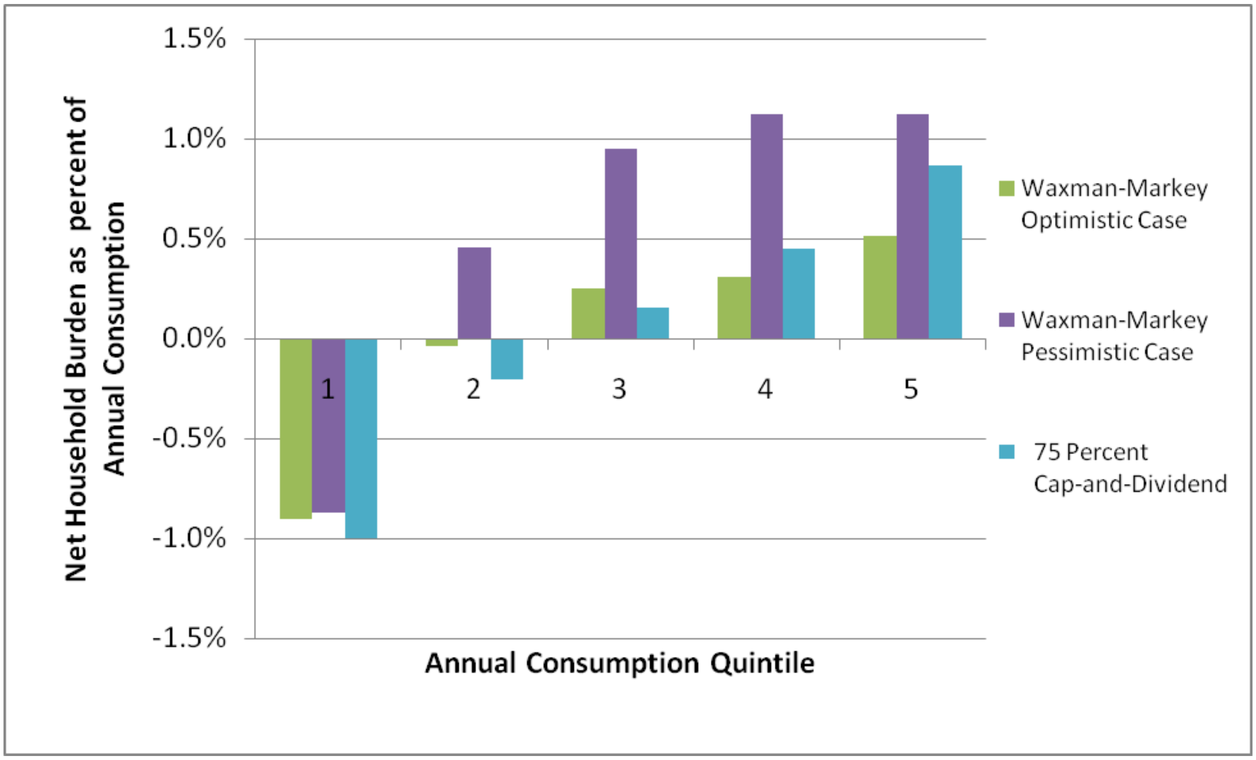


The results suggest that the uncertainty in outcomes in the Waxman-Markey bill does not lead to sharp differences in the *relative* impacts on different income groups, just differences in the absolute impacts. For example, the second quintile's burden as a percent of total burden across all quintiles is equal to 3 percent and 5 percent in the optimistic and pessimistic cases respectively; the fifth quintile's burden is 39 and 49 percent of the total in each case. These are small differences considering the absolute differences in burdens between the optimistic and pessimistic scenarios.

The first income quintile is a slight exception, however. As explained above, it has roughly the same burden as a percent of income in either the optimistic and pessimistic case. This is a result of our assumption about how the bill's provisions for low-income consumers flow to households (15 percent of total allowance value), which we hold constant across the optimistic and pessimistic scenarios.

Economists have long understood that current consumption is often based more on lifetime or permanent income than on current income. Some households with low current earnings, for example, might actually be consuming at a higher level due to their position in their career path (beginning or retirement) or other factors. For this reason, an analysis of the distributional impacts of a tax or other policy that groups households by annual income may misrepresent the true distributional impacts (Fullerton and Rogers 1993). Other problems such as inaccuracy in the reporting of annual incomes in a survey could contribute to the problem.[25]

Figure 3. Average Net Household Burden as a Percent of Consumption of Three Cap-and-Trade Scenarios, by Consumption Quintile



Unfortunately, in cross-section data such as the CES, a measure of lifetime income is unavailable. As in other cross-section studies, however, we can use current consumption as a proxy for lifetime income (Poterba 1989; Hassett, Marthur, and Metcalf 2009; Burtraw, Sweeney, and Walls 2009). Figure 3 displays net household burdens as a percent of consumption for all three policy scenarios. The results are quite similar to those using annual income. Minor differences include the cap-and-dividend scenario being slightly more progressive than when annual income is

[25] It is important to note that starting in 2004 (our first year of data) the consumer expenditure survey started imputing annual income. This fills in nonresponess and improves the overall qualtiy of CES annual income data (Fisher 2006).

used and the two Waxman-Markey scenarios looking progressive across the full distribution rather than just through the fourth quintile.

