Who Will Pay What? Modeling the Distribution of Costs of Climate Change Policies

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Disclaimer

Analysis and conclusions presented here are my own and should not be interpreted as those of the Congressional Budget Office.

Overview

- Climate Change Modeling
- Linking Demographic, Tax, and Expenditures Data
- IO Model
- Results

Climate Change Modeling

- Cross-divisional work at CBO
  - Microsimulation of distributional effects small part
  - Estimating allowance price trajectory
  - Budgeting effects
  - International trade effects
  - International & Domestic offsets
  - Transportation & Electricity sector

Basic Problem

CO_2

And some other gases, too

Basic Solution

- Put a price on carbon
- Can be achieved directly with a tax, or indirectly with a “cap-and-trade” program
  - Tax = price certain, quantity uncertain
  - Cap = quantity certain, price uncertain

Why Microsimulation?

Distributional Analysis

- Analyze Regressivity/Progressivity of Policies
- Rank by income?
- Rank by expenditures? (permanent income hypothesis)
- Regional analysis

Database Preparations

- Standard CBO database for tax distribution analyses links the Census Bureau's Current Population Survey with the Internal Revenue Service's Statistics of Income data
- Need to match expenditures data to this database
  - 2006 Consumer Expenditures Survey data

Consumer Expenditure Survey

- Collects detailed expenditures information on households over 12 month period
- Designed to calculate basket weights in CPI calculation
- Two separate surveys: Interview & Diary
- Released as quarterly cross-sections, but we convert to annual panel files

Consumer Expenditure Survey

Consumer Expenditure Survey Rotation Scheme

CBO Longitudinal Wave		2005:Q2			2005:Q3			2005:Q4			2006:Q1			2006:Q2			2006:Q3			2006:Q4			2007:Q1		
Panel		Panel A	Panel B	Panel C	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C	Panel A	Panel B	Panel C
Panel Start Date		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
Interview month	Dec-04	no data																							
	Jan-05	INT	no data																						
	Feb-05	x	INT	no data																					
	Mar-05	x	x	INT	no data																				
	Apr-05	INT	x	x	INT	no data																			
	May-05	x	INT	x	x	INT	no data																		
	Jun-05	x	x	INT	x	x	INT	no data																	
	Jul-05	INT	x	x	INT	x	x	INT	no data																
	Aug-05	x	INT	x	x	INT	x	x	INT	no data															
	Sep-05	x	x	INT	x	x	INT	x	x	INT	no data														
	Oct-05	INT	x	x	INT	x	x	INT	x	x	INT	no data													
	Nov-05	x	INT	x	x	INT	x	x	INT	x	x	INT	no data												
	Dec-05	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data											
BLS	Jan-06	INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data										
Cross-sectional	Feb-06		INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data									
2006:Q1 data file	Mar-06			INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data									
BLS	Apr-06				INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data								
Cross-sectional	May-06					INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data						
2006:Q2 data file	Jun-06						INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data						
BLS	Jul-06							INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data					
Cross-sectional	Aug-06								INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data				
2006:Q3 data file	Sep-06									INT	x	x	INT	x	x	INT	x	x	INT	x	x	INT	no data			
BLS	Oct-06										INT	x	x	INT	x	x	INT	x	x	INT	no data					
Cross-sectional	Nov-06											INT	x	x	INT	x	x	INT	x	x	INT	no data				
2006:Q4 data file	Dec-06												INT	x	x	INT	x	x	INT	x	x	INT	no data			
BLS	Jan-07													INT	x	x	INT	x	x	INT	x	x	INT	x	x
Cross-sectional	Feb-07														INT	x	x	INT	x	x	INT	x	x	INT	x
2007:Q1 data file	Mar-07															INT	x	x	INT	x	x	INT	x	x	INT
	Apr-07																INT	x	x	INT	x	x	INT	x	x
	May-07																	INT	x	x	INT	x	x	INT	x
	Jun-07																		INT	x	x	INT	x	x	INT
	Jul-07																			INT	x	x	INT	x	x
	Aug-07																				INT	x	x	INT	x
	Sep-07																					INT	x	x	INT
	Oct-07																						INT	x	x
	Nov-07																							INT	x
	Dec-07																								INT

