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Communication

Design and implementation of carbon cap and dividend policies

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ABSTRACT

An important concept in discussions of carbon management policies is cap and dividend, where some fraction of the revenues of an auction on emission allowances is returned to citizens on an equal per capita basis. This policy tool has some important features; it emphasizes the fact that the atmosphere is a common property resource, and it is a highly transparent measure that can be effectively used to protect the income of low-income individuals. In this paper we examine this policy in the California context, and focus on the costs and impacts of a cap and dividend scheme when applied to carbon emissions associated with electricity, natural gas and transportation services. We find that cap and dividend can effectively be used to address the economic impacts of carbon management policies, making them progressive for the lowest-income members of society. We find that the majority of households receive positive net benefits from the policy even with the government retaining half of the auction revenue. If auction revenues are instead dedicated only to low-income households, the majority of low-income households can be fully compensated even with the state government retaining upwards of 90% of auction revenues for other purposes.

1. 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. Each year, the number of available permits declines according to the cap. Under a cap and dividend policy, all permits are auctioned and a significant fraction of the auction revenue is distributed back to households annually on an equal per capita basis. Carbon cap and trade programs, as they have been proposed in the U.S. Congress, 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. Under cap and dividend, low-income households received a higher fraction of their income back in the form of dividends, so the policy may have a progressive impact on income distribution.[1] Cap and dividend policy has now been proposed at the U.S. federal level in the form of the CLEAR Act (S. 2877) and has been endorsed by the Economic and Allocation Advisory Committee to the California Air Resources Board (EAAC, 2010).

A cap and dividend policy promotes the concepts of the atmosphere as a public resource and of common ownership of nature's wealth. Members of the public are treated as joint owners of the atmosphere; corporations owe the public compensation for the right to emit greenhouse gases into the atmosphere (Barnes et al., 2008). Another advantage of cap and dividend is that it may help ensure the durability of a carbon policy by mitigating the public's reaction to higher fuel prices. On the other hand, cap and dividend prevents some of the auction revenue from being directed to competing uses, such as research and development (R&D) and policy mechanisms that further promote the transition to a low-carbon economy. We begin to explore this trade-off in this paper by considering a scenario in which the fraction of auction revenue not used for dividends is used to support a feed-in tariff to promote renewable electricity generation.

We assess the impact of a cap and dividend policy in California across different regions of the state for different levels of household income. The focus of this paper is on analyzing how households are impacted by direct fuel price increases under a carbon price, and whether returning auction revenue as dividends can result in a progressive distributional impact. 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 model

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[1] Throughout this paper, "dividend" refers to direct payments to individuals from carbon auction revenues, not to the so-called "double dividend" that results from raising government revenue by taxing a negative externality like pollution.

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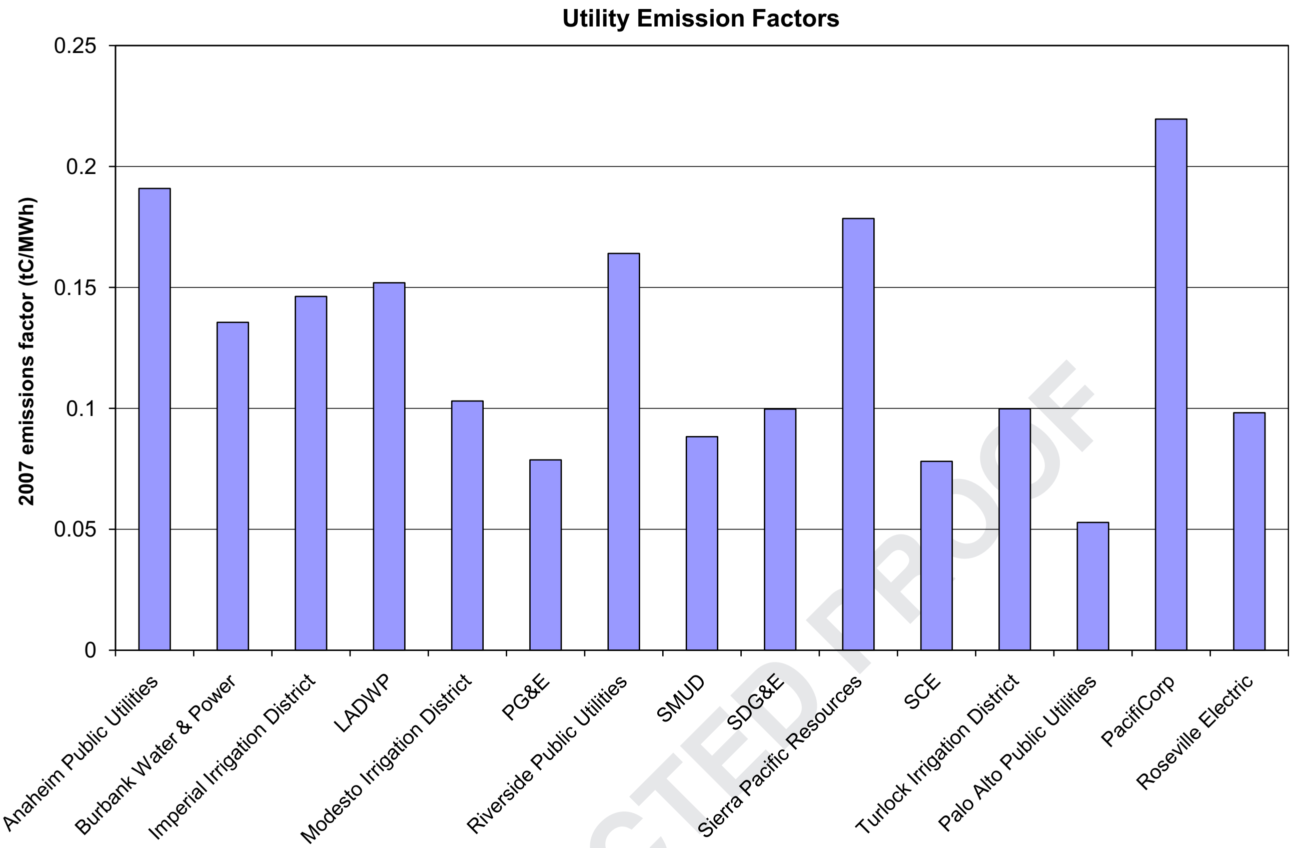

