Simulating policy-effects through structural demand and supply models: Achievements and challenges

Pierre Dubois

Toulouse School of Economics

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  - Dubois P, R. Griffith, M. O'Connell (2018) "The Effects of Banning Advertising in Junk Food Markets", Review of Economic Studies, 85, 1, 396-436
  - Dubois P, R. Griffith, M. O'Connell (2020) "How Well Targeted are Soda Taxes?", American Economic Review, 110(11), 3661-3704

Introduction

Obesity and diet-related diseases call for policy interventions

- Education and information campaigns
- Fiscal measures (soda tax)
- Regulations of advertising
- Nutritional labels
- Incentives for products reformulation

Challenges for ex ante simulation

- How policy intervention will affect consumer behavior
  - Identification of price effects or information effects or advertising effects on demand
  - How policies will affect long term demand differently from short term (habit formation)
- Effects of policies on firms behavior
  - How firms change product prices (tax pass through), products assortments
  - How firms change dynamic strategies like advertising
  - Firms reorganization, innovation, entry, acquisitions, mergers

Challenges for an advertising ban

- UK bans advertising of foods high in fat, salt or sugar during children's programs. What would be the effects of a complete ban?
- Ex ante we don't know what will be the impact on markets which depends on
  - How the demand shape changes with advertising
  - Whether advertising is expansionary or pure business stealing
  - Strategic response of firms: price equilibrium
- Need counterfactual evaluation of supply and demand
- As well as questioning on evaluating welfare effects

Outline

- 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
- Estimate the model on the typical junk food market in the UK (potato chips)
- Simulate the impact of advertising ban on equilibrium outcomes (prices, expenditures, quantities, nutrition)
- Consider welfare evaluation depending on whether advertising distorts consumer's choices

Advertising in consumer demand model

Consumer demand model such that:

- Allow cooperative or rival effects of advertising such that increase in advertising of one brand may:
  - Increase demand for another brand (cooperative)
  - Decrease demand for another brand (predatory)
  - Lead to expansion or contraction of market
- Allow dynamic effects of advertising on demand:
  - Advertising exposure of consumer i for brand b: $\mathbf{a}_{ibt}$ must depend current and past advertising expenditures

Consumer discrete choice model

- Random utility for consumer i, brand b, pack size s, time (market) t

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

  where:

  - p_{bst} is price
  - x_b is nutrient score
  - $\mathbf{a_{ibt}}$ is advertising states for brand b; $\mathbf{a_{it}} = (\mathbf{a_{i1t}}, ..., \mathbf{a_{iBt}})$
  - z_{bs} are functions of pack size
  - ξ_b is an unobserved brand characteristic
  - ϵ_{ibst} individual deviation that may contain some product speficic time varying unobservables

- With outside good : $\bar{v}_{i00t} = \zeta_{d0t} + \epsilon_{i00t}$

Consumer discrete choice model

- A flexible specification:

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

- Coefficients differ by demographics (d_i) and purchase occasion
- Impact of advertising on demand is flexible

Advertising exposure

- Exposure measure based on TV viewing behavior:

$$a_{ibt} = \sum_{s,k,c} w_{iskc} T_{bskct}$$

where w_{iskc} is consumer i viewing show s on time slot k and channel c, T_{bskct} is brand b advertising

Average TV advertising per week by brand across all TV channels

Brand	Weeks with zero adverts	Adverts per week	SD adverts per week	Expenditure (£) per week	Length (seconds) per week
Walkers Regular	46	322	406	77,270	8,928
Walkers Sensation	78	63	223	12,554	1,665
Walkers Doritos	65	161	379	24,373	3,671
Walkers Other	61	257	439	47,185	7,722
Pringles	31	359	333	56,795	10,256
KP	70	162	374	28,024	4,873
Golden Wonder	87	9	62	837	89
Asda	88	8	78	1,216	83
Other	53	286	409	54,220	6,992

Willingness to pay for reduction in nutrient score

- Advertising affects willingness to pay:

