Lecture 2
Measurement of Consumer Welfare

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CES Lectures, April 2017

Introduction

- Common use of empirical demand models is to evaluate consumer welfare consequences of
  - introduction of new goods
  - mergers, regulation, taxes
- and to evaluate the distributional effects
  - Nevo (2011) "Empirical models of consumer behavior" *Annual Reviews of Economics*
  - Griffith, Nesheim and O'Connell (2017) "Income effects and the welfare consequences of tax in differentiated product oligopoly" *Quantitative Economics*
  - Dubois, Griffith, O'Connell (2017) "The effects of banning advertising in junk food markets" *Review of Economic Studies*

Consumer welfare

- Consider discrete choice demand models of the form we considered in the last lecture, indirect utility given by

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

  ε_{ijt} i.i.d. extreme value

- The *inclusive value* from a subset $A \subseteq \{1, 2, ..., J\}$ of alternatives:

$$\omega_{iAt} = \ln\left(\sum_{j \in A} \exp\left\{x_{jt}\beta_i - \alpha_i p_{jt} + \xi_{jt}\right\}\right)$$

  - is the expected utility from A prior to observing $(\varepsilon_{i0t}, ...\varepsilon_{iJt})$, knowing choice will maximize utility after observing shocks

Consumer welfare

- If no heterogeneity ($\beta_i = \beta$, $\alpha_i = \alpha$) then the inclusive value ω_{At} captures average utility in the population
- with heterogeneity need to integrate over it
  - heterogeneity important to get welfare effects right
    - e.g. see Petrin (2003) use to value introduction of mini-vans and Nevo (2000) on impact of mergers
- income effects
  - if utility is linear in price then can convert to dollars by dividing by α_i, Small and Rosen (1981)
  - what happens if we allow income effects, and are income effects likely to matter?

Griffith, Nesheim and O'Connell (2017)

- Majority of applications of logit random utility models make strong assumptions about the marginal utility of income
  - either assume it's constant, include income as a "preference shifter", or include income minus price in utility in log form
- These assumptions place strong restrictions on (1) income effects and (2) demand curvature
  - what happens if we allow for more flexible income effects and curvature of consumer level (and hence market) demands
  - GNO apply to a product category that represents a small fraction of expenditure (butter and margarine)
  - simulate introduction of an excise tax on market equilibrium and welfare
- Potentially important for assessing distributional consequences and pass-through of tax

Consumer demand

Individual consumer solves:

$$V(\mathbf{p}, y, \mathbf{x}, \varepsilon) = \max_{j \in \{0,\dots,J\}} U(y - p_j, \mathbf{x_j}) + \varepsilon_j$$

- written for individual consumers, so i omitted
- $j = 0, 1, \dots, J$ indexes alternatives; $j = 0$ indexes 'outside option'
- y is total budget (or income)
- p_j is price of option j; $p_0 = 0$
- $\mathbf{x_j}$ are product characteristics (observed and unobserved)
- ε_j unobserved component of utility, i.i.d. type I extreme value

Consider alternatives for how income enters utility

- Vast majority of applications assume either
  - "Linear"
  $$\begin{aligned} U_j =& \alpha p_j + x_j' \beta + \epsilon_j \\ \alpha =& \alpha_0 + \nu \end{aligned}$$
  - "Preference shifter"
  $$\begin{aligned} U_j =& \alpha p_j + x_j' \beta + \epsilon_j \\ \alpha =& \alpha_0 + \alpha_1 y + \nu \end{aligned}$$
  - "Log utility"
  $$U_j = \alpha \ln(y - p_j) + x_j' \beta + \epsilon_j$$
- We consider more general specification

$$U_j = f(y - p_j; \alpha) + x_j' \beta + \epsilon_j$$

for a flexible function f

Consumer welfare

- Interested in welfare effects of change in price equilibrium from $\mathbf{p}$ to $\mathbf{p}'$
- When there are income effects
  - consumer welfare differs depending on whether evaluated prior to or after the logit shocks are realised (McFadden (1999)
    - ex ante if genuine uncertainty from the consumer perspec- tive
    - ex post if unobserve heterogeneity
- We compute ex post compensating variation, defined implicitly by:

$$V\left(\mathbf{p}, y, \mathbf{x}, \varepsilon\right) = V\left(\mathbf{p}', y - cv, \mathbf{x}, \varepsilon\right)$$

