Design of optimal corrective taxes in the alcohol market

Rachel Griffith, Martin O'Connell and Kate Smith

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Motivation

- Taxes can improve welfare when consumption creates negative externalities
- Pigou (1920): If the marginal externality each consumer creates is constant and equal across each unit consumed, tax can fully correct for the externality
- However marginal externalities will often vary
  - externalities may be nonlinear in quantity consumed
  - conditional on quantity, some people may be more prone to engage in socially costly behaviour

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Motivation

- Diamond (1973) considers case of heterogeneous marginal externalities and a homogeneous good
    - a linear tax can no longer achieve the first best
    - optimal policy sets tax rate equal to weighted average marginal externality
- In this paper we:
    - consider optimal corrective taxes when consumers are potentially heterogeneous in their tastes for different products, their price responsiveness and their marginal externalities, and where the externality generating commodity is available in many products
    - and apply the framework empirically in the UK alcohol market

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Summary: Corrective taxes with heterogeneous consumers and products

- We characterise optimal taxes when the externality generating characteristic (ethanol) is available in many products
  - varying tax rates across products can improve welfare relative to a single ethanol tax rate
- This is the case if consumer responses (their product level demand curves) are correlated with the marginal externality that their ethanol consumption generates:
  - higher tax rates on alcohol products disproportionately consumed by high marginal externality consumers...
  - ... allows the planner to specifically target high externality generating consumption

Summary: Empirical application

- We show that these theoretical results have empirical relevance when applied to the UK market for alcoholic drinks
- We estimate a flexible model of demand in the alcohol market using detailed longitudinal data
  - consistently heavy drinkers systematically purchase a different mix of products to lighter drinkers
  - they are also more willing to switch between alcohol products in response to price changes
- Optimally set alcohol taxes can result in substantial welfare gains relative to the current system
  - moving to an optimally set tax system that differentiates rates across products closes half of the welfare gap between the current UK system and first best tax system

Outline

1. Motivation and contribution
2. Theoretical framework for corrective tax design
3. Application to the UK alcohol market
   - flexible demand model and estimates
   - specification of the externality function
4. Optimal tax results
5. Summary and conclusions

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Consumer demand

Consumer indirect utility:

$$V_i(y_i, \mathbf{p}_i, \mathbf{z}, \mathbf{x}) = \alpha_i y_i + v_i(\mathbf{p}_i, \mathbf{z}, \mathbf{x})$$

- i consumers; j alcohol products
- y_i income; α_i marginal utility of income
- $\mathbf{p}_i = (p_{i1}, \ldots, p_{iJ})'$ post-tax prices
- z_j ethanol (pure alcohol); $\mathbf{x}_j$ other characteristics

Yields demand functions:

$$q_{ij} = f_{ij}(\mathbf{p}_i, \mathbf{z}, \mathbf{x})$$

which we collect in a vector, $\mathbf{q}_i = (q_{i1}, \ldots, q_{iJ})'$

External costs of alcohol consumption

- Alcohol consumption generates costs that are not considered by the individual when making their consumption decision e.g. health care costs, crime costs

- We specify the external cost from consumption as a function of derived ethanol demand $Z_i = \sum_j z_j q_{ij}$ ▸ Evidence

- The external cost associated with consumer i's ethanol consumption is $\phi_i(Z_i)$, and total external costs are $\Phi = \sum_i \phi_i(Z_i)$

- Consumers ignore the externality when making choices; the goal of the planner is to use taxes to get consumers to internalise the externality

Social planner's problem

- The social planner sets tax rates, $\boldsymbol{\tau}$, levied per unit of ethanol
- The planner trades off the benefits of minimising social costs against the reduction in consumer surplus (net of tax revenue) that arises due to the higher prices
- The planner chooses $\boldsymbol{\tau}$ to maximise:

$$\max_{\boldsymbol{\tau}} W(\boldsymbol{\tau}) = \underbrace{\sum_i \left[y_i + \frac{v_i(\boldsymbol{\tau})}{\alpha_i} \right]}_{\text{consumer surplus}} + \underbrace{R(\boldsymbol{\tau})}_{\text{tax revenue}} - \underbrace{\Phi(\boldsymbol{\tau})}_{\text{external costs}}$$

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Optimal tax policies

First best: consumer specific taxes

- Optimal is to set tax rates that are equal to marginal externalities

$$\tau_i^* = \phi_i'$$

which achieves first best (Pigou, 1920)

Single ethanol tax rate

- If constrained to a single rate the optimal rate is:

$$\tau^* = \underbrace{\bar{\phi}'}_{\text{Average marginal externality}} + \underbrace{\frac{\text{cov}(\phi_i', |Z_i|))}{|\bar{Z}'|}}_{\text{covariance of the marginal externality and slope of ethanol demands}}$$

where $Z_i' = \sum_j z_j \frac{\partial q_{ij}}{\partial \tau}$ (Diamond, 1973)

Differentiated tax rates

- If the planner can set differentiated tax rates, the optimal rates will solve the first order conditions for each τ_j

$$\sum_i \sum_k \left[(\tau_k - \phi_i') z_k \frac{\partial q_{ik}}{\partial \tau_j} \right] = 0$$

- All else equal the tax rate on a product will:

    1. be higher if it has relatively high demand among high marginal externality consumers
    2. be higher the stronger is the correlation between the marginal externality and the own-price elasticity
    3. be lower the stronger is the correlation between the marginal externality and cross slopes of demand

