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Introduction

Like cap and trade, a cap and dividend policy imposes a declining cap on greenhouse gas emissions and may allow pollution permits to be traded among polluters. The key difference is in how the permits are distributed; cap and dividend is the name given to the subset of cap and trade policies in which all permits are auctioned and a significant fraction of the auction revenue is distributed back to households on an equal per capita basis. Cap and trade programs generally allow for some portion of the pollution permits to be given away ("grandfathered") to certain polluters, and revenues from the auctioned permits are not necessarily returned to households or consumers. If the cost of complying with the cap is passed on to consumers, such policies will be regressive because lower income households spend a higher fraction of their income on energy than higher income households.

We assess the impact of a cap and dividend policy in California across different regions of the state for different levels of household income. We model the cap and dividend policy by assuming that 100% of permits are auctioned and a given fraction of the auction revenue is returned to the public in the form of equal per capita dividends. We also model the impact on consumers of increased costs of electricity, natural gas, and transportation fuels, and the increased cost of general consumer goods. We expect these costs to vary geographically because of the large variation in carbon intensity of electricity by region, as well as the variation in natural gas use and gasoline use (both electricity carbon intensity and gasoline consumption vary by nearly a factor of four across the state and natural gas consumption varies by a factor of three, as shown in Figures 1 through 3).

Note that we do not need to predict actual fuel prices in 2020, but only the contribution to the fuel price from the carbon price. This is because the goal of the cap and dividend policy is not to compensate households for rising fuel prices in general, but rather to promote the notion of the air as a public good to which each citizen has an equal share. Cap and dividend also reverses the potential regressivity of cap and trade by returning auction revenues to households. Although cap and dividend is progressive, it is not specifically designed to address fuel poverty because equal per capita dividends are also given to wealthier segments of the population. In our analysis, we also consider a scenario in which dividends are returned only to consumers who qualify for existing fuel poverty assistance programs, in order to allow for the possibility of larger, targeted payments to explicitly address the fuel poverty issue.

Methodology

The American Community Survey provides data on household incomes and electricity and natural gas expenditures for about 375,000 households in CA, which we aggregate into 41 regions (individual counties or groups of counties) and sort into deciles of per capita income. Matching each region with the electricity and natural gas utility(s) serving the region, we can calculate the increase in expenditure due to higher fuel prices in 2020[1]. We model the cap and trade system by assuming a fixed price for carbon in 2020.

Our goal is to estimate the change in household expenditures solely as a result of the carbon price in 2020; in other words, we want to compare the household expenditure under a carbon price with what the household expenditure would be in the absence of a carbon price. Without a carbon price, demand will be higher. It is easy to show that the change in expenditure for a given fuel is approximately:

$$\Delta(Expenditure) = Q^*(P_{carbon})^*(EF)^*(1+\varepsilon) \quad (1)$$

where Q is the quantity of that fuel consumed in 2020 assuming a carbon price, P_{carbon} is the carbon price, EF is the emissions factor of that fuel and ε is its elasticity of demand (typically negative). Note that when calculating the fraction of households who receive positive net benefits (dividends greater than expenditure increase), the value of the carbon price does not matter because both the dividend and the expenditure increase are directly proportional to the carbon price. In the following subsections, we discuss how to estimate 2020 demand, emissions factors, and elasticities for electricity, natural gas, and gasoline.

Electricity

Household electricity demand is assumed to stay constant through 2020, consistent with the California Energy Commission's 2007 Integrated Energy Policy report (CEC, 2007). The electricity sector is assumed to de-carbonize by 13% relative to 2006. This assumption is based on ARB's Climate Change Scoping Plan, according to which the electricity sector should be responsible for 96 MtCO2e in 2020 (the baseline of 139.2 MtCO2e less the emissions reductions from energy efficiency and the RPS) (CARB, 2008a). Under ARB's business as usual scenario, demand in 2020 is estimated at 294TWh, implying an emissions factor of 0.327 tCO2e/MWh in 2020 (CARB, 2009a). In 2006, the electricity sector was responsible for 106 MtCO2e and delivered 282 TWh, for an emissions factor of 0.376 tC/MWh (CARB, 2009b; CEC, 2008). Thus, we assume that all utilities follow the same path and decarbonize by 13% in order to estimate utility-specific emissions factors. The elasticity of demand for electricity is estimated at -0.2 (Boyce and Riddle, 2007).

Natural gas

Household natural gas consumption is assumed to decrease by 12% by 2020. According to CA's Greenhouse Gas Inventory, the residential and commercial sectors emitted 37.9 MtCO2e from natural gas in 2006; under ARB's business as usual scenario, this is

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[1] A few of the regions are missing data for important local electric utilities. Specifically, the region comprising Del Norte, Lassen, Modoc, and Siskiyou Counties is missing Lassen MUD, Pluma/Sierra Co-op, and Surprise Valley Electric Corporation. The region of Colusa, Glenn, Tehama, and Trinity Counties is missing Trinity County Public Utility District. And the region of Nevada, Plumas, and Sierra Counties is missing Lassen MUD and Plumas/Sierra Co-op.

forecast to increase to 42.9 $MtCO_2e$ by 2020 (CARB, 2009b; CARB, 2008b). The natural gas efficiency measures laid out in ARB's Scoping Plan are expected to shave off 4.3 $MtCO_2e$, leading to a net increase in natural gas consumption of 1.9% in the residential and commercial sectors by 2020 (CARB, 2008a). Combining this with the projected population increase of 15.7% between 2006 and 2020 implies that individual household natural gas consumption should fall on average by 12% by 2020 (U.S. Census, 2009a; U.S. Census, 2008). Initial natural gas consumption for a given household is calculated from the household's 2005-2007 natural gas expenditures using an average of 2005-2007 natural gas prices for the utility serving that region.[2] For natural gas, the emissions factor is 0.0547 tCO_2/Mcf and the elasticity of demand is assumed to be -0.2 (EIA, no date; Boyce and Riddle, 2007).

