Modelling Demand for New Cars using Aggregate & Disaggregate Data

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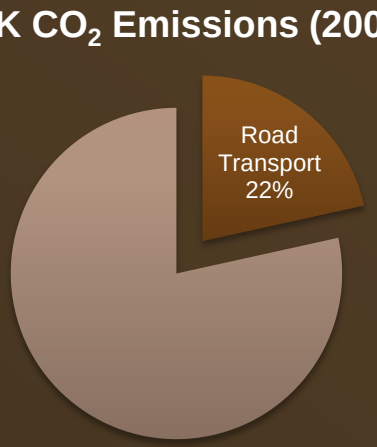
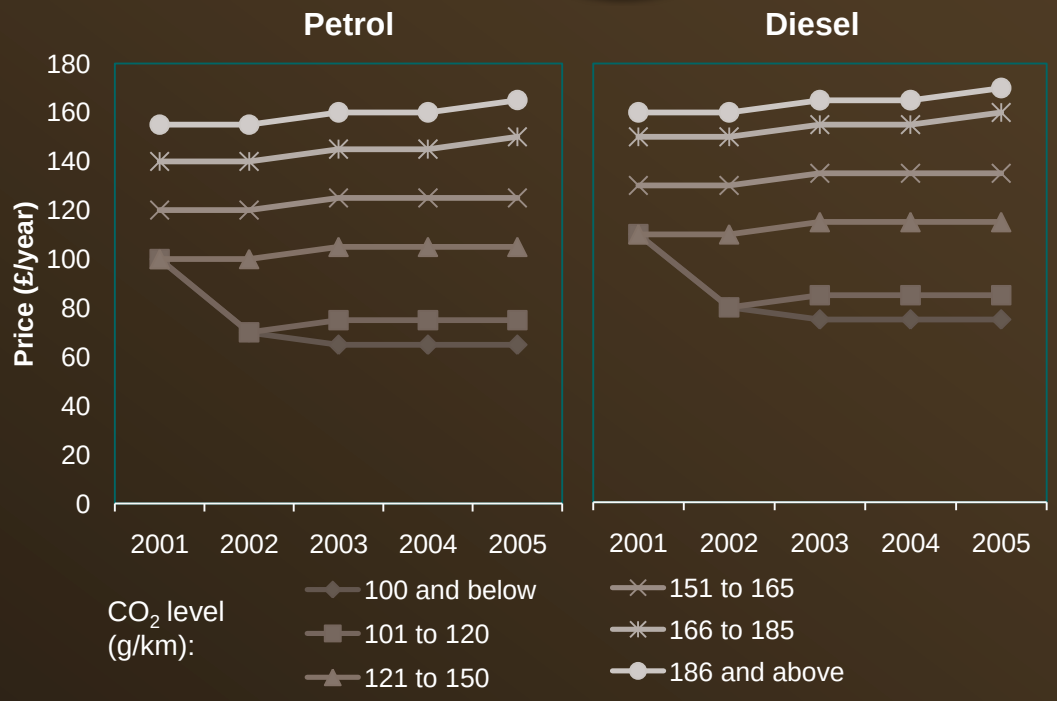
11th November, 2008

Motivation

- Road Transport & CO_2 emissions
- 2001 Vehicle Excise Duty reform
- Tool to forecast impact of changes in tax

Department for Transport





Presentation Outline

1. Model of choice in new car market
2. Empirical models using aggregate data
3. Relaxing limitations of aggregate data analysis using disaggregate data

Model of Demand for New Cars

$$U_{ji} = \text{Benefits}_{ji} - \text{Costs}_{ji}$$
$$= B(x_j, \xi_j; \beta) - C(P_j, VC_j, FC_j; \alpha)$$

Model of Demand for New Cars

... etc.

Decision Rule:

Choose option giving max U_{ji}

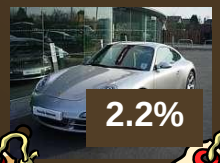
$$U_{ji} = B(x_j, \xi_j; \beta) - C(P_j, VC_j, FC_j; \alpha)$$

Model of Demand for New Cars

Disaggregate Data

$$U_{ji} = B(x_j, \xi_j; \beta_i) - C(P_j, VC_j, FC_j; \alpha_i)$$

Model of Demand for New Cars

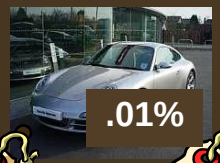


... etc.