  - methods for simulation provided by McFadden (1999), Herriges and Kling (1999) and Dagsvik and Karlström (2005)

Curvature of market demand and pass-through

- Common question in IO literature is
  - how are changes in costs or taxes passed through to consumer prices?
- Series of papers show a key determinant of pass-through is curvature of (the log of) market demand
  - e.g. Anderson et al (2001) and Weyl and Fabinger (2013)
- For instance, a monopolist facing constant marginal cost will over (under) shift a cost shock if it faces log-convex (log-concave) demand
- Making strong *a priori* assumptions about demand curvature can prejudice empirical studies of tax pass-through

Market demand

- Let
  - each consumer be indexed by (y, θ), where y is income and θ denotes all observable and unobservable consumer attributes entering utility
  - $P_j(y, \theta)$ individual purchase probability
  - $g(y, \theta)$ joint density of y and θ
- Market demand for option j is given by:

$$q_j(\mathbf{p}) = \int P_j(y, \theta) g(y, \theta) dy d\theta$$

- Curvature defined by the second derivative of log of market demand with respect to price is given by:

$$\frac{\partial^2 \ln q_j}{\partial p_j^2} = \int \frac{P_j(y,\theta)}{q_j} \frac{\partial^2 \ln P_j(y,\theta)}{\partial p_j^2} g(y,\theta) dy d\theta + \left[\int \frac{P_j(y,\theta)}{q_j} \left(\frac{\partial \ln P_j(y,\theta)}{\partial p_j} \right)^2 g(y,\theta) dy d\theta - \left(\int \frac{P_j(y,\theta)}{q_j} \frac{\partial \ln P_j(y,\theta)}{\partial p_j} g(y,\theta) dy d\theta \right)^2 \right]$$

Market demand

- Curvature (and thus pass-through) depends on two terms
  - first is weighted average of second derivatives of log individual demand, weights are consumers contribution to the market demand curve
    - negative if individual level demand is log-concave
  - second is weighted variance of slope of log individual level demand
    - non-negative, positive when there is heterogeneity in individual demands
- Log demand will be
  - concave if individual demand is log-concave and if the cross-sectional variance of the slope of log demand is not too big
  - convex if individual log demand is convex or if the variance term is large enough in magnitude.

Market demand

- In order to allow flexibility in pass-through of costs or taxes
  - Including preference heterogeneity relaxes curvature restrictions of market demand by introducing variance in slopes of individual (log) demands
  - Allowing utility to be nonlinear in $(y - p_j)$ further relaxes curvature restrictions on market demand by relaxing restrictions on the curvature of individual consumer demands

Market demand in simple logit model

- In a simple logit model with constant marginal utility of income and no preference heterogeneity we have

$$\frac{\partial^2 \ln q_j}{\partial p_j^2} = \frac{\partial^2 \ln P_j}{\partial p_j^2} = -\alpha^2 P_j (1 - P_j) < 0$$

  - curvature of market demand is same as individual demand
  - market demand depends only on α and aggregate market share
  - pass-through is strongly restricted

GNO application

- What would be the impact of a tax on saturated fat
- Estimate for butter and margarine market
  - butter the single largest source of saturated fat in UK
- Small budget share item
- Purchase patterns correlated with total expenditure (income)
- Market is dominated by small number of multi-product firms

GNO data

- Household level data from Kanter Worldpanel for calendar year 2010
- We observe all grocery purchases by a panel of 10,000 households at transaction level
- Households buy butter or margarine on 34% of choice occasions, spending £1.35 on average (3.5% of their grocery spend)
- They choose between 48 butter and margarine products defined by brand-pack size (plus no purchase option)

Demand specification

- Utility is

$$U_{ijt} = f(y_i - p_{jt}; \alpha_i) + x_j'\beta_i + \epsilon_{ijt}$$

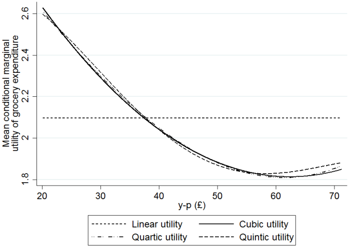
  - Consider various forms for $f(y_i - p_{jt}; \alpha_i)$

$$\begin{aligned} \text{Polynomial utility: } &= \sum_{n=1}^{3} \alpha_i^n (y_i - p_{jt})^n \\ \text{Log utility: } &= \alpha_i^1 \ln(y_i - p_{jt}) \\ \text{Preference shifter: } &= \left(\alpha_i^1 + \alpha_i^y y_i\right) p_{jt} \end{aligned}$$

