


THE WELFARE IMPLICATIONS OF CARBON TAXES VERSUS CARBON CAPS: A LOOK AT U.S. HOUSEHOLDS

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Background

- **U.S. $CO2_e$ emissions are 23.4 tons** per capita per year (in 2005).
  - More than **twice** EU levels (10.7 tons per capita)
  - Over **four times** world average of 5.8 tons (WRI 2009)
- **Congress** has been pondering policy proposals for several years now:
  - **McCain & Lieberman's 2005** Climate Stewardship & Innovation Act
  - Bingaman & Specter's 2007 Low Carbon Economy Act
  - **Waxman & Markey's 2009** American Clean Energy & Security Act.
- Emphasis has been on the introduction of **carbon taxes** or implementation of a **cap & trade** (& distribute) strategy, both **upstream**, with the latter now very likely.
- What about **end-user carbon budgets?**
- **Can we hit 80% reduction by 2050?** And 20% by 2020?
- **What are the welfare implications**, by policy?

Past work

- **Little is known on how households will react** to energy pricing.
- And **downstream cap-and-trade** policies are rarely discussed.
  - Thumin & White (2008) estimated that **71% of U.K. households** in the **lowest three income deciles** would have **surplus allowances to sell**, while 55% of households in the highest three would have to buy allowances or reduce emissions.
- Dinan & Rogers (2002) examined the effects of a **15% cut** in household carbon emissions, & estimated that…
  - **15% cut** would translate to roughly a **3.3% income loss** for the **lowest income quintile** (lowest 20%) of US households, &
  - **1.7%** of income for average household in **top US quintile**.
- ***This work*** examines **household trade-offs** (including travel demand & emissions impacts) under **policies of taxation & downstream caps**.

Policies in Practice

- **Finland** was the first country to adopt a tax, in 1990. Current **tax** is $24 (€18) per ton of CO_2.
- **Sweden** adopted a **tax** in **1991**, presently at $150 per ton of CO_2, but no tax on fuels used for electricity generation, & industries pay only 50% of the tax (Johansson 2000).
- **Boulder, CO** implemented this nation's first carbon **tax on gas & electricity bills** in 2007. (Approx. $25/ton of CO_2 [Kelley 2006])
- **EU** established the world's first system of **cap & trade** for industries in **2005**.

Useful Data Sets

- BLS' 2002 **Consumer Expenditure Survey** (CEX) data
  - Information on household incomes & expenditures (by category) + demographics (including employment status)
- **Final data set:** Expenditures by **4,472 households** across NBER's 109 categories, then aggregated into **9 key categories**:

✓Household Savings
✓Natural Gas
✓Electricity
✓Air Travel
✓Public Transit
✓Gasoline
✓Food Consumed in Home
✓Food Consumed Outside (dining out)
✓Other expenditures (electronics, vehicles, health, etc.)

- 4-region **Price data** from BLS, CPI, USDOT, & NTD (& $1 on Other & Savings)

Methodology

- **Demand Theory:** Households choose quantities that **maximize budget-constrained utility** expressions (e.g., Christensen et al.'s (1975) translog for direct & indirect utility, & Deaton & Muellbauer's (1980) AIDS)
- **Carbon Taxes** increase all prices based on (estimated) intensity of each goods' carbon emissions.
- Under **Carbon Caps** households have to meet a second (carbon) budget, resulting in the following problem:

$$\max u(\mathbf{x}) \text{ s.t. } \mathbf{px} \leq M \ \& \ \mathbf{cx} \leq B$$

Translog Expressions

- To estimate preference function parameters, demanded quantities & welfare impacts under both policy settings, Christensen et al.'s (1975) flexible translog specification for $U(\mathbf{x})$ is used.

$$U(\mathbf{x}) = \alpha + \sum_{\mathrm{i}} \alpha_{\mathrm{i}} \ln(x_i) + 0.5 \sum_i \sum_j \beta_{ij} \ln(x_i) \ln(x_j)$$

- Singly onstrained optimization results in the following **expenditure shares**:

$$\frac{p_j x_j}{M} = \frac{\alpha_j + \sum_i \beta_{ij} \ln(x_i)}{\sum_k \alpha_k + \sum_k \sum_i \beta_{ik} \ln(x_i)}$$

- All parameters estimated using **SES** to ensure consistency across equations.
- The associated ***indirect*** utility expression (for two budgets) cannot be obtained directly, so **numerical methods** provided demanded quantities under the carbon-cap scenarios.

Setting Carbon Taxes

- **Policies need to be designed carefully**: Low tax rates (or high caps) may not motivate any behavioral shifts, while higher rates (or lower caps) may excessively burden low-income (or higher consuming) households.
- Tol's (2005) assessment of 103 published estimates of marginal **CO2e costs** yielded an average of $12.4 per ton. IPCC's (2007) Working Group II survey of 100 estimates suggests **$3 to $95** range.
- In order to stabilize GHG emissions, prices are expected to be $25 to $70/ton by 2020, rising to $127 to $230 by 2050 (Clarke et. al 2007).
- **Here**, to motivate reasonable behavioral shifts, **$50 & $100 per ton taxes** are imposed, to anticipate welfare implications across household classes.

