Consumer Welfare in Empirical Industrial Organization

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Consumer Welfare

- A common use of empirical demand models is to compute consumer welfare
- Compensating variation measures change in a consumer's income that equates utility in a particular economic environment to some chosen benchmark utility (Hicks, 1946).
- The methods can be used broadly for evaluating:
  - mergers, regulation
  - Consumer Price Index
- For example to measure consumer surplus change after a merger in discrete choice models
- Other example: welfare gains from the introduction of new goods

Consumer Welfare Using Discrete Choice Model

- Assume the indirect utility is given by

$$u_{ijt} = x_{jt}\beta_i - \alpha_i p_{jt} + \xi_{jt} + \varepsilon_{ijt}$$

- With ε_{ijt} i.i.d. extreme value, the *inclusive value* (or social surplus) from a subset $A \subseteq \{1, 2, .., J\}$ of alternatives:

$$\begin{aligned} \omega_{iAt} &= E_{\varepsilon_{ijt}}\left(\max_{j\in A} u_{ijt}\right) \\ &= \ln\left(\sum_{j\in A} \exp\left\{x_{jt}\beta_i - \alpha_i p_{jt} + \xi_{jt}\right\}\right) \end{aligned}$$

- The expected utility from A prior to observing $(\varepsilon_{i0t}, ...\varepsilon_{iJt})$, knowing choice will maximize utility after observing shocks.
  - If no heterogeneity ($\beta_i = \beta$, $\alpha_i = \alpha$), captures average utility
  - With heterogeneity, need to integrate over it
  - If utility linear in price convert to dollars by dividing by α_i
  - With income effects conversion to dollars done by simulation

Applications: Trajtenberg, 1989

- Trajtenberg "The Welfare Analysis of Product Innovations, with an Application to Computed Tomography Scanners" Journal of Political Economy, 1989
- Estimates a (nested) Logit model and uses it to measure the benefits from the introduction of Computed Tomography scanners
- Does not control for endogeneity (pre BLP) so gets positive price coefficient because correlated with characteristics of scanners
- Quality of scanners: speed at which a CT scanner can "take a picture" of a thin cross-sectional slice of organ examined. Since internal organs are subject to involuntary motions, the faster the CT scanner is, the less distortion in the picture. First scanners were very slow and could be used only for the brain.

Applications: Trajtenberg, 1989

- Problem of observing quality, needs to do "hedonic" correction

$$p_j = p(z_j) + \tilde{p}_j$$

- Utility model

$$V_{ij} = -\alpha p_j + \phi_1(z_j) + \phi_2(z_j^u) + \varepsilon_{ij}$$

where z_j^u is unobserved

- As p_j may be correalted with z_j and z_j^u, after hedonic correction, it gives:

$$\begin{aligned} V_{ij} &= -\alpha p_j + \phi_1(z_j) + \phi_2(z_j^u) + \varepsilon_{ij} \\ &= [\phi_1(z_j) - \alpha p(z_j)] + (\beta - \alpha)\,\tilde{p}_j + \varepsilon_{ij} \end{aligned}$$

where $\tilde{p}_j$ captures the correlation with z_j^u for example such that $\phi_2(z_j^u) = \beta \tilde{p}_j$.

Applications: Trajtenberg, 1989

- Problem: residual price coefficient is no longer the marginal utility of income α but rather $(\beta - \alpha)$
- Solution: assumes no unobserved characteristic of head scanners in order to identify marginal utility of income and do welfare analysis on more innovative recent body scanners i.e. need to assume $\beta = 0$ to identify α and do welfare analysis.

Applications: Petrin, 2003

- Petrin "Quantifying the Benefits of New Products: The Case of the Minivan" Journal of Political Economy, 2003
- Compensating variation measures changes in consumer welfare from the introduction of the minivan.
- Uses the BLP data to repeat the Trajtenberg exercise for the introduction of mini-vans
    - adds micro moments to BLP estimates
    - predictions of model with micro moments more plausible
    - attributes this to the fact that "micro data appear to free the model from heavy dependence on the idiosyncratic logit “taste” error"

Applications: Petrin, 2003

- In the counterfactual environment, there are no minivans, and other vehicle prices solve set of equilibrium first-order conditions (without minivans)
- Compensating variation is the dollar amount a consumer would need to be just indifferent between equilibrium with minivans and the one without.
- For minivan purchasers, it is the dollar amount a (former) minivan consumer needs to be compensated at new equilibrium prices to achieve the "minivan standard of living."