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Data

- We focus on off trade (alcohol purchased in supermarkets and off-licenses) – accounts for 77% of ethanol purchased On trade details
- Data are household scanner data (Kantar Worldpanel)
- Contain transaction level information on purchases of all groceries
- Panel of 10,289 households over 2010-2011
- 2010 is pre-sample; estimate demand on 2011 data

Household categories by pre-sample average ethanol consumption

	Percentage of		Average weekly
Average ethanol (2010):	Households	Total ethanol	Ethanol units (2011)
Less than 7 units	62.5	23.2	2.9
7-14 units	17.9	20.4	9.2
14-21 units	7.9	15.3	15.6
21-35 units	7.2	19.8	19.8
More than 35 units	4.5	21.2	47.1
Total	100.0	100.0	8.6

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Empirical model of alcohol demand

- Two key features of model
  - captures switching across disaggregate alcohol products
  - captures correlation between product level demands with total derived ethanol demand
- We use a discrete choice demand model
  - avoids curse of dimensionality
  - rationalises zero purchases
  - well suited for incorporating rich preference heterogeneity
- Data contain information on over 7000 alcohol UPC
  - we aggregate these to 80 options (40 products available in different sizes) ▸ Beer ▸ Wine ▸ Spirits ▸ Cider

Discrete choice demand

- j product, s size; $(j = 0, s = 0)$ outside option (not purchase)
- Utility household i gets from option (j, s) in period t is:

$$u_{ijst} = \nu(p_{jst}, z_{js}, \mathbf{x}_{jst}; \theta_i) + \epsilon_{ijst}$$

  where ϵ_{ijst} is distributed Type I extreme value

- Households i's demand for option (j, s) is

$$q_{ijst} = \frac{\exp(\nu(p_{jst}, z_{js}, \mathbf{x}_{jst}; \theta_i))}{1 + \sum_{j'>0,s'>0} \exp(\nu(p_{j's't}, z_{j's'}, \mathbf{x}_{j's't}; \theta_i))}$$

- And expected utility is

$$v_{it}(\mathbf{p}_{jt}, \mathbf{z}_{jst}, \mathbf{x}_{jst}) = \ln \sum_{j>0,s>0} \exp\{\nu(p_{jst}, z_{js}, \mathbf{x}_{jst}; \theta_i)\} + C$$

Utility specification

- We model utility household i gets from option (j, s) in period t as

$$\nu(.) = \alpha_i p_{jst} + \beta_i w_j + \sum_{m=1}^{4} 1[j \in \mathcal{M}_m] \cdot (\gamma_{i,1m} z_{js} + \gamma_{i,2m} z_{js}^2) + \xi_{ijt}.$$

p: price, w: strength, z: ethanol and $m = 1, ..., 4$ indexes beer, wine, spirits and cider segments

- Unobserved product characteristic:

$$\xi_{ijt} = \eta_{ij} + \zeta_{k_j t}$$

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Empirical demand model

- We include a set of consumer specific (random) coefficients
  - $(\alpha_i, \beta_i, \gamma_i)$ on observed product attributes
  - $\boldsymbol{\eta}_i$ on unobserved attributes
  - model as mixture of conditional normal distributions
  - conditioning is based on pre sample average ethanol purchases
- We include a set of time effects which vary by alcohol type (gin, vodka, whisky etc) to capture common shocks to demand
- We isolate price variation driven by cost shifters by including a control function based on
  - exchange rates, producer prices, retail wages index and tax rates

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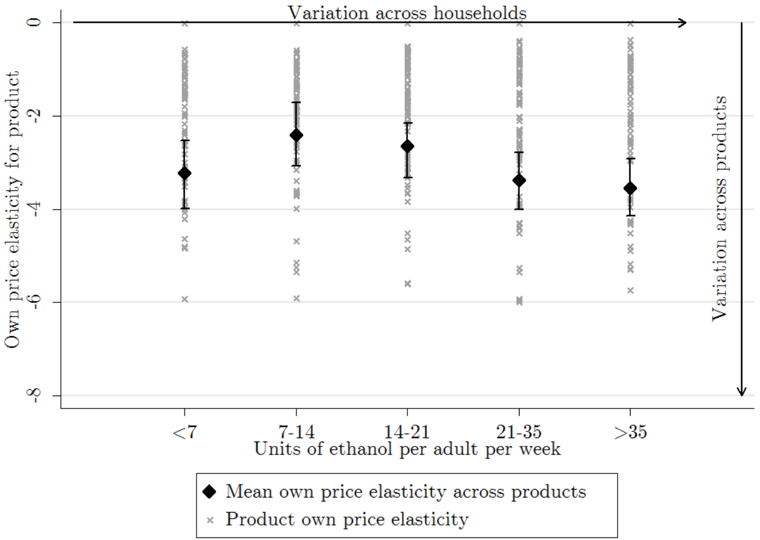
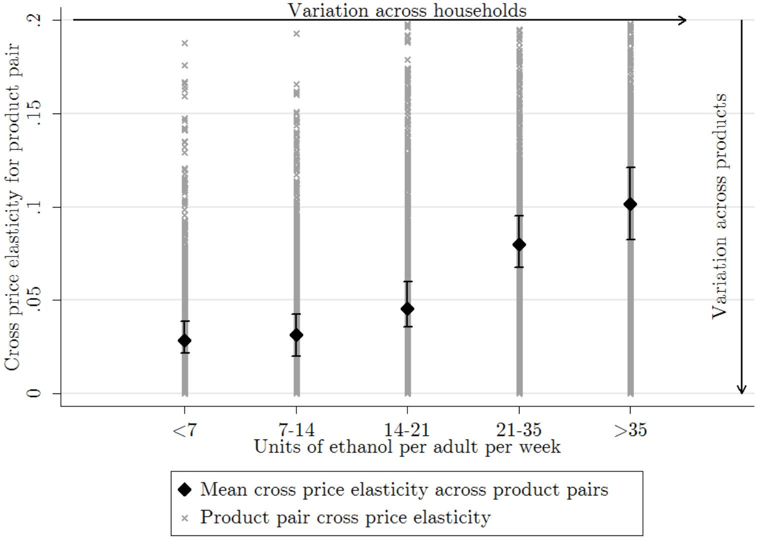
Product own price elasticities