Gasoline

Household transportation expenditures are not included in the American Community Survey data. They are estimated using Bureau of Labor Statistics Consumer Expenditure Survey data to calculate per capita gasoline consumption by decile in California; the results are given in Table 1. These expenditures are then weighted by region based on California Energy Commission data on total gasoline consumption by region in 2006 to arrive at an estimate of per capita gasoline consumption by decile in each region of the state. To estimate per capita gasoline consumption in 2020, we assume demand for gasoline decreases 22%. This is based on combining ARB's business as usual emissions projection (160.8 $MtCO_2e$ from passenger vehicles in 2020, equivalent to 18.1 billion gallons of gasoline) with the ARB Scoping Plan's goal of reducing gasoline demand by 4.6 billion gallons by 2020 (CARB, 2008b; CARB, 2008a). This implies gasoline consumption of 13.5 billion gallons in 2020, which is 10% lower than 2006 consumption of 15.0 billion gallons. Combining this with the expected 15.7% population increase yields a per capita decline in gasoline consumption of 22% by 2020. The emissions factor for gasoline is 0.0089 tCO_2/gallon and the elasticity of demand is assumed to be -0.3 (EIA, no date; Boyce and Riddle, 2007).

Additional considerations

In one of our scenarios, we also include the "indirect" cost from rising prices of other consumer goods as a result of higher energy prices. We assume that this indirect cost varies by decile (since wealthier deciles consume more) but not by region. Table 2 gives an estimate of the indirect per capita carbon footprint by decile in CA. Note that assuming that all of these emissions are covered by the cap and trade program (as we do here) is an overestimate because not all goods consumed in CA are produced in CA. Thus, our scenario that incorporates this indirect cost should be interpreted as an upper bound.

We also consider the sensitivity of our results to different assumptions regarding demand elasticities for gasoline. It should be clear from Equation 1 that our analysis is fairly sensitive to assumptions about elasticities. It has been noted that demand for gasoline is

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[2] Natural gas prices for 2007 were obtained from EIA Form 176 for the following utilities: City of Long Beach, Pacific Gas and Electric, San Diego Gas and Electric, Southern California Gas, and Southwest Gas. For the remaining utilities, an average price of $11.57/Mcf was used.

more elastic for lower deciles, despite the fact that households in these deciles use less gasoline to begin with. Thus, we consider a scenario in which gasoline consumption is determined by using demand elasticities that vary by quintile from West and Williams, 2002[3]; elasticities are given in Table 3. (Note: West and Williams divides households into quintiles by household income, not per capita income, but we ignore this difference for the moment). The average elasticity in Table 3 is approximately -0.65, which is a plausible estimate for the long-term elasticity of gasoline.[4,5]

Finally, we consider a scenario in which dividends are only given to households that already qualify for fuel poverty assistance. Table 4 summarizes the federal poverty guidelines and the guidelines for eligibility in two state programs – the CARE (California Alternate Rate for Energy) and LIEE (Low Income Energy Efficiency) Programs, both of which target low income households. It should be noted that a large fraction of the population is eligible for the CARE and LIEE programs; roughly a third of the population meets the income eligibility requirements (which are the same for both programs).

Results

Table 5 summarizes the fraction of households that receive positive net benefits (i.e. their household dividend is larger than the increase in household fuel expenditures) for all regions and deciles. If we do not consider the indirect (non-fuel) component of the carbon footprint, about half of all households receive positive net benefits with 40% of auction revenue going to dividends. If we do consider the indirect carbon footprint, about half of all households receive positive net benefits with 90% of the auction revenue going to dividends.

Figure 4 shows how the fraction of households that receive positive net benefits varies across the state in the scenario where we only consider expenditure increases from direct fuel price increases. For clarity, and to emphasize the geographic variation, Figure 4 includes only selected regions representative of the full variation across regions. The region of Del Norte/Lassen/Modoc/Siskiyou fares the worst. This region has high household electricity consumption, driven by the cheap price of electricity from PacifiCorp, the dominant utility; PacifiCorp also has the highest carbon intensity of any of the utilities considered. (However, results for Del Norte/Lassen/Modoc/Siskiyou may be misleading because we are missing carbon intensity data for 2 utilities serving the region: Lassen MUD and Plumas/Sierra Co-op.) San Francisco County fares best, due to a combination of low natural gas consumption, low gasoline consumption, and the low carbon intensity of PG&E's electricity. As shown by Figure 5, the cap and dividend policy is progressive, with a greater fraction of households in the poorest deciles receiving positive net benefits. Table 6 shows the average household expenditure increases for different regions for households living in poverty.

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[3] S.E. West and R.C. Williams, "Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes" *Journal of Environmental Economics and Management* 47.3 (2004): 535-558.

[4] K. Storchmann, "Long-run gasoline demand for passenger cars: the role of income distribution", Energy Economics, Vol 27, 2005.

[5] A.M. Bento, L.H. Goulder, M.R. Jacobsen, and R.H. von Haefen, "Distributional and efficiency impacts of increased U.S. gasoline taxes," American Economic Review, Vol. 99 (3), 2009.

We note that with 100% of revenue distributed in the form of per capita dividends, more than 90% of households in all but 3 regions receive positive net benefits if only direct fuel expenditure is counted on the cost side. With 50% of revenue distributed as per capita dividends, only 8 of our regions (representing only 4% of the state's population) have fewer than half of households receiving dividends. Moreover, the households that receive positive net benefits from the policy are more likely to be in the poorer income deciles.