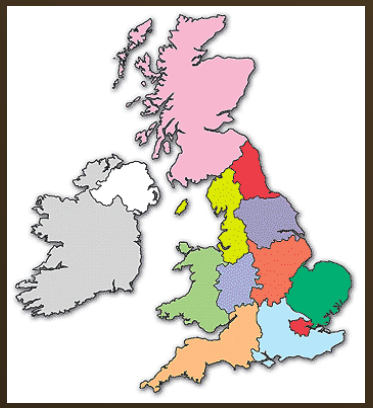
Aggregate Data

$$U_{ji} = B(x_j, \xi_j; \beta_i) - C(P_j, VC_j, FC_j; \alpha_i)$$

Model of Demand for New Cars



... etc.

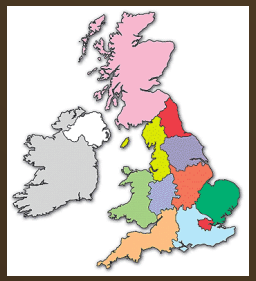


$$U_{ji} = B(x_j, \xi_j; \beta_i) - C(P_j, VC_j, FC_j; \alpha_i)$$

The Aggregate Data

- Aggregate Sales Data

New Car Registrations:



- 11 GORs of GB
- 2001 to 2005
- 55 markets
- > 6 million sales

The Aggregate Data

- Aggregate Sales Data
- Car Attribute Data

Model year	2004
Make	FORD
Model	FOCUS
Version	1.6 GHIA
Trim level	GHIA
Body type	hatchback
Num doors	5
Fuel type	unleaded
Engine Size	1.6

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Power hp/PS	100
0-100km/h	11.4
Driven wheels	front
Transmission type	manual
Num speeds	5
ABS	standard
Fuel tank	standard
Capacity	55
Kerb weight	1,197
Length	4,174
Width	1,702
Height	1,430

Emission control level	standard
standard met	EU4
CO2g/km combined	163
Fuel consumption	standard
standard	ECE 99/100
combined (mpg)	41.5
combined (l/100km)	6.8

Air conditioning	standard
Electric windows	front:rear
Wheel rim type	alloy
Front airbag	driver:passenger
Side airbag	front
Roof airbag	not available

Price	£13,862.00
Insurance	standard
Description	6E

The Aggregate Data

- Aggregate Sales Data
- Car Attribute Data

- 12 mth resale price at time of purchase

The Aggregate Data

- Aggregate Sales Data
- Car Attribute Data
- Choice Occasions

- Each household once per year
- Evidence from Expenditure & Food Survey

Number of Cars	2001	2002	2003	2004	2005	2006
0	94.76%	94.32%	94.59%	94.98%	95.28%	95.80%
1	4.95%	5.40%	4.96%	4.74%	4.49%	3.97%
2	0.25%	0.27%	0.44%	0.28%	0.22%	0.23%
3	0.04%	0.01%	0.01%	0.00%	0.01%	0.00%

The Aggregate Data

- Aggregate Sales Data
- Car Attribute Data
- Choice Occasions
- Choice Options

2,190 unique options

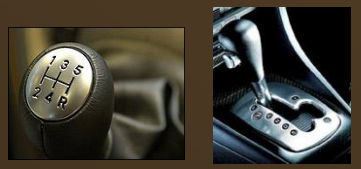
70,000 Market Shares

Make …

Model …

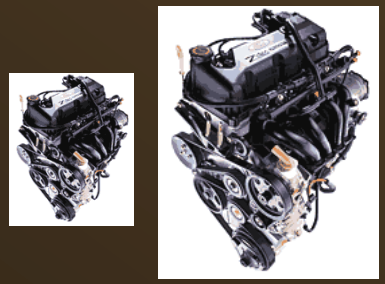
Body Type …

Transmission …

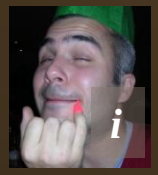


Fuel Type …

Engine Size…

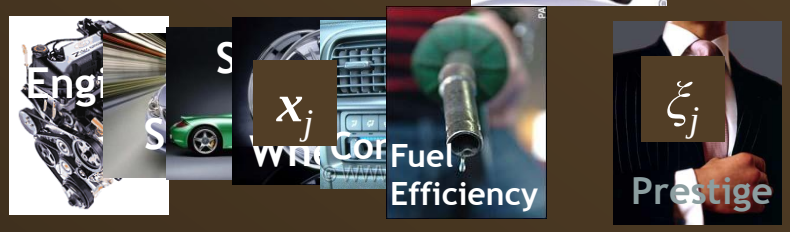


General Empirical Model

Household: 