Product cross price elasticities



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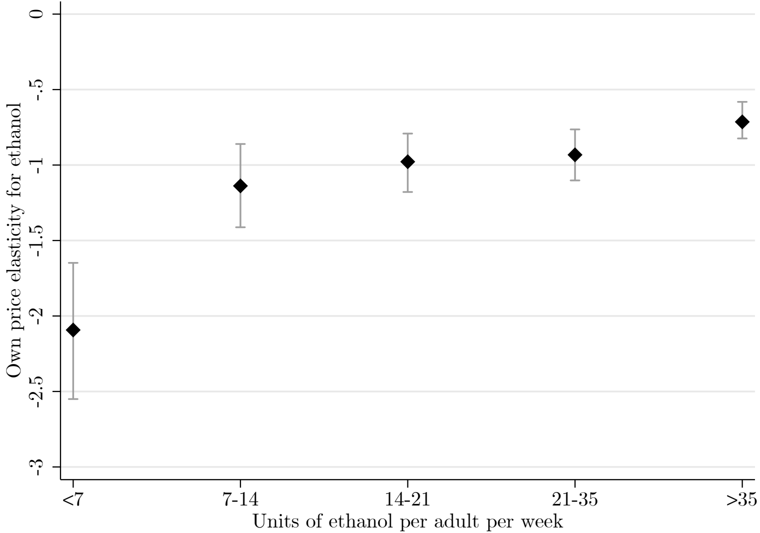
Ethanol own price elasticities



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Externality function

- We assume the externality function takes the form:

$$\phi_i(Z_{it}) = \phi_{0i}(\exp(\phi_{1i} Z_{it}) - 1)$$

$Z_{it} = \sum_j z_j q_{ijt}$ denotes derived ethanol demand

  - Subtracting one from the term in brackets ensures that the external cost of zero ethanol demand is zero
  - ϕ_1 controls the convexity, measured as the ratio of second to first derivatives
  - ϕ_0 governs the aggregate external cost

Externality function

- We calibrate
  - ϕ_0 to match UK government estimate of aggregate external costs (£7.25 billion in 2011)
  - ϕ_1 based on evidence from the literature, such as
    - estimates of an almost 18 times increase in the probability of an accident after consumer 140g rather than 14g of ethanol
    - estimates that external costs for low SES households are almost 40% higher than for high SES households
- Importantly, we show how results vary with different calibrations of aggregate external costs (ϕ_0) and degree of convexity (ϕ_1) Details

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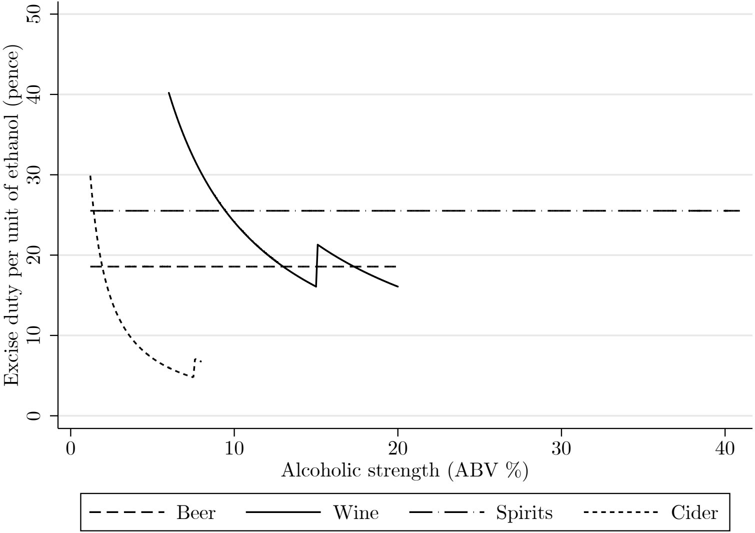
UK Alcohol Taxes



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Tax regimes

- We consider three possible tax regimes

1. **Consumer specific taxes**: planner can set a separate per ethanol tax rate for each individual, achieves first best (Pigou)
2. **Single ethanol tax rate**: planner can only set one per ethanol tax rate for all products and all consumers
3. **Differentiated tax rates**: planner can set different per ethanol tax rates across products, but common across consumers
    - we show rates that are allowed to be differentiated across 18 alcohol types (ale, lager, gin, rum, cider, ...)

Effective average ethanol tax rates

- To illustrate we show the effective average ethanol tax rate (EATR) for different types of consumers
  - average tax rate across products and consumers
  - using ethanol share weights
  - show separately for households by 2010 ethanol consumption
  - for the single ethanol tax rate the EATR is equal to the rate and does not vary across households
  - for the consumer specific taxes a household's EATR equals the single tax rate it faces.

