A Tax is a Signal: Theory and Evidence

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Introduction: why the UK sugar tax

- "The evidence for action": Public Health England (October 2015)
  - *"We are eating too much sugar and it is bad for our health.*
    - *Consumption of sugar and sugar sweetened drinks is particularly high in school age children.*
  - *Almost 25% of adults, 10% of 4 to 5 year olds and 19% of 10 to 11 year olds in England are obese, with significant numbers also being overweight.*
  - *Treating obesity and its consequences currently costs the National Health Service £5.1bn every year."*

- On March 2016, the UK Government announced a tax on sweetened drinks.

Conceptual framework

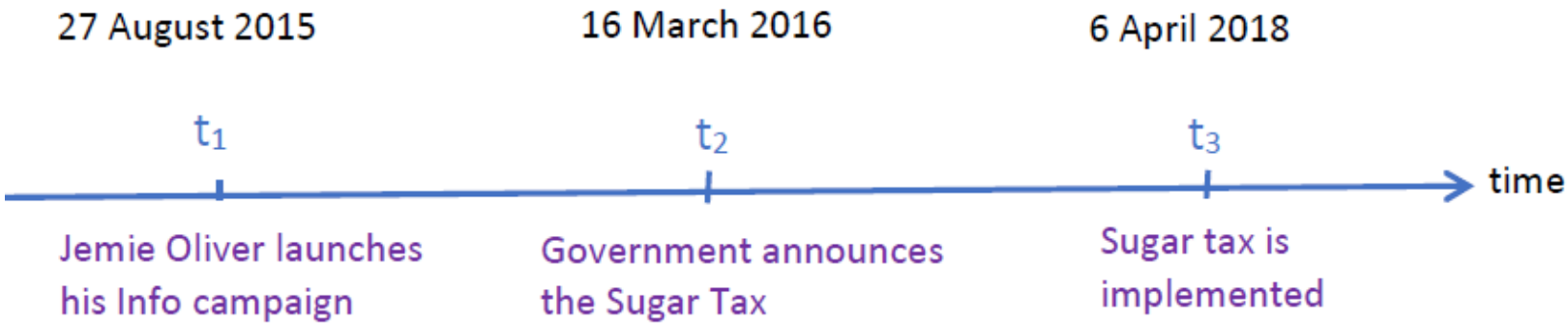
- We study the information content of a tax policy.
- Health damages of unhealthy goods are often misperceived by consumers;
  - i.e. sugar-sweetened beverages, junk food, alcohol, tobacco, etc.
- Governments have access to more precise information (i.e. via experts' knowledge) than consumers.
- *Negative externalities* (e.g. the cost to the NHS) coexist with negative internalities.
- Governments set taxes to curb consumption of unhealthy goods.
- A tax affects:
  1. *consumption price*;
  2. *tax revenue* (relevant for government);
  3. *consumers' beliefs* on health damages *via* a signaling mechanism.

Research questions

- Can tax policies convey information to consumers? If yes, how effective are they in providing information?
- Theoretical model studying consumer's Bayesian updating.
- The model's predictions are tested using the UK sugar tax and GB Kantar Fast Moving Consumer Good panel data on individual transactions and a DID specification:
  - exploit the *announcement* of the two-tiered structure of the UK tax:
    - tax free if sugar content $< 5g/100ml$;
    - tax of £0.18/liter if sugar content $\in [5g, 8g]/100ml$;
    - tax of £0.24/liter if sugar content $> 8g/100ml$.

Time line

- Tax is announced after an information campaign against sugar-sweetened beverages.



- The tax is announced two years before its implementation to encourage producers' *reformulation* (reduction of soft drinks' sugar content).

Theory

- **Two sequential "influence games."**
  - Informed agents $\longrightarrow$ 2 senders (S1=Jamie Oliver; S2=Government).
  - Representative consumer $\longrightarrow$ receiver; she chooses soft drinks quantity in each period.

1. **Information campaign**: in period 1, S1 informs *on the detrimental effects of sugar-added soft-drinks.*
   - Cheap talk model. The consumer updates beliefs on sugar's side effects and makes her choice.
   - Results: partial information transmission is possible.
2. **Tax policy**: S2 announces sugar tax in period 2 and implements it in period 3.
   - Signaling game. Consumer (further) updates beliefs and makes her choice in period 2 and in period 3. Price effect $\longrightarrow$ period 3.
   - Result: accurate information transmission.

