Households' Demand for Energy: Update to Year 2006 of the Econometric Estimations Based on the American Consumer Expenditure Survey

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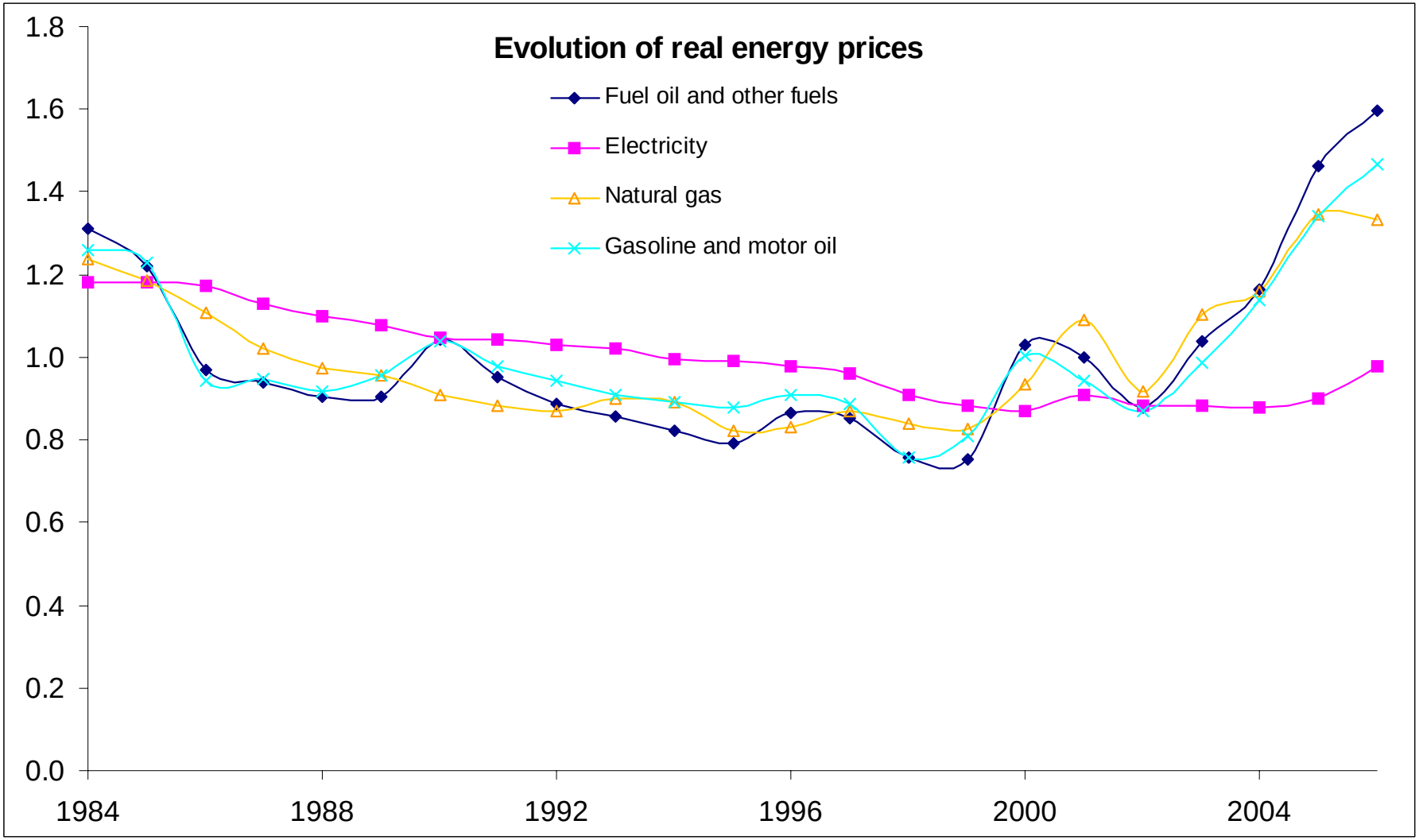
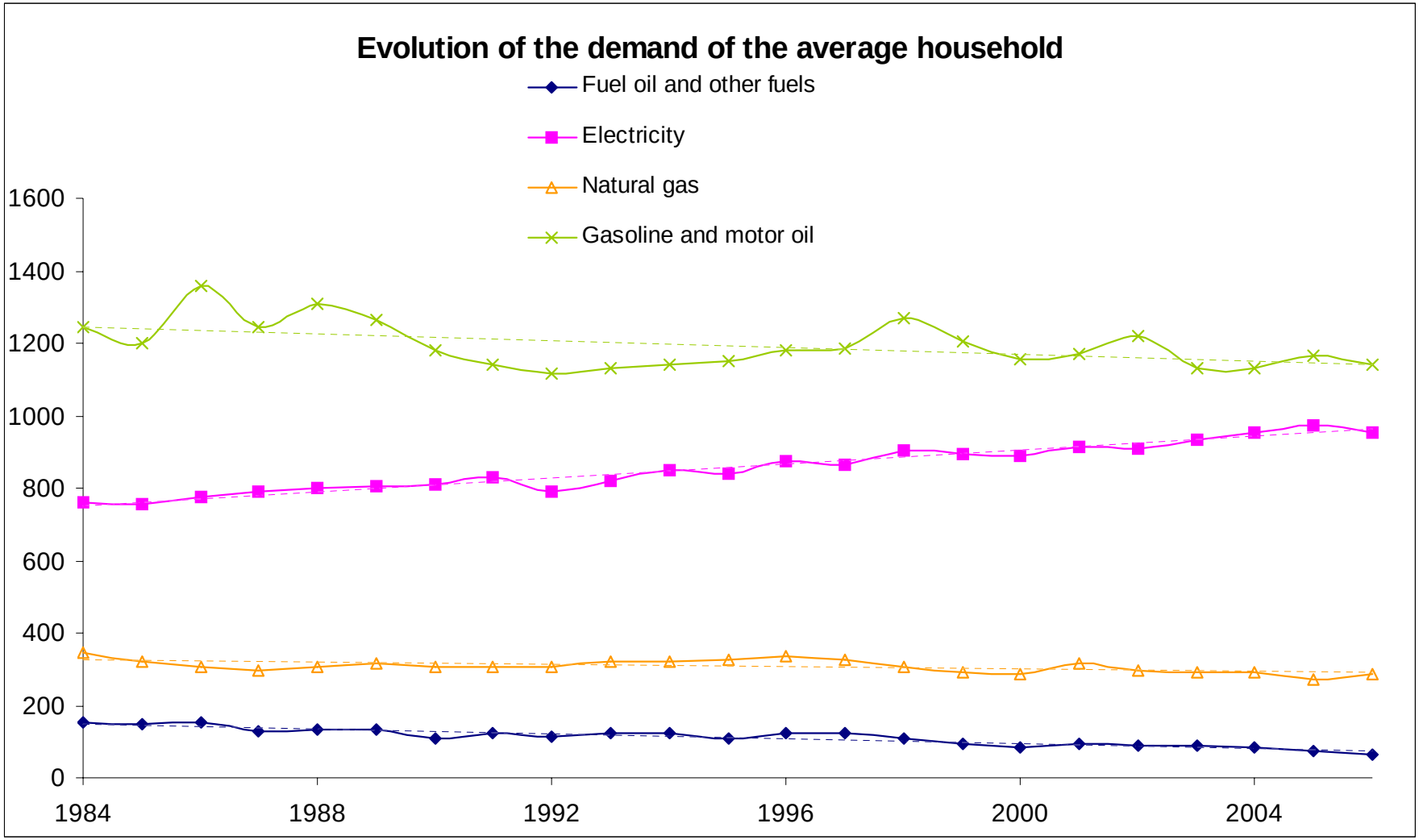
Purpose and tools