Consumer Expenditure Survey

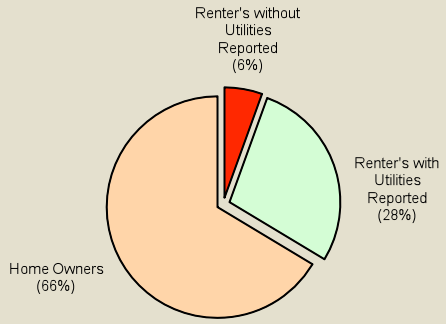
Average Annual Household Utility and Gasoline Expenditures by Income Quintile, 2007

	All Households	Quintiles				
		Lowest	Second	Middle	Fourth	Highest
Dollars						
Electricity	1,303	848	1,104	1,285	1,445	1,831
Natural Gas	480	273	369	428	559	773
Fuel Oil	151	82	123	127	177	243
Total Utilities	1,934	1,203	1,596	1,840	2,181	2,847
Gasoline & Motor Oil	2,384	1,046	1,768	2,418	2,988	3,696
Total Energy-Intensive Expenditures	4,318	2,249	3,364	4,258	5,169	6,543
Percent of Income						
Electricity	2.1	8.1	4.0	2.8	2.0	1.2
Natural Gas	0.8	2.6	1.3	0.9	0.8	0.5
Fuel Oil	0.2	0.8	0.4	0.3	0.2	0.2
Total Utilities	3.1	11.4	5.8	4.0	3.0	1.8
Gasoline & Motor Oil	3.8	9.9	6.4	5.2	4.1	2.3
Total Energy-Intensive Expenditures	6.8	21.4	12.2	9.2	7.1	4.1

Source: Bureau of Labor Statistics, Consumer Expenditure Survey, 2007
Available at http://www.bls.gov/cex/2007/Standard/quintile.pdf

CE Adjustments: Renters

Missing Critical Information for 6% of the Sample



CE Adjustments: Diary Data

Multiplicative Adjustment Factors

Food Away	*	1.617609
Food at Home	*	0.823904
Alcohol Away	*	1.217858
Alcohol at Home	*	1.634421
Clothing and Shoes	*	1.603027
Furniture	*	1.321044

Additive Adjustment Amounts

Toiletries	+	$317.00
Nondurables	+	$594.47
Prescription Drugs	+	$130.88
Business Services	+	$36.79
Tolls	+	$14.60
Other Education	+	$70.55

Imputing Expenditures

Two Methods Used:

- Hot deck imputation
  - Single households <$150,000 income
  - Married households <$300,000 income
- Regression imputation for high income households

Statistical Match SOI/CPS & CE

- Hot deck routine with both rigid and flexible matching criteria
  - Fixed: Region
  - Flexible: Age (+/- 1 year increments)
    Income (+/- 2% increments)
    Family Type (+/- 1 child only)
- Use CPS Income as bridge to SOI income
- Carry over expenditure ratios

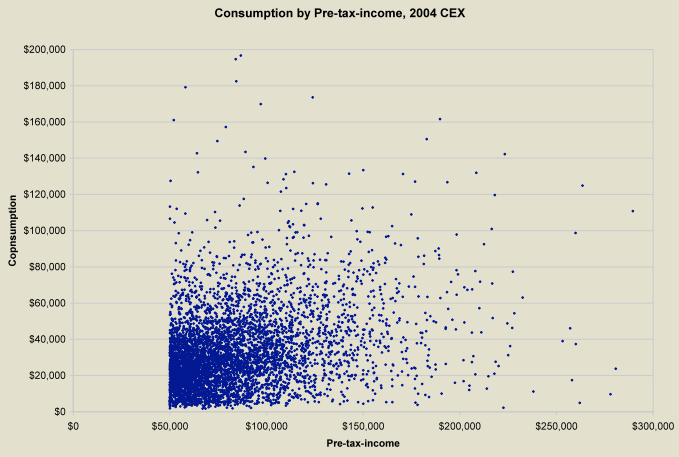
High Income Regressions

- Both income and expenditure amounts are top coded
- Impute expenditure amounts based on regression models for high-income households
- Separate models for electricity, gasoline, fuel oil, natural gas, and total expenditures