#SugarRush

- *Jamie Oliver: "Health experts say sugar in soft drinks is as dangerous as alcohol and tobacco."*
  This is cheap talk.

Results and tested implications

- Compare consumption before and after info campaign and tax announcement.

1. **Information campaign** may provide partial information:
   - sugar intake from drinks may fall;
   - together with the purchased volumes of sugary drinks (no identifiable pattern across the not-yet-announced tax rates).
2. Subsequent *announcement* of the two-tiered structure of the **tax policy** provides more accurate information:
   - sugar intake from drinks (further) falls;
   - consumption of soft drinks announced to enter the high tax rate decreased relatively more than consumption of soft drinks announced to enter the low tax rate;
   - consumption of soft drinks exempted from the tax did not respond to the tax announcement.

Related literature

- Theory:
  - Cheap Talk: Crawford and Sobel (1982).
  - Signaling: Mailath (1987); Barigozzi and Villeneuve (2006).
- Evidence on sin taxes:
  - firms' reactions to sin taxes (i.e. price passthrough): Bonnet and Requillart (2013);
  - consumers' reaction to sin taxes: Dubois et al. (2020); Capacci et al. (2020);
  - rational addiction and sin taxes: Gruber and Koszegi (2001);
  - non-pecuniary effects of sin taxes: Cornelsen et al. (2017); Taylor et al. (2019); Ahn and Lusk (2020); Rees-Jones and Rozema (2022);
    - possibly generated by reactance, *social norms*, and *information* (no theoretical models describing the last two mechanisms).
    - Evidence: non-pecuniary effects might exist, but the size and the direction of the effect is ambiguous.

Theoretical model: the representative consumer

- Two soft-drinks whose quantities are y and z.
- The representative consumer's utility is:

$$V(y, z, g; \theta, \eta) = u(y, z) - \eta\bar{x} - \theta x + g$$

where:

  - x is total sugar intake from soft-drinks y and z;
  - $\bar{x}$ is average sugar intake in the population ($\bar{x} = x$)
  - $\eta\bar{x}$ is the negative externality
  - θx is side effect of sugar; $\theta \in [\underline{\theta}, \overline{\theta}]$; $\theta \sim f$
  - g is a numeraire good.

- Budget constraint: $I = p_y y + p_z z + g$
  - p_y; p_z unit prices of the two soft-drinks.

The representative consumer: reduced form

- Substituting the budget constraint:

$$V(y,z;\theta,\eta) = u(y,z) - (\theta+\eta)(\underbrace{ay+bz}_{x}),$$

where:

  - x is total sugar intake from soft-drinks y and z;
  - $a < b$ are sugar contained in from soft drinks y, z;
  - $p_y = p_z = 0$

- Representative consumer solves:

$$\max_{y,z} \quad U(y,z;f) = u(y,z) - E_f[\theta](\underbrace{ay+bz}_{x})$$

  - **consumer observes the distribution of** θ, not its realization: $E_f[\theta]$ = **consumer's prior**;
  - consumer neglects the externality.

Information campaign (period 1)

- Sender1=$S1$; message $= m \in [\underline{\theta}, \overline{\theta}]$. Sender solves:

$$\max_m V^{S1}(y_1, z_1; \theta, \eta) = u(y_1, z_1) - (\theta + \eta)(\underbrace{ay_1 + bz_1}_{x_1}),$$

message m **possibly affects** V^{S1} **indirectly via** x_1.

- Consumer is the receiver and solves:

$$\max_{y_1, z_1} U(y_1, z_1; f|_m) = u(y_1, z_1) - E_{f|m}[\theta](ay_1 + bz_1).$$

- $E_{f|m}[\theta]$ expected value of θ after info campaign.
- $\eta =$ disalignment sender-receiver (Crawford and Sobel, 1982):
  - S1 care for the externality, the consumer does not;
  - standard cheap-talk model: **some information transmission is possible** (if η sufficiently low).