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

- Increases or decreases with $\mathbf{a_{ibt}}$ depending on the sign of

$$\psi_{1i}\alpha_{0i} - \psi_{0i}\alpha_{1i}$$

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
- Estimation is innocuous to product entry and exit firm optimization

Profit

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

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

where

$$\mathbf{a}_{bt} = f(e_{bt}, e_{bt-1}, e_{bt-2}, \ldots, e_{b0})$$

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

Price first order conditions

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

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

- ... we can identify marginal costs without solving for the value function
- Optimality conditions of advertising decisions 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)

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

where

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

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

- Can check exit decisions for all possible assortments

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

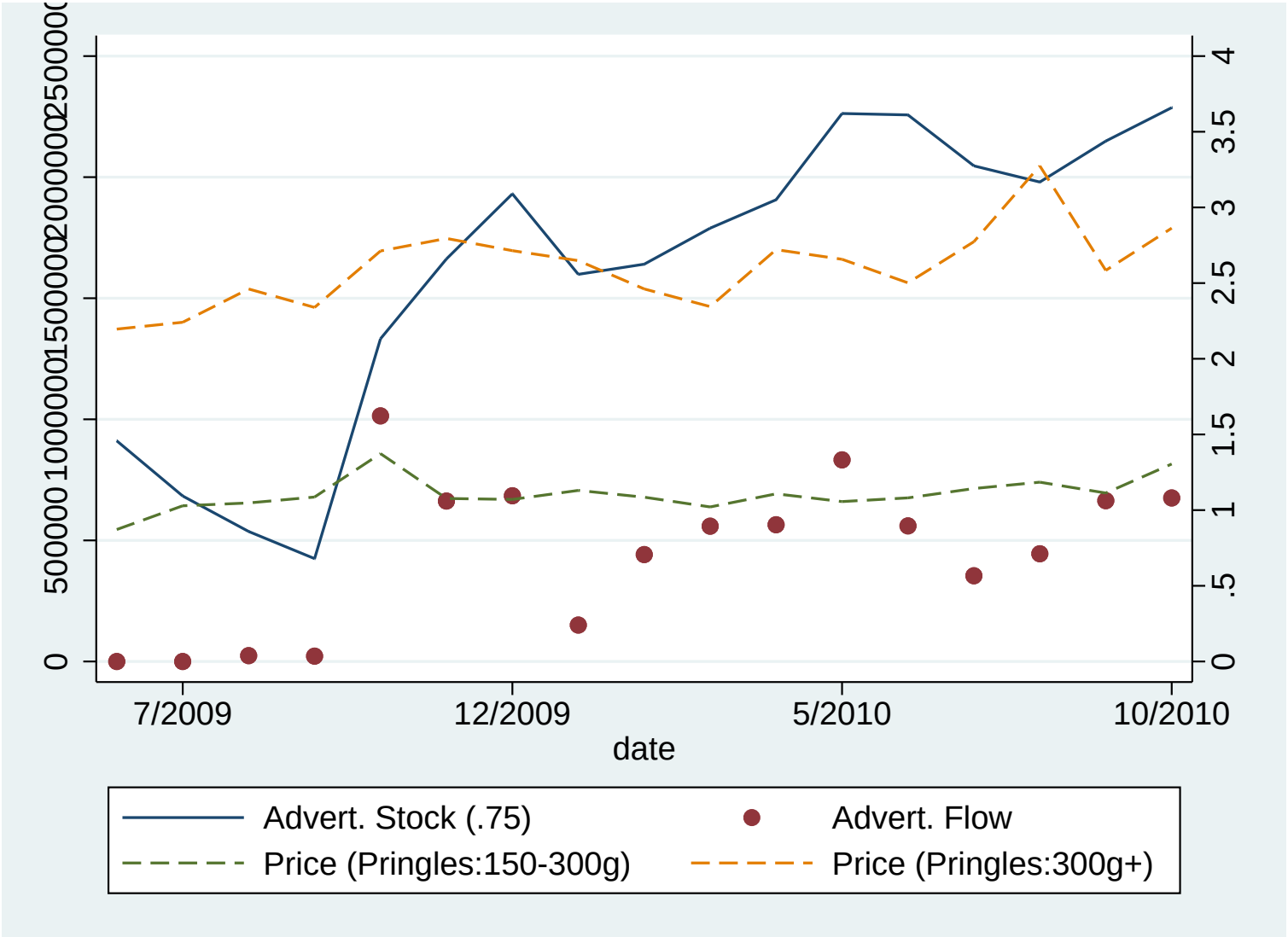
Brand	Nutrient score	Energy (kj per 100g)	Saturated fat (g per 100g)	Sodium (g per 100g)
Pringles	16	2160	6.31	0.62
Walkers Reg	10	2164	2.56	0.59
Walkers Sens	11	2023	2.16	0.71
Walkers Dor	12	2095	2.86	0.66
Walkers Oth	15	2020	2.50	0.82
KP	18	2158	5.87	0.85
GW	16	2101	4.01	0.92
Asda	15	2125	4.13	0.75
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)