Prices Under Taxes

	Base Prices ($ per unit)		CO2e Emissions (lbs per unit)		Tax at $50/ton ($ per unit)	Taxed Prices ($ per unit)	*% Price Change*
Natural Gas	$8.11	1000 cuft	120	1000 cuft	$2.72	$10.83	**33.56%**
Electricity	0.096	kWh	1.3	kWh	0.03	0.13	**30.72**
Air Travel	0.1703	mile	0.934	mile	0.02	0.1903	**12.0**
Transit	0.03	mile	0.30	mile	0.01	0.04	**21.14**
Gasoline	1.51	gallon	19.56	gallon	0.44	1.95	**29.39**
Food at Home	1	unit	1	unit	0.02	1.02	**2.27**
Food Outside	1	unit	1	unit	0.02	1.02	**2.27**

Points to note

- **Data aggregation** was used here, & the associated functional specification **can be quite limiting** for certain emissions-savings (& other) behaviors that exist.
- **Gasoline** category is quite homogeneous, but…
- Categories like Air Travel & Public Transport offer different options that may be more or less efficient
- **Other** category includes a tremendous diversity of energy implications (from one car to the next, one refrigerator to the next, & so forth).
- **Substitution among alternatives** (e.g., those of different carbon intensity) within a category **should be enabled**, to allow for lower carbon emissions.

Carbon Caps with Trade

- **Cap** was set at **10 & 15 tons per person** per year.
- **Excess credits** (typically enjoyed by lower-income & larger households) can be sold (effectively increasing income).
- Households facing a binding cap **can buy credits at $50 & $100**/ton (from those that have *excess* credits to sell).
- Though the credit cost is pre-determined (rather than market-determined) in these scenarios, the solution mechanisms used still ensure that the emissions-per-capita target is met.

Average Emissions (tons/HH by Class)

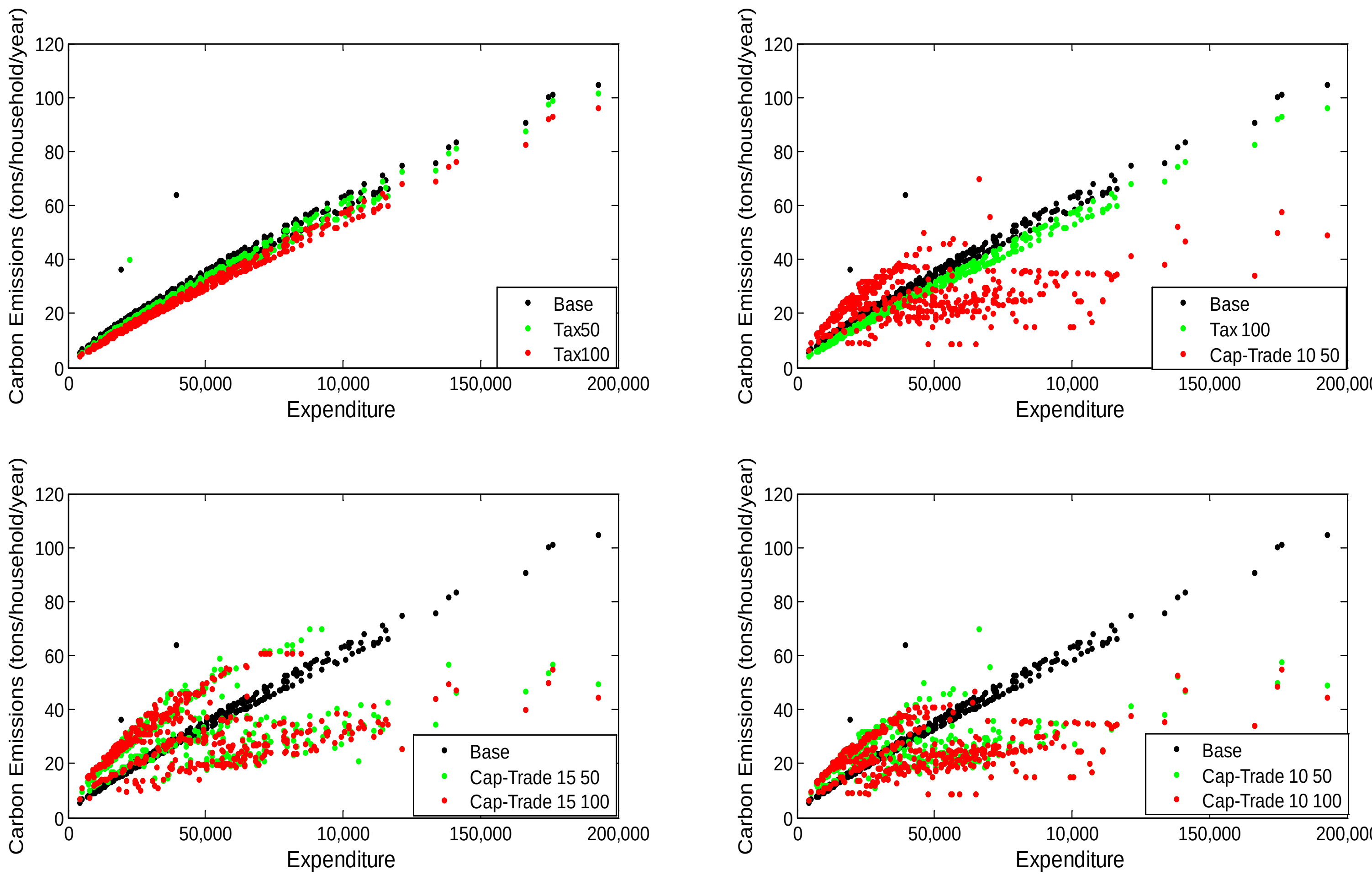
- Low-income HHs respond most to $100 tax, but may significantly increase emissions under caps.
- High-income HHs respond most to 10-ton caps.