Tax announcement/implementation (periods 2 and 3)

- Suppose sugar contents are such that a tax τ_z will be imposed on z, while y will not be taxed.
- After tax announcement, in period 2, consumer solves:

$$\max_{y_2,z_2} \quad U(y_2,z_2;f|m,\tau_z) = u(y_2,z_2) - E_{f|m,\tau}[\theta](\underbrace{ay_2+bz_2}_{x_2})$$

  - where $E_{f|m,\tau}[\theta]$ is expected value of θ after the tax announcement.
- In period 3, consumer solves:

$$\max_{y_3,z_3} \quad U(y_3,z_3;f|m,\tau_z,\tau_z) = u(y_3,z_3) - E_{f|m,\tau}[\theta](\underbrace{ay_3+bz_3}_{x_3}) - \tau_z z_3.$$

Tax announcement/implementation (con't)

- At the beginning of period 2, Sender2= $S2$ (government) chooses the optimal tax on z by anticipating consumer's consumption choices.
- Government solves:

$$\max_{\tau_z} V^{S2} = \underbrace{u(y_2, z_2) - (\theta + \eta)(ay_2 + bz_2)}_{\text{tax announced } (t_2)} +$$

$$\underbrace{\delta[\underbrace{u(y_3, z_3) - (\theta + \eta)(ay_3 + bz_3) - \tau_z z_3}_{\text{Consumer's}} + \underbrace{(1 + \lambda)\tau_z z_3}_{\text{tax revenue}}]}_{\text{tax implemented } (t_3)}$$

where δ is the discount factor.

- Gov likes taxes: $\lambda \in (0, 1)$.
- Tax τ_z **affects** V^{S2} **indirectly in period 2 and directly in period 3**.

Tax announcement/implementation (cont'd)

- Government solves:

$$\max_{\tau_z} V^{S2} = \underbrace{u(y_2, z_2) - (\theta + \eta)(ay_2 + bz_2)}_{\text{tax announced } (t_2)} + \underbrace{\delta\left[u(y_3, z_3) - (\theta + \eta)(ay_3 + bz_3) + \lambda\tau_z z_3\right]}_{\text{tax implemented } (t_3)}$$

- Government cares about externality AND tax revenue
- Optimal tax depends on θ : **the tax can be a signal**.

Taxes and propaganda

- Recall that the *tax internalizes the externality, generates tax revenue AND informs consumer*.
- Government has incentive to misreport side effect θ.
- Two opposing forces at play:
  - optimistic message on side effects $\theta \Rightarrow$ small reduction of consumption $\Rightarrow$ tax revenue $\uparrow$
  - pessimistic message on side effects $\theta \Rightarrow$ large reduction of consumption $\Rightarrow$ negative externality internalized.

