

# Modelling Demand for New Cars using Aggregate & Disaggregate Data

Brett Day, University of East Anglia

11<sup>th</sup> November, 2008

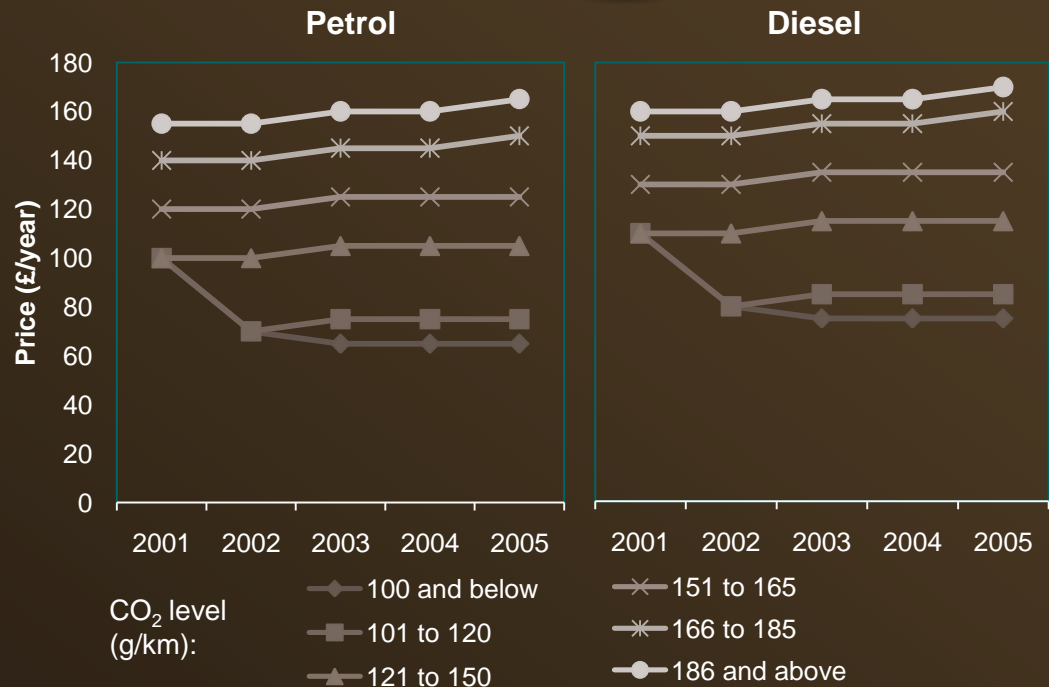
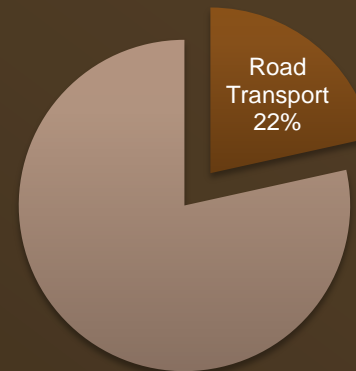


# Motivation

- Road Transport & CO<sub>2</sub> emissions
- 2001 Vehicle Excise Duty reform
- Tool to forecast impact of changes in tax



UK CO<sub>2</sub> Emissions (2006)



# 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:**

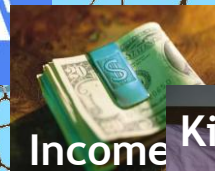
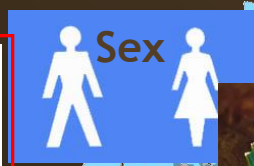
Choose option giving  
 $\max U_{ji}$

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

# Model of Demand for New Cars



... etc.



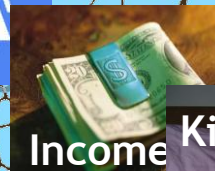
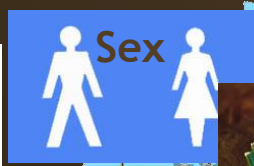
Disaggregate  
Data

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

# 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.



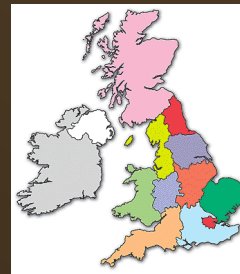
$$U_{ji} = B(x_j, \xi_j; \beta_i) - C(P_j, VC_j, FC_j; \alpha_i)$$

# 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



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 ...

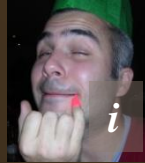


Engine Size...