	Overall	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
		(<20 k)	($20-30 k)	($30-45 k)	($45-60 k)	($60-100 k)	(>$100 k)
No. of households	444	81	86	98	66	85	28
Avg. Income	$47,619	$13,885	$24,933	$37,325	$51,896	$75,748	$147,569
Base	**31.9**	**13.3**	**19.9**	**27.5**	**35.9**	**47.9**	**79.6**
Tax $50/ton	30.0	11.7	18.6	25.4	34.0	45.8	77.2
Tax $100/ton	27.9	**10.6**	**16.9**	**23.6**	31.7	42.9	72.7
Cap 10 tons ($50)	25.8	18.1	25.1	28.3	24.9	27.7	38.1
Cap 10 tons ($100)	**24.7**	18.5	22.7	27.7	**24.1**	**25.7**	**37.5**
Cap 15 tons ($50)	30.5	19.4	**27.7**	**33.4**	34.4	33.9	42.2
Cap 15 tons ($100)	29.5	**20.1**	27.3	32.0	32.5	31.5	40.8

Note: ($XX) refers to cases where household emissions are capped but can be traded at a fixed rate of $XX per ton. Caps are per household member, so large-household totals are regularly several times the per-person cap.

Emissions Comparisons

(tons/household/year by Scenario)



Welfare Implications

($/year across Household Classes)

		Class1	Class2	Class3	Class4	Class5	Class6
	All HHs	**(<$20k)**	**($20-30k)**	**($30-45k)**	**($45-60k)**	**($60-100k)**	**(>$100 k)**
Equivalent Variation (EV) as a % of income…							
Tax $50/ton	**-2.9%**	-3.2%	-3.7%	-2.6%	-2.4%	-2.1%	-3.7%
Tax $100/ton	**-6.5%**	-7.5	-6.7	-6.5	-6.1	-5.7	-5.5
Cap 10 tons ($50)	**-11.4%**	2.1	-12.7	-16.6	-24.8	-36.0	-44.3
Cap 10 tons ($100)	-20.8%	2.7	-2.1	-14.3	-31.6	-40.7	-49.1
Cap 15 tons ($50)	-18.4%	6.8	-10.8	-17.7	-19.8	-28.2	-36.4
Cap 15 tons ($100)	-14.7%	**8.1**	-8.4	-13.8	-22.0	-30.0	-38.8

- **Under taxes**, the relative impacts & emissions reductions appear rather **uniformly distributed** (across household classes).
- Under a **household-level cap-and-trade** policy, the **majority of negative impacts (& GHG savings**) are predicted to come from the **highest income groups**.
- Recall: **These are worst-case scenarios**, given the substitution opportunities that exist.

Results

- Assuming just 9 consumption classes (without substitution within each), the **$100/ton tax** is predicted to reduce household CO2 emissions by over **12%**.
- The **10-ton cap** (per person per year) yields greater savings: **19% & 23%** when credits can be sold & bought at $50 & $100, respectively. But the welfare impacts are several times as severe, on average.
- **Larger households** are more likely to have **unused carbon credits** (thanks to economies of density in shared energy services [such as heating & lighting]), which may pose a public relations issue for a downstream cap policy.

Conclusions

- This **model is primarily for illustration** of the evaluation methods & some basic sense of policy implications; far **more substitution is needed**.
- It provides an introduction to the issues involved in modeling household responses to policy changes, along with **useful methods for estimating** emission **savings & evaluating** policy **impacts** under different settings.
- **Carbon taxes** appear relatively regressive, as expected.
- **Cap-and-trade** policies offer an opportunity for welfare gain by many low-income households.
- Actual **welfare impacts will be less severe, & GHG savings greater.** (The 9-category model neglects many opportunities that households have to reduce emissions more flexibly.)

Future Work

- **Nested preference functions** to allow for **substitution** within a vehicle expenditure category & **complementarity** across fuel & vehicle purchases.
- Preference functions recognizing **demographics** (e.g., household size & climate).
- Microsimulation of **credit market** (for trading).
- Evaluation of **tax redistribution** schemes.

Thank you!

Paper available at

www.ce.utexas.edu/prof/kockelman