Effective average ethanol tax rates

Household mean units (2010):	Effective average ethanol tax rate UK taxes	Single rate	Differentiated rates	Consumer specific taxes
0-7	27.4			
7-14	27.2			
14-21	27.0			
21-35	27.2			
35+	27.2			
All	27.2			

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Effective average ethanol tax rates

	Effective average ethanol tax rate			
Household mean units (2010):	UK taxes	Single rate	Differentiated rates	Consumer specific taxes
0-7	27.4	35.9		
7-14	27.2	35.9		
14-21	27.0	35.9		
21-35	27.2	35.9		
35+	27.2	35.9		
All	27.2	35.9		

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7-14	27.2	35.9	28.9	
14-21	27.0	35.9	29.6	
21-35	27.2	35.9	29.9	
35+	27.2	35.9	31.1	
All	27.2	35.9	29.0	

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Effective average ethanol tax rates

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7-14	27.2	35.9	28.9	24.0
14-21	27.0	35.9	29.6	29.0
21-35	27.2	35.9	29.9	33.4
35+	27.2	35.9	31.1	39.2
All	27.2	35.9	29.0	22.9

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14-21	27.0	35.9	29.6	29.0
21-35	27.2	35.9	29.9	33.4
35+	27.2	35.9	31.1	39.2
All	27.2	35.9	29.0	22.9

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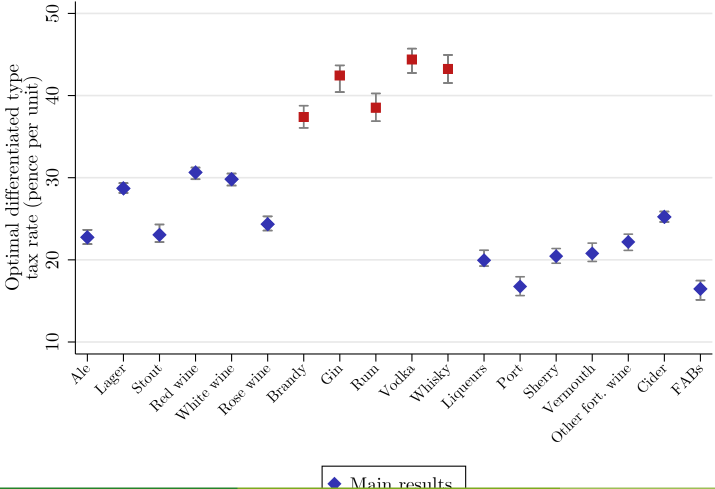
How do Optimal differentiated tax rates vary across products

All else equal the tax rate on a product will:

1. be higher if it has relatively high demand among high marginal externality consumers
2. be higher the stronger is the correlation between the marginal externality and the own-price elasticity
3. be lower the stronger is the correlation between the marginal externality and cross slopes of demand

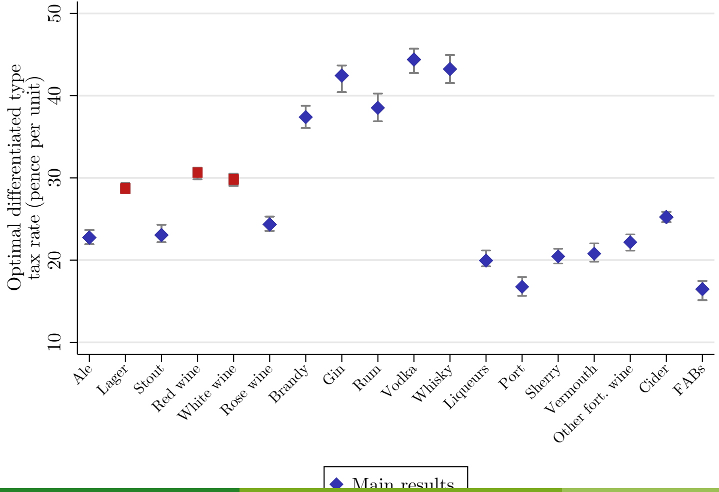
Optimal differentiated tax rates

higher if it has relatively high demand among high marginal externality consumers



Optimal differentiated tax rates

higher the stronger is the correlation between the marginal externality and the own-price elasticity



Welfare impact of tax changes

$billion per year	(1) External cost	(2) Tax revenue	(3) Change in consumer surplus	$(2)+(3)-(1)$ Change in social welfare
UK taxes	7.25	7.16	–	–
Optimal:				
Single rate				
Differentiated type				
First best:				
Consumer specific				

Notes: 95% confidence intervals shown in square brackets.

▸ Across households

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$billion per year	(1) External cost	(2) Tax revenue	(3) Change in consumer surplus	$(2)+(3)-(1)$ Change in social welfare
UK taxes	7.25	7.16	–	–
Optimal:				
Single rate	-2.00 [-2.33, -1.67]	0.31 [0.14, 0.48]	-1.85 [-2.03, -1.65]	0.46 [0.35, 0.56]
Differentiated type				
First best:				
Consumer specific				

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Optimal:				
Single rate	-2.00 [-2.33, -1.67]	0.31 [0.14, 0.48]	-1.85 [-2.03, -1.65]	0.46 [0.35, 0.56]
Differentiated type	-2.15 [-2.44, -1.79]	-0.47 [-0.58, -0.34]	-0.63 [-0.77, -0.47]	1.05 [0.89, 1.20]
First best:				
Consumer specific				

Notes: 95% confidence intervals shown in square brackets.