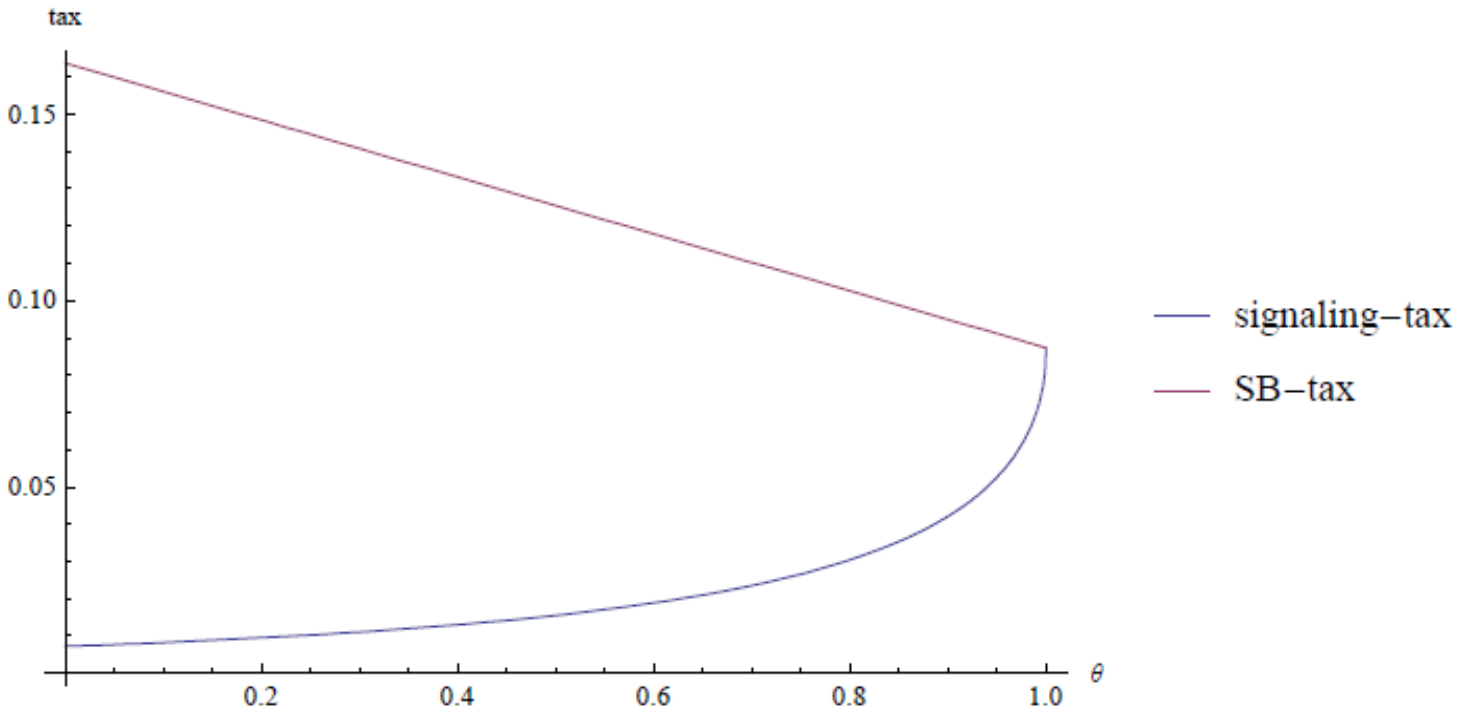
- **Single-crossing condition** holds: a **fully revealing tax** exists.
  - to be credible, the tax is distorted w.r.t. τ_z^{SB}.

Fully revealing tax

- The tax is fully informative on θ.
- The fully revealing tax **when no externality exists** ($\eta = 0$) is the solution to:

$$\tau_z^{*\prime}(\theta) = \frac{(\beta - \alpha\gamma)\frac{1+\lambda}{1+2\lambda}\tau_z^*(\theta)}{\tau_z^{SB}(\theta) - \tau_z^*(\theta)}$$

  - with boundary condition $\tau_z^*(\bar{\theta}) = \tau_z^{SB}(\bar{\theta})$.



Results and testable implications

- Compare effects on consumption of y and z generated by the info campaign and the tax announcement.

1. **Information campaign** may provide some information:
   - sugar intake, x, may fall in period 1.
2. Subsequent *announcement* of the two-tiered structure of the **tax policy** provides (additional) information:
   - in period 2, consumer learns that y will be exempted from the tax while z will be taxed.
   - sugar intake, x, (further) falls in period 2.

Empirical analysis: Data

- Kantar GB *Fast Moving Consumer Goods* panel; 36,000 GB households per year, 2015-2016 (about 30,000 did not rotate)
- Top quartile (7,500 non-rotating households) of taxed drinks' purchasers before tax announcement (about 1.90 litres per week).

		All households		Heavy purchasers 1st quartile SSB $>$ 5 g/100ml	
	Unit	Mean	(S.D.)	Mean	(S.D.)
Number of households		36,089		7,571	
Age of the main shopper	Years	49.41	(15.34)	48.48	(13.46)
Household size		2.72	(1.32)	3.20	(1.38)
Number of children		0.63	(0.96)	0.83	(1.09)
Household income	,000 £per year	32.35	(19.51)	32.75	(18.86)
Body Mass Index		22.18	(11.13)	22.31	(11.91)
Food expenditure	£per week	43.20	(23.20)	52.47	(26.01)
Expenditure in non-alcoholic drinks	£per week	1.87	(2.00)	3.90	(2.83)
Total quantity of non-alcoholic drinks purchased	liters per week	2.93	(3.22)	5.68	(4.37)
Sugar content of total food and drink purchases	grams per day	180.02	(106.54)	248.38	(130.53)
Sugar content of drink purchases only	grams per day	13.30	(19.80)	39.40	(28.94)
Average price of soft drinks	£per liter	0.99	(0.23)	0.99	(0.70)