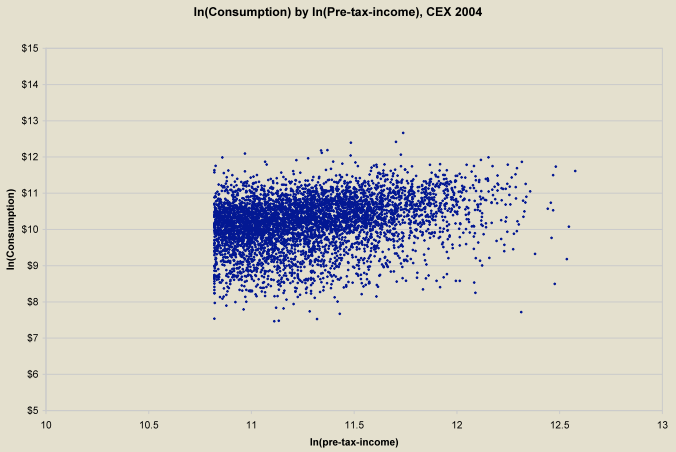
High Income Regressions

- Estimate electricity, gasoline, fuel oil, natural gas expenditures
- Estimate total expenditures
- Distribute non-carbon intensive expenditures based on observed distribution in high income CE households

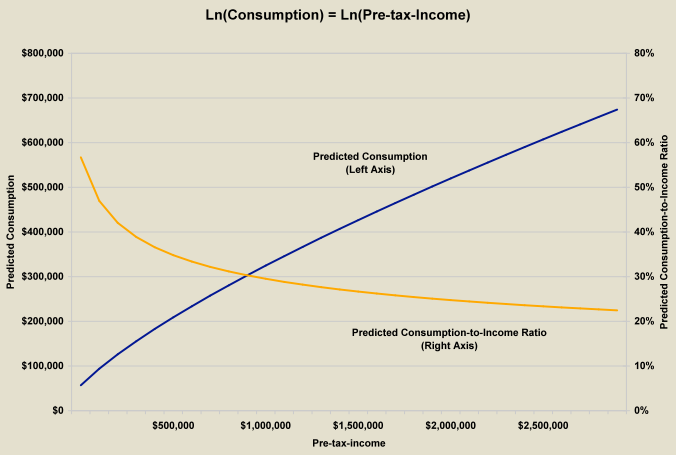
High Income Regressions



High Income Regressions



High Income Regressions



Now What?

IO Model

- Need to simulate the effects a carbon cap-and-trade policy will have on consumer prices
- Leontief (1941)
- Fullerton (1995); Metcalf (1998, etc.)

IO Model: Make & Use Tables

	Commodities 1, 2, …, m	Total Output
Industries 1 2 . . n	Make Table V	g
Total Input	q'	

V: Make matrix, industry-by-commodity (i x c)
q: Total commodity output, column vector (c x 1)
g: Total industry output, row column vector (I x 1)

	Industries 1, 2, …, i	Final Demand 1, 2, …, k	Total Output
Commodities 1 2 . . c	Use Table U	E	q
Value Added 1 2 . . j	W		
Total Commodity Output	g'		

U: Intermediate use matrix, commodity-by-industry (c x i)
q: Total commodity output, column vector (c x 1)
g: Total industry output, row column vector (i x 1)
E: Final Demand (c x k)
W: Value Added (j x i)