Fig. 1. . 2007 emissions factors for major CA utilities.
Source: California Climate Action Registry (no date).

the impact on consumers of increased costs of electricity, natural gas, and transportation fuels (and consider a scenario that includes the increased cost of other consumer goods under a carbon price). We expect increases in household fuel 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 Figs. 1–3). Fig. 4 shows the average household carbon dioxide emissions from electricity, natural gas, and gasoline consumption for selected regions to illustrate the variation across the state; as expected, household carbon emissions vary by roughly a factor of three across the state.

2. Methodology

In order to estimate the distributional and regional impact of the cap and dividend policy, we first estimate the change in household fuel expenditures as a result of the carbon price in 2020; in other words, we want to compare the household fuel expenditure under a carbon price with what the expenditure would be in the absence of a carbon price.

A full analysis of the distributional impact of a cap and dividend policy would also include the impact on labor supply and employment, using a general equilibrium framework. This analysis has been done at the national level for different carbon policies but not (to our knowledge) broken down by income decile or region (see, e.g., Metcalf, 2008; Paltsev et al., 2007). This would be a useful step for future analysis at the state level. Our goal in this paper is to provide a first-order approximation of distributional and regional effects at the state level by taking the labor market as fixed and considering only household income effects from rising prices and per capita dividends.

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[2]. We model the carbon cap by assuming a fixed price for carbon in 2020. For the jth fuel, the change in a household's expenditure on that fuel under a carbon price, P_{carbon} ($/ton CO_2), is given by

$$\Delta(Expenditure)_j = Q_{final,j} * (P_{carbon} * EF_j + P_{initial,j,k}) - Q_{initial,j} * P_{initial,j,k} \quad (1)$$

where $Q_{initial,j}$ is the hypothetical quantity of the jth fuel consumed in 2020 without a carbon price, $Q_{final,j}$ the quantity of that fuel consumed after the carbon price is imposed, EF_j the emissions factor (tons CO_2 per unit of fuel), and $P_{initial,j,k}$ the price of the fuel before the carbon price is imposed in the kth region. Note that this approach assumes full pass-through of the carbon price to households, which may overestimate the adverse impact

[2] 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.

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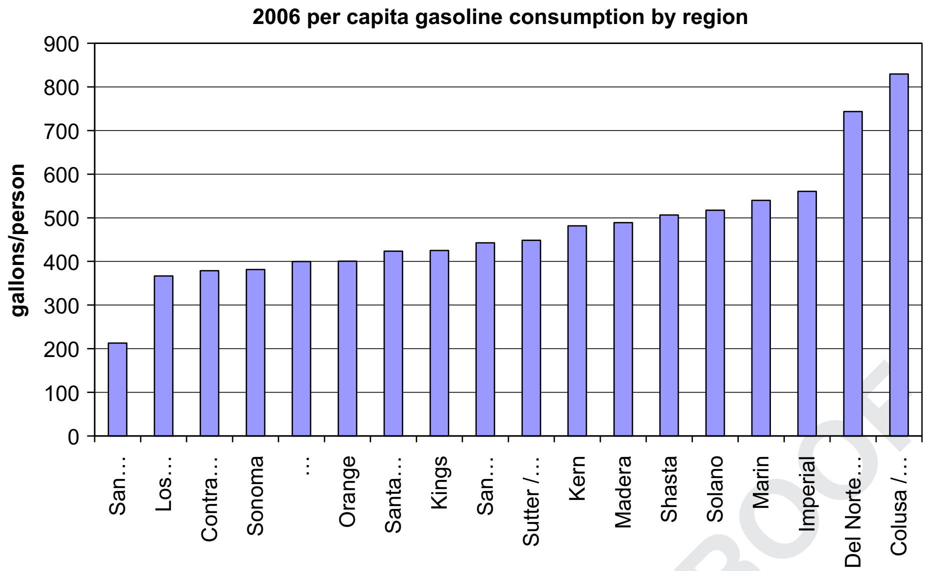

Fig. 2. Per capita gasoline consumption for selected regions.
Source: California Energy Commission (no date-a, no date-b, no date-c), and U.S. Census Bureau (2009b).