Indirect costs included

With indirect carbon costs included, the regional variation is qualitatively similar (since indirect costs are assumed not to vary across regions), but the fraction of households receiving positive net benefits is of course lower for all deciles and regions. Figure 6 shows the variation of households receiving positive net benefits across income deciles. For example, with 80% of auction revenue distributed as dividends, more than 80% of households in the bottom four deciles and half the households in the fifth decile receive positive net benefits.

Variable demand elasticities

We also consider a scenario in which the demand elasticity for gasoline varies by decile; the elasticities are given in Table 3. Figure 7 shows the variation of positive net benefits by decile counting only direct fuel costs; as expected, households do better overall because the demand for gasoline is more elastic for all deciles than was assumed in Figure 5.

Dividends only to low income households

Figures 8 and 9 show the results of only giving equal per capita dividends to low income households. We consider two definitions of low income – the federal poverty line and the CARE eligibility guideline, which is roughly double the federal poverty line. Not surprisingly, almost all low income households can be fully compensated, even with a relatively small fraction of auction revenue dedicated to dividends. This is because the same pool of money is being split among fewer people; in the case of CARE, a third of the population would be eligible for dividends.

Conclusions

We find that cap and dividend is a progressive policy that can result in the majority of California households receiving positive net benefits, depending on the fraction of carbon allowance revenue allocated towards equal per capita dividends. Despite the variation in fuel consumption and electricity carbon intensity across the state, it is still possible to return positive net benefits counting only direct fuel costs to the majority of households in regions representing 96% of the state's population, even with the government retaining half of the allowance revenue. If auction revenue are instead dedicated only to low-income households, the majority of low-income households can be fully compensated even with the state government retaining 80-90% of auction revenues for other purposes.

The largest uncertainty in this analysis are the demand elasticities. In this paper, we have conservatively chosen to use short-run elasticities for fuels that do not vary across deciles. Using larger (i.e. long-run) elasticities for gasoline results in more households receiving positive net benefits; using elasticities that vary across deciles results in more progressive results because poorer households are more sensitive to changes in gasoline prices. We did not consider scenarios in which the demand elasticity for natural gas or electricity varies across deciles, but presumably this would have a similar effect on the analysis (although not as large since electricity and natural gas make up a smaller proportion of household carbon budgets).

It is important to note that this paper is considering a narrow definition of "benefits" to households; by considering only the direct per capita dividends, we are ignoring the benefits that all households receive from reduced climate change damages. Estimates of the climate change mitigation benefits of the Waxman-Markey legislation in 2020 range from $7.6 billion to $130 billion, or per capita benefits of $22 to $380.[6] Under a cap and dividend scenario for California with 100% revenue returned as dividends, the per capita dividend in 2020 is $252.[7] Thus, the additional benefits from climate change mitigation are likely to be of the same order of magnitude as the direct dividends, implying that benefits to households from the cap and dividend policy are significantly greater than those included in our analysis.

Tables

Decile	1	2	3	4	5	6	7	8	9	10
Per capita gasoline consumption (relative to poorest decile)	1.0	1.3	1.8	1.9	2.0	2.3	2.6	2.9	2.8	3.7

Table 1. Per capita gasoline consumption by per capita income decile in CA. Source: Bureau of Labor Statistics Consumer Expenditure Survey

Decile	Per capita CO2 from consumer goods & services
0	1.21
1	1.84
2	2.38
3	2.92
4	3.52
5	4.23
6	5.12
7	6.35
8	8.35
9	13.36

Table 2. Per capita carbon footprint from non-fuel expenditures. Source: Jim Boyce, personal communication, October 6, 2009.

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[6] J.S. Holladay and J.A. Schwartz, "The Other Side of the Coin: The economic benefits of climate legislation," Institute for Policy Integrity, New York University School of Law, September 2009.

[7] This number was calculated by assuming that the 2020 target of 427 million tons CO2e emissions is reached. 85% of initial emissions (484 million tons CO2e in 2006) are covered by the cap and trade system. Permits cost $30/tCO2e, and the projected CA population in 2020 is 42.2 million.

1st	2nd	3rd	4th	5th
-0.67	-0.79	-0.69	-0.78	-0.34

Table 3. Price elasticity of demand for gasoline by quintile. Source: West and Williams, 2002.

	Household income	
Household size	Poverty level	CARE eligibility
1	$10,830	$30,500
2	$14,570	$30,500
3	$18,310	$35,800
4	$22,050	$43,200
5	$25,790	$50,600
6	$29,530	$58,000
7	$33,270	$65,400
8	$37,010	$72,800
per additional person	$3,740	$7,400

Table 4. Cutoffs for the federal poverty line and for eligibility in the California Alternate Rate for Energy Program. Source: U.S. Department of Health and Human Services, CA Public Utilities Commission.

	Fraction of households receiving positive net benefits	
% revenue to households	Not including indirect C footprint	Including indirect C footprint
100%	97%	59%
90%	95%	52%
80%	92%	45%
70%	88%	36%
60%	81%	27%
50%	69%	18%
40%	50%	11%
30%	30%	3%
20%	11%	0%
10%	1%	0%

Table 5. Fraction of households receiving positive net benefits across all deciles and regions in CA.