IO Model: Basic

$$
\begin{aligned}
a_{11}p_1 &+ a_{21}p_2 + \cdots + a_{n1}p_n + v_1 = p_1,\\
a_{12}p_1 &+ a_{22}p_2 + \cdots + a_{n2}p_n + v_2 = p_2,\\
&\vdots \qquad\quad \vdots \qquad\quad \cdots \qquad\quad \vdots \qquad\quad \vdots \qquad\quad \vdots\\
a_{1n}p_1 &+ a_{2n}p_2 + \cdots + a_{mn}p_n + v_n = p_n
\end{aligned}
$$

IO Model: Basic

$$\begin{array}{ccccccccccc} a_{11}p_1 & + & a_{21}p_2 & + & \cdots & + & a_{n1}p_n & + & v_1 & = & p_1, \\ a_{12}p_1 & + & a_{22}p_2 & + & \cdots & + & a_{n2}p_n & + & v_2 & = & p_2, \\ \vdots & & \vdots & & \cdots & & \vdots & & \vdots & & \vdots \\ a_{1n}p_1 & + & a_{2n}p_2 & + & \cdots & + & a_{mn}p_n & + & v_n & = & p_n \end{array}$$

$$A'P + V = P$$

$$P = (I - A')^{-1}V$$

IO Model: Basic

$$\begin{array}{ccccccccccc} a_{11}p_1 & + & a_{21}p_2 & + & \cdots & + & a_{n1}p_n & + & v_1 & = & p_1, \\ a_{12}p_1 & + & a_{22}p_2 & + & \cdots & + & a_{n2}p_n & + & v_2 & = & p_2, \\ \vdots & & \vdots & & \cdots & & \vdots & & \vdots & & \vdots \\ a_{1n}p_1 & + & a_{2n}p_2 & + & \cdots & + & a_{mn}p_n & + & v_n & = & p_n \end{array}$$

$$A'P + V = P$$

$$P = (I - A')^{-1}V$$

And then we add a Tax Matrix

$$P = (I - A')^{-1}(V + (AT)'1)$$

IO Model
Imports & Non-Combustive Uses

$$
\begin{aligned}
a^d_{11}p^d_1 + a^m_{11}p^m_1 + a^d_{21}p^d_2 + a^m_{21}p^m_2 + \cdots + a^d_{n1}p^d_n + a^m_{n1}p^m_n + v_1 &= p^d_1,\\
a^d_{12}p^d_1 + a^m_{12}p^m_1 + a^d_{22}p^d_2 + a^m_{22}p^m_2 + \cdots + a^d_{n2}p^d_n + a^m_{n2}p^m_n + v_2 &= p^d_2,\\
\vdots \quad \vdots \quad \vdots \quad \vdots \quad \cdots \quad \vdots \quad \vdots \quad \vdots &= \vdots\\
a^d_{1n}p^d_1 + a^m_{1n}p^m_1 + a^d_{2n}p^d_2 + a^m_{2n}p^m_2 + \cdots + a^d_{nn}p^d_n + a^m_{nn}p^m_n + v_n &= p^d_n
\end{aligned}
$$

$$P^d = \left(I - A_d^{'}\right)^{-1}\left(V + \left(A_d T\right)1 + \left\{A_i^{'} P^m\right\}\right)$$

Additional adjustments are made for non-combustive uses of fossil fuels
(but I won't bore you further with the equations)

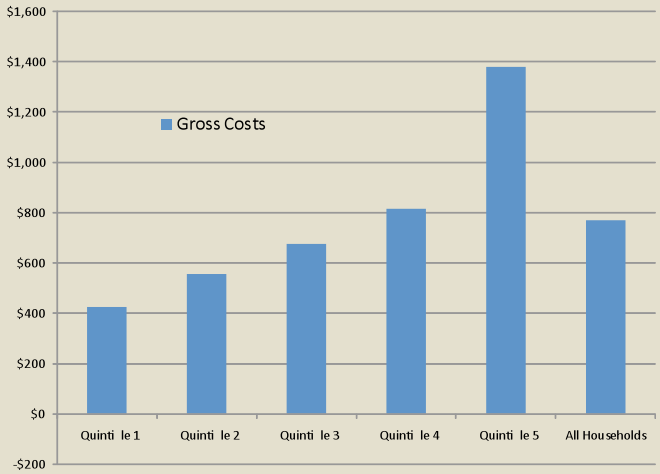
IO Model Results

- Policy Simulation based on 2006 economy
- Allowance price of $19 per metric ton of CO_2 (including imported petroleum products)
- Total allowance revenues of about 0.7% of GDP