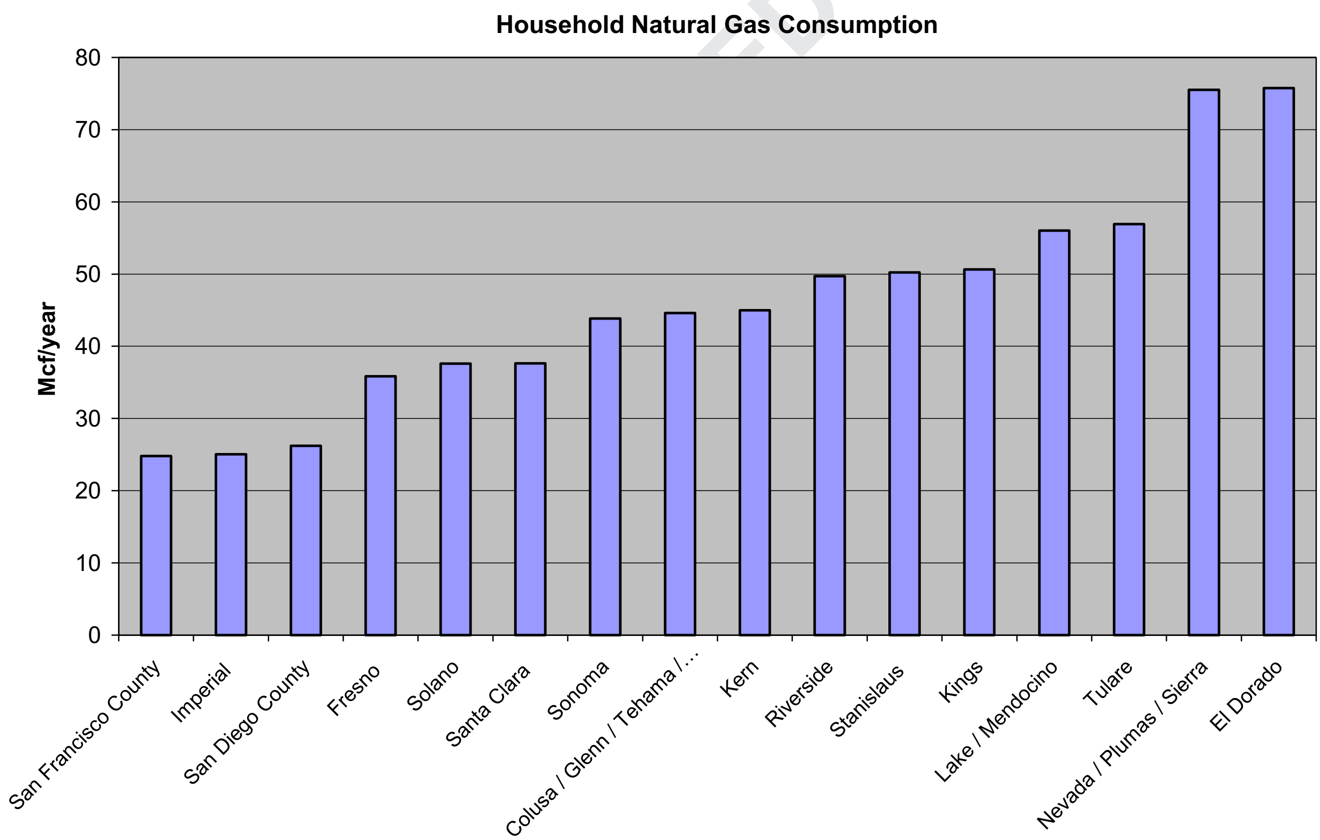

Fig. 3. Natural gas consumption for selected regions.
Source: American Community Survey (2005–2007).

on households. The quantity consumed after the carbon price is imposed is given by

$$Q_{final,j} = Q_{initial,j} * \left(1 + \varepsilon_j * \frac{(P_{carbon} * EF_j)}{P_{initial,j,k}}\right) \quad (2)$$

where ε_j is the short-run elasticity of demand (typically negative) of the jth fuel. Note that elasticities are assumed constant across both income level and space. Substituting this into Eq. (1), we find that

$$\Delta(Expenditure)_j = Q_{final,j} * (P_{carbon} * EF_j + P_{initial,j,k}) - \frac{Q_{final,j}}{(1 + \varepsilon_j * ((P_{carbon} * EF_j)/P_{initial,j,k}))} * P_{initial,j,k} \quad (3)$$