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Differentiated type	-2.15 [-2.44, -1.79]	-0.47 [-0.58, -0.34]	-0.63 [-0.77, -0.47]	1.05 [0.89, 1.20]
First best:				
Consumer specific	-1.38 [-1.74, -0.86]	0.57 [0.27, 0.85]	0.19 [0.00, 0.31]	2.14 [1.70, 2.39]

Notes: 95% confidence intervals shown in square brackets.

Across households

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Summary and conclusions

- We consider corrective tax design to correct consumption externalities in markets in which
  - Marginal externalities vary across consumers
  - Many products potentially create external costs
- And show these ideas have empirical relevance in the UK alcohol market
  - Moving to an optimal system that differentiates tax rates across alcohol types would close almost half the gap between the UK system and the first best
- The framework we develop is well suited to other applications
  - e.g. sugar taxes in the soda market

Future work

- Incorporating internalities
  - Evidence some consumers face self-control problems - e.g. purchase more sugary drink varieties when bought for immediate consumption
- Supply side considerations
  - Some firms may under- or over-shift tax
  - Question of whether tax policy should weigh externality/internality corrections with imperfect competition

APPENDIX

Dynamics in demand

Reduced form tests for evidence of:

- habit formation:
  - estimate probability of purchasing ethanol, and quantity purchased, as a function of quantity of ethanol previously purchased
  - once we condition on household fixed effects there is only a very weak relationship between past and current purchases
- stocking up:
  - estimate probability purchasing ethanol, and quantity purchased, as a function of constructed inventory variable (following Hendel and Nevo (2006))
  - find a very weak positive relationship between inventory variable and current purchase

Coeffient estimates I

Household group:	< 7	7-14	14-21	21-35	> 35
Panel A: Preferences for observable product characteristics					
Means					
Price	-0.327	-0.258	-0.254	-0.273	-0.283
	(0.039)	(0.028)	(0.025)	(0.023)	(0.024)
Beer*Total ethanol content	0.271	0.268	0.229	0.232	0.238
	(0.022)	(0.016)	(0.014)	(0.014)	(0.014)
Wine*Total ethanol content	0.030	0.036	0.047	0.064	0.107
	(0.025)	(0.017)	(0.015)	(0.014)	(0.013)
Spirits*Total ethanol content	0.336	0.144	0.089	0.049	0.064
	(0.061)	(0.057)	(0.041)	(0.047)	(0.039)
Cider*Total ethanol content	0.224	0.181	0.183	0.208	0.187
	(0.029)	(0.022)	(0.020)	(0.022)	(0.020)
Beer*Total ethanol content^2	-0.339	-0.337	-0.221	-0.201	-0.191
	(0.030)	(0.021)	(0.017)	(0.017)	(0.018)
Wine*Total ethanol content^2	0.056	0.070	0.107	0.121	0.057
	(0.046)	(0.027)	(0.021)	(0.020)	(0.017)
Spirits*Total ethanol content^2	-0.415	-0.108	0.008	0.091	0.095
	(0.085)	(0.080)	(0.056)	(0.063)	(0.051)
Cider*Total ethanol content^2	-0.486	-0.269	-0.263	-0.267	-0.169
	(0.076)	(0.052)	(0.046)	(0.057)	(0.040)

Coeffient estimates II

Household group:	< 7	7-14	14-21	21-35	> 35
Panel A: Preferences for observable product characteristics					
Variances					
Price	0.043	0.047	0.068	0.061	0.053
	(0.009)	(0.006)	(0.007)	(0.006)	(0.004)
Total ethanol content	0.010	0.006	0.009	0.012	0.009
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Strength	0.312	0.490	0.387	0.332	0.374
	(0.037)	(0.041)	(0.030)	(0.022)	(0.030)
Covariances					
Price*Total ethanol content	-0.018	-0.014	-0.023	-0.026	-0.021
	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)
Price*Alcohol strength	-0.013	-0.058	-0.050	0.020	0.012
	(0.011)	(0.009)	(0.010)	(0.006)	(0.005)
Total ethanol content*Alcohol strength	-0.016	-0.005	-0.003	-0.018	-0.005
	(0.005)	(0.003)	(0.003)	(0.003)	(0.002)

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Coeffient estimates III

Household group:	< 7	7-14	14-21	21-35	> 35
Panel B: Preferences for unobserved product characteristics					
Mean product effects for each segment					
Beer	-1.338	-1.144	-0.969	-0.849	-0.830
	(0.037)	(0.030)	(0.030)	(0.028)	(0.031)
Wine	-6.467	-5.496	-5.067	-4.167	-4.290
	(0.134)	(0.112)	(0.113)	(0.101)	(0.116)
Spirits	-6.279	-4.472	-3.751	-2.872	-3.297
	(0.305)	(0.297)	(0.232)	(0.286)	(0.240)
Cider and FABs	-8.143	-5.648	-4.042	-1.958	-2.697
	(0.693)	(0.675)	(0.524)	(0.657)	(0.542)
Variances					
Beer	2.303	2.109	2.895	2.292	1.805
	(0.199)	(0.209)	(0.234)	(0.188)	(0.144)
Wine	1.817	1.505	2.341	2.494	1.525
	(0.172)	(0.128)	(0.199)	(0.181)	(0.119)
Spirits	1.016	0.431	2.121	1.007	2.191
	(0.264)	(0.087)	(0.294)	(0.119)	(0.209)
Cider and FABs	1.766	3.688	3.301	2.582	3.069
	(0.226)	(0.322)	(0.323)	(0.242)	(0.274)
Product effects			Yes		
Type-time effects			Yes		
Control function			Yes		
Number of households			2250		
Number of purchase occasions			56250		