	Households eligible for CARE			Households below poverty line		
Region	Direct C expenditure ($)	Indirect C expenditure ($)	Dividend ($)	Direct C expenditure ($)	Indirect C expenditure ($)	Dividend ($)
Alameda	151	126	475	130	93	488
Alpine / Amador / Calaveras / Inyo / Mariposa / Mono / Tuolumne	246	125	430	213	90	465
Butte	150	119	442	131	92	470
Colusa / Glenn / Tehama / Trinity	279	135	520	245	108	572
Contra Costa	149	134	494	134	97	510
Del Norte / Lassen / Modoc / Siskiyou	346	122	454	304	94	476

El Dorado	216	127	440	172	90	468
Fresno	184	149	617	166	121	650
Humboldt	160	116	409	131	82	410
Imperial	305	148	616	278	120	638
Kern	211	152	628	192	123	660
Kings	213	169	690	197	135	734
Lake / Mendocino	208	130	488	185	98	515
Los Angeles County	181	144	571	161	108	571
Madera	227	160	662	194	128	685
Marin	174	115	371	135	74	362
Merced	215	160	669	197	131	703
Monterey/San Benito	172	162	639	144	117	619
Napa	151	129	454	134	88	453
Nevada / Plumas / Sierra	235	119	397	193	74	385
Orange	169	150	579	143	106	562
Placer	202	126	427	167	81	401
Riverside	211	151	590	190	113	606
Sacramento County	187	137	518	171	103	541
San Bernardino	222	157	632	201	121	648
San Diego County	156	138	519	133	101	533
San Francisco County	75	106	372	59	70	343
San Joaquin	198	154	611	171	118	625
San Luis Obispo	178	123	448	151	88	455
San Mateo	159	132	481	140	91	471
Santa Barbara	162	141	537	144	104	549
Santa Clara	153	136	521	133	99	526
Santa Cruz County	141	129	478	124	91	472
Shasta	217	124	460	203	93	474
Solano	191	142	536	160	100	524
Sonoma	145	127	450	121	87	446
Stanislaus	205	150	587	186	117	622
Sutter / Yuba	191	149	578	161	114	600
Tulare	203	160	684	186	133	718
Ventura	164	149	576	141	113	595
Yolo	175	137	527	145	100	525

Table 6. Average increases in household expenditures and average household dividends due to a carbon price of \$30/tCO2, assuming that 80% of auction revenues are directed to dividends. "Direct" expenditures refer to expected fuel expenditure increases in 2020, and "indirect" refer to rising prices of other consumer goods in 2020.

Figures

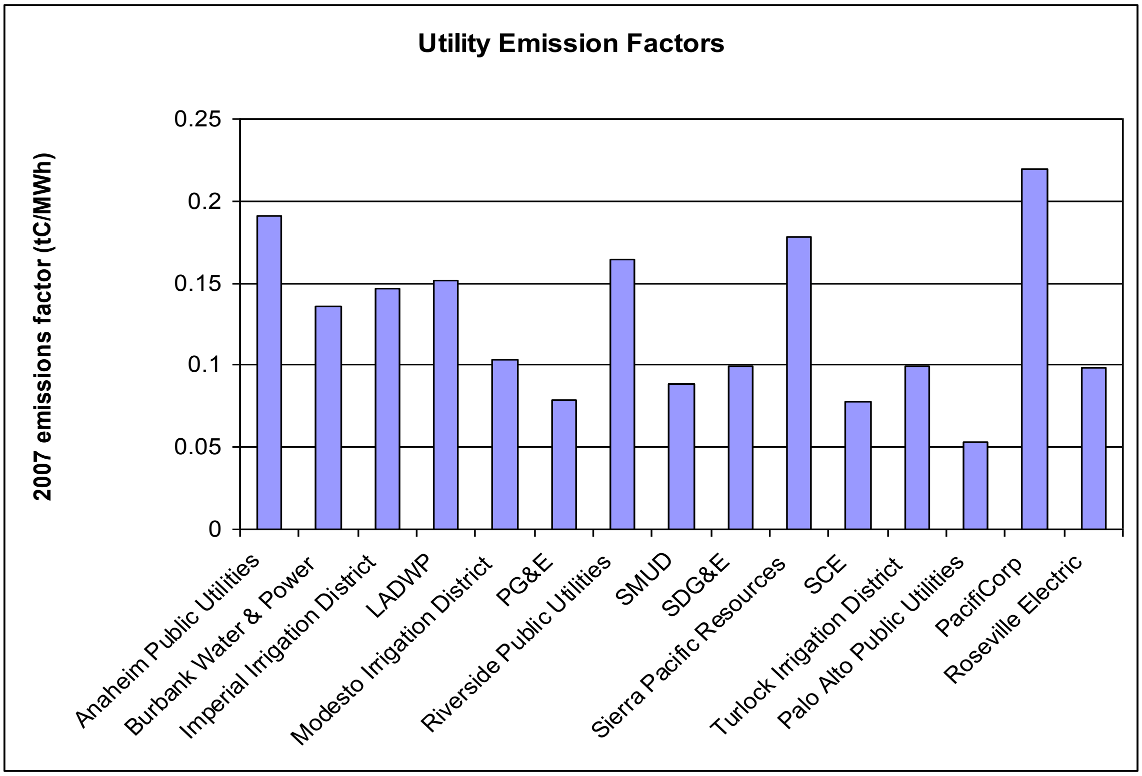

Figure 1. 2007 emissions factors for major CA utilities. Source: California Climate Action Registry.