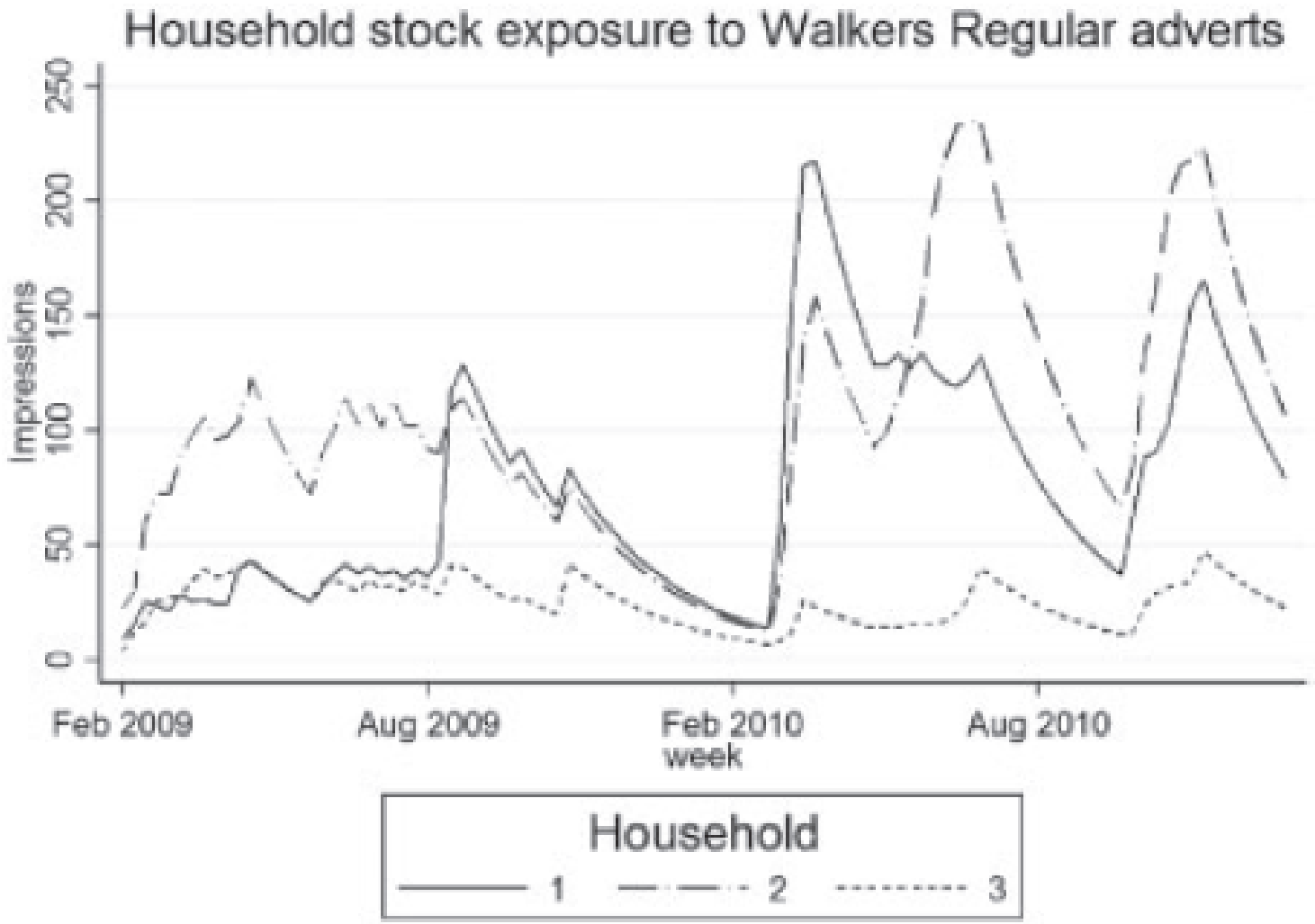
Advertising Expenditures

	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

Advertising Stocks, Flows and Prices



Consumer variation of advertising exposure



Advertising effects on brand demand

% 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	**-2.77**	**1.39**	**0.63**
	[-4.30, -1.44]	[1.06, 1.72]	[0.50, 0.76]
Pringles	**3.43**	**-19.53**	**0.25**
	[2.78, 4.10]	[-21.54, -17.97]	[0.11, 0.39]
KP	**-0.35**	**0.03**	**-2.63**
	[-0.81, 0.11]	[-0.35, 0.39]	[-3.36, -1.99]
...	...	...	...
	-1.15	-1.10	-0.42
	[-1.46, -0.85]	[-1.41, -0.79]	[-0.53, -0.31]

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

Effect of advertising on own price elasticities

	Walkers Regular		Pringles		KP	
	Obs. advert. exp.	Zero advert. exp.	Obs. advert. exp.	Zero advert. exp.	Obs. advert. exp.	Zero advert. exp.
<150g					-1.33	-1.37
					[-1.38, -1.29]	[-1.42, -1.32]
150-300g	-1.49	-1.62	-1.40	-1.53	-1.68	-1.74
	[-1.57, -1.44]	[-1.69, -1.57]	[-1.46, -1.35]	[-1.60, -1.49]	[-1.75, -1.63]	[-1.80, -1.68]