Table 4: Demand estimates

TABLE 4
PARAMETER ESTIMATES FOR THE DEMAND-SIDE EQUATION

Variable	OLS Logit (1)	Instrumental Variable Logit (2)	Random Coefficients (3)	Random Coefficients and Microdata (4)
	A. Price Coefficients (α's)			
α_1	.07 (.01)**	.13 (.01)**	4.92 (9.78)	7.52 (1.24)**
α_2			11.89 (21.41)	31.13 (4.07)**
α_3			37.92 (18.64)**	34.49 (2.56)**
	B. Base Coefficients (β's)			
Constant	−10.03 (.32)**	−10.04 (.34)**	−12.74 (5.65)**	−15.67 (4.39)**
Horsepower/weight	1.48 (.34)**	3.78 (.44)**	3.40 (39.79)	−2.83 (8.16)
Size	3.17 (.26)**	3.25 (.27)**	4.60 (24.64)	4.80 (3.57)*
Air conditioning standard	−.20 (.06)**	.21 (.08)**	−1.97 (2.23)	3.88 (2.21)*
Miles/dollar	.18 (.06)**	.05 (.07)	−.54 (3.40)	−15.79 (.87)**
Front wheel drive	.32 (.05)**	.15 (.06)**	−5.24 (3.09)	−12.32 (2.36)**
Minivan	.09 (.14)	−.10 (.15)	−4.34 (13.16)	−5.65 (.68)**
Station wagon	−1.12 (.06)**	−1.12 (.07)**	−20.52 (36.17)	−1.31 (.36)**
Sport-utility	−.41 (.09)**	−.61 (.10)**	−3.10 (10.76)	−4.38 (.41)**
Full-size van	−1.73 (.16)**	−1.89 (.17)**	−28.54 (235.51)	−5.26 (1.30)**
% change GNP	.03 (.01)**	.03 (.01)**	.08 (.02)**	.24 (.02)**

Table 5: Random coefficient estimates

TABLE 5
RANDOM COEFFICIENT PARAMETER ESTIMATES

	Random Coefficients (γ's)	
Variable	Uses No Microdata (1)	Uses CEX Microdata (2)
Constant	1.46	3.23
	(.87)*	(.72)**
Horsepower/weight	.10	4.43
	(14.15)	(1.60)**
Size	.14	.46
	(8.60)	(1.07)
Air conditioning standard	.95	.01
	(.55)*	(.78)
Miles/dollar	.04	2.58
	(1.22)	(.14)**
Front wheel drive	1.61	4.42
	(.78)**	(.79)**
γ_{mi}	.97	.57
	(2.62)	(.10)**
γ_{sw}	3.43	.28
	(5.39)	(.09)**
γ_{su}	.59	.31
	(2.84)	(.09)**
γ_{pv}	4.24	.42
	(32.23)	(.21)**

Table 8: Welfare estimates

TABLE 8
AVERAGE COMPENSATING VARIATION CONDITIONAL ON MINIVAN PURCHASE, 1984: 1982–84 CPI-ADJUSTED DOLLARS

	OLS Logit	Instrumental Variable Logit	Random Coefficients	Random Coefficients and Microdata
Compensating variation:				
Median	9,573	5,130	1,217	783
Mean	13,652	7,414	3,171	1,247
Welfare change from difference in:				
Observed characteristics $(\delta_j + \mu_{ij})$	−81,469	−44,249	−820	851
Logit Error (ϵ_{ij})	95,121	51,663	3,991	396
Income of minivan purchasers:				
Estimate from model	23,728	23,728	99,018	36,091
Difference from actual (CEX)	−15,748	−15,748	59,542	−3,385

Discussion

- The micro moments clearly improve the estimates and help pin down the non-linear parameters in demand
- Compensating variation of mini-van purchasers shows that consumers of minivans dislike the utility provided by its observed characteristics except in the fourth model
- What is driving the change in welfare?
  - Welfare is an order statistic, by adding another option we increase the number of draws, hence (mechanically) increase welfare.

Discussion

- The analysis has 2 steps
  1. Simulate the world without\with minivans (depending on the starting point)
  2. Summarize the simulated\observed prices and quantities into a welfare measure
- Both steps require a model
- If we observe pre- and post- introduction data, might avoid step 1
  - but it does not isolate the effect of the introduction
- Logit model fails because heterogeneity is important

Red-bus-Blue-bus Example

- Originally, used to show the IIA problem of Logit
- Worst case scenario for Logit
- Consumers choose between driving car to work or (red) bus
  - working at home not an option
  - decision of whether to work does not depend on transportation
- Half the consumers choose the car and half choose the red bus
- Artificially introduce a new option: a blue bus
  - consumers color blind
  - no price or service changes
- In reality half the consumers choose car, rest split between the two color buses
- Consumer welfare has not changed

Red-bus-Blue-bus Example

- Suppose we want to use the Logit model to analyze consumer welfare generated by the introduction of the blue bus

$$u_{ijt} = \xi_{jt} + \varepsilon_{ijt}$$

- Normalizing $\xi_{car0} = 0$, therefore $\xi_{bus0} = 0$ because same market share
- Welfare at $t = 0$

$$\begin{aligned} \omega_{i0} &= E_{\varepsilon_{ij0}}\left(\max_j u_{ij0}\right) \\ &= \ln\left(\exp \xi_{00} + \exp \xi_{01}\right) \end{aligned}$$