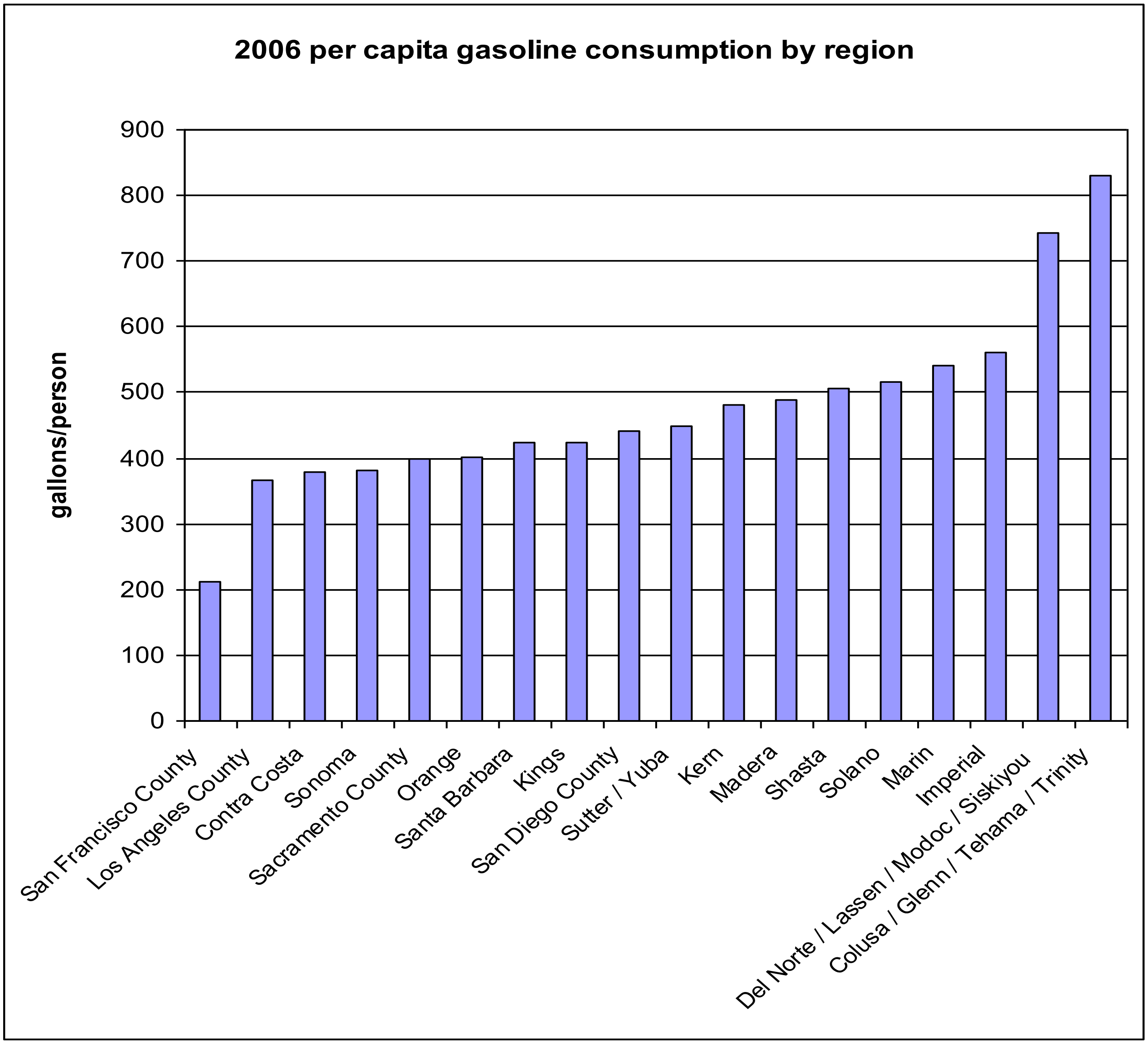

Figure 2. Per capita gasoline consumption for selected regions. Source: California Energy Commission, and U.S. Census Bureau

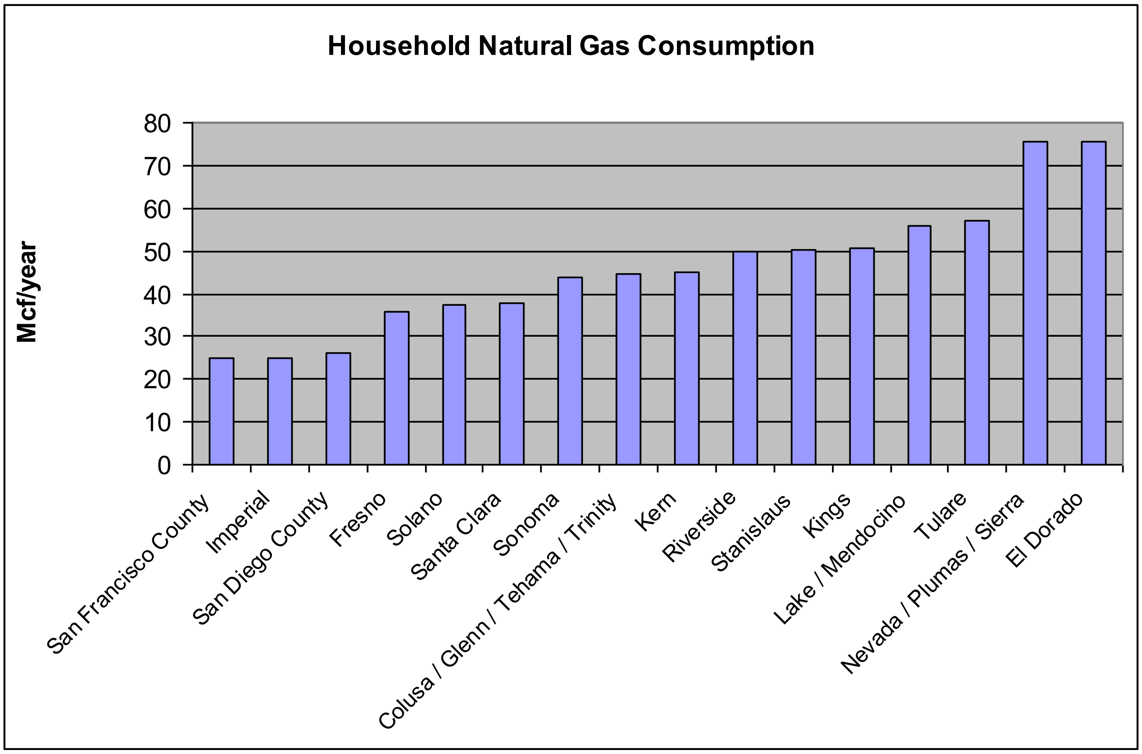

Figure 3. Natural gas consumption for selected regions. Source: American Community Survey, 2005-2007