300g+	-2.20	-2.54	-2.37	-2.74	-2.77	-2.88
	[-2.32, -2.10]	[-2.67, -2.44]	[-2.51, -2.26]	[-2.88, -2.64]	[-2.89, -2.67]	[-3.01, -2.79]

Willingness to pay for one point reduction in nutrient score

Advertising:	None	Medium	High
Food at home			
Willingness to pay in pence	5.3	3.5	0.6
	[4.7, 5.8]	[3.0, 3.9]	[-0.4, 1.6]
% of mean price	2.5	1.7	0.3
	[2.3, 2.8]	[1.5, 1.9]	[-0.2, 0.8]
Food on-the-go			
Willingness to pay in pence	0.9	0.0	-0.8
	[0.7, 1.1]	[-0.2, 0.1]	[-0.9, -0.5]
% of mean price	1.7	-0.1	-1.5
	[1.3, 2.1]	[-0.4, 0.3]	[-1.8, -1.0]

Numbers are median WTP in pence.

Counterfactual 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
  - The big advertisers (e.g. Walkers and Pringles) lower prices
  - For instance, Walkers reduces price of its most popular brand by the most, 34p (or 28%) reduction for the 150-300g pack, and 56p (or 20%) for the 300g+ pack
- Besides advertising ban, no products exit the market (keeping all products is a Nash equilibrium)