Red-bus-Blue-bus Example

$$u_{ijt} = \xi_{jt} + \varepsilon_{ijt}$$

$t=0$			$t=1$			
	observed		predicted		observed	
option	share	ξ_{j0}	share	ξ_{j1}	share	ξ_{j1}
car	0.5					
red bus	0.5					
blue bus	–					
welfare						

Red-bus-Blue-bus Example

$$u_{ijt} = \xi_{jt} + \varepsilon_{ijt}$$

$t = 0$			$t = 1$			
	observed		predicted		observed	
option	share	ξ_{j0}	share	ξ_{j1}	share	ξ_{j1}
car	0.5	0				
red bus	0.5	0				
blue bus	–	–				
welfare	$\ln(2)$					

Red-bus-Blue-bus Example

- Let's introduce the blue bus
- If nothing changed, one might be tempted to hold ξ_{jt} fixed that is

$$\xi_{j1} = \xi_{j0} = 0$$

Red-bus-Blue-bus Example

$$u_{ijt} = \xi_{jt} + \varepsilon_{ijt}$$

$t = 0$			$t = 1$			
	observed		predicted		observed	
option	share	ξ_{j0}	share	ξ_{j1}	share	ξ_{j1}
car	0.5	0	0.33	0		
red bus	0.5	0	0.33	0		
blue bus	–	–	0.33	0		
welfare	$\ln(2)$		$\ln(3)$			

Red-bus-Blue-bus Example

- We obtained the usual result: with predicted shares Logit gives welfare gains
- Now, suppose we observed actual shares

Red-bus-Blue-bus Example

$$u_{ijt} = \xi_{jt} + \varepsilon_{ijt}$$

$t = 0$			$t = 1$			
	observed		predicted		observed	
option	share	ξ_{j0}	share	ξ_{j1}	share	ξ_{j1}
car	0.5	0	0.33	0	0.5	
red bus	0.5	0	0.33	0	0.25	
blue bus	–	–	0.33	0	0.25	
welfare	$\ln(2)$		$\ln(3)$			

Red-bus-Blue-bus Example

- To rationalize observed shares we need to let ξ_{jt} vary
- What did it exactly mean to introduce blue bus?

Red-bus-Blue-bus Example

$$u_{ijt} = \xi_{jt} + \varepsilon_{ijt}$$

$t = 0$			$t = 1$			
	observed		predicted		observed	
option	share	ξ_{j0}	share	ξ_{j1}	share	ξ_{j1}
car	0.5	0	0.33	0	0.5	0
red bus	0.5	0	0.33	0	0.25	$\ln(0.5)$
blue bus	–	–	0.33	0	0.25	$\ln(0.5)$
welfare	$\ln(2)$		$\ln(3)$		$\ln(2)$	

Generalizing from the example

- In the example, the Logit model fails in the first step (counterfactual simulation)
- Holds more generally:
  - with Logit, expected utility is $\ln\left(\sum_j \exp\left\{x_{jt}\beta - \alpha p_{jt} + \xi_{jt}\right\}\right) = \ln(1/s_{0t})$
  - since s_{0t} did not change in the observed data the Logit model predicted no welfare gain

Generalizing from the example

- With heterogeneity, the change in outside good market share is not the welfare change because

$$\int \left[\ln\left(\frac{1}{s_{i,0,t}}\right) - \ln\left(\frac{1}{s_{i,0,t-1}}\right) \right] dP_\tau(\tau) = \int \ln\left(\frac{s_{i,0,t-1}}{s_{i,0,t}}\right) dP_\tau(\tau)$$
$$\neq \ln\left(\frac{1}{s_{0,t}}\right) - \ln\left(\frac{1}{s_{0,t-1}}\right)$$

  - Difference depends on the change in the heterogeneity in the probability of choosing the outside option, $s_{i,0,t}$
  - Difference can be positive or negative

Generalizing from the example

- The key in the above example is that ξ_{jt} was allowed to change to fit the data.
- This works when we see data pre and post (allows us to tell how we should change ξ_{jt})
- What if we do not have data for the counterfactual?
    - have a model of how ξ_{jt} is determined
    - make an assumption about how ξ_{jt} changes
    - bound the effects

Motivation

- The Effects of Banning Advertising in Junk Food Markets (Dubois, Griffith, O'Connell)
- Growing obesity and diet-related disease across developed world
- Many policies proposed (education and information campaigns, fiscal measures, regulations), one is banning junk food advertising
- But ex ante we don't know what will be the impact on markets which depends on
    - whether advertising is expansionary or contractionary
    - strategic response of firms
- We also don't know what will be the welfare effects

Contribution

- Develop model of consumer demand and oligopoly supply with multi-product firms competing in price and advertising
- Allow advertising to impact demand in a flexible way
- Allow past advertising to impact current demand meaning firms play a dynamic game
- Estimate the model on the UK potato chips markets
- Simulate the impact of advertising ban on equilibrium outcomes and on welfare
- Consider advertising to be persuasive: taking into account distorted consumer's choices when measuring welfare