- An update to 2006 of previous econometric estimations
- Aim is to determine, as precisely as possible, the households' behavior with respect to energy, according to:
  - their various characteristics
  - the level of income
- Numerous possible applications, for TOCSIN as for any climate change assessment:
  - in determining the effects of a change in prices and in energy efficiency
  - in measuring equity effects (case of an oil shock, a carbon tax)
- Tools:
  - A database on consumer expenditures, built from an American survey
  - A methodology for estimating the demand function, and the main relevant parameters (price and income elasticities)

What brings the recent evolution (2002-2006)




Evolution of the demand of the average household
Fuel oil and other fuels
Electricity
Natural gas
Gasoline and motor oil
1600
1400
1200
1000
800
600
400
200
0
1984
1988
1992
1996
2000
2004

The database

- Combines the two BLS surveys CEX and CPI concerning the American consumer
- Very rich, freely and easily loadable from the BLS website
- Not the exhaustive survey but the extraction by classes of income

Dimensions of the global database

Number of end-use commodities: 53 (8 Major Functions, 25 sub-functions)

Classes of income: 13 brackets, starting from Under 5 000$ of income before taxes to 150 000$ and over (but less for some years and/or some categories of households)

Categories of households:

- *by region*: four regions, Middle West, North East, South, West
- *by size*: five, from 1 to 5 and over
- *by age of the reference person*: six, from Under 25 to 65 and over

- *Period*: from 1984 to 2006

Energy commodities in households' consumption

- Housing (residential energy): 3 commodities
  - Fuel oil and other fuels
  - Electricity
  - Natural gas
- Transportation: 1 commodity
  - Gasoline and motor oil (Motor Fuel)
- Alternately: the complete model of demand for Private Transportation (3 commodities)
  - Vehicle purchase and insurance
  - Gasoline and motor oil
  - Other vehicle charges (maintenance and operation)

Econometric estimation

• General specification: a linearized demand function, at the order (rank) 3 or 4

• Incorporating “technical progress” (increase in efficiency of the commodity or change in preferences over time)

- totally flexible (no constraint on estimated parameters)

$$c_i^t = f_i\left(p_j^t e^{-\gamma_j t}, r^t\right)$$

- or additively separable (a primal property that can be represented in the dual)

$$U = \sum_i f_i\left(c_i e^{\gamma_i t}\right)$$

• A reduced model (energy commodities and current good, for each function)

Econometric results: gasoline alone (All households together, Rank 3)