IO Model: Price Change Results

Food	0.5%
Clothing	0.2%
Nondurables	0.4%
Electricity	8.8%
Natural Gas	11.4%
Gasoline	4.2%
All Expenditures	0.7%

Waxman-Markey Distribution (2020 policy in 2010 $s)



Based on CBO letter to Senator Camp, June 19, 2009

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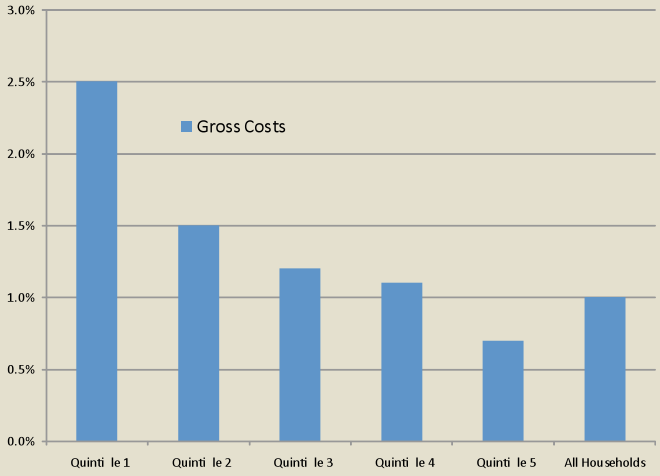

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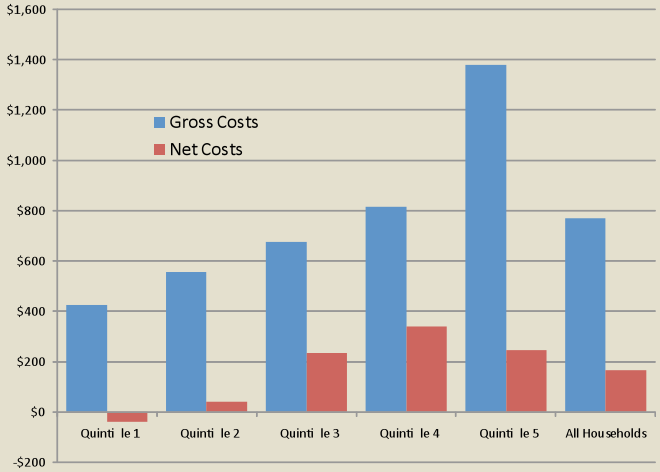

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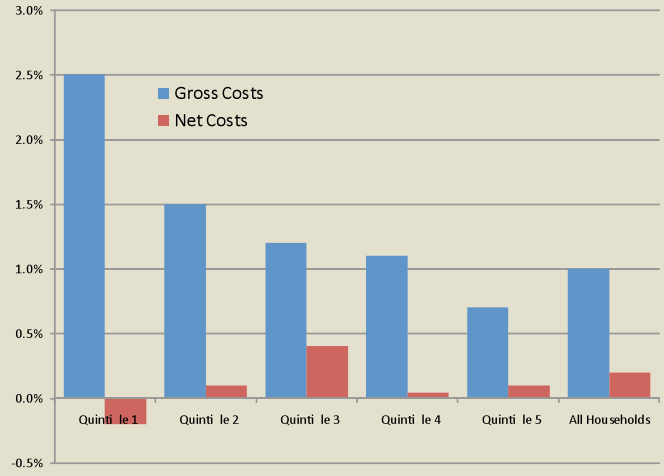

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