Identification

- Panel difference-in-differences

$$y_{ict} = \mu_{ic} + \eta_t + \boxed{\beta_c A_{ct}} + \psi \mathbf{X}_{ict} + \epsilon_{ict}$$

y_{ict} is volume of (tax) category c purchased by household i on week t;
$A_{ct} \in \{0, 1\}$ 1 purchase of of (tax) category c after announcement;
$\mathbf{X}_{ict}$ covariates (stock, price, non-drink expenditure);

- "Trick" to estimate the effect on total sugar intakes:
  - Total sugar content of SSBs "factual" vs. total volumes "counterfactual"
  - Apply pre-announcement average sugar content per liter ()same scale/measurement unit)
  - Constant average sugar content per liter of purchased drink $\longrightarrow$ parallel trends
  - Reduced sugar intakes (substitutions) $\longrightarrow$ intake and volumes "depart"

Results (1)

Table: Announcement effects, without and with sample selection correction

	Jamie O (1)	Gov (2)	Jamie O (3)	Gov (4)
x - Total sugar intake (g/week) × announcement	-20.678	-15.493	-22.630	-16.474
	(2.253)	(2.081)	(3.337)	(3.052)
y - (SSBs < 5g / 100ml) × announcement (1)	-0.140	0.038	-0.134	0.015
	(0.026)	(0.025)	(0.078)	(0.075)
z - Taxed SSBs (> 5g / 100ml) × announcement (2)	-0.136	-0.174	-0.097	-0.303
	(0.019)	(0.018)	(0.067)	(0.066)
Number of households	7,571	7,423	7,571	7,423
Time FE	Yes	Yes	Yes	Yes
Household-Tax category FE	Yes	Yes	Yes	Yes
Sample selection correction	No	No	Yes	Yes
t-statistics on treatment coefficients, H0: effect on non-taxed SSBs = effect on taxed SSBs				
(1) = (2)	0.02	89.34	0.28	36.84

Notes: Robust standard errors clustered by household and drink category in brackets.

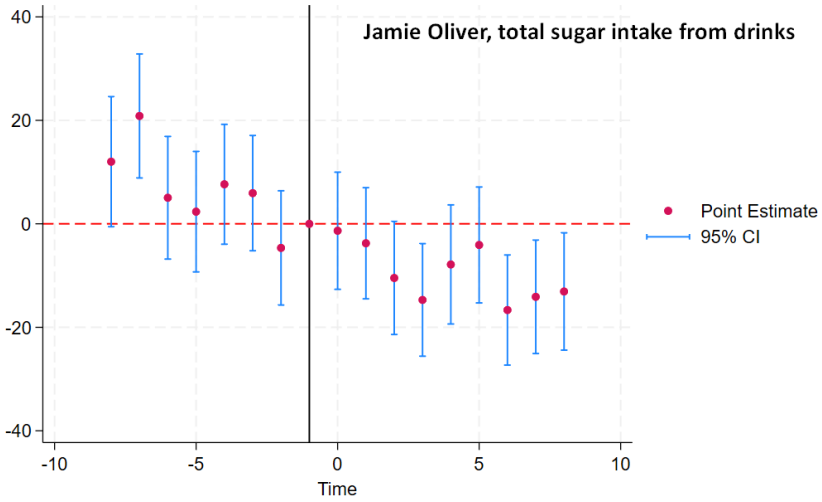
Results (2): tax rates

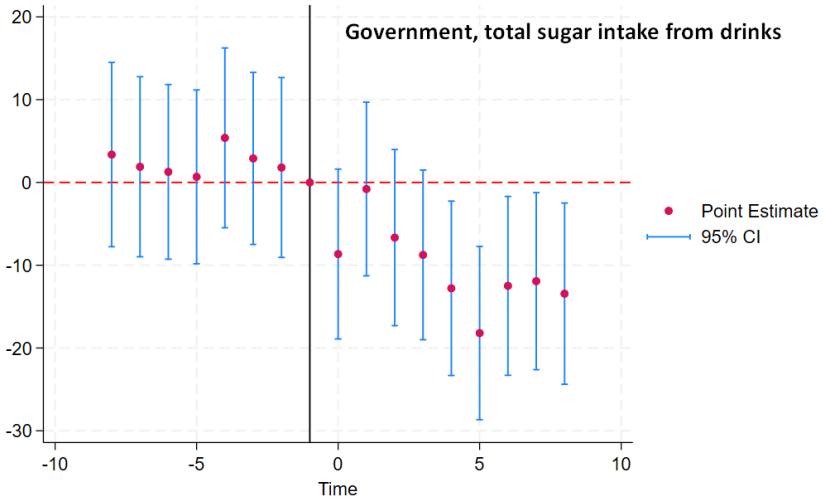
Table: Announcement effects, without and with sample selection correction