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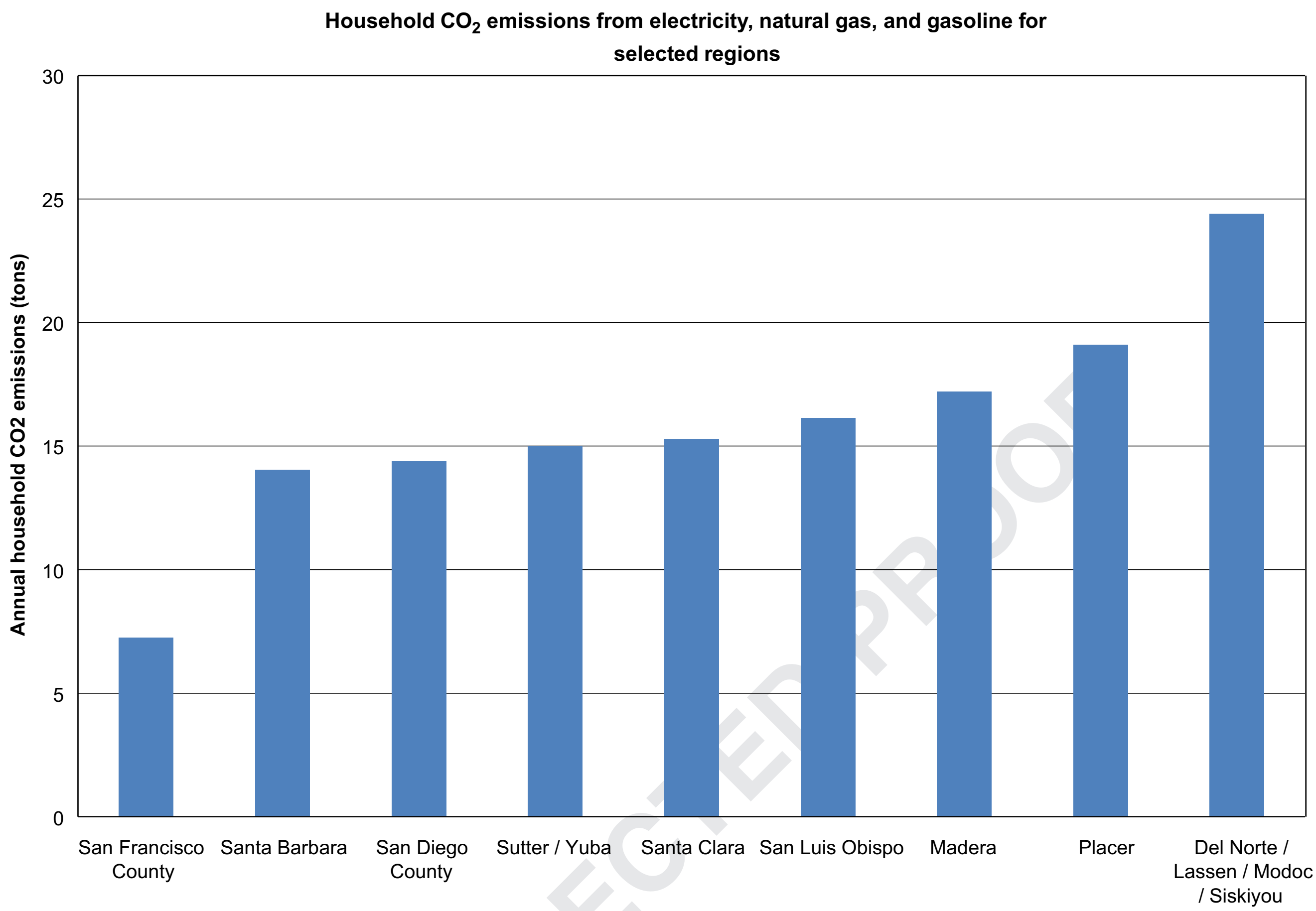

Fig. 4. Average household carbon dioxide emissions from electricity, natural gas, and gasoline consumption for selected counties and multi-county regions in California.

Making the assumption that the carbon price times the elasticity is a small perturbation to the total fuel price[3], then to first order

$$\Delta(Expenditure)_j = Q_{final,j} * P_{carbon} * EF_j * (1+\varepsilon_j) \quad (4)$$

Note that when calculating the fraction of households who receive positive net benefits under the policy (dividends greater than expenditure increase), the value of the carbon price is irrelevant 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 under the carbon policy ($Q_{final,j}$), emissions factors (EF_j), and elasticities (ε_j) for electricity, natural gas, and gasoline.

2.1. 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 the California Air Resources Board's (CARB) Climate Change Scoping Plan, according to which the electricity sector should be responsible for 96 $MtCO_2e$ in 2020 (the baseline of 139.2 $MtCO_2e$ less the emissions reductions from energy efficiency and the Renewable Portfolio Standard) (CARB, 2008a). Under CARB's business as usual scenario, demand in 2020 is estimated at 294 TWh, implying an emissions factor of 0.327 tCO_2e/MWh in 2020 (CARB, 2009a). In 2006, the electricity sector was responsible for 106 $MtCO_2e$ 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 short-run elasticity of demand for electricity is estimated at -0.2 (Boyce and Riddle, 2007).

2.2. 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 $MtCO_2e$ from natural gas in 2006; under CARB's business as usual scenario, this is forecast to increase to 42.9 $MtCO_2e$ by 2020 (CARB, 2009b, 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, 2008). Initial natural gas consumption for a given household is calculated from the household's 2005–2007 natural gas

[3] This is a reasonable assumption. For example, if residential natural gas prices are around $12/Mcf and the emissions factor for natural gas is 0.0.055 ton CO_2/Mcf, then a carbon price of $50/ton CO_2 is $2.7/Mcf. Multiplying this by the short-run elasticity (-0.2) and dividing by the natural gas price of $12/Mcf gives 0.05. This is small enough that the Taylor series approximation used to derive Eq. (4) from Eq. (3) is valid.

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Table 1
Per capita gasoline consumption by per capita income decile in CA, relative to lowest income decile.
Source: Bureau of Labor Statistics Consumer Expenditure Survey (2007).

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

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

Decile	Per capita CO2 from consumer goods & services (tons)
1	1.21
2	1.84
3	2.38
4	2.92
5	3.52
6	4.23
7	5.12
8	6.35
9	8.35
10	13.36

expenditures using an average of 2005–2007 natural gas prices for the utility serving that region.[4] For natural gas, the emissions factor is 0.0547 tCO_2/Mcf and the short-run elasticity of demand is assumed to be −0.2 (EIA, no date; Boyce and Riddle, 2007).