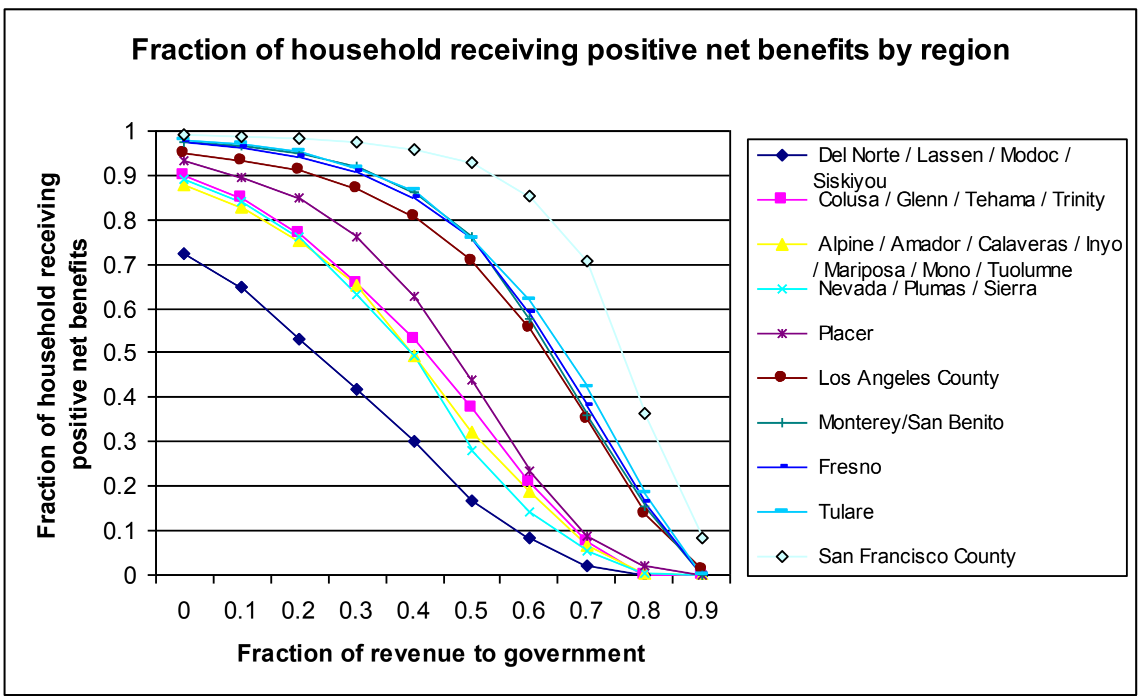

Figure 4. Fraction of households receiving positive net benefits, counting only direct fuel costs, for selected regions as a function of revenue returned to government.

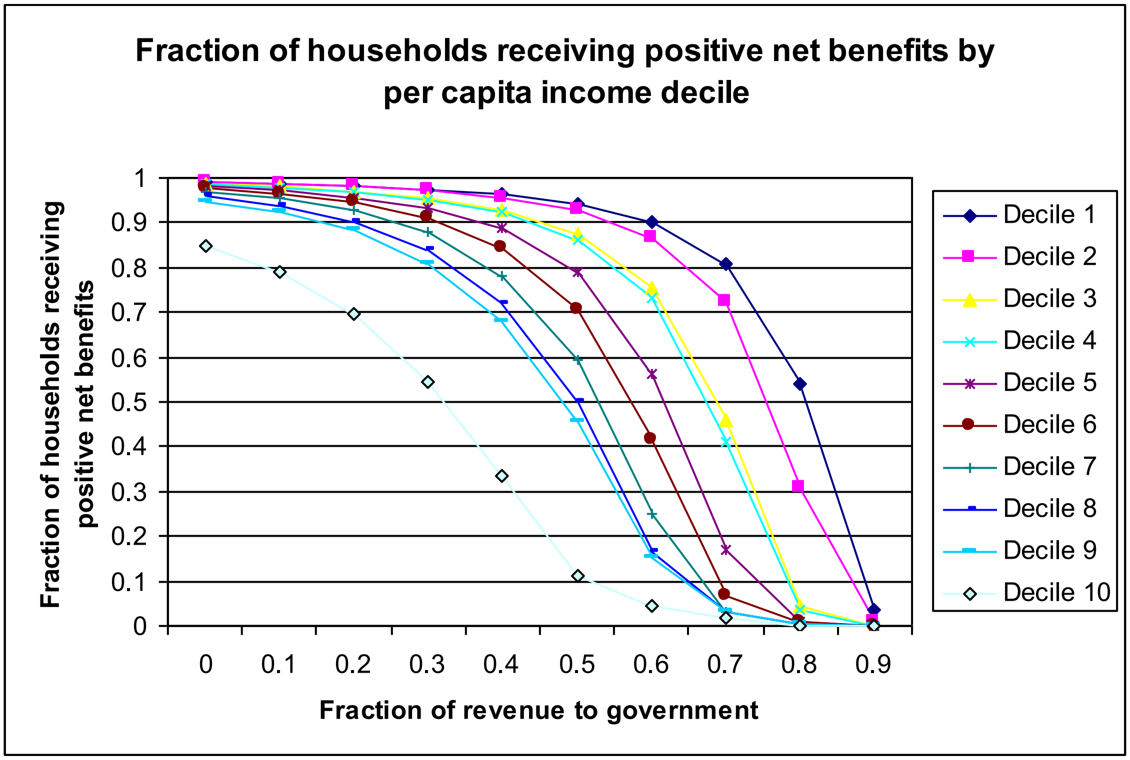

Figure 5. Fraction of households receiving positive net benefits, counting only direct fuel costs, by per capita income decile.