	Jamie O (1)	Gov (2)	Jamie O (3)	Gov (4)
(SSBs $<$ 5g / 100ml) $\times$ announcement (1)	-0.140	0.038	-0.134	0.015
	(0.026)	(0.025)	(0.078)	(0.075)
(SSBs 5-8g / 100ml) $\times$ announcement (2)	0.027	-0.102	0.057	-0.219
	(0.018)	(0.017)	(0.079)	(0.075)
(SSBs $>$ 8g / 100ml) $\times$ announcement (3)	-0.274	-0.233	-0.131	-0.321
	(0.024)	(0.022)	(0.071)	(0.069)
Number of households	7,571	7,423	7,571	7,423
Time FE	Yes	Yes	Yes	Yes
Household-Tax category FE	Yes	Yes	Yes	Yes
Sample selection correction	No	No	Yes	Yes
t-statistics on treatment coefficients, H0: effect on non-taxed SSBs = high tier tax SSBs				
(1) = (3)	22.89	106.24	0.01	35.49

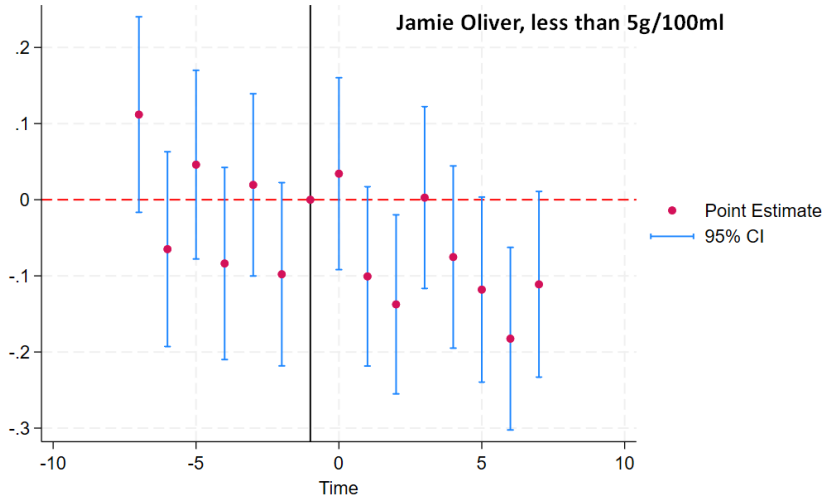
Notes: Robust standard errors clustered by household and drink category in brackets.