Counterfactual advertising ban: Effect on quantities/expenses

Effect of advertising ban on purchases

	Pre ban	Advertising banned	
		No price response	With price response
Expenditure (£m)	100.85	85.62	87.11
	[99.78, 101.91]	[82.44, 88.26]	[84.25, 89.77]
% change		−15.10	−13.62
		[−17.83, −12.67]	[−16.18, −11.18]
Quantity (mKg)	14.80	12.55	13.36
	[14.64, 14.98]	[12.05, 12.97]	[12.96, 13.71]
% change		−15.24	−9.72
		[−17.93, −12.61]	[−11.83, −7.40]

Counterfactual advertising ban: Effect on nutrients

Effect of advertising ban on nutrient purchases

	Pre ban	Advertising banned	
		No price response	With price response
Energy	313.70 [310.22, 316.37]	265.94 [256.46, 274.18]	283.23 [274.70, 290.29]
% change		−15.23 [−17.33, −12.55]	−9.71 [−11.45, −7.18]
Saturates	584.79 [576.73, 589.84]	489.78 [472.66, 506.86]	515.24 [498.46, 528.92]
% change		−16.25 [−18.05, −13.56]	−11.89 [−13.57, −9.66]
Salt	264.94 [261.89, 266.95]	224.18 [216.29, 231.02]	237.67 [230.45, 243.13]
% change		−15.38 [−17.41, −12.78]	−10.29 [−12.01, −7.84]
Nutrient score	13.78 [13.74, 13.80]	13.72 [13.66, 13.74]	13.62 [13.56, 13.65]
% change		−0.46 [−0.83, −0.13]	−1.19 [−1.55, −0.92]
Saturates intensity	3.95 [3.93, 3.97]	3.90 [3.87, 3.92]	3.85 [3.83, 3.87]
% change		−1.19 [−1.73, −0.72]	−2.41 [−2.90, −2.03]
Salt intensity	1.79 [1.79, 1.79]	1.79 [1.78, 1.79]	1.78 [1.77, 1.78]
% change		−0.17 [−0.37, 0.01]	−0.63 [−0.83, −0.48]

Consumer welfare

- But what about welfare?
- Consumers may be hurt by advertising ban
- 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)

Consumer welfare: advertising as a characteristic

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

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

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

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:

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

Consumer welfare: advertising distorts decisions

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

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

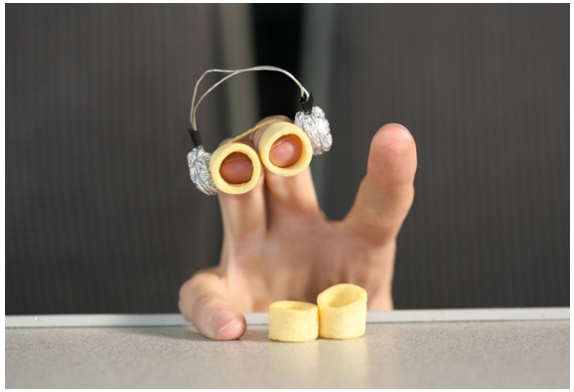
Consumer welfare: advertising distorts decisions

- Denote $\mathbf{p}^0$ a counterfactual price equilibrium with no advertising
- Welfare difference between the post and pre advertising ban is:

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

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

Typical Junk Food Advertising



Welfare Effects

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 [3.1, 4.3]	3.7 [3.1, 4.3]
Total compensating variation (£m)	18.7 [17.7, 20.4]	−19.5 [−21.3, −16.7]
Change in profits (£m)	−5.1 [−6.0, −3.7]	−5.1 [−6.0, −3.7]
Total change in welfare (£m)	13.6 [12.7, 15.1]	−24.6 [−27.0, −20.4]

Conclusion and research directions

- Substitution to healthier products with advertising ban (higher WTP)
- At constant prices, quantity of potato chips purchased would decrease
- But stronger price competition leads to lower prices and lower reduction in quantity consumed and total calories but not significant changes in salt or saturated fat
- If advertising is viewed as distorting prices, total welfare would rise
- Dynamic effects of policies such as a soda tax need to solve fully for firms' equilibrium policy functions
- Most soda tax papers are static simulations
- How would firms adjust their price and advertising strategies in response to introduction of a nutrient tax? an advertising tax?