Advertising in consumer demand model

- Dynamic effects of advertising on demand
- Cooperative or rival effects of advertising such that increase in advertising of one brand may:
  - Increase demand for a second brand (cooperative)
  - Decrease demand for a second brand (predatory)
  - Lead to expansion or contraction of market
- Denote advertising state vector for brand b: $\mathbf{a_{bt}}$ which can include current and past advertising

Consumer choice model

- Random utility discrete choice model:

$$\bar{v}_{ibst} = \alpha_i \left(\mathbf{a_{bt}}, p_{bst}\right) + \psi_i \left(\mathbf{a_{bt}}, x_b\right) + \gamma_{bi}(\mathbf{a_t}) + \eta_i(\mathbf{z}_{bs}, \xi_b) + \epsilon_{ibst}$$

  i: consumer, b: brand, s: pack size, t time (market)
  p_{bst} is price
  x_b is nutrient score
  $\mathbf{a_{bt}}$ is advertising states for brand b; $\mathbf{a_t} = (\mathbf{a_{1t}}, ..., \mathbf{a_{Bt}})$
  z_{bs} are functions of pack size
  ξ_b is an unobserved brand characteristic
- With outside good : $\bar{v}_{i00t} = \eta_{i0} + \epsilon_{i00t}$

Consumer choice model

- A flexible enough specification:

$$\bar{v}_{ibst} = \alpha_i\left(\mathbf{a_{bt}}, p_{bst}\right) + \psi_i\left(\mathbf{a_{bt}}, x_b\right) + \gamma_{bi}(\mathbf{a_t}) + \eta_i(\mathbf{z}_{bs}, \xi_b) + \epsilon_{ibst}$$

$$\begin{aligned}
\alpha_i\left(\mathbf{a_{bt}}, p_{bst}\right) &= \left(\alpha_{0i} + \alpha_{1i}\mathbf{a_{bt}}\right) p_{bst} \\
\psi_i\left(\mathbf{a_{bt}}, x_b\right) &= \left(\psi_{0i} + \psi_{1i}\mathbf{a_{bt}}\right) x_b \\
\gamma_{bi}(\mathbf{a_t}) &= \lambda_i \mathbf{a_{bt}} + \rho_i \left(\sum\nolimits_{l \neq b} \mathbf{a_{lt}}\right) \\
\eta_i(\mathbf{z}_{bs}, \xi_b) &= \eta_{1i} z_{bs} + \eta_{2i} z_{bs}^2 + \eta_i \xi_b
\end{aligned}$$

- $\pi_i^u = (\alpha_{0i}, \lambda_i, \rho_i, \eta_i)$ such that $\pi_i^u = \pi_0^u + \pi_1^u d_i + \upsilon_i d_i$ with $\upsilon_i \sim N\left(0, \Sigma_\pi\right)$
- $\pi_i^o = (\alpha_{1i}, \psi_{1i}, \eta_{1i}, \eta_{2i})$ with $\pi_i^o = \pi_0^o + \pi_1^o d_i$
- Coefficients differ by demographics (d_i) and purchase occasion

Consumer choice model

- From choice set Ω_κ consumer chooses (b, s) if:

$$\bar{v}_{ibst} \geq \bar{v}_{ib's't} \ (b', s') \in \Omega_\kappa$$

- Probability of purchasing (b, s) :

$$s_{ibs}(\mathbf{p_t}, \mathbf{a_t}) = \frac{\exp[\alpha_i\left(\mathbf{a_{bt}}, p_{bst}\right) + \psi_i\left(\mathbf{a_{bt}}, x_b\right) + \gamma_{bi}(\mathbf{a_t}) + \eta_i(\mathbf{z_{bs}}, \xi_b)]}{\sum_{(b',s')\in\Omega_\kappa} \exp\left[\alpha_i\left(\mathbf{a_{b't}}, p_{b's't}\right) + \psi_i\left(\mathbf{a_{b't}}, x_{b'}\right) + \gamma_{bi}(\mathbf{a_t}) + \eta_i(\mathbf{z_{b's'}}, \xi_{b'})\right]}$$

- Then aggregate demand is:

$$s_{bs}(\mathbf{p_t}, \mathbf{a_t}) = \int s_{ibs}(\mathbf{p_t}, \mathbf{a_t}) dF(\upsilon_i, d_i)$$

Consumer welfare

- How we measure welfare depends on whether we view advertising as:
  - Informative about prices/characteristics (Stigler, 1961; Nelson, 1995)
  - A characteristic that consumers value (Stigler and Becker, 1977)
  - Persuasive (Marshall, 1921; Robinson, 1933; Kaldor, 1950)
- We focus on persuasive view
  - Advertising can lead consumers to act as non-standard decision makers, by providing environmental "cues" to consumers (Bernheim and Rangel, 2005).
  - Bernheim and Rangel (2009): *"choices made in the presence of those cues are predicated on improperly processed information, and welfare evaluations should be guided by choices made under other conditions"*