Car: 

Money: 

Attributes: 

$$U_{ij} = \alpha_i (y_i - p_j + \alpha^r r_j - \alpha^t tax_j - \alpha^i ins_{ij}) + \mathbf{x}_j \boldsymbol{\beta}_i + \xi_j + \varepsilon_{ij}$$

$$\alpha_i = \alpha + \pi_\alpha \mathbf{d}_i + \sigma_\alpha \mu^\alpha{}_i$$

$$\beta_i = \beta + \pi_\beta \mathbf{d}_i + \sigma_\beta \mu^\beta{}_i$$

No Car: 

$$U_{i0} = \eta_i + \varepsilon_{i0}$$

$$\eta_i = \eta + \pi_\eta \mathbf{d}_i + \sigma_\eta \mu^\eta{}_i$$

General Estimation Method

$$U_{ij} = -\eta_i + \alpha_i (y_i - p_j + \alpha^r r_j - \alpha^t tax_j - \alpha^i ins_{ij}) + \boldsymbol{x}_j \beta_i + \xi_j + \varepsilon_{ij}$$

$$v_{ij}(D_i, X_j, \theta) \qquad \sim iid\ EV$$

Prob *i* chooses *j*:

$$p_{ij}(\theta) = \frac{exp(v_{ij}(D_i, X_j, \theta))}{1 + \sum_k exp(v_{ik}(D_i, X_j, \theta))}$$

Predicted share *j*:

$$\hat{s}_j(\theta) = \frac{1}{N} \sum_{i=1}^{N} p_{ij}(\theta)$$

Choose θ so that ... $\hat{s}_j(\theta) = s_j$

... endogeneity of prices

... modelable fixed effects

Simple Aggregate Models

Logit Model :

Assume Identical Tastes: $\alpha_i = \alpha \quad \beta_i = \beta \quad \eta_i = \eta$

$$U_{ij} = -\eta_i - \alpha(p_j - \alpha^r r_j + \alpha^t tax_j + \alpha^i \overline{ins_j}) + \boldsymbol{x}_j \beta + \xi_j + \varepsilon_{ij}$$

- All heterogeneity into ε_{ij}
- Modelled Utility solely a function of car attributes
- Unrealistic substitution possibilities

Nested Logit Model :

Assume pattern of correlation in ε_{ij}

- Richer substitution possibilities allowed

Nested Logit Model: Selected Results

- Costs (α)

Purchase Price	-1.016	0.000
Resale Price	0.705	0.000
Tax	-1.917	0.003

… No Resale Price

-0.525	0.000
-	
-0.367	0.568

- Vehicle Attributes (β)

Automatic	0.081	0.000
Num Gears	0.037	0.000
Fuel Cost per 100km	-0.385	0.000
Size (L x W)	0.001	0.000
BHP	0.002	0.000
Acceleration	-0.010	0.000

Airbags	0.020	0.000
Air Con	0.009	0.203
Alloy Wheels	0.024	0.000
ABS	-0.416	0.000
Doors	0.050	0.000

Nested Logit Model: Policy Modelling

- 1% increase in Purchase Price (Sales Tax)