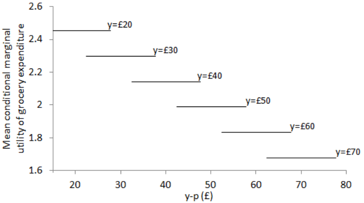
  - where heterogeneity takes the form:
    - α_i^1 includes a random coefficient (varies with unobserved heterogeneity)
    - all coefficients vary with observed heterogeneity

Marginal utility of income

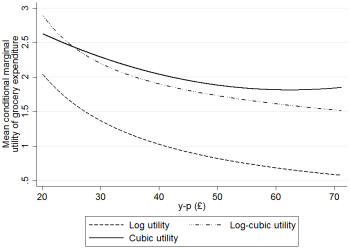
(a) Polynomial utility



(b) Preference shifter



(c) Log utility



Use demand estimates to simulate impact of a tax

- Assume the firms in the market play a Nash-Bertrand game
  - R_r is set of products firm r produces
- Assuming observed prices are the equilibrium outcomes of this game, we can use demand estimates to infer firms' marginal costs:

$$q_j(\mathbf{p_t}) + \sum_{k \in R_r} (p_{kt} - c_{kt}) \frac{q_k(\mathbf{p_t})}{p_{jt}} = 0 \quad \forall j \in R_r.$$

- and simulate the counterfactual equilibrium price vector $\mathbf{p}'_\mathbf{t}$ after the introduction of tax

$$q_j(\mathbf{p}'_\mathbf{t} + t\boldsymbol{\eta}) + \sum_{k \in R_r} (p'_{kt} - c_{kt}) \frac{q_k(\mathbf{p}'_\mathbf{t} + t\boldsymbol{\eta})}{p_{jt}} = 0 \quad \forall j \in R_r, \text{ and } \forall r \in 1, ..., R.$$

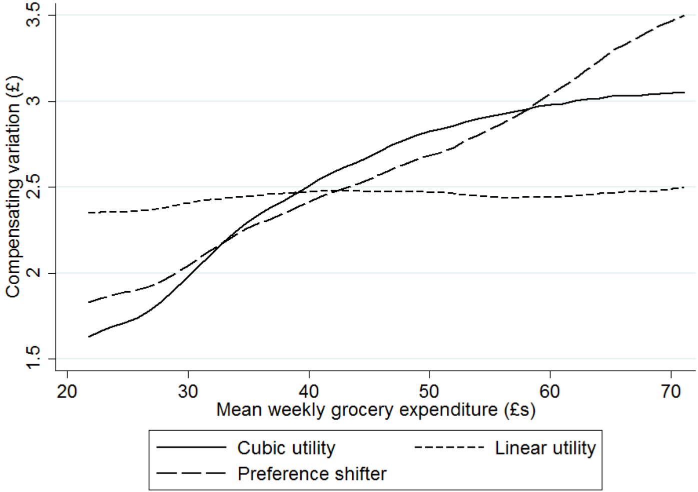
Pass-through of a tax

- Model the effects of imposing a tax on fat in butter and margarine
  - allowing utility to depend on a nonlinear function of $y - p_j$ allows the possibility of household level demands that are log-convex (something that is typically ruled out in applied applications)
  - estimates suggest that in this application demand is not log-convex, but the key thing is that this result is not driven by functional form assumptions
  - preference heterogeneity is important, omitting it leads to lower estimates of pass-through

Distributional consequences of a tax

- Show that a cubic function of $(y - p_j)$ fits well
  - Linear model generates estimates that capture the average but completely fail to capture distributional effects
  - Preference shifter specification does better
    - generates estimates that are on average similar to more flexible model
    - curvature restrictions are not rejected by the data
    - fails to fully recover distributional effects
  - Log utility model performs poorly, yielding implausible elasticities, costs and pass-through

Compensating variation from tax



Will preference shifter model always get distributional effects wrong?