Consumer welfare: advertising as a characteristic

- If advertising is a characteristic, the payoff function represents the consumer's (indirect) utility function; the consumer makes decisions to maximize utility
- Expected utility is given by:

$$W_{it}(\mathbf{p}_t, \mathbf{a}_t) = E\left[\max_{(b,s)\in\Omega_\kappa} \bar{v}_{ibst}\right]$$

$$= \ln\left[\sum_{(b,s)\in\Omega_\kappa} \exp\left[\alpha_i\left(\mathbf{a_{bt}}, p_{bst}\right) + \psi_i\left(\mathbf{a_{bt}}, x_b\right) + \gamma_{bi}(\mathbf{a_t}) + \eta_i(\mathbf{z_{bs}}, \xi_b)\right]\right]$$

- Issue: the normalization of common advertising effect on outside good will affect welfare changes of the ban
- Model with $\bar{v}_{ibst}(\mathbf{a}_t) - \gamma(\mathbf{a}_t)$ and $\bar{v}_{i00t} - \gamma(\mathbf{a}_t)$ is observationally equivalent but welfare change depends on $\gamma(\mathbf{a}_t)$ being on inside or outside good

Consumer welfare: advertising as a characteristic

- Denote $\mathbf{p}^0$ a counterfactual price equilibrium with no advertising
- The welfare consequences of banning advertising is:

$$\begin{aligned} & W_i\left(\mathbf{0}, \mathbf{p}_\mathbf{t}^\mathbf{0}\right) - W_i\left(\mathbf{a}_\mathbf{t}, \mathbf{p}_\mathbf{t}\right) \\ = & W_i\left(\mathbf{0}, \mathbf{p}_\mathbf{t}\right) - W_i\left(\mathbf{a}_\mathbf{t}, \mathbf{p}_\mathbf{t}\right) \qquad \text{(characteristic effect)} \\ + & W_i\left(\mathbf{0}, \mathbf{p}_\mathbf{t}^\mathbf{0}\right) - W_i\left(\mathbf{0}, \mathbf{p}_\mathbf{t}\right) \quad \text{(price competition effect)} \end{aligned}$$

Consumer welfare: advertising distorts decisions

- If advertising is distorting, then consumer's ("experience") utility (Kahneman et al. 1997) should be evaluated in the absence of advertising :

$$\widehat{v}_{ibst} = \alpha_i\left(\mathbf{0}, p_{bst}\right) + \psi_i\left(\mathbf{0}, x_b\right) + \gamma_{bi}(\mathbf{0}) + \eta_i(\mathbf{z_{bs}}, \xi_b) + \epsilon_{ibst}$$

- Expected "experience" utility from the choice made with different "decision" utility is:

$$\widehat{W}_i\left(\mathbf{a_t}, \mathbf{p_t}\right) = E\left[\widehat{v}_{\substack{\arg\max\{\bar{v}_{ibst}\} \\ (b,s)\in\Omega_K}}\right]$$

Consumer welfare: advertising distorts decisions

- Expected "experience" utility from the choice made with different "decision" utility:

$$\begin{aligned}\widehat{W}_i(\mathbf{a_t}, \mathbf{p_t}) =& E\left[\widehat{v}_{\arg\max_{(b,s)\in\Omega_K}\{\bar{v}_{ibst}\}}\right] \\ =& W_{it}(\mathbf{p}_t, \mathbf{a}_t) \\ &- \sum_{(b,s)\in\Omega_K} s_{ibst}\left[\left(\alpha_i(\mathbf{a_{bt}}, p_{bst}) - \alpha_i(\mathbf{0}, p_{bst})\right)\right. \\ &\left. + \left(\psi_i(\mathbf{a_{bt}}, x_b) - \psi_i(\mathbf{0}, x_b)\right) + \left(\gamma_{bi}(\mathbf{a_t}) - \gamma_{bi}(\mathbf{0})\right)\right]\end{aligned}$$

Consumer welfare: advertising distorts decisions

- When advertising distorts decision making, welfare impact of advertising evaluated under preferences in absence of advertising
- Welfare difference between the post and pre advertising ban is:

$$
\begin{aligned}
& W_i\left(\mathbf{0}, \mathbf{p_t^0}\right) - \widehat{W}_i\left(\mathbf{a_t}, \mathbf{p_t}\right) \\
= \; & W_i\left(\mathbf{0}, \mathbf{p_t}\right) - \widehat{W}_i\left(\mathbf{a_t}, \mathbf{p_t}\right) \qquad \text{(choice distortion effect)} \\
+ & W_i\left(\mathbf{0}, \mathbf{p_t^0}\right) - W_i\left(\mathbf{0}, \mathbf{p_t}\right) \qquad \text{(price competition effect)}
\end{aligned}
$$

where we use $\widehat{W}_i\left(\mathbf{0}, \mathbf{p}\right) = W_i\left(\mathbf{0}, \mathbf{p}\right)$

Supply overview

- Multi-product firms compete by setting simultaneously two strategic instruments to maximize profits
  - prices and advertising expenditures
- Firms' problem is dynamic because
  - advertising today affects future demand and hence profits
- We abstract from product entry and exit and reformulation