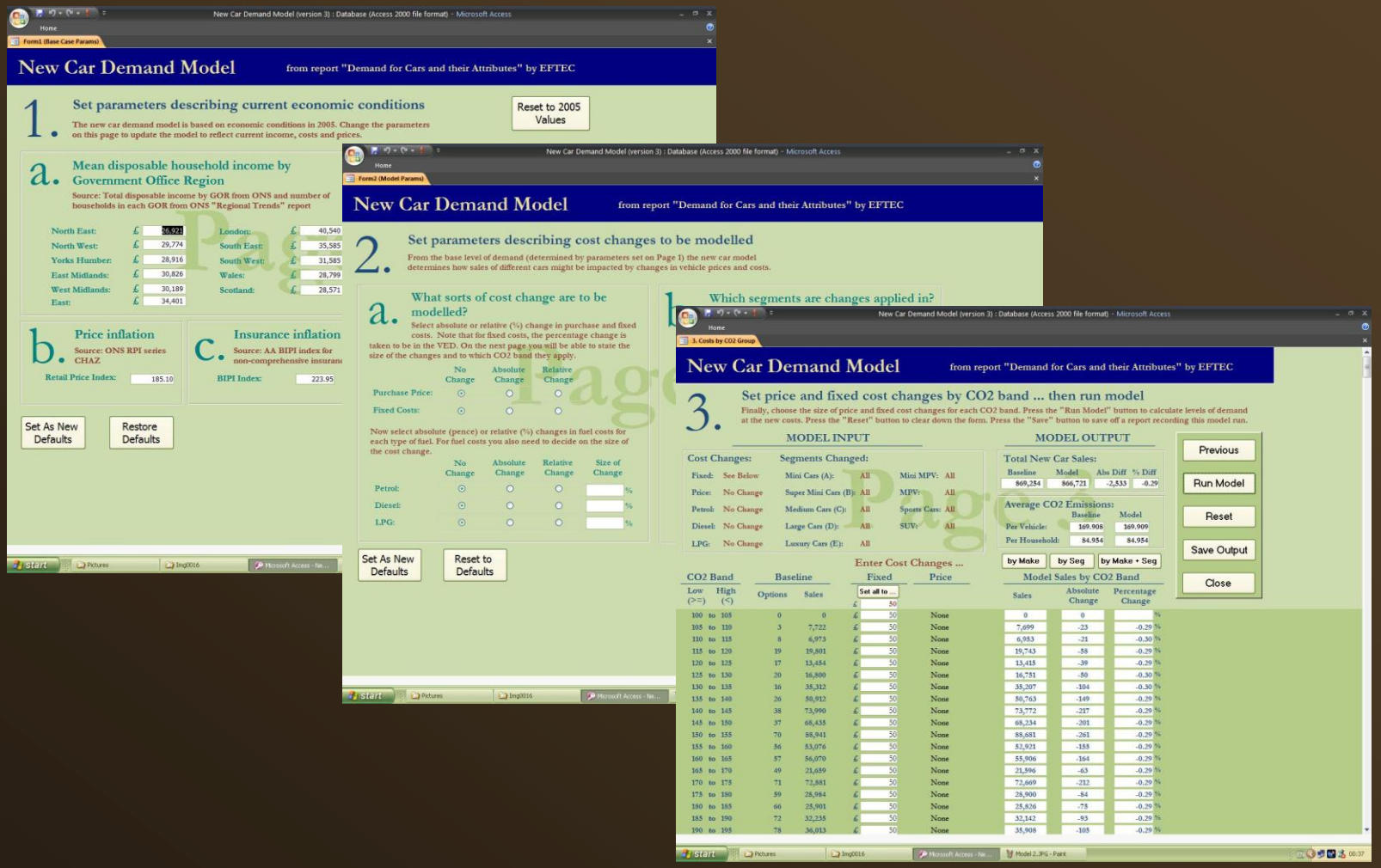
CO_2g/km	2005 Sales	Change in Sales for Vehicles in Row Category from 1% Change in Price for Vehicles in Column Category															
		100 to 110	111 to 120	121 to 130	131 to 140	141 to 150	151 to 160	161 to 170	171 to 180	181 to 190	191 to 200	200 to 225	226 to 250	251 to 275	275 to 300	300 to 400	400 to 500
Outside Good	23,142,289	11	71	101	281	501	651	351	541	351	351	651	361	351	191	151	61
100 to 110	5,719	-205	32	30	20	104	8	1	6	8	0	0	0	0	0	0	0
111 to 120	25,857	33	-983	72	123	315	160	50	91	52	13	9	3	0	0	1	0
121 to 130	32,011	28	69	-1,263	143	316	207	107	148	78	35	22	9	1	0	2	0
131 to 140	87,324	19	134	151	-3,006	780	689	279	431	213	90	57	21	2	2	5	0
141 to 150	161,520	94	315	324	766	-4,641	1,166	374	696	363	142	116	39	5	5	7	1
151 to 160	164,892	8	165	208	654	1,102	-5,304	605	841	454	250	293	113	11	12	16	3
161 to 170	87,145	0	50	111	300	383	637	-3,021	587	323	204	176	82	8	7	18	2
171 to 180	124,628	5	82	140	395	607	806	580	-4,275	370	275	253	100	17	11	19	3
181 to 190	75,216	5	40	64	174	288	409	279	345	-2,572	140	177	75	23	16	15	6
191 to 200	61,911	0	11	32	83	122	228	182	267	134	-1,770	173	74	37	20	21	11
200 to 225	94,011	0	6	19	48	89	244	144	219	145	160	-2,192	149	85	46	45	35
226 to 250	43,366	0	2	7	16	27	82	56	75	53	61	135	-1,106	45	25	23	18
251 to 275	33,849	0	0	1	1	2	6	4	11	13	25	62	38	-619	22	20	10
275 to 300	15,094	0	0	0	1	2	6	3	6	7	12	30	18	19	-366	9	6
300 to 400	10,285	0	1	1	3	4	8	9	10	7	10	23	13	14	6	-351	3
400 to 500	1,904	0	0	0	0	0	0	0	0	1	3	11	5	3	2	2	-157
Market avg CO_2	173.643	173.65	173.68	173.68	173.71	173.69	173.68	173.65	173.60	173.59	173.61	173.58	173.58	173.60	173.61	173.59	173.61
Pop. avg CO_2	7.363	7.363	7.364	7.364	7.364	7.361	7.360	7.361	7.357	7.358	7.359	7.355	7.358	7.358	7.360	7.360	7.361