# General Empirical Model

Household:



$i$



Inco



$d_i$   
Kids



Fleet

Car:



$j$

Money:



$p_j$



$r_j$



$tax_j$



$ins_{ij}$

Attributes:



Eng



S



$x_j$



Fuel Efficiency



$\xi_j$

Prestige

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

$$\alpha_i = \alpha + \pi_\alpha d_i + \sigma_\alpha \mu_i^\alpha$$

$$\beta_i = \beta + \pi_\beta d_i + \sigma_\beta \mu_i^\beta$$

No Car:



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

$$\eta_i = \eta + \pi_\eta d_i + \sigma_\eta \mu_i^\eta$$

# General Estimation Method

$$U_{ij} = \underbrace{-\eta_i + \alpha_i(y_i - p_j + \alpha^r r_j - \alpha^t \text{tax}_j - \alpha^i \text{ins}_{ij}) + \mathbf{x}_j \boldsymbol{\beta}_i}_{v_{ij}(D_i, X_j, \boldsymbol{\theta})} + \underbrace{\zeta_j + \varepsilon_{ij}}_{\sim \text{iid EV}}$$

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

Predicted share  $j$ : 
$$\hat{s}_j(\boldsymbol{\theta}) = \frac{1}{N} \sum_{i=1}^N p_{ij}(\boldsymbol{\theta})$$

Choose  $\boldsymbol{\theta}$  so that ...  $\hat{s}_j(\boldsymbol{\theta}) = s_j$  ... endogeneity of prices  
... modelable fixed effects

# Simple Aggregate Models

## Logit Model :

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

$$U_{ij} = -\eta_i - \alpha(p_j - \alpha^r r_j + \alpha^t \text{tax}_j + \alpha^i \overline{\text{ins}}_j) + \mathbf{x}_j \boldsymbol{\beta} + \zeta_j + \varepsilon_{ij}$$

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

## Nested Logit Model :

Assume pattern of correlation in  $\varepsilon_{ij}$

- Richer substitution possibilities allowed

# Nested Logit Model: Selected Results



- Costs ( $\alpha$ )

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 ( $\beta$ )



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)

		Change in Sales for Vehicles in Row Category from 1% Change in Price for Vehicles in Column Category															
CO <sub>2</sub> /km	2005 Sales	1% Change in Price															
		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 <sub>2</sub>	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 <sub>2</sub>	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)

		Change in Sales for Vehicles in Row Category from £10 Change in VED for Vehicles in Column Category															
CO <sub>2</sub> /km	2005 Sales	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 <sub>2</sub>	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 <sub>2</sub>	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

**New Car Demand Model** from report "Demand for Cars and their Attributes" by EFTEC

**1. Set parameters describing current economic conditions**  
 The new car demand model is based on economic conditions in 2005. Change the parameters on this page to update the model to reflect current income, costs and prices.

**a. Mean disposable household income by Government Office Region**  
 Source: Total disposable income by GOR from ONS and number of households in each GOR from ONS "Regional Trends" report

North East:	£ 26,921	London:	£ 40,540
North West:	£ 29,774	South East:	£ 35,585
Yorkshire:	£ 28,916	South West:	£ 31,583
East Midlands:	£ 29,826	Wales:	£ 28,799
West Midlands:	£ 30,189	Scotland:	£ 28,571
East:	£ 34,401		

**b. Price inflation**  
 Source: ONS RPI series CHAZ  
 Retail Price Index: 185.10

**c. Insurance inflation**  
 Source: AA BIPI index for non-comprehensive insurance  
 BIPI Index: 223.95

**2. Set parameters describing cost changes to be modelled**  
 From the base level of demand (determined by parameters set on Page 1) the new car model determines how sales of different cars might be impacted by changes in vehicle prices and costs.

**a. What sorts of cost change are to be modelled?**  
 Select absolute or relative (%) change in purchase and fixed costs. Note that for fixed costs, the percentage change is taken to be in the VED. On the next page you will be able to state the size of the changes and to which CO2 band they apply:

**3. Which segments are changes applied in?**

**3. Set price and fixed cost changes by CO2 band ... then run model**  
 Finally, choose the size of price and fixed cost changes for each CO2 band. Press the "Run Model" button to calculate levels of demand at the new costs. Press the "Reset" button to clear down the form. Press the "Save" button to save off a report recording this model run.