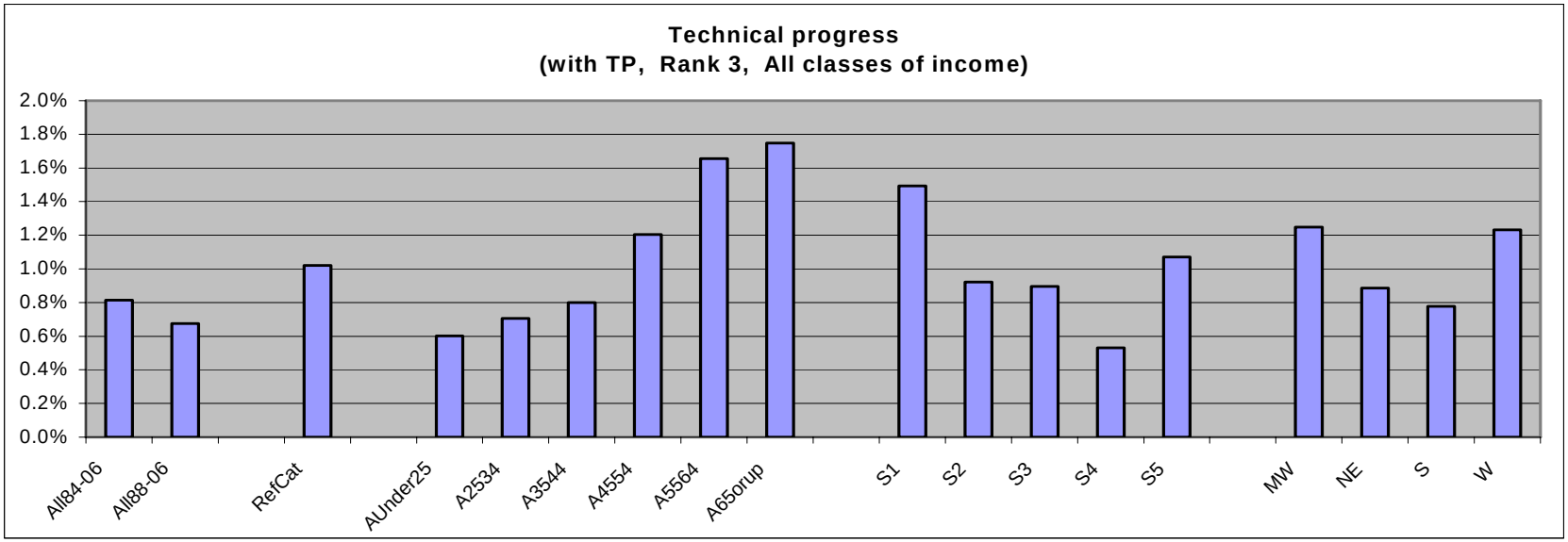
At the centre of the sample (average income)

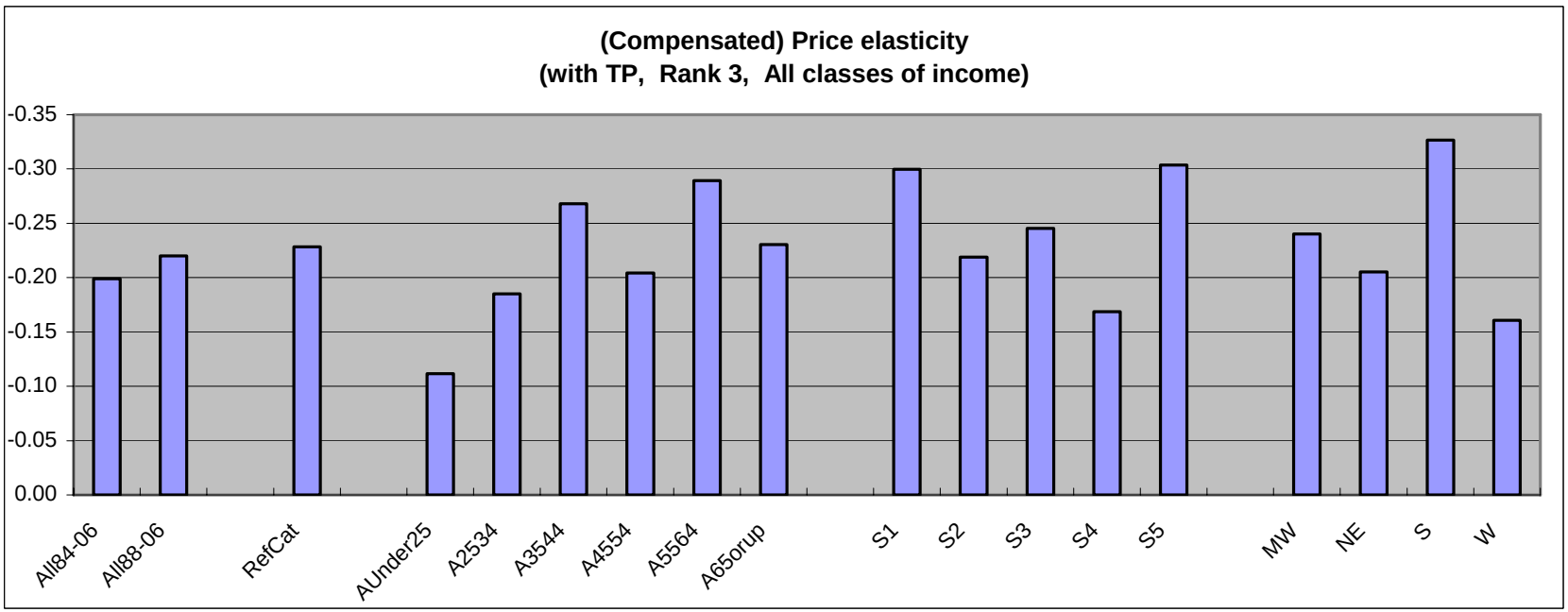
	Coefficient	Student
Income derivative		
v	0,039	(110,5)
v'	-0,038	(37,7)
Price derivative		
s	0,009	(11,0)
s'	0,015	(9,0)
Technical progress	0,81%	(13,8)