Nested Logit Model: Policy Modelling

- £10 increase in VED (Road Tax)

CO_2g/km	2005 Sales	Change in Sales for Vehicles in Row Category from £10 Change in VED for Vehicles in Column Category															
		100 to 110	111 to 120	121 to 130	131 to 140	141 to 150	151 to 160	161 to 170	171 to 180	181 to 190	191 to 200	200 to 225	226 to 250	251 to 275	275 to 300	300 to 400	400 to 500
Outside Good	23,142,289	1	11	21	51	91	101	51	71	41	31	51	21	19	11	11	1
100 to 110	5,719	-57	9	8	6	26	2	0	1	2	0	0	0	0	0	0	0
111 to 120	25,857	9	-204	17	27	71	31	8	15	8	2	1	0	0	0	0	0
121 to 130	32,011	8	16	-238	29	69	36	16	23	11	4	2	0	0	0	0	0
131 to 140	87,324	5	27	29	-559	160	124	45	67	30	12	7	2	0	0	0	0
141 to 150	161,520	27	72	69	160	-887	213	60	108	52	18	12	4	1	1	1	0
151 to 160	164,892	2	31	37	124	212	-846	92	122	59	29	28	9	1	1	1	0
161 to 170	87,145	0	8	17	45	60	92	-455	86	41	26	19	8	1	0	1	0
171 to 180	124,628	1	15	23	67	108	122	86	-616	47	34	25	8	1	0	1	0
181 to 190	75,216	1	7	11	29	51	59	41	47	-335	16	16	5	1	0	0	0
191 to 200	61,911	0	2	5	12	18	30	26	35	16	-204	15	6	2	1	1	0
200 to 225	94,011	0	1	3	7	12	28	19	26	16	15	-200	11	5	2	2	1
226 to 250	43,366	0	1	1	2	4	10	8	9	6	6	11	-83	3	1	1	1
251 to 275	33,849	0	0	0	0	0	1	1	1	1	2	5	3	-35	1	1	0
275 to 300	15,094	0	0	0	0	0	1	1	1	1	1	2	1	1	-17	0	0
300 to 400	10,285	0	0	0	1	1	1	2	2	1	1	2	1	1	1	-15	0
400 to 500	1,904	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-3
Market avg CO_2	173.643	173.64	173.65	173.65	173.65	173.65	173.65	173.64	173.64	173.64	173.64	173.64	173.64	173.64	173.64	173.64	173.64
Pop. avg CO_2	7.363	7.363	7.363	7.363	7.363	7.362	7.362	7.362	7.362	7.362	7.362	7.362	7.362	7.363	7.363	7.363	7.363

Nested Logit Model: Policy Modelling



Nested Logit Model: Policy Outcome

dismal.
An exclusive YouGov survey for *The Daily Telegraph* today shows the Conservatives leading Labour by 41 per cent to 33

moll, the poll shows that voters are no longer convinced by the Prime Minister's claims of economic competence.
Most voters, 52 per cent, say

Mr Brown's Government has performed badly.