Profit

- Multi-product firm j chooses (p_{bst}, e_{bt}) to maximize intertemporal profit:

$$\sum_{t=0}^{\infty} \beta^t \left[\sum_{(b,s)\in N_j^{bs}} (p_{bst} - c_{bst})\, s_{bs}(\mathbf{p}_t, \mathbf{a}_t)\, M_t - \sum_{b\in N_j^b} e_{bt} \right]$$

where

$$\mathbf{a_t} = f(e_{bt}, e_{bt-1}, e_{bt-2}, \ldots)$$

N_j^{bs}: set of products owned by firm j
N_j^{b}: set of brands owned by firm j
c_{bst}: constant marginal cost
M_t: size of the potential market
e_{bt}: advertising expenditure

Structure of game

- Timing of the game:
  - at beginning of each period firms observe state variables $(\mathbf{a}_{t-1}, \theta_t)$
  - play their strategy σ_j mapping states to decisions $(p_{bst}, e_{bt})_{((b,s)\in N_j^{bs})}$
  - individual demand shocks are realized and firms get current profit
- We assume:
  - cost and market size follow independent Markov processes such that $\mathbb{E}_t[c_{bst+1}] = c_{bst}$ and $\mathbb{E}_t[M_{t+1}] = M_t$
  - firms play strategies which depend only on payoff relevant state variables, so $\sigma_j(\mathbf{a}_{t-1}, \theta_t)$ (where $\theta_t \equiv (\mathbf{c}_t, \mathbf{M}_t)$)

Markov perfect equilibrium

- Firm j makes an assumption on competitive strategy profile $\sigma_{-j} = (\sigma_1, ..., \sigma_{j-1}, \sigma_{j+1}, ..., \sigma_j)$ and chooses its own strategy σ_j
- Value function $\pi_j^*(.,.)$ from Bellman equation conditional on specific strategy profile σ_{-j} :

$$\pi_j^*(\mathbf{a}_{t-1}, \theta_t) = \max_{\sigma_j = (p_{bst}, e_{bt}) \in N_j^{bs}} \Bigg\{ \sum_{(b,s) \in N_j^{bs}} (p_{bst} - c_{bst}) s_{bs}(\mathbf{p}_t, \mathbf{a}_t) M_t - \sum_{b \in N_j^b} e_{bt} + \beta E[\pi_j^*(\mathbf{a}_t, \theta_{t+1})] \Bigg\}$$

- A Markov perfect equilibrium is a list of strategies $\sigma^* = (\sigma_1^*, ..., \sigma_J^*)$ such that no firm has an incentive to deviate from the action prescribed by σ_j^* in the subgame that starts from the state $(\mathbf{a}_{t-1}, \theta_t)$

Markov perfect equilibrium

- Assume existence of a subgame perfect Markov equilibrium, and restrict attention to Markov Perfect Equilibrium in pure strategies (Maskin and Tirole, 2001)
- Ericson and Pakes (1995), Doraszelski and Satterthwaite (2003) give general conditions for the existence of equilibria in similar games, but model set up is different, so may not apply
- Each solution of Bellman equation π_j^* corresponds to each MPE of dynamic game.
- Do not need to assume equilibrium is unique

Price first order conditions

- Price first order conditions depend on Markov perfect equilibrium only through observed state vector $(\mathbf{p}_t, \mathbf{a}_t)$

$$s_{bs}(\mathbf{p}_t, \mathbf{a}_t) + \sum_{(b',s')\in N_j} (p_{b's't} - c_{b's't}) \frac{\partial s_{b's'}(\mathbf{p}_t, \mathbf{a}_t)}{\partial p_{bst}} = 0$$

- ... we can identify marginal costs without solving for the value function π_j^*
- Some optimality conditions of advertising exist but not needed for identification of costs

Advertising Ban

- Simulate counterfactual equilibrium with ban on advertising ($\mathbf{a}_t = 0$)
- New price equilibrium will be played and satisfy the following per period Bertrand-Nash conditions, for all (b, s)

$$s_{bs}(\mathbf{p}, \mathbf{0}) + \sum_{(b',s') \in N_j} (p_{b's't} - c_{b's't}) \frac{\partial s_{b's'}(\mathbf{p}, \mathbf{0})}{\partial p_{bs}} = 0$$

where

$$s_{bs}(\mathbf{p}, \mathbf{0}) = \int s_{ibs}(\mathbf{p}, \mathbf{0}) dF(\upsilon_i, d_i)$$

is aggregate demand for product (b, s) when advertising is banned

Purchase data

- From Kantar/TNS Worldpanel
- June 2009 - October 2010
- Use information on a subset of households
  - all groceries brought into home by 2873 households (food at home), 161,513 transactions
  - all snacks bought for consumption outside the home by 2306 individuals (food on the go), 99,636 transactions
- Observe all barcodes bought and transaction level prices
- Plus demographics and product characteristics

Food at home - 26 products in total

Brand	Size	Purchase Share	Price (£)
Pringles:	150-300g	1.34%	1.10
	300g+	5.54%	2.63
Walkers Regular:	150-300g	1.77%	1.25
	300g+	23.98%	2.77
Walkers Sensations:	150-300g	0.43%	1.26
	300g+	1.81%	2.52
Walkers Doritos:	150-300g	1.30%	1.21
	300g+	3.29%	2.47
Walkers Other:	<150g	0.69%	1.24
	150-300g	3.73%	1.77
	300g+	8.66%	3.17
Golden Wonder:	<150g	0.10%	1.28
	150-300g	0.25%	1.35
	300g+	1.15%	2.70
...			