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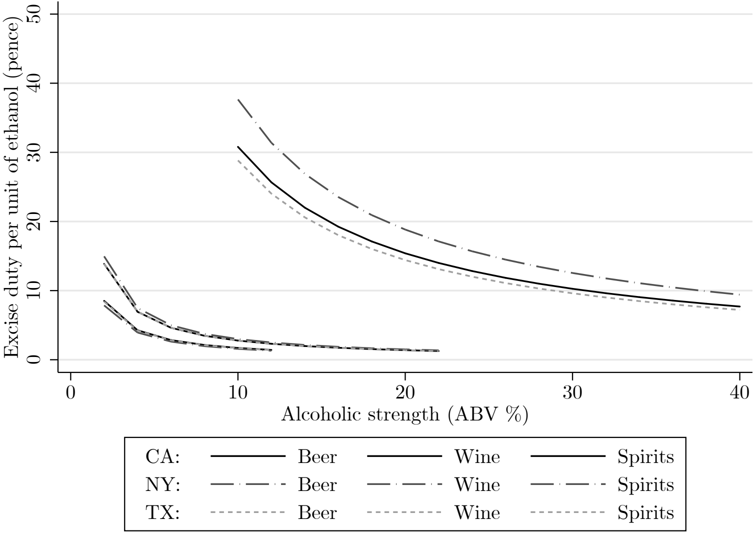
US Alcohol Taxes



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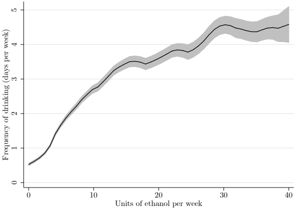
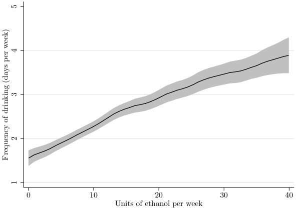
Ethanol consumption, binge and frequency of drinking

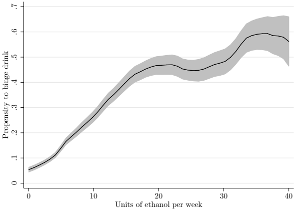
(a) UK: frequency of drinking



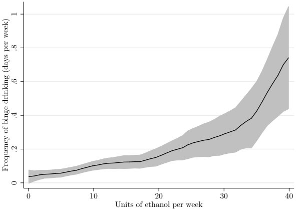
(b) US: frequency of drinking



(c) UK: binge drinking



(d) US: binge drinking



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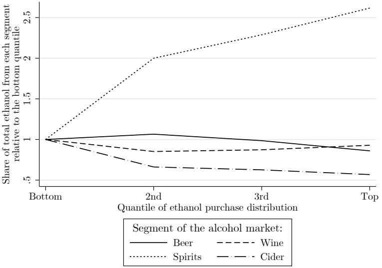
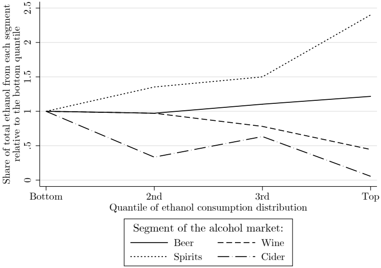
▸ Back

Variation in alcohol types bought across the total ethanol distribution

(a) UK



(b) US



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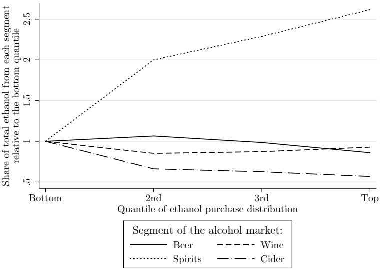
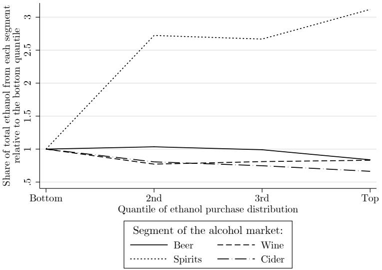
On- and off-trade alcohol purchases

(a) UK: on and off-trade



(b) UK: off-trade only



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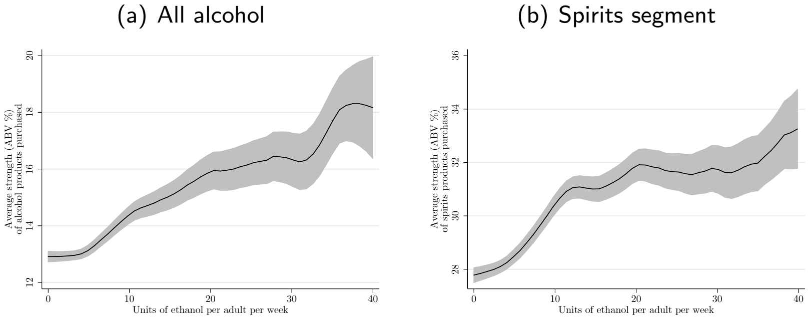
Variation in strength of alcohol purchased across the total ethanol distribution