Demand of gasoline by level of income

Relative Income	0.6	0.8	1	1.2	1.4
Demand	0.0256	0.0358	0.0445	0.0517	0.0573
Share of gasoline in income	0.0427	0.0448	0.0445	0.0430	0.0410
Engel coefficient	0.0546 (71.4)	0.0471 (83.3)	0.0396 (108.1)	0.0321 (59.4)	0.0246 (33.3)
Price elasticity	-0.111 (1.9)	-0.164 (5.0)	-0.199 (10.5)	-0.230 (10.5)	-0.259 (10.1)

Gasoline by category of households





Private transportation
(Rank 3)

Technical Progress

Vehicle purchase & insurance	-0.73%	(1.7)
Gasoline and motor oil	0.73%	(2.2)
Other vehicle charges	-0.15%	(1.2)
Current good	0.09%	(0.9)

Matrix of price-elasticities

	Price of:			
Commodity:	Vehicle purchase & insurance	Gasoline and motor oil	Other vehicle charges	Current good
Vehicle purchase & insurance	-1.009	-0.185	0.392	0.802
	(4.3)	(5.0)	(6.8)	(3.0)
Gasoline and motor oil	-0.541	-0.248	0.053	0.736
	(5.0)	(10.1)	(1.4)	(5.6)
Other vehicle charges	1.501	0.069	-4.718	3.148
	(6.8)	(1.4)	(9.6)	(5.4)
Current good	0.131	0.041	0.134	-0.307
	(3.0)	(5.6)	(5.4)	(5.4)

Residential energy
(Rank 3)

Technical Progress

Fuel oil and other fuels	3.25%	(4.0)
Electricity	1.22%	(2.7)
Natural gas	-1.54%	(9.0)
Current good	-0.03%	(1.8)

Matrix of price-elasticities

Price of: / *Commodity:*	Fuel oil and other fuels	Electricity	Natural gas	Current good
Fuel oil and other fuels	-0.409	0.414	0.106	-0.111
	(3.8)	(2.0)	(0.9)	(0.6)
Electricity	0.045	-0.605	0.164	0.396
	(2.0)	(7.6)	(5.3)	(5.5)
Natural gas	0.036	0.518	-0.287	-0.267
	(0.9)	(5.3)	(4.3)	(2.9)
Current good	0.000	0.013	-0.003	-0.010
	(0.6)	(5.5)	(2.9)	(3.5)

Aggregate price elasticity
(case of proportional variations of energy prices)

-0.210 (16.6)

Equity effects of the recent oil shock

Change in the prices of commodities, 2002 to 2006

Private transportation	
Vehicle purchase & insurance	-9%
Gasoline and motor oil	69%
Other vehicle charges	3%
Residential energy	
Fuel oil and other fuels	81%
Electricity	11%
Natural gas	46%

Measure of the welfare cost
(Harberger's triangle)

$$S = dr - \Sigma_i c_i \, dp_i - 0.5 \, \Sigma_i \Sigma_j \, s_{ij} \, dp_i \, dp_j$$

with :

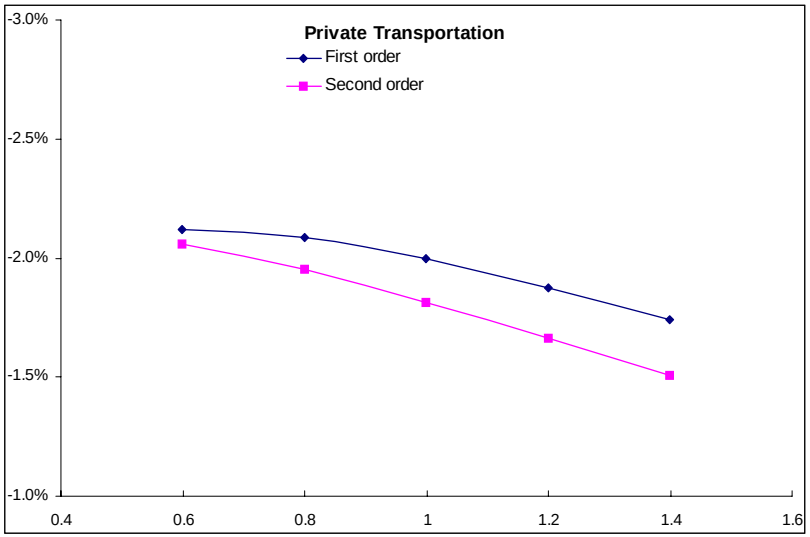
s_{ij} price derivative (compensated)