Examining the carbon pricing component alone, ignoring the distribution of allowance value, shows the policy to be regressive on the basis of annual income but approximately proportional on the basis of consumption. This is a typical finding in studies of energy taxes, general sales taxes, and other consumption-based taxes.[26] But with the complex distribution of allowance value to households, these differences in results across the two different income measures are muted and results for the two metrics are roughly comparable. It is important to note also that a large share of the rebate programs in Waxman-Markey (and as represented in this analysis) are means tested based on annual income. Allocation to shareholders is also based on annual income, not consumption. These factors help explain why the income and consumption measures of burden are similar, despite differences in the effects of carbon pricing before accounting for allowance value.

Conclusion

Climate change poses an extraordinarily challenging coordination problem for the international community and for the domestic body politic. This difficulty is exacerbated because the science of climate change, the underlying characterization of opportunities to reduce emissions, and the prospects for technological change are all extremely uncertain. Although the uncertainty about effects and outcomes may be seen by the scientific community as the motivation for the implementation of policy to reduce emissions, the same sources of uncertainty have emerged among critics as fundamental reasons to object to climate policy in political debate.

This paper focuses not on scientific or economic uncertainty, and only partially on technological uncertainty. Instead, we focus on a new source of uncertainty that is introduced in the design and implementation of policy intended to address this challenge. Specifically, we focus narrowly on uncertainty about the level and distribution of the burden on households that result from the formula for the allocation of emissions allowances in recent bills in the U.S. Congress. Even with

[26] The Poterba (1989) study showed this, as have several others since then. Indeed, in our earlier study, we showed that the effects of carbon pricing alone were regressive on the basis of annual income but roughly proportional on the basis of annual consumption (Burtraw, Sweeney, and Walls 2009). However, the *net* effect, incorporating the distribution of allowance value (in various alternative schemes) looked quite similar across the two income measures.

this narrow focus, we find uncertainty about the implementation of the program and its costs on households to be substantial. The finding that policy design may exacerbate the fundamental characteristic that makes climate policy such a daunting challenge in the first place may be important to making progress on the policy debate.

We examine the allocation under H.R. 2454 (the Waxman-Markey bill) under bookend scenarios that we label optimistic and pessimistic. In the scenarios, we explore the possible outcome with respect to three sets of issues. The first two scenarios explore the effect of allocations to electricity LDCs (30 percent of allowances) and the effect of allocations to promote efficiency (5.3 percent) and energy technology (8.14 percent). The remaining allowance allocations are held constant across the scenarios. In the optimistic scenario, we assume that the allocation to LDCs introduces relatively minimal distortions away from efficient pricing of electricity, although distortions remain important for the residential class of customers, and we assume favorable outcomes with respect to expenditures on efficiency and technology development. The pessimistic scenario has contrary assumptions; in fact, in the pessimistic case, we assume that efficiency and technology investments are wasted. For comparison, we consider a third scenario that directs 75 percent of allowance value directly back to households, keeping the remaining 25 percent directed to some of the categories that are held constant in the other two scenarios; this “cap-and-dividend” scenario is similar to the Cantwell-Collins bill (S. 2877).

Although the assumptions underlying our optimistic and pessimistic scenarios are bookends, they highlight the wide range of potential outcomes under a complex allocation scheme such as espoused in current climate bills, and they represent assessments that are commonly found as part of the contemporary political debate. We find that if investments in electricity energy efficiency programs and technology development pay off, and if, for industrial and commercial class customers, allocations to electricity LDCs do not dampen the rise in electricity prices brought about by climate policy, then the average net household burden experienced by households is only $136 in 2016 and the allowance price is as low as $13.20/ton. On the other hand, if the energy efficiency and technology investments are wasted and LDC allocations do dampen price rises for all electricity customers, the net household burden rises to $420, with an allowance price of $23.43/ton.

Shapley values help untangle the contribution of each policy in contributing to cost savings under the optimistic assumptions. The LDC assumption is only responsible for 7 percent of the savings, with a large part of the benefits accruing to the highest income quintile at the expense of the lower quintiles. The electricity energy efficiency programs, on the other hand, are responsible for 69 percent of the average savings to households through a combination of reduced electricity expenditures and emissions. These results point to the potential gains to households from energy efficiency spending if the program produces results along the lines of the optimistic assumption.

There are important questions about and limitations to our analysis, but we conclude by drawing attention to just two. One important limitation is the use of partial equilibrium modeling for what is fundamentally a general equilibrium problem. The partial equilibrium approach allows us greater flexibility in manipulating institutional representation in the model, but important feedbacks within the economy are lost to the analysis including, for example, the hidden costs associated with introducing new regulatory costs to the economy. A second limitation is the actual schedule of opportunities for energy efficiency and technological innovation. Under each of our scenarios that assume optimistic or pessimistic outcomes, we assume a constant return to scale for these endeavors. In fact, efficiency or technology could exhibit increasing cost, but through learning by doing and other factors, it could alternatively exhibit decreasing costs. Moreover, the examination of these technological possibilities on a piecewise basis rather than in an integrated technological model introduces the opportunity for double counting of emissions reductions opportunities. While concerns about returns to scale arguably introduce bias in any direction, the possibility for double counting is likely to bias our cost estimates downward. In any event, this illustrates one more way in which the cost of climate policy to households is uncertain.

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