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Beer and ale

	Product (j)	Size (s)	Price(£) (p_{jst})	Alcohol units (z_{js})	Alcohol strength (w_j)
(1)	Ale: low strength	c. 500ml	1.97	2.51	3.60
(2)		c. 4x440ml	3.38	6.31	3.60
(3)		c. 12x440ml	11.53	25.73	3.60
(4)	Ale: mid strength, bottles	c. 500ml	3.24	4.69	4.54
(5)		$>$ 1x500ml	6.60	11.86	4.54
(6)	Ale: mid strength, cans	c. 4x500ml	6.71	16.03	4.50
(7)	Ale: high strength	c. 500ml	2.98	4.91	5.67
(8)		$>$ 1x500ml	7.89	16.34	5.67
(9)	Lager: branded, low strength	c. 4x440ml	3.78	7.15	3.91
(10)		c. 12x440ml	9.70	22.37	3.91
(11)		c. 20x440ml	17.46	45.92	3.91
(12)	Lager: branded, mid strength	c. 4x330ml	3.99	6.85	4.65
(13)		c. 12x330ml	11.30	23.53	4.65
(14)	Lager: branded, high strength, bottles	c. 660ml	2.37	3.91	5.11
(15)		c. 4x330ml	3.87	6.94	5.11
(16)		c. 12x275ml	6.00	12.17	5.11
(17)		c. 15x275ml	12.78	31.17	5.11
(18)	Lager: branded, high strength, cans	c. 4x440ml	4.34	10.39	5.47
(19)		c. 10x440ml	12.73	33.11	5.47
(20)	Lager: store brand	c. 4x500ml	5.06	15.91	4.10
(21)	Stout	c. 500ml	2.43	3.13	4.23
(22)		c. 4x440ml	4.47	6.90	4.23
(23)		c. 10x440ml	13.55	25.04	4.23

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Wine

	Product (j)	Size (s)	Price(£) (p_{jst})	Alcohol units (z_{js})	Alcohol strength (w_j)
(24)	Red wine: store brand	c. 750ml	5.66	12.38	12.52
(25)		$>$ 1x750ml	12.00	30.21	12.52
(26)	Red wine: branded	c. 750ml	8.24	15.66	12.60
(27)		c. 2x750ml	11.90	23.61	12.60
(28)		$>$ 2x750ml	17.19	38.66	12.60
(29)	White wine: still, store brand	c. 750ml	5.08	10.77	11.91
(30)		$>$ 1x750ml	11.32	27.60	11.91
(31)	White wine: still, branded	c. 750ml	7.21	13.64	12.28
(32)		c. 2x750ml	11.08	21.62	12.28
(33)		$>$ 1x750ml	16.84	37.32	12.28
(34)	White wine: sparkling, store brand	c. 750ml	5.56	8.11	10.45
(35)		$>$ 1x750ml	13.06	20.93	10.45
(36)	White wine: sparkling, branded	c. 750ml	6.86	8.04	9.14
(37)		$>$ 1x750ml	9.16	21.50	9.14
(38)	Rose wine: still, store brand	c. 750ml	4.26	9.44	11.84
(39)		$>$ 1x750ml	10.20	25.25	11.84
(40)	Rose wine: still, branded	c. 750ml	5.05	9.56	11.41
(41)		$>$ 1x750ml	12.20	25.08	11.41
(42)	Rose wine: sparkling, store brand	c. 750ml	6.73	10.48	9.42
(43)	Rose wine: sparkling, branded	c. 750ml	6.17	8.02	10.17
(44)		$>$ 1x750ml	15.53	21.00	10.17

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Spirits

	Product (j)	Size (s)	Price(£) (p_{jst})	Alcohol units (z_{js})	Alcohol strength (w_j)
(45)	Brandy	c. 700ml	10.75	24.26	37.28
(46)		c. 1.4l	17.71	40.93	37.28
(47)	Gin; store brand	c. 700ml	8.74	24.63	38.38
(48)		c. 1.4l	15.29	43.96	38.38
(49)	Gin; branded	c. 700ml	11.52	26.33	38.23
(50)		c. 1.4l	18.44	44.10	38.23
(51)	Rum	c. 700ml	10.73	25.50	37.15
(52)		c. 1.4l	17.20	42.77	37.15
(53)	Vodka; store brand	c. 700ml	8.08	22.42	37.55
(54)		c. 1.4l	15.95	44.35	37.55
(55)	Vodka; branded	c. 700ml	10.38	25.79	37.63
(56)		c. 1.4l	16.35	43.05	37.63
(57)	Whisky; store brand	c. 700ml	10.61	25.87	40.00
(58)		c. 1.4l	17.89	45.64	40.00
(59)	Whisky; branded	c. 700ml	14.97	28.42	40.11
(60)		c. 1.4l	17.17	41.93	40.11
(61)	Liqueurs	c. 700ml	10.55	16.70	21.50
(62)		c. 1.4l	15.68	25.70	21.50
(63)	Port	c. 750ml	8.61	17.26	19.82
(64)	Sherry	c. 750ml	7.51	18.86	16.74
(65)	Vermouth	c. 1.4l	6.65	18.04	14.94
(66)	Other fort. wine	c. 1l	6.22	17.88	14.61

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Cider and Flavoured Alcoholic Beverages (FABs)