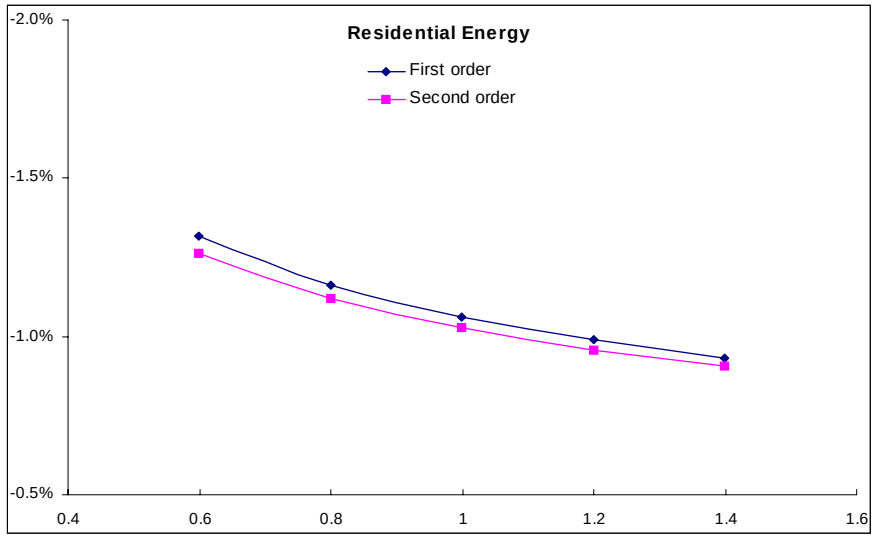
First order term: change in net budget at constant demand

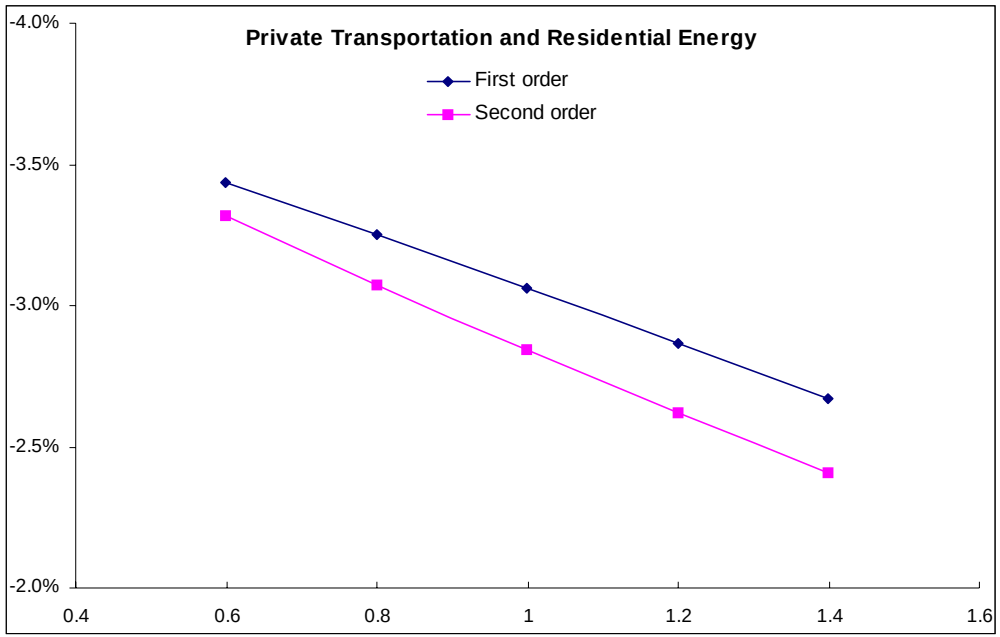
Second order term: effect of reoptimization of demand (always positive)

Equity effects by sub-function and total

(2006 compared to 2002)