Analysis: Page 4
Editorial Comment: Page 27

Green tax plan for gas-guzzlers

By David Millward
Transport Editor

MOTORISTS face having to pay new green taxes as ministers step up their war on "gas-guzzling" cars.
Two reports commissioned by the Department for Transport and published yesterday examine the impact of raising the cost of buying the most-polluting vehicles, and of increasing running costs by raising road tax or fuel prices.
They conclude that the measures would be effective in encouraging motorists to buy greener cars and cutting carbon dioxide emissions.
Labour's plans, although not as advanced, echo those announced by the Tories last year for a series of "green supertaxes" which would add up to £3,000 to the showroom price of bigger cars.
The DfT said the studies were "routine research" without policy recommendations.

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The Daily Tel

SHOWDOWN IN BA
UNITED AGONY OVER P

WIN TICKETS FOR THE RETURN LEG SEE PAGE 55

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BRITAIN'S BEST-SELLING QUALITY

'Useless' green levy on drivers rakes in £4 billion

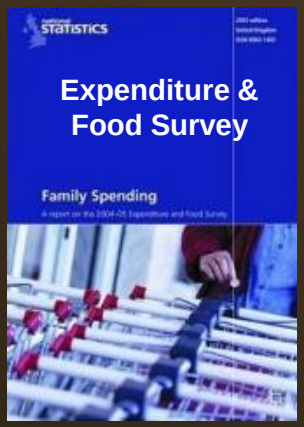
By Robert Winnett
Deputy Political Editor

THE "green levy" on motorists announced in Alistair Darling's first Budget will double car tax revenue to £4 billion but reduce vehicle emissions by less than one per cent, Treasury figures showed yesterday.
The Chancellor announced a significant increase in car tax in March.
This will result in the own-

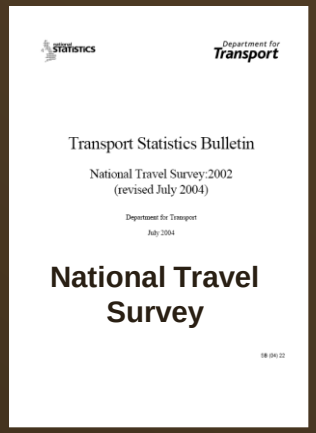
duty increases next year and complain to their MPs.
The Budget announced a radical overhaul of the taxation system for cars – known as vehicle excise duty – claiming that the "majority of motorists will be better or no worse off in 2009".
However, that claim has been undermined by analysis showing that nine out of 10 vehicle models will be taxed more heavily from next year.
Under the scheme, cars will

- New bands for VED ... no tax on cars under 100g CO_2 per km
- New "Show Room" tax ... upto £950 on most polluting cars

Homogenous Taste Parameters?



- Annual survey
- 6,000 hshlds per year
- socioeconomics
- Car purchases
- Purchase price



- Annual survey
- 8,000 hshlds per year
- socioeconomics
- New car purchases
- Car model - 6 types