	Product (j)	Size (s)	Price(£) (p_{jst})	Alcohol units (z_{js})	Alcohol strength (w_j)
(67)	Dry cider, low strength	c. 1l	2.47	3.95	4.36
(68)		c. 4l	6.32	18.09	4.36
(69)	Dry cider, high strength, store brand	c. 2l	2.28	9.95	5.82
(70)		c. 5l	5.36	27.42	5.82
(71)	Dry cider, high strength, branded	c. 500ml	3.05	6.61	5.99
(72)		c. 2l	3.84	11.51	5.99
(73)		c. 12x440ml	10.01	34.80	5.99
(74)	Pear cider	c. 568ml	2.36	4.70	5.01
(75)		c. 3l	6.77	18.72	5.01
(76)	Fruit cider	c. 1l	4.63	6.00	4.47
(77)	Pre-mixed spirit	c. 750ml	4.13	4.54	6.16
(78)	Alcopops	c. 700ml	3.66	4.32	4.90
(79)		c. 2x700ml	8.27	10.03	4.90

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Calibration of externality function

	Aggregate external cost (£billion)	Ratio of external costs of heaviest to lightest drinkers	Calibrated parameters (ϕ_0, ϕ_1)
Central	7.25	20	$(1.2980, 0.0615)$
High aggregate cost	8.50	20	$(1.5220, 0.0615)$
Low aggregate cost	6.00	20	$(1.0740, 0.0615)$
High convexity	7.25	30	$(0.8177, 0.0695)$
Low convexity	7.25	10	$(3.1730, 0.0435)$

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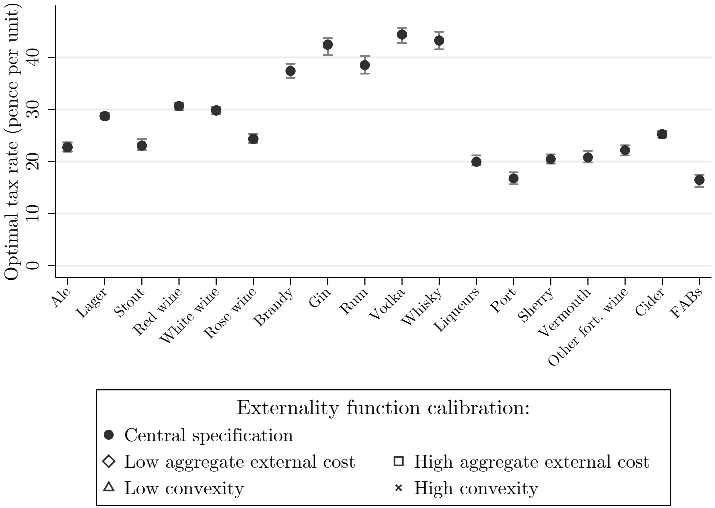
Differentiate tax rate solutions



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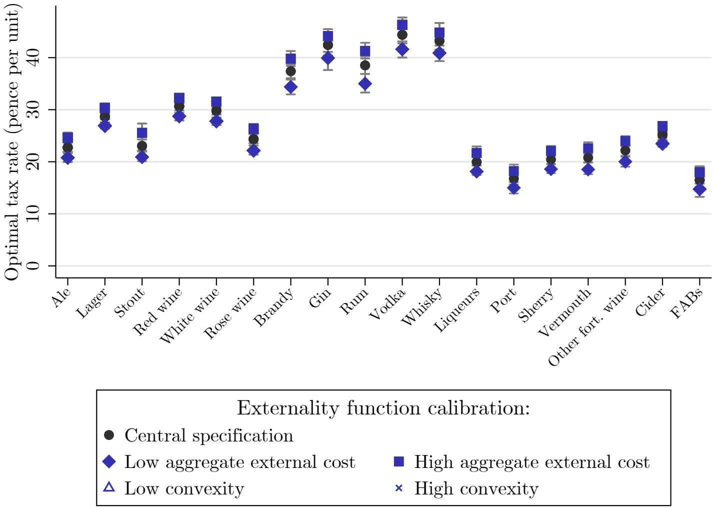
Differentiate tax rate solutions



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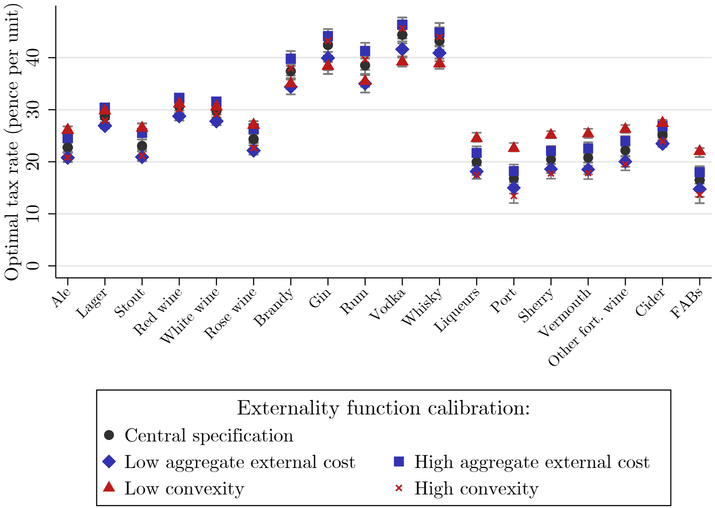
Differentiate tax rate solutions



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