Food on the go - 11 products in total

Brand	Size	Purchase Share	Price (£)
Walkers Regular	34.5g	27.16%	0.45
	50g	7.19%	0.63
Walkers Sensations	35g	2.04%	0.61
Walkers Doritos	50g	4.70%	0.54
Walkers Other	<30g	4.34%	0.45
	30g+	8.94%	0.61
KP	35g	0.83%	0.57
Golden Wonder:	<40g	3.08%	0.39
	40g+	1.09%	0.73
Other	<40g	17.57%	0.48
	40g+	20.01%	0.59
...			

Nutrient score

- Interested in nutrient characteristics of the products
- Use nutrient profile model developed by Rayner et al. (2005), used by FSA and Ofcom
- The nutrient profiling model aggregates all nutrient characteristics into a single score
  - For potato chips, relevant nutrients are the amount of energy, saturated fat and sodium
  - Score is the sum of points, 1 point for each 335kJ per 100g, 1 for each 1g of saturated fat per 100g, and 1 for each 90mg of sodium per 100g

Nutrient score

Brand	Nutrient score	Energy (kj per 100g)	Saturated fat (g per 100g)	Sodium (g per 100g)
Pringles	18	2160	8.35	0.62
Walkers Reg	10	2164	2.56	0.59
Walkers Sens	11	2023	2.16	0.71
Walkers Dor	12	2095	2.86	0.66
Walkers Oth	15	2020	2.50	0.82
KP	18	2158	5.87	0.85
GW	16	2101	4.01	0.92
Asda	15	2125	4.13	0.75
Tesco	15	2145	4.65	0.77
Other	12	2084	3.84	0.70

- proposal is to ban advertising for score above 4 (fiber and protein not shown)

Advertising data (AC Nielsen digest of advertising)

- Advertising expenditure by brand and month from 2001 to 2010
- Includes all potato chips advertising appearing on TV, in press, on radio, on outside posters and internet
- We compute the stock of advertising goodwill according to:

$$\mathbf{a}_t = \delta \mathbf{a}_{t-1} + \mathbf{e}_t$$

with $\delta = 0.75$

Advertising expenditure

	Monthly expenditure (£100,000)			Total
	Mean	Min	Max	(06/09-10/10)
Pringles	4.50	0.00	10.14	76.54
Walkers Regular	4.97	0.00	18.29	84.47
Walkers Sensations	0.54	0.00	1.46	9.12
Walkers Doritos	1.75	0.00	8.25	29.67
Walkers Other	2.89	0.00	8.99	49.07
KP	2.09	0.00	8.49	35.60
Golden Wonder	0.08	0.00	0.80	1.34
Asda	0.01	0.00	0.23	0.23
Tesco	0.08	0.00	0.68	1.44
Other	1.58	0.00	5.74	26.83

Demographic group			Number of purchase occasions	
			food at home	food on-the-go
Composition	skill level	income		
HH no children	high	high	22721	14371
		medium	13178	8376
		low	13341	8219
	low	medium-high	10187	6667
		low	16147	8559
Pensioners			14384	6016
HH children	high	high	20426	12786
		medium	14292	8502
		low	7091	4494
	low	medium-high	15349	9549
		low	14397	8932
Child purchase				3165

- All parameters are allowed to vary across cells

Identification: price effects

- Price maybe correlated with an unobserved product effect
- Use individual transaction level data
- National pricing in the UK means concerns over endogeneity are whether differences in price either across products or through time are correlated with the *individual level* errors (ϵ_{ibst}), conditional on all other characteristics
  - Marketing activities are observed and controlled for
  - We control for seasonal effects, brand effects
- Identification from time series and differences across brand in non-linear pricing with respect to pack size

Identification: advertising effects

- Advertising could be correlated with demand shocks
- We add common time effects
- But brand advertising flows e_{bt} may be correlated with brand-market unobserved shocks to demand
- Use control function approach (Blundell and Powell, 2004 and Petrin and Train, 2010): advertising expenditure on ready-meals interacted with brand fixed effects are used as instruments; they are significant and lower the effects of advertising

Demand specification

- Product characteristics and advertising
  - Price
  - Brand advertising interacted with price and nutrient score
  - Competitor advertising
  - Pack size (and its square)
  - Brand dummies
- Random coefficients
  - Price (log normal)
  - Own and competitor advertising (normal)
  - Walkers dummy (normal)
- All preference parameters vary by
  - Education of household head
  - Household income
  - Demographics (pensioner, household with children, child purchaser)
  - Food at home vs. Food on the go