2.3. 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 CARB'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 CARB Scoping Plan's goal of reducing gasoline demand by 4.6 billion gallons by 2020 (CARB, 2008b, 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 short-run elasticity of demand is assumed to be −0.3 (EIA, no date; Boyce and Riddle, 2007).

2.4. Additional considerations

In one of our scenarios, we include the "indirect" cost from the increased 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 California, derived from an input–output analysis

[4] 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.

Table 3
Cutoffs for the federal poverty line and for eligibility in the California Alternate Rate for Energy and Low Income Energy Efficiency Programs.
Source: U.S. Department of Health and Human Services (2010), CA Public Utilities Commission (no date).

Household size	Household income	
	Poverty level	CARE and LIEE 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	$3740	$7400

Table 4
Fraction of households receiving positive net benefits across all deciles and regions in CA.

% Revenue to households (%)	Fraction of households receiving positive net benefits (%)
100	97
90	95
80	92
70	88
60	81
50	69
40	50
30	30
20	11
10	1

described in more detail in Boyce and Riddle (2009). Note that assuming that all of these emissions are covered by the cap and dividend program (as we do here) is an overestimate because not all goods consumed in California are produced in California and subject to the carbon policy. Thus, our scenario that incorporates this indirect cost should be interpreted as an upper bound.

Cap and dividend is not specifically designed to address fuel poverty because equal per capita dividends are also given to wealthier segments of the population. We consider a scenario in which fuel poverty is explicitly addressed by targeting dividends only to consumers that already qualify for fuel poverty assistance. Table 3 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. Roughly a third of California's population is eligible for the CARE and LIEE programs.

3. Results

Table 4 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. About half of all households receive positive net benefits with 40% of auction revenue going to dividends.

Fig. 5 shows how the fraction of households that receive positive net benefits varies across the state. For clarity, and to emphasize the geographic variation, Fig. 5 includes only selected

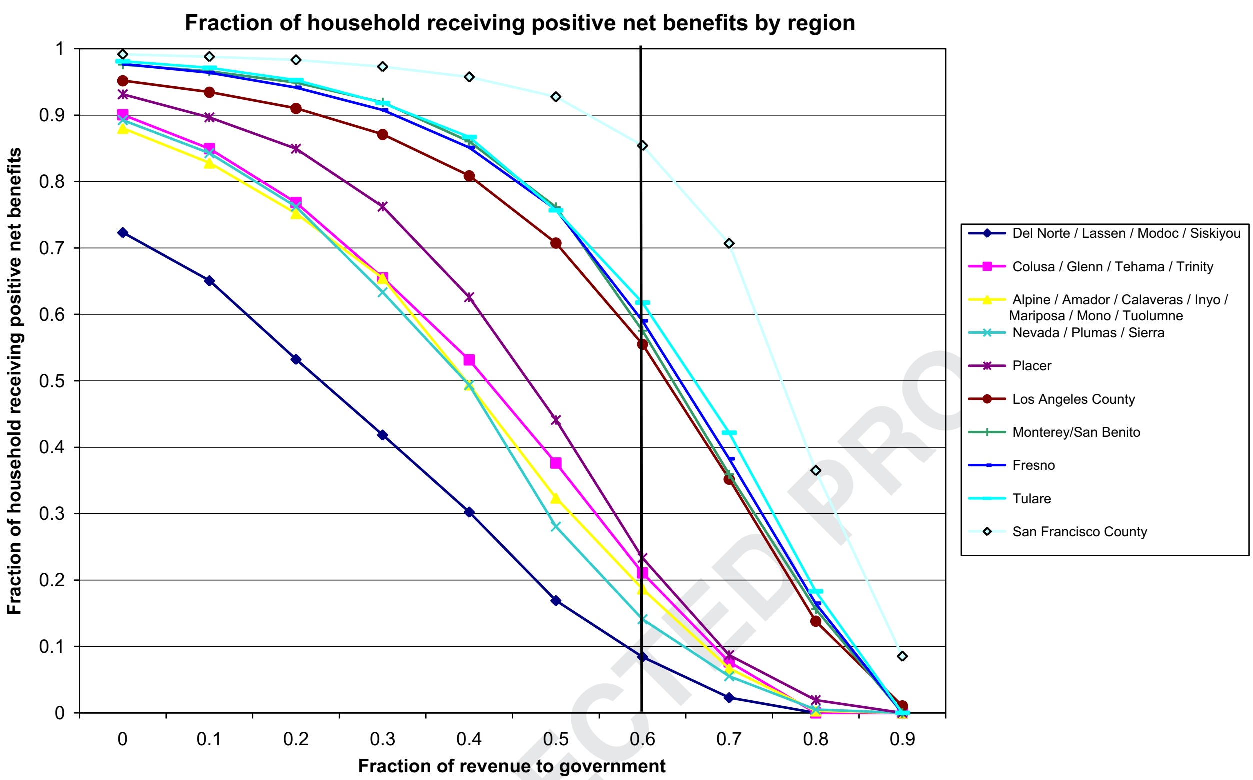

Fig. 5. Fraction of households receiving positive net benefits, counting only direct fuel costs, for selected regions as a function of revenue returned to government. The vertical line illustrates the case where 60% of revenue is used for a feed-in tariff, enough to fully fund the feed-in tariff at a carbon price of $50/t$CO_2$e.