- In our application utility takes the form:

$$U_j = \sum_{k}^{3} \alpha_k (y - p_j)^k + \mathbf{x_j}'\beta + \epsilon_j$$

- Linearizing around $p_j = 0$ (and dropping constant terms), yields

$$U_j \approx -(a_1 + a_2 y + a_3 y^2) p_j + \mathbf{x_j}'\beta + \epsilon_j$$

  where $a_1 \approx \alpha_1$, $a_2 \approx 2\alpha_2$ and $a_3 \approx 3\alpha_3$

- This linearized model does a good job of recovering distributional effects

Summary GNO (2017)

- Relaxing the restrictions commonly placed on the marginal utility of income in discrete choice demand models can be important
  - even in a small budget share market, especially if interest lies in distributional effects of a policy
- In some cases the commonly used preference shifter model can be improved by adding higher order terms
- This will work for counterfactuals that involve small price changes that don't themselves induce income effects

Dubois, Griffith, O'Connell (2017)

- Study the impact of restricting advertising in junk food markets
  - will depend on
    - how advertising affects the shape of demand
    - strategic response of firms
- Specify a demand model allowing advertising to have a flexible impact on demand
  - estimate the model on a junk food market (potato chips)
  - show that allowing for demand flexibility is important
    - ban leads to direct reduction in demand and switch to healthier varieties
    - but also leads to lower equilibrium prices, inducing offsetting increase in demand
  - consider welfare consequences of an advertising ban

Consumer choice model

- For this application it is important that advertising enters flexibly
  - payoff from inside products ($j > 0$):

$$\bar{v}_{ijt} = \alpha_{1i} p_{jt} + \psi_{1i} x_j + \xi_{ij} + \left[\lambda_i a_{ijt} + \rho_i \left(\sum_{l \neq j} a_{ilt}\right) + \alpha_{2i} a_{ijt} p_{jt} + \psi_{2i} a_{ijt} x_j\right] + \epsilon_{ijt}$$

i: consumers, j: products, t: time
a_{ijt}: advertising
p_{jt}: price
x_j: characteristics (inc. nutrients)
ξ_{ij}: unobserved characteristics

  - payoff from outside option:

$$\bar{v}_{i0t} = \zeta_t + \epsilon_{i0t}$$

ζ_t: aggregate demand shocks

- Assume ϵ_{ijt} are iid extreme value $\rightarrow$ logit choice probabilities, s_{ijt}

Effects of advertising on demand shape

1. Effect on purchase probabilities
2. Effect on demand slope
3. Effect on marginal rate of substitutions
4. Dynamic effect of advertising

Effects of advertising on demand shape

1. Effect on purchase probabilities - **no competitor advertising ($\rho_i = 0$)**

$$\frac{\partial s_{ijt}}{\partial a_{ijt}} = \tilde{\lambda}_{ijt} s_{ijt}(1 - s_{ijt})$$

$$\frac{\partial s_{ij't}}{\partial a_{ijt}} = -\tilde{\lambda}_{ijt} s_{ijt} s_{ij't} \qquad \text{for } j' \neq (0, j)$$

$$\frac{\partial s_{i0t}}{\partial a_{ijt}} = -\tilde{\lambda}_{ijt} s_{i0t} s_{ijt}$$

- where $\tilde{\lambda}_{ijt} = \lambda_i + \alpha_{2i} p_{jt} + \psi_{2i} x_j$
- if $\rho_i = 0$
  - and assuming that $\tilde{\lambda}_{ijt} > 0$ so that $\frac{\partial s_{ijt}}{\partial a_{ijt}} > 0$
  - then advertising would necessarily be predatory, stealing market share from competitor products ($\frac{\partial s_{ij't}}{\partial a_{ijt}} < 0$) and it would necessarily lead to market expansion ($\frac{\partial s_{i0t}}{\partial a_{ijt}} < 0$)