- EFS Data Heckman Regression Participation & Price Paid
  - Participation

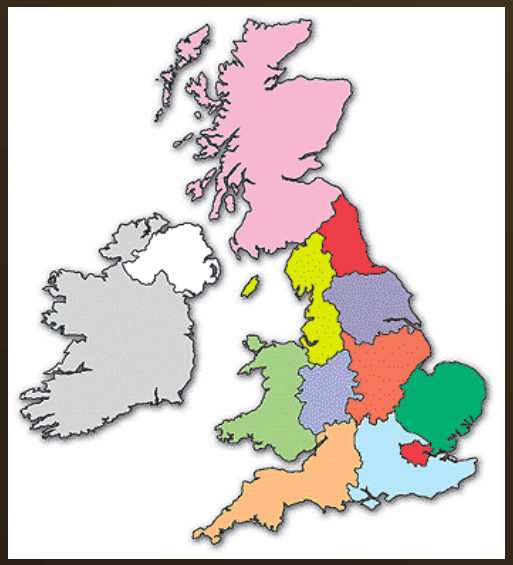
Income	0.088	0.000
Age	0.061	0.000
Age Squared	-0.001	0.000
Female	-0.218	0.000
Kids	0.008	0.562
House	0.302	0.000
Rent	-0.657	0.000
Council	-0.949	0.000
Pension	-0.619	0.000
Cars/Adult	-1.445	0.000

  - Price Paid

Income	7.77	0.000
Age	273.65	0.000
Age Squared	-2.31	0.001
Female	-1,772.09	0.000
Kids	1,114.76	0.000
House	-446.50	0.496
Rent	-1,819.62	0.064
Council	-3,944.90	0.000
Pension	-2,901.67	0.000

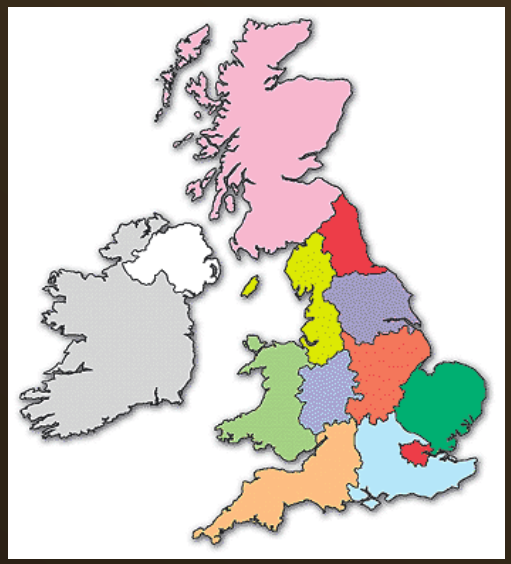
Identification through Regional Variation

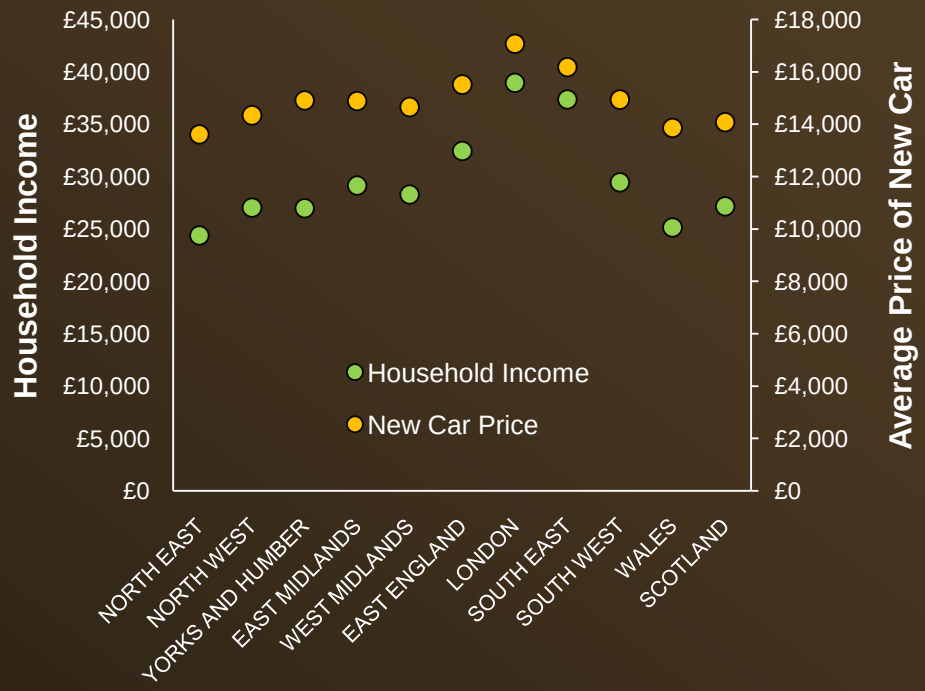
- Method suggested by Berry, Levinsohn & Pakes (1995)
- Socioeconomics differ across regions