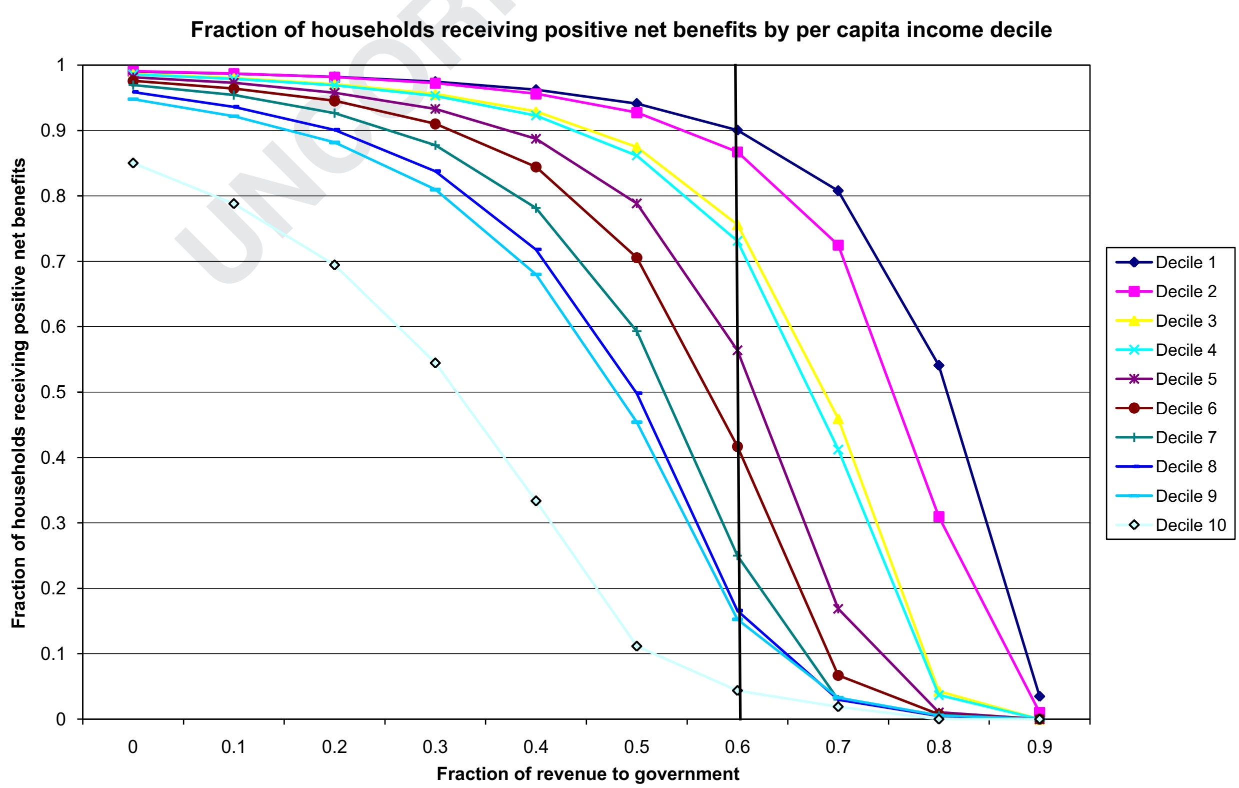

Fig. 6. Fraction of households receiving positive net benefits by per capita income decile. The vertical line illustrates the case where 60% of revenue is used for a feed-in tariff, enough to fully fund the feed-in tariff at a carbon price of $50/t$CO_2$e.

Table 5
Average increases in household expenditures and average household dividends due to a carbon price of $30/t$CO_2$, assuming that 80% of auction revenues are directed to dividends.

Region	Households eligible for CARE		Households below poverty line	
	Household C expenditure ($)	Dividend ($)	Household C expenditure ($)	Dividend ($)
Alameda	151	475	130	488
Alpine/Amador/Calaveras/Inyo/Mariposa/Mono/Tuolumne	246	430	213	465
Butte	150	442	131	470
Colusa/Glenn/Tehama/Trinity	279	520	245	572
Contra Costa	149	494	134	510
Del Norte/Lassen/Modoc/Siskiyou	346	454	304	476
El Dorado	216	440	172	468
Fresno	184	617	166	650
Humboldt	160	409	131	410
Imperial	305	616	278	638
Kern	211	628	192	660
Kings	213	690	197	734
Lake/Mendocino	208	488	185	515
Los Angeles County	181	571	161	571
Madera	227	662	194	685
Marin	174	371	135	362
Merced	215	669	197	703
Monterey/San Benito	172	639	144	619
Napa	151	454	134	453
Nevada/Plumas/Sierra	235	397	193	385
Orange	169	579	143	562
Placer	202	427	167	401
Riverside	211	590	190	606
Sacramento County	187	518	171	541
San Bernardino	222	632	201	648
San Diego County	156	519	133	533
San Francisco County	75	372	59	343
San Joaquin	198	611	171	625
San Luis Obispo	178	448	151	455
San Mateo	159	481	140	471
Santa Barbara	162	537	144	549
Santa Clara	153	521	133	526
Santa Cruz County	141	478	124	472
Shasta	217	460	203	474
Solano	191	536	160	524
Sonoma	145	450	121	446
Stanislaus	205	587	186	622
Sutter/Yuba	191	578	161	600
Tulare	203	684	186	718
Ventura	164	576	141	595
Yolo	175	527	145	525

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 two 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 Pacific Gas & Electric's electricity. As shown in Fig. 6, the cap and dividend policy is progressive, with a greater fraction of households in the poorest deciles receiving positive net benefits. Table 5 shows the average household expenditure increases for different regions for households living in poverty. Note that the variation in household dividends across regions in Table 5 is due to differences in average household size across the regions. The variation in household dividends between CARE-eligible households (those below roughly 200% of the federal poverty line) and households below the poverty line also reflects different average household sizes in those two income brackets.