Effects of advertising on demand shape

1. Effect on purchase probabilities

$$
\begin{aligned}
\frac{\partial s_{ijt}}{\partial a_{jt}} &= s_{ijt}\left[\tilde{\lambda}_{ijt}(1-s_{ijt})-\rho_i(1-s_{ijt}-s_{i0t})\right] \\
\frac{\partial s_{ij't}}{\partial a_{jt}} &= s_{ij't}\left[\rho_i s_{i0t}-(\tilde{\lambda}_{ijt}-\rho_i)s_{ijt}\right] \qquad \text{for } j' \neq (0,j) \\
\frac{\partial s_{i0t}}{\partial a_{jt}} &= -s_{i0t}\left[\rho_i(1-s_{i0t})+(\tilde{\lambda}_{ijt}-\rho_i)s_{ijt}\right]
\end{aligned}
$$

- where $\tilde{\lambda}_{ijt}=\lambda_i+\alpha_{2i}p_{jt}+\psi_{2i}x_j$
    - ρ_i captures the extent to which time variation in competitor advertising affects the valuation or weight the consumer places on the unobserved brand effect

Effects of advertising on demand shape

1. Effect on purchase probabilities
   - where $\tilde{\lambda}_{ijt} = \lambda_i + \alpha_{2i} p_{jt} + \psi_{2i} x_j$
     - ρ_i captures the extent to which time variation in competitor advertising affects the valuation or weight the consumer places on the unobserved brand effect
     - λ_i: how time series exposure to advertising affects the valuation or weight the consumer places on the unobserved brand effect
     - α_{2i} allows the marginal effect of price on the payoff function to shift with own advertising
     - ψ_{2i}: allows the marginal effect of the nutrient characteristic on the payoff function to also shift with own advertising

Effects of advertising on demand shape

1. Effect on purchase probabilities
2. Effect on demand slope

$$\frac{\partial s_{ijt}}{\partial p_{jt}} = (\alpha_{1i} + \alpha_{2i} a_{ijt})(1 - s_{ijt}) s_{ijt}$$
$$\frac{\partial s_{ij't}}{\partial p_{jt}} = -(\alpha_{1i} + \alpha_{2i} a_{ijt}) s_{ijt} s_{ikt} \qquad \text{for } j' \neq j.$$

- allows the slope of demand to shift with advertising

Effects of advertising on demand shape

1. Effect on purchase probabilities
2. Effect on demand slope
3. Effect on marginal rate of substitutions

   Willingness to pay for healthiness (x_j):

$$WTP_{ijt}(a_{ijt}) = -\frac{\partial \bar{v}_{ijt}/\partial x_j}{\partial \bar{v}_{ijt}/\partial p_{jt}} = -\frac{\psi_{0i} + \psi_{1i} a_{ijt}}{\alpha_{0i} + \alpha_{1i} a_{ijt}}$$

- allows the willingness to pay for a characteristic (e.g. nutrition) to potentiall shift with advertising

Effects of advertising on demand shape

1. Effect on purchase probabilities
2. Effect on demand slope
3. Effect on marginal rate of substitutions
4. Dynamic effect of advertising

$$\mathbf{a_t} = \mathcal{A}(\mathbf{e_t}, \mathbf{e_{t-1}}, .., \mathbf{e_{t_0}}) = \sum_{n=0}^{t-t_0} \delta^n \mathbf{e_{t-n}}$$
$$= \delta \mathbf{a_{t-1}} + \mathbf{e_t}$$

- advertising exposure depends not only on advertising today but also advertising in the past
- we assume there are no dynamics in price

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

Firms

- Firms face market demands

$$s_j(\mathbf{a_t}, \mathbf{p_t}, \zeta_{\boldsymbol{t}}) = \int s_{ij}(\mathbf{a_t}, \mathbf{p_t}, \zeta_{\boldsymbol{t}}) dF(\pi_i^u, \pi_i^o)$$

- Current advertising decisions affect future demand, so firms play a dynamic game
- But since
  - i) we observe advertising states, and
  - ii) prices do not directly affect evolution of the state variables

  we can identify marginal costs from (static) price first order condition
- In counterfactual we consider advertising ban, therefore game collapses to static Nash-Bertrand competition