Identification through Regional Variation

- Method suggested by Berry, Levinsohn & Pakes (1995)
- Socioeconomics differ across regions
- Reflected in market shares
- Use to identify interaction & random parameters





BLP Method

- Obtain random sample of N_s households for each market
- Calculate individual specific choice probs

Prob *i* chooses *j*: $$p_{ij}(\theta) = \frac{exp(v_{ij}(D_i, X_j, \theta))}{1 + \sum_k exp(v_{ik}(D_i, X_j, \theta))}$$

- Simulate market share using sample households d_i and random draws for μ_i

Simulated share *j*: $$\hat{s}_j(\theta) = \frac{1}{N_s} \sum_{i=1}^{N_s} p_{ij}(\theta, d_i, \mu_i)$$

- Choose θ to fit simulated market shares to observed market shares

BLP Model results

- Draw simulation samples of 200 for each market from EFS
- Use model of insurance premia to provide household specific insurance cost

- Participation

η	9.410	0.000
Income	-0.000	0.549
Cars/Adult	0.860	0.573

- Costs

Price	-0.0034	0.000
Income	0.0002	0.992
Random	0.0001	0.984
Resale Price	0.0031	0.000
Insurance	-0.0139	0.000
VED	-0.0162	0.000

- Car Attributes

ABS	-0.477	0.000
Acceleration	-0.065	0.001
Automatic	-0.226	0.000
BHP	0.031	0.000
Fuel Cost	-0.001	0.047
Num Air Bags	0.015	0.030
Size	0.002	0.000

Combining Disaggregate and Aggregated Data

- More information in disaggregate data to exploit
- Covariance of socioeconomics with purchase price of car

Observed in EFS

Price Band	Income	Female	Cars/Adult
0	£30,081	0.360	0.565
£10,000	£41,508	0.316	0.289
£12,500	£43,820	0.225	0.282
£15,000	£49,412	0.218	0.299
£17,500	£56,827	0.166	0.256
£20,000	£57,291	0.166	0.275
£25,000	£58,847	0.196	0.348
£30,000	£62,719	0.212	0.421
£50,000	£86,902	0.174	0.418
£100,000	£94,283	0.128	0.571

Predicted

Price Band	Income
0	£30,036
£10,000	£31,490
£12,500	£31,434
£15,000	£31,382
£17,500	£31,095
£20,000	£31,054
£25,000	£30,876
£30,000	£30,352
£50,000	£30,014
£100,000	£28,308

- Choose θ to match predicted covariances with observed

Combined Data Results

- Participation

η	7.397	0.000
Income	-0.0001	0.004
Cars/Adult	5.605	0.000

- Costs

Price	-0.0036	0.000
Income	0.0017	0.000
Random	0.0001	0.888
Resale Price	0.0033	0.000
Insurance	-0.0138	0.000
VED	-0.0131	0.000

- Car Attributes

ABS	-0.534	0.000
Acceleration	-0.011	0.507
Automatic	-0.087	0.004
BHP	0.030	0.000
Fuel Cost	-0.001	0.000
Num Air Bags	0.044	0.000
Size	0.002	0.000

- Covariances

Price Band	Observed	Modelled
0	£30,081	£29,404
£10,000	£41,508	£35,651
£12,500	£43,820	£37,893
£15,000	£49,412	£40,539
£17,500	£56,827	£43,276
£20,000	£57,291	£47,885
£25,000	£58,847	£54,284
£30,000	£62,719	£63,537
£50,000	£86,902	£77,613
£100,000	£94,283	£108,694

Closing Remarks

- Aggregate data:

  ... identifies car attribute parameters β

  ... limited ability to recover interaction parameters π & σ

- Disaggregate data:

  ... identifies socioeconomic interactions π & σ

  ... limited ability to recover β unless very large data sets

- Combine Aggregate & Disaggregate for best of both

Next Steps ...

- Add disaggregate moment conditions from EFS & NTS data
- Consider optimal weighting of moment conditions
- Correct parameter standard errors for simulation

Suggestions?

- Applications other than to assessment of fiscal policies?
- Model specification & choice of interactions?