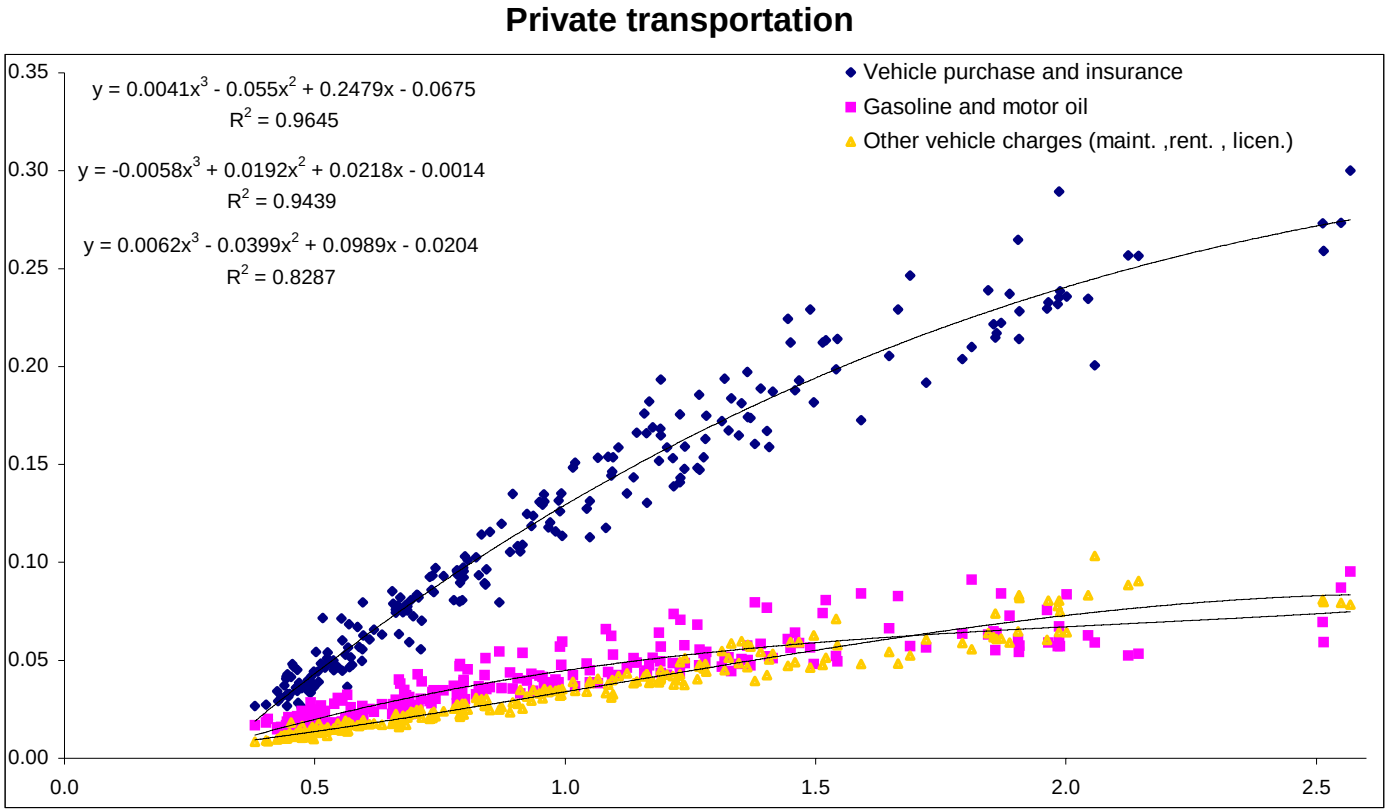
Summary of results and conclusion

- Possibility of a very precise estimation of households' demand for energy, by category and by class of income
- Importance of representing technical change (in particular concerning gasoline)
- On the whole, very low price elasticities:
  - in the bracket –0.15 to –0.3 in the case of gasoline
  - in the bracket –0.2 to –0.3 in the case of aggregate residential energy
- However direct price elasticities of residential energy items are higher (mainly electricity) showing important substitutability with other items (natural gas)
- An increase in energy prices –either resulting from a market adjustment or from taxation- penalizes more the low-income than the affluent households