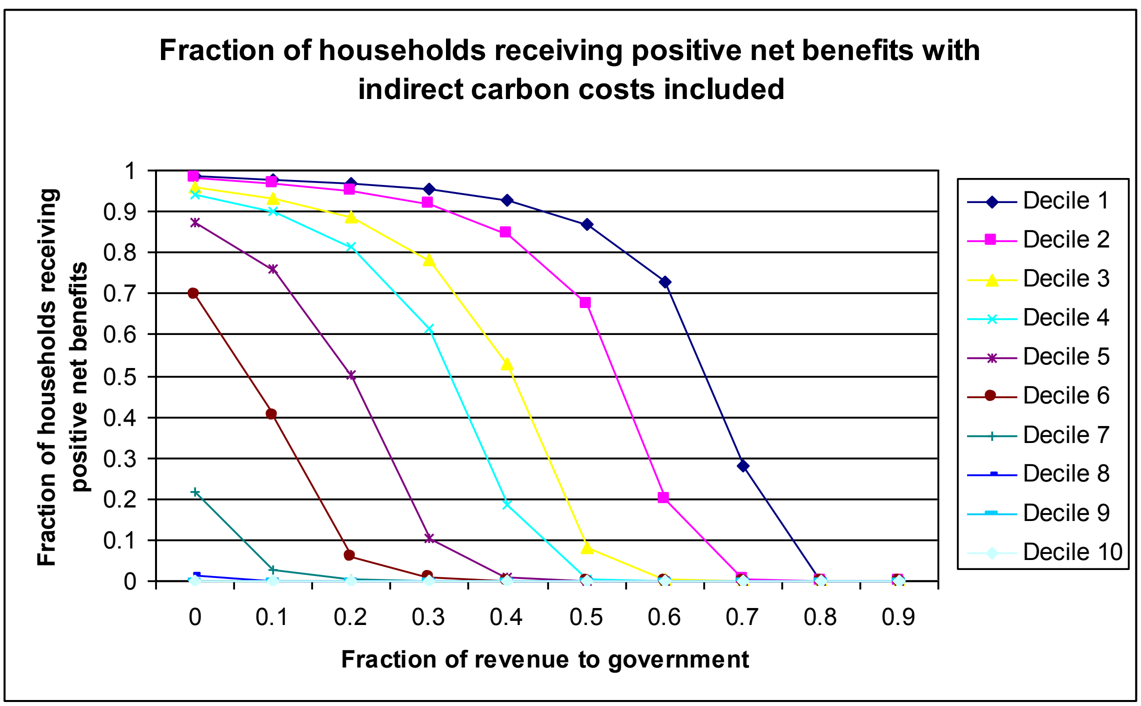

Figure 6. Fraction of households receiving positive net benefits by per capita income decile. Indirect carbon expenditures are included.

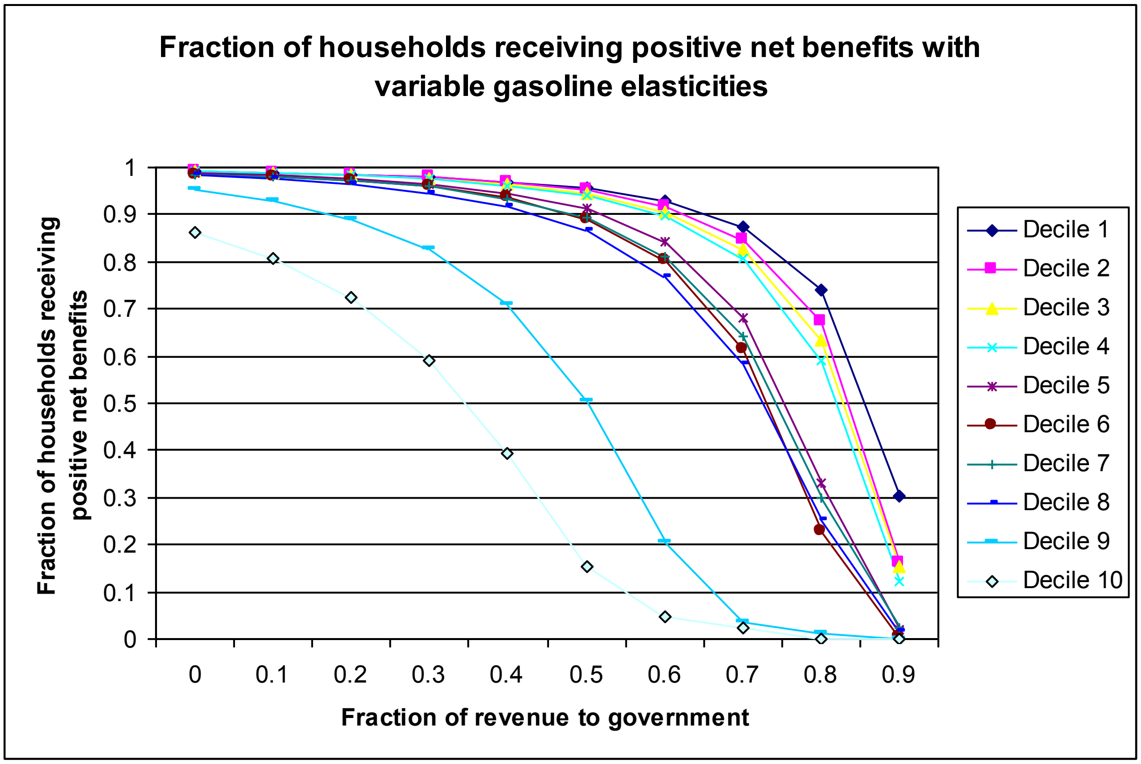

Figure 7. Fraction of households receiving positive net benefits, counting only direct fuel costs, by per capita income decile. Gasoline elasticities vary across deciles, as given in Table 3.