**MODEL INPUT**

Cost Changes: Fixed: See Below; Price: No Change; Petrol: No Change; Diesel: No Change; LPG: No Change

Segments Changed: Mini Cars (A): All; Super Mini Cars (B): All; Medium Cars (C): All; Large Cars (D): All; Luxury Cars (E): All; Mini MPV: All; MPV: All; Sports Cars: All; SUV: All

**MODEL OUTPUT**

Total New Car Sales:

Baseline	Model	Abs Diff	% Diff
869,254	866,721	-2,533	-0.29

Average CO2 Emissions:

Per Vehicle	Baseline	Model
	169,903	169,909
Per Household	84,954	84,954

**Enter Cost Changes ...**

CO2 Band	Options	Fixed		Price	Model Sales by CO2 Band		
		Sales	Price		Sales	Absolute Change	Percentage Change
100 to 105	0	0	£ 50	None	0	0	0%
105 to 110	3	7,722	£ 50	None	7,699	-23	-0.29%
110 to 115	8	6,973	£ 50	None	6,953	-21	-0.30%
115 to 120	19	19,801	£ 50	None	19,743	-58	-0.29%
120 to 125	37	13,454	£ 50	None	13,415	-39	-0.29%
125 to 130	20	16,800	£ 50	None	16,751	-49	-0.30%
130 to 135	16	38,312	£ 50	None	38,267	-45	-0.30%
135 to 140	26	50,912	£ 50	None	50,763	-149	-0.29%
140 to 145	38	73,990	£ 50	None	73,772	-217	-0.29%
145 to 150	37	68,435	£ 50	None	68,234	-201	-0.29%
150 to 155	70	88,941	£ 50	None	88,681	-261	-0.29%
155 to 160	36	53,076	£ 50	None	52,921	-155	-0.29%
160 to 165	37	56,070	£ 50	None	55,906	-164	-0.29%
165 to 170	49	78,659	£ 50	None	78,398	-261	-0.30%
170 to 175	71	72,881	£ 50	None	72,669	-212	-0.29%
175 to 180	59	28,964	£ 50	None	28,900	-64	-0.29%
180 to 185	66	25,901	£ 50	None	25,826	-75	-0.29%
185 to 190	72	32,235	£ 50	None	32,142	-93	-0.29%
190 to 195	78	36,033	£ 50	None	35,908	-125	-0.29%

# 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

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

Most voters, 52 per cent, say

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.

included holiday now comes with an extraordinary 25% discount and a free flight

- New bands for VED ... no tax on cars under 100g CO<sub>2</sub> per km
- New "Show Room" tax ... upto £950 on most polluting cars

ONLINE **BORIS JOHNSON** ANSWERS YOUR QUESTIONS LIVE A

# The Daily Telegraph

WIN TICKETS FOR THE FOUR LEGS SEE PAGE 35

## SHOWDOWN IN BA UNITED AGONY OVER P

www.telegraph.co.uk •• 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-

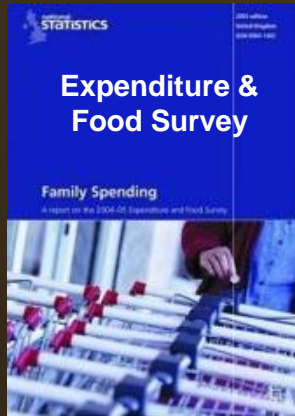
duy increases next year and complain to their MPs.  
The Budget announced a radical overhaul of the taxation system for cars - known as vehicle excise duty - claiming that the "majority of motorists will be better or no worse off in 2009".  
However, that claim has been undermined by analysis showing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

ON STRIKE SCHOOL CLOSURE ON STRIKE

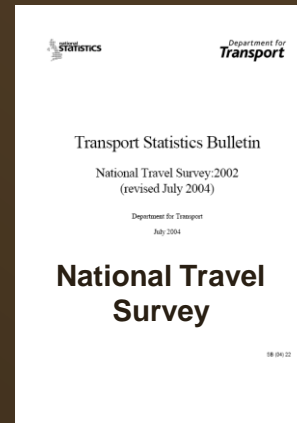
Due to Industrial Action the school will be closed on Thursday 24th April 2008 and will re-open Friday 25th April

ON STRIKE ON STRIKE

# 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

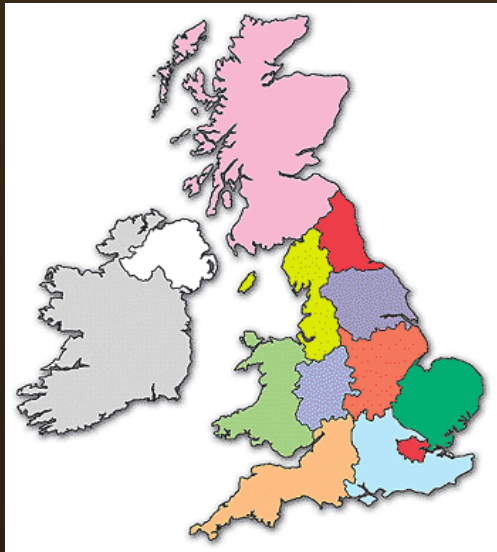
Income	0.088	0.000
Age	0.061	0.000
Age Squared	-0.001	0.000
Female	-0.218	0.000
Kids	0.008	0.562
House	0.302	0.000
Rent	-0.657	0.000
Council	-0.949	0.000
Pension	-0.619	0.000
Cars/Adult	-1.445	0.000