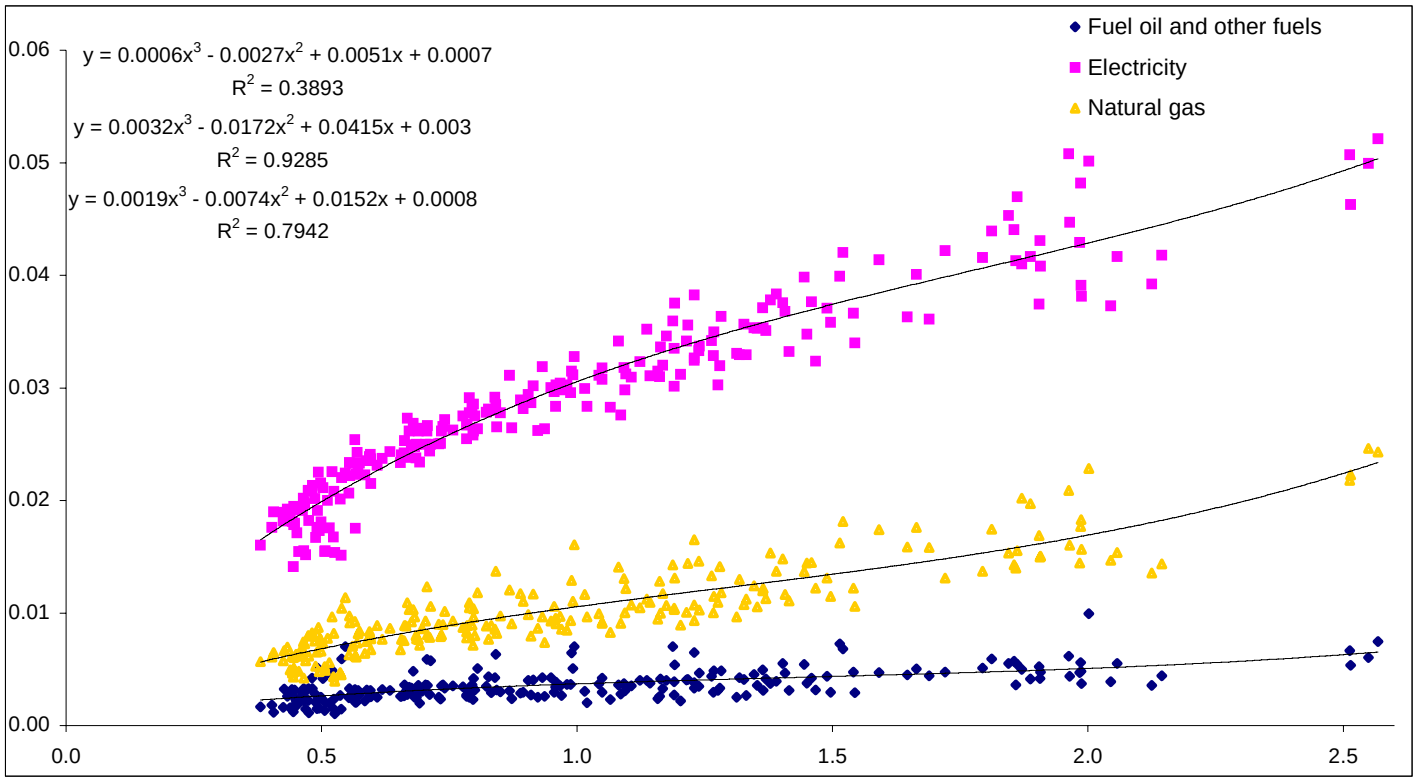
Thank you

Appendix

… and transversal



Residential energy



Estimates of the demand for private transportation by level of income (rank 3)

Relative Income	0.6	0.8	1	1.2	1.4
Demand					
Vehicle purchase and insurance	0.061	0.097	0.129	0.158	0.184
Gasoline and motor oil	0.026	0.036	0.044	0.052	0.057
Other vehicle charges	0.017	0.026	0.034	0.042	0.050
Current good	0.496	0.642	0.793	0.948	1.108
Engel coeff.					
Vehicle purchase and insurance	0.186	0.170	0.154	0.138	0.122
	(43.1)	(52.9)	(72.9)	(44.9)	(29.2)
Gasoline and motor oil	0.054	0.047	0.039	0.032	0.025
	(72.7)	(84.6)	(108.8)	(61.0)	(34.7)
Other vehicle charges	0.042	0.041	0.041	0.040	0.040
	(45.6)	(60.9)	(92.5)	(62.7)	(45.6)
Current good	0.719	0.742	0.766	0.790	0.813
	(164.6)	(228.4)	(358.9)	(254.4)	(192.7)
Price elasticity					
Vehicle purchase and insurance	-0.413	-0.797	-0.999	-1.142	-1.263
	(0.4)	(1.7)	(4.1)	(4.2)	(4.2)
Gasoline and motor oil	-0.196	-0.223	-0.246	-0.270	-0.294
	(2.5)	(5.1)	(9.7)	(9.2)	(8.6)
Other vehicle charges	-5.096	-4.843	-4.724	-4.658	-4.620
	(3.2)	(5.6)	(9.3)	(9.1)	(8.7)
Current good	-0.279	-0.297	-0.306	-0.311	-0.313
	(1.6)	(2.9)	(5.2)	(4.7)	(4.3)

Estimates of the demand for residential energy by level of income (rank 3, with TP)

Relative Income	0.6	0.8	1	1.2	1.4
Demand					
Fuel oil and other fuels	0.003	0.003	0.003	0.004	0.004
Electricity	0.023	0.027	0.031	0.035	0.038
Natural gas	0.007	0.009	0.010	0.011	0.012
Current good	0.567	0.761	0.956	1.151	1.346
Engel coeff.					
Fuel oil and other fuels	0.002	0.002	0.002	0.002	0.002
	(10.4)	(13.4)	(19.5)	(12.3)	(8.4)
Electricity	0.022	0.020	0.018	0.016	0.014
	(29.5)	(36.4)	(50.9)	(30.3)	(19.6)
Natural gas	0.007	0.007	0.007	0.006	0.006
	(20.9)	(27.5)	(41.4)	(27.0)	(19.4)
Current good	0.969	0.972	0.974	0.976	0.978
	(904.1)	(1226.3)	(1900.6)	(1268.1)	(931.9)
Price elasticity					
Fuel oil and other fuels	-0.296	-0.357	-0.407	-0.449	-0.486
	(1.1)	(2.0)	(3.7)	(3.3)	(3.0)
Electricity	-0.663	-0.626	-0.606	-0.596	-0.594
	(4.2)	(5.6)	(7.5)	(6.8)	(6.2)
Natural gas	-0.271	-0.280	-0.287	-0.293	-0.298
	(2.0)	(2.9)	(4.2)	(4.1)	(3.9)
Current good	-0.013	-0.011	-0.010	-0.009	-0.009
	(1.5)	(2.2)	(3.4)	(2.9)	(2.5)

Rank 3 demand functions, definition by W. Gorman (« Some Engel Curves »)

Problem: specification of demand functions having Engel curves of the general form:

$$x_i = \sum_{r \in R} b^{r_i}(p)\psi^r(m)$$

Theorem: if the Engel curves represent well-behaved preferences:

(i) The rank of the coefficient matrix $B(p) = \left[b^{r_i}(p)\right]$ is at most 3

(ii) When the rank is 3, either

(a) each $\psi^r(m) = m(\ln m)^r$ and each $r \in R$ is an integer, or

(b) each $\psi^r(m) = m^{r+1}$, or

(c) each $\psi^r(m) = m\sin(r \ln m)$ or $m\cos(r \ln m)$ for each $r \geq 0$,

with $0 \in R$ in each case.