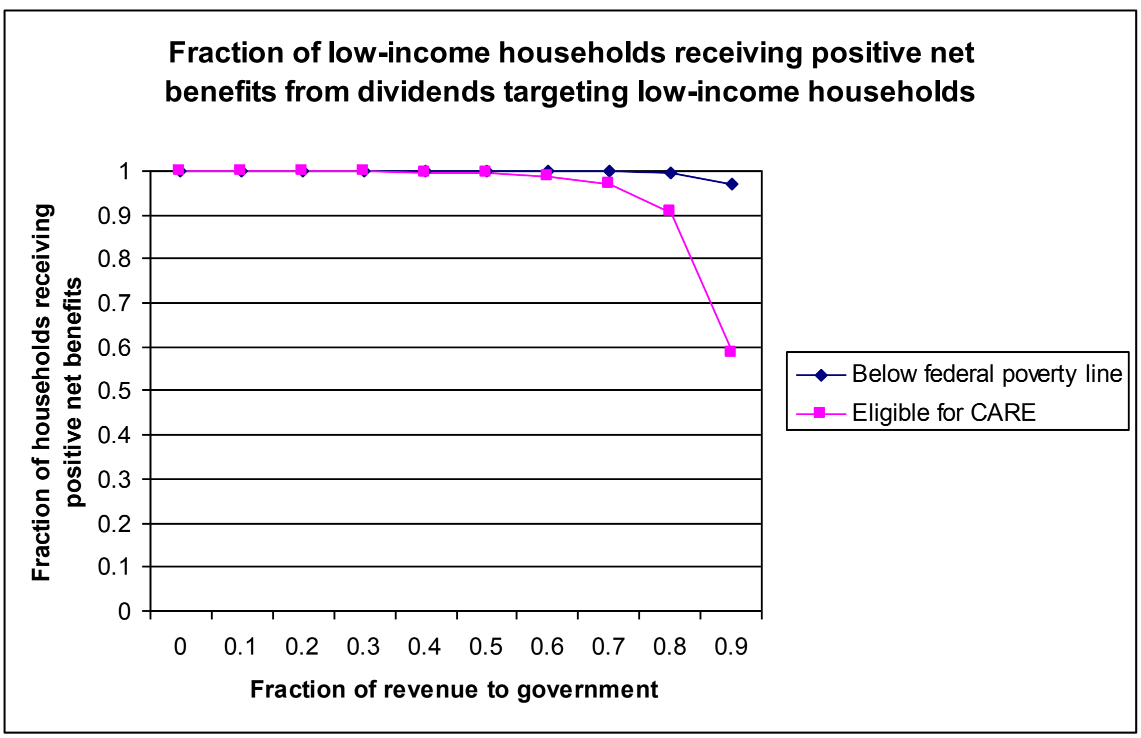

Figure 8. Fraction of low-income households that receive positive net benefits, counting only direct

fuel costs, under a policy in which only households meeting low-income eligibility requirements receive dividends. Indirect carbon costs are not included.

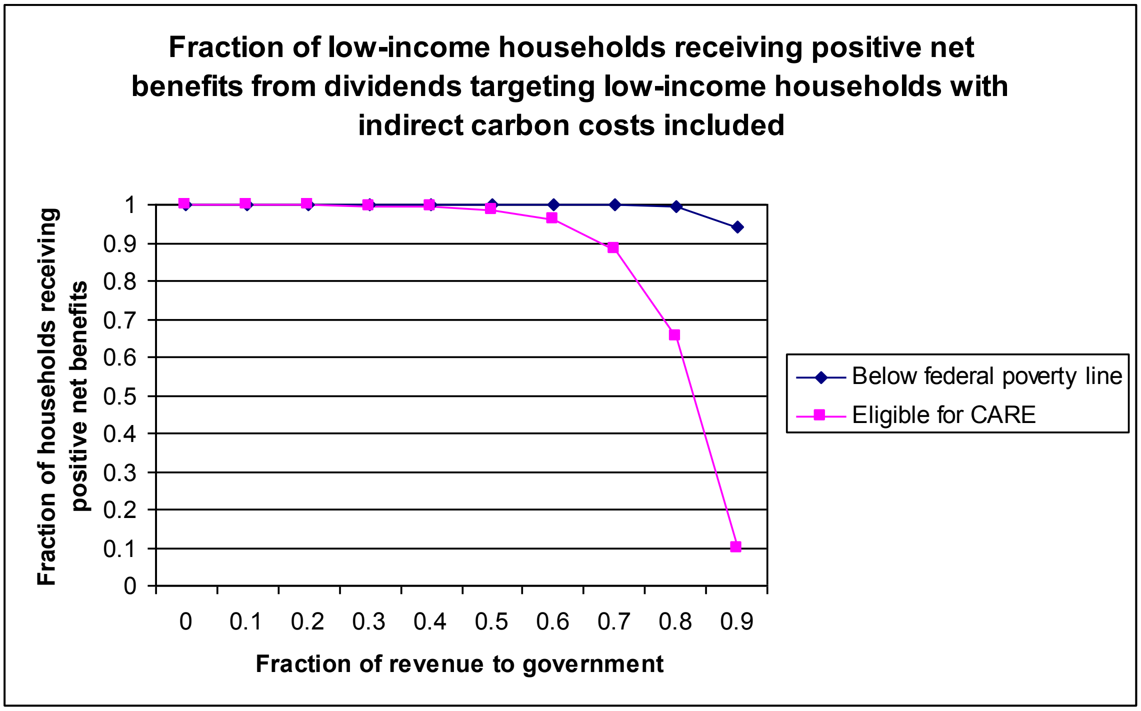

Figure 9. Fraction of low-income households that receive positive net benefits under a policy in which only households meeting low-income eligibility requirements receive dividends. Indirect carbon costs are included.

Data Sources:

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