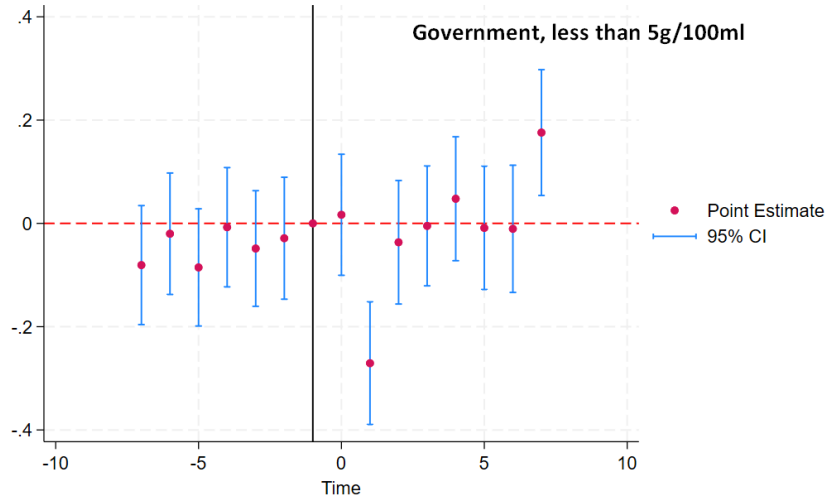
Pre-existing trends: sugar intake

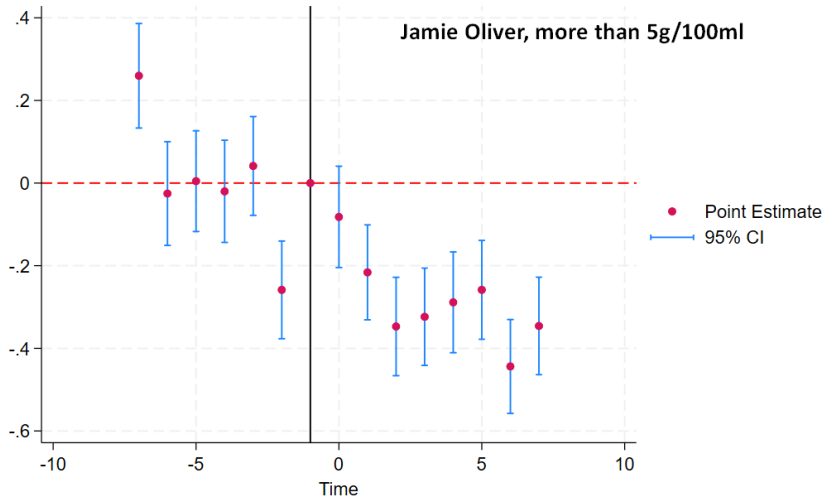


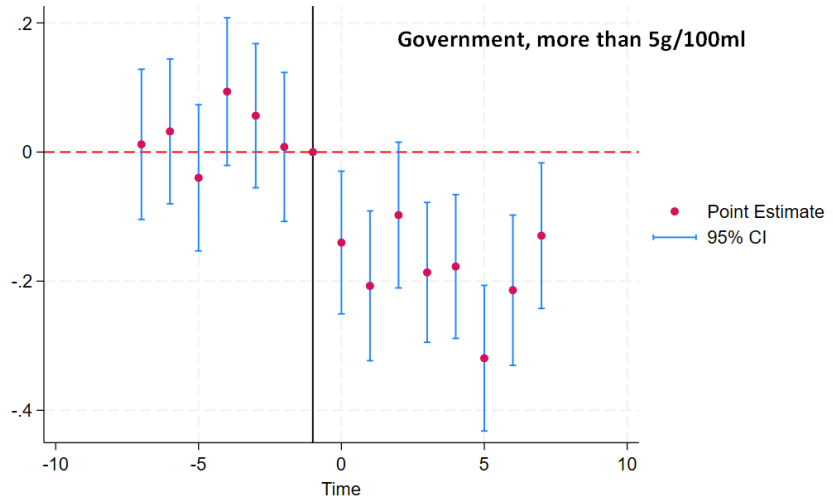


Pre-existing trends: volumes









Conclusion

- Theory: a **tax** is an effective signal and provides more accurate information than an **information campaign**.
- Empirical analysis:
  - after being exposed to the information campaign, consumers (further) react to the tax announcement;
  - consumption of soft drinks announced to enter the high tax rate decreased relatively more than consumption of soft drinks announced to enter the low tax rate;
  - consumption of soft drinks exempted from the tax did not respond to the tax announcement.

Post implementation

- The UK sugar tax is widely regarded as a success.
  - The total sugar sold in softdrinks by retailers and manufacturers decreased by 35.4% between 2015 and 2019, from 135,500 tonnes to 87,600 tonnes.
  - Over the same period, the sales-weighted average sugarcontent of soft drinks declined by 43.7%, from 5.7g/100ml to 2.2g/100ml.
  - Almost 1/5 of drinks above the 5g/100ml threshold when the levy was announced had dropped below it by 50 days before implementation.
  - Prices for high-tax (un-reformulated) drinks have increased, with studies reporting a range of pass-through rates from 31% (7.5p/litre) to 140% (33.6p/litre).
  - Some big brands like Coca-Colahave confirmed they have reduced product sizes for their highest-sugar products.
  - Excess weight and obesity in the UK have continued to increase, with latest figures showing 64% of adults in England are overweight or obese.

Figures post implementation