Willingness to pay for reduction in nutrient profiling score

- How is advertising affecting choices?
- It affects willingness to pay:

$$WTP_{ibt} = \frac{\partial \bar{v}_{ibst} / \partial x_b}{\partial \bar{v}_{ibst} / \partial p_{bst}} = \frac{\psi_{0i} + \psi_{1i}\mathbf{a_{bt}}}{\alpha_{0i} + \alpha_{1i}\mathbf{a_{bt}}}$$

Willingness to pay for one point reduction in nutrient score

Advertising:	None	Medium	High
Food at home			
Willingness to pay in pence	6.3	4.6	1.3
	[5.7, 6.8]	[4.1, 5.0]	[0.3, 2.7]
% of mean price	3.0	2.2	0.6
	[2.7, 3.3]	[2.0, 2.4]	[0.1, 0.3]
Food on-the-go			
Willingness to pay in pence	2.1	1.1	0.0
	[2.1, 2.6]	[1.0, 1.3]	[-0.2, 0.4]
% of mean price	4.6	2.3	0.1
	[4.2, 5.1]	[1.9, 2.5]	[-0.3, 0.7]

Numbers are median WTP in pence.

Advertising effects

% change in demand if advertising expenditure set to zero (ceteris paribus)

	Walkers Regular	Pringles	KP
Adv exp (£m)	0.497	0.450	0.209
Walkers Regular	-2.01	1.11	0.47
	[-3.70, -0.69]	[0.79, 1.43]	[0.33, 0.59]
Pringles	3.07	-15.61	0.25
	[2.41, 3.87]	[-17.63, -13.96]	[0.09, 0.41]
KP	-0.50	-0.16	-2.42
	[-0.93, -0.03]	[-0.53, 0.22]	[-3.31, -1.69]
...	...	...	...
Total	-1.11	-0.98	-0.40
	[-1.44, -0.82]	[-1.29, -0.68]	[-0.53, -0.28]

Numbers are means across markets (i.e. months).

Counterfactual

- Estimate marginal costs using supply model
- Simulate counterfactuals
  - no pricing response
  - with pricing response

Advertising ban: pricing response

- Banning advertising leads to toughening price competition
- The average price in the market falls by 9%
- Pricing response differs across firms and over products
- For food in:
  - The big advertisers (e.g. Walkers and Pringles) lower prices
  - For instance, Walkers reduces price of its most popular brand by the most, 33p (or 26%) reduction for the 150-300g pack, and 55p (or 20%) for the 300g+ pack
- For food on the go, prices increase slightly

Advertising ban

	Pre ban	Post ban	
		No firm response	With firm response
Expenditure (£m)	231.1	214.1	220.2
	[227.2, 233.2]	[201.4, 223.7]	[208.2, 229.2]
% change		-7.4	-4.7
		[-12.3, -2.9]	[-9.4, -0.7]
Quantity (m kg)	33.7	30.6	36.5
	[33.1, 34.0]	[28.8, 32.1]	[34.4, 38.1]
% change		-9.3	8.5
		[-14.2, -4.7]	[3.1, 13.2]
Probability of selecting	0.39	0.37	0.39
potato chips	[0.38, 0.39]	[0.35, 0.39]	[0.36, 0.40]
% change		-3.11	0.38
		[-9.71, 2.05]	[-5.72, 4.82]
Mean pack size	0.17	0.16	0.18
cond. on purchase (kg)	[0.17, 0.17]	[0.15, 0.17]	[0.18, 0.19]
% change		-6.41	7.90
		[-10.18, -1.64]	[4.47, 12.49]
Nutrient score	13.6	13.1	12.9
	[13.5, 13.6]	[13.1, 13.2]	[12.8, 13.0]
% change		-3.1	-5.2
		[-3.6, -2.4]	[-5.7, -4.5]

Consumer welfare: advertising distorts decisions

	Advertising banned	
	No price resp.	With price resp.
Choice distortion effect (£m)	36.2	36.2
	[34.8, 42.0]	[34.8, 42.0]
Price competition effect (£m)	0.0	20.8
		[16.9, 23.8]
Total compensating variation (£m)	36.2	57.0
	[34.8, 42.0]	[54.0, 63.3]
Change in profits (£m)	-0.1	-1.0
	[-6.2, 5.6]	[-6.8, 4.0]
Total change in welfare (£m)	36.1	56.0
	[31.5, 44.6]	[50.3, 64.5]

Aggregate impact of ban

We find that in response to introduction of an advertising ban in potato chips markets:

- Quantity of potato chips purchased would increase but nutrient score decrease due to substitution towards healthier products
- Effect is due to a large extent by firms lowering their prices
- Profitability in the market would slightly decrease
- If advertising is viewed as distorting prices, total welfare would rise
- Welfare would decrease if advertising as a characteristic, but identification problem due to normalization of outside good