### • 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

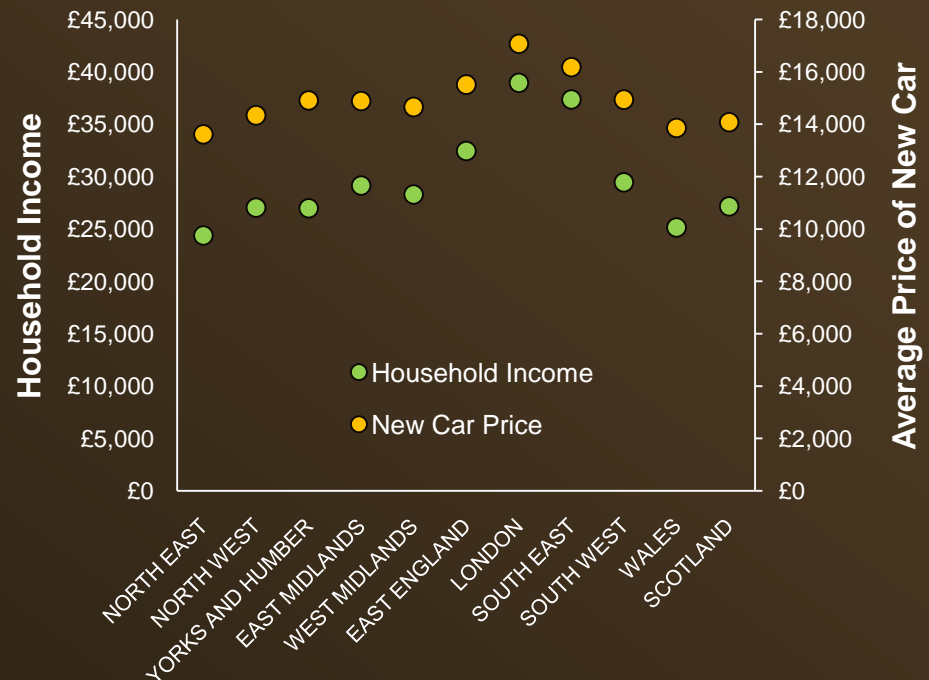
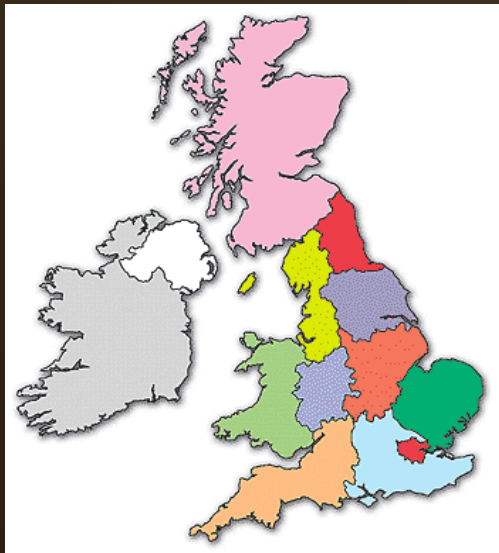
# Identification through Regional Variation

- 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

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

- Simulate market share using sample households  $d_i$  and random draws for  $\mu_i$

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

- Choose  $\theta$  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

$\eta$	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				Predicted	
Price Band	Income	Female	Cars/Adult	Price Band	Income
0	£30,081	0.360	0.565	0	£30,036
£10,000	£41,508	0.316	0.289	£10,000	£31,490
£12,500	£43,820	0.225	0.282	£12,500	£31,434
£15,000	£49,412	0.218	0.299	£15,000	£31,382
£17,500	£56,827	0.166	0.256	£17,500	£31,095
£20,000	£57,291	0.166	0.275	£20,000	£31,054
£25,000	£58,847	0.196	0.348	£25,000	£30,876
£30,000	£62,719	0.212	0.421	£30,000	£30,352
£50,000	£86,902	0.174	0.418	£50,000	£30,014
£100,000	£94,283	0.128	0.571	£100,000	£28,308

- Choose  $\theta$  to match predicted covariances with observed

# Combined Data Results

- Participation

$\eta$	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  $\beta$
  - ... limited ability to recover interaction parameters  $\pi$  &  $\sigma$
- Disaggregate data:
  - ... identifies socioeconomic interactions  $\pi$  &  $\sigma$
  - ... limited ability to recover  $\beta$  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?