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. 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.

3.1. Indirect costs

When the impact of a carbon price on the price of other goods and services is 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 lower for all deciles and regions. Fig. 7 shows the variation of households receiving positive net benefits across income deciles. 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.

3.2. Dividends to low-income households

Fig. 8 shows the results of only giving equal per capita dividends to low-income households. We consider two definitions

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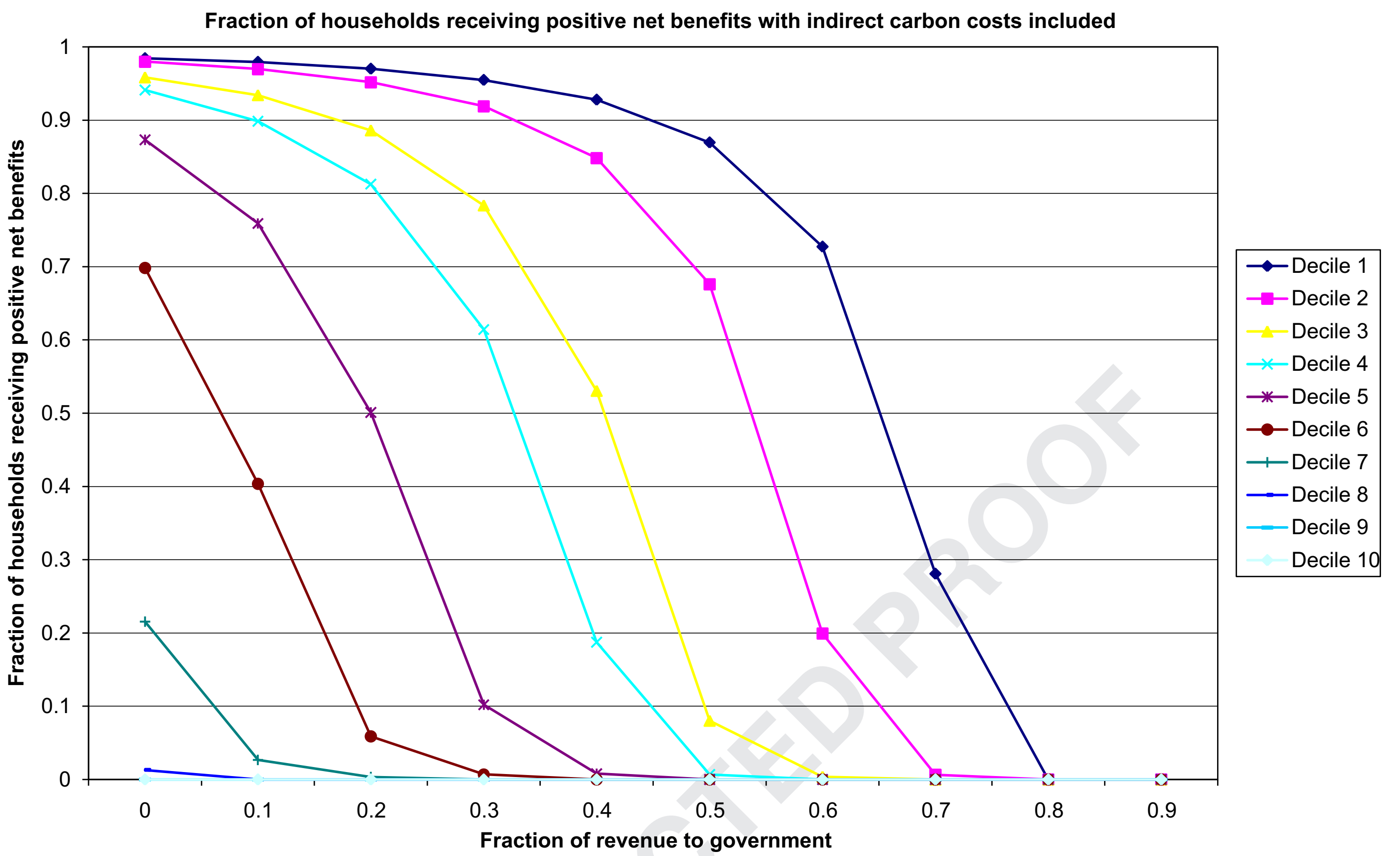

Fig. 7. Fraction of households receiving positive net benefits by per capita income decile. Indirect carbon expenditures are included.