(iii) When the rank is 3 the cost function underlying the demand function may be written

$$m = \phi(\alpha(p), \beta(p), \gamma(p), u)$$

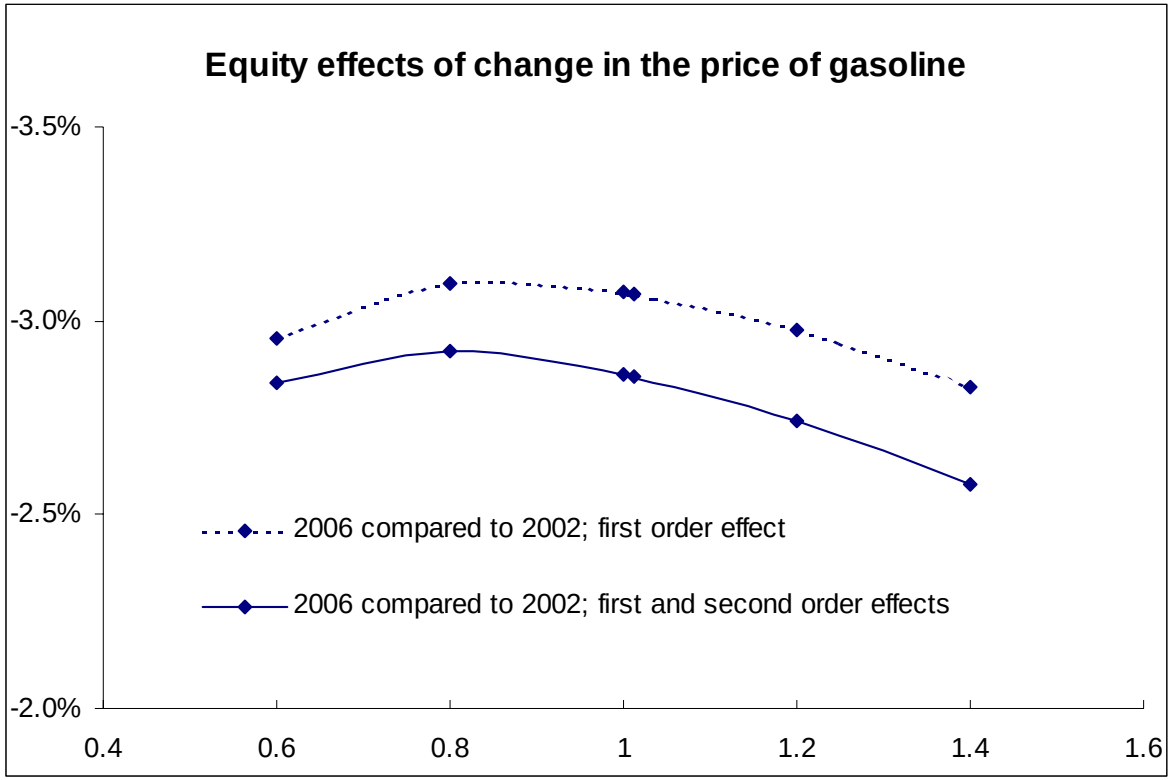
where α, β and γ are unit cost functions, which may be thought of as corresponding to baskets of commodities.

The Quadratic Expenditure System of Howe, Pollack and Wales corresponds to the case (b), with the three values of r: -1, 0 and 1.

The rank 3 demand function can be considered as a flexible functional form of order 3.

Comparative econometric results: gasoline alone (All households together)

	Without Technical Progress		With Technical Progress			
	Rank 3	Rank 4	Rank 3	Rank 4	Rank 3	Rank 4
	All classes of income		All classes of income		All classes except lowest	
v	0.039	0.039	0.039	0.038	0.037	0.036
	(89.6)	(70.1)	(110.5)	(84.7)	(104.9)	(73.5)
v'	-0.038	-0.039	-0.038	-0.040	-0.038	-0.041
	(31.1)	(16.2)	(37.7)	(21.0)	(36.6)	(23.4)
v''		0.004		0.011		0.014
		(0.6)		(2.1)		(2.5)
a	-0.008	-0.004	-0.009	-0.005	-0.009	0.006
	(8.4)	(3.4)	(11.0)	(5.1)	(10.9)	(5.2)
a'	-0.011	-0.005	-0.015	-0.008	-0.014	0.007
	(5.7)	(2.1)	(9.0)	(4.0)	(7.9)	(3.7)
a''		0.007		0.012		0.013
		(1.0)		(2.1)		(2.2)
TP			0.81%	0.69%	0.75%	0.63%
			(13.8)	(13.8)	(12.9)	(12.6)
x(1)	0.0435	0.0436	0.0445	0.0448	0.0445	0.0449
v(1)	0.0396	0.0391	0.0396	0.0388	0.0399	0.0390
	(88.0)	(67.8)	(108.1)	(81.4)	(93.2)	(62.5)
e(1)	-0.188	-0.100	-0.199	-0.119	-0.187	-0.115
	(8.2)	(3.3)	(10.5)	(4.9)	(8.5)	(4.1)


Equity effects of change in the price of gasoline
-3.5%
-3.0%
-2.5%
-2.0%
0.4
0.6
0.8
1
1.2
1.4
1.6
2006 compared to 2002; first order effect
2006 compared to 2002; first and second order effects

Change in energy demand according to price and efficiency in consumption (technical progress):

$$dc/c = \varepsilon\, dp/p - (1 + \varepsilon)\, df/f$$

with

dp/p : change in price

df/f : increase in efficiency

ε: price elasticity

- *df/f is the ex-ante effect of efficiency improvement (constant service)*
- *ε df/f is the rebound effect*