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

$$s_j(\mathbf{p}, \mathbf{0}) + \sum_{j' \in N_j} (p_{j't} - c_{j't}) \frac{\partial s_{j'}(\mathbf{p}, \mathbf{0})}{\partial p_j} = 0$$

where

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

is aggregate demand for product j when advertising is banned

Application

- Apply model to potato chip market, characterised by:
  - multi product firms
  - large advertising budgets
  - well established brands
  - purchases made both for future consumption and "on-the-go"
- Data
  - individual purchase transactions
  - 7 firms, 10 brands, 26 food at home products, 11 food on-the-go products
  - information on prices, nutrients, etc
  - advertising exposure of individuals to different brands

Effect of advertising on demand

Willingness to pay for healthier product, on-the-go market

	Advertising level		
	None	Medium	High
Willingness to pay in pence	0.8	-0.1	-0.7
	[0.6, 1.0]	[-0.2, 0.1]	[-0.9, -0.6]
% of mean price	1.6	-0.2	-1.5
	[1.2, 2.0]	[-0.4, 0.2]	[-1.8, -1.1]

Counterfactual: an advertising ban

- Ban results in non-marginal changes in all advertising; effect will depend on full shape of demand:
- Simulate the ban and find that:
  - it results in a direct reduction in demand
  - but firms respond by lowering their prices, on average, mitigating the direct effects

Effect of ban on nutrients

% changes

	No price response	With price response
Calories	-13.42	5.34
	[-17.99, -8.49]	[0.50, 10.54]
Saturates intensity (g/100g)	-4.48	-7.96
	[-5.14, -3.69]	[-8.74, -6.92]
Salt intensity (g/100g)	-0.80	-3.24
	[-1.06, -0.52]	[-3.54, -2.84]
Saturated fat	-17.35	-3.58
	[-21.92, -12.37]	[-8.26, 1.65]
Salt	-14.15	1.45
	[-18.70, -9.27]	[-3.24, 6.40]

Numbers in [] are confidence intervals.

Effect of ban on consumer welfare

- We would like to be able to say what the effects of the ban are on welfare
  - we model advertising as effecting the payoff to consumers, but how does it affect underlying utility?
- Advertising can be viewed as:
  - a valued 'characteristic'
    - Becker and Murphy (1993), Stigler and Becker (1977)
  - persuasive
    - Marshall (1921), Braithwaite (1928), Robinson (1933), Kaldor (1950) and Dixit and Norman (1978), Gabaix and Laibson (2006), McClure et al. (2004), Bernheim and Rangel (2004, 2005)
  - informative
    - Stigler (1961) and Nelson (1995), Sovinsky Goeree (2008), Ackerberg (2001, 2003)

Effect of ban on consumer welfare

Characteristics view of advertising

- Under the characteristics view of advertising
  - the payoff function and utility are the same
- Welfare effect of ban include
  - a negative term representing the loss in utility from the loss of advertising
  - a positive effect from increased price competition effect

Effect of ban on consumer welfare

Persuasive advertising

- Under the persuasive view of advertising
  - the payoff function and utility are no longer the same
  - we consider utility as defined by the non-distorted preferences
  - we compare utility from the choice made in the presence of advertising (evaluated at preferences when no advertising)
  - with utility from the choice made in the absense of advertising
- Welfare effect of ban include
  - a positive term from the removal of the distortion of choice
  - a positive effect from increased price competition effect

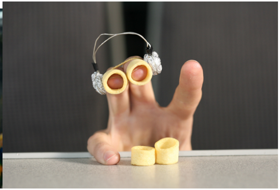
Effect of ban on consumer welfare

TABLE 13

Effect of advertising ban on welfare

	Persuasive view	Characteristic view
Choice distortion effect (£m)	15.0	
	[14.2, 16.1]	
Characteristic effect (£m)		-23.2
		[-25.4, -20.4]
Price competition effect (£m)	3.7	3.7
	[3.1, 4.3]	[3.1, 4.3]
Total compensating variation (£m)	18.7	-19.5
	[17.7, 20.4]	[-21.3, -16.7]
Change in profits (£m)	-5.1	-5.1
	[-6.0, -3.7]	[-6.0, -3.7]
Total change in welfare (£m)	13.6	-24.6
	[12.7, 15.1]	[-27.0, -20.4]

Crisps adverts



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Summary

- It is important to consider what your empirical specification imposes in terms of economic effects and your interests
- Even in complicated dynamic models you can sometimes simplify things so that you can still say something interesting
- We're often interested in welfare effects, and we need to think carefully about how to construct these