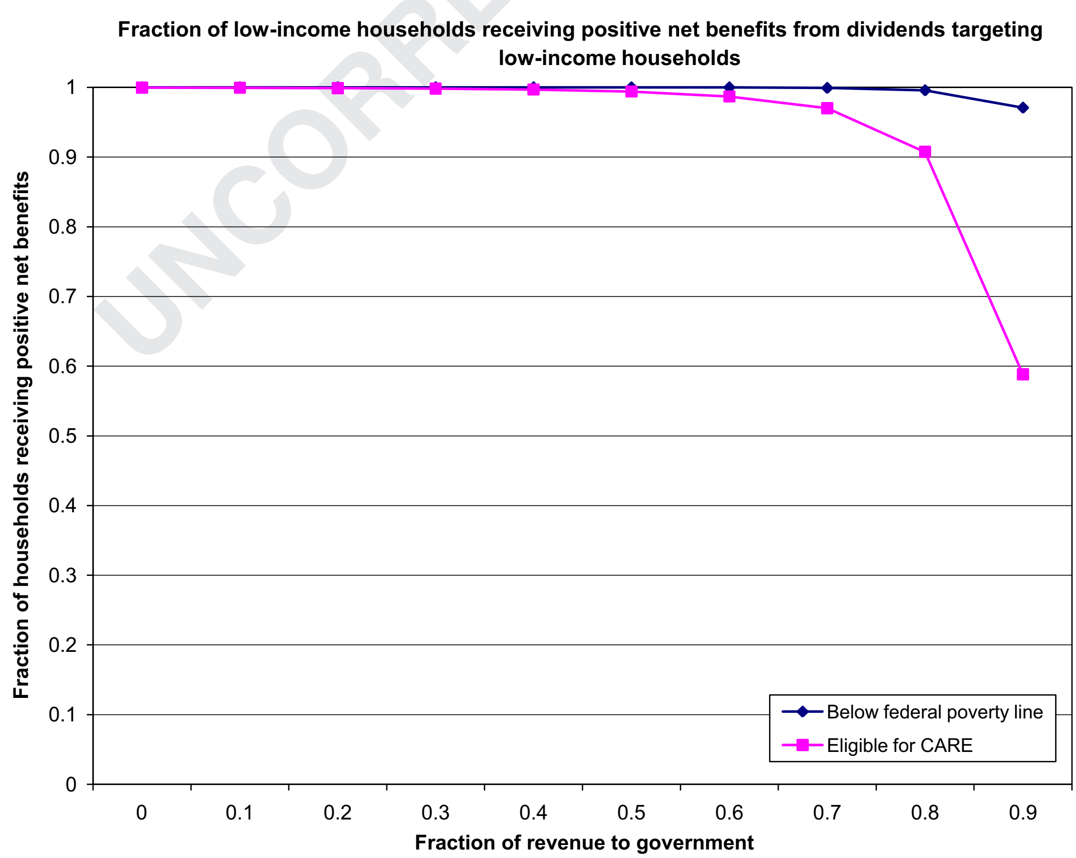

Fig. 8. Fraction of low-income households that receive positive net benefits under a policy in which only households meeting low-income eligibility requirements receive dividends.

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Table 6
Long-run price elasticity of demand for gasoline by quintile.
Source: West and Williams (2004).

Decile	1st	2nd	3rd	4th	5th (wealthiest)
Elasticity	−0.67	−0.79	−0.69	−0.78	−0.34

of low income—the federal poverty line and eligibility for California fuel poverty programs (see Table 3). 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; using state eligibility guidelines, a third of the population would be eligible for dividends. Note that this is probably not a politically feasible method of allocating dividends because households just below the poverty cut-off receive the full dividend and those just above receive nothing; a more gradual cut-off would be more feasible.

3.3. Trade-off with other revenue uses

To illustrate the trade-off between per capita dividends and other potential uses of auction revenue, we consider a scenario in which some of the auction revenue is used to fund a feed-in tariff. We assume that the feed-in tariff pays renewable electricity generators a fixed price for 10 years; the price starts at $0.170/kWh in 2011 and declines 5% per year until 2020 (Lewis, 2010). According to the California Energy Commission, 75 TWh of new renewables generation is needed to meet the 33% RPS goal in 2020 (Douglas et al., 2009). Assuming this renewable generation is built at a constant rate between 2011 and 2020, the feed-in tariff will cost $10.2 billion in 2020. At a carbon price of $50/tCO$_2$e, the feed-in tariff would require about 60% of the auction revenue. This case is illustrated in Figs. 5 and 6; with 60% of revenue used for a feed-in tariff, enough revenue is available for per capita dividends so that more than 70% of households in the bottom four deciles receive positive net benefits.

3.4. Elasticities

It should be clear from Eq. (4) that our analysis is fairly sensitive to assumptions about elasticities. It has been noted that demand for gasoline is less elastic at higher incomes, despite the fact that households in these deciles consume more gasoline; Table 6 shows an estimate of long-run elasticities for gasoline by household income quintile (West and Williams, 2004). The average elasticity in Table 2 is approximately −0.65, which is a plausible estimate for the long-term elasticity of gasoline (see, e.g. Storchmann, 2005; Bento et al., 2009). In this paper, we have conservatively chosen to use short-run elasticities for fuels that do not vary across deciles. Using elasticities that vary across deciles would have resulted in more progressive results because poorer households would be more sensitive to price changes.

4. 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 is 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.

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 (passed by the U.S. House of Representatives in June 2009) in 2020 range from $7.6 billion to $130 billion, or per capita benefits of $22 to $380. Under a cap and dividend scenario for California with 100% revenue returned as dividends, the per capita dividend in 2020 is $252 if the carbon price is $30 per ton of carbon dioxide.[5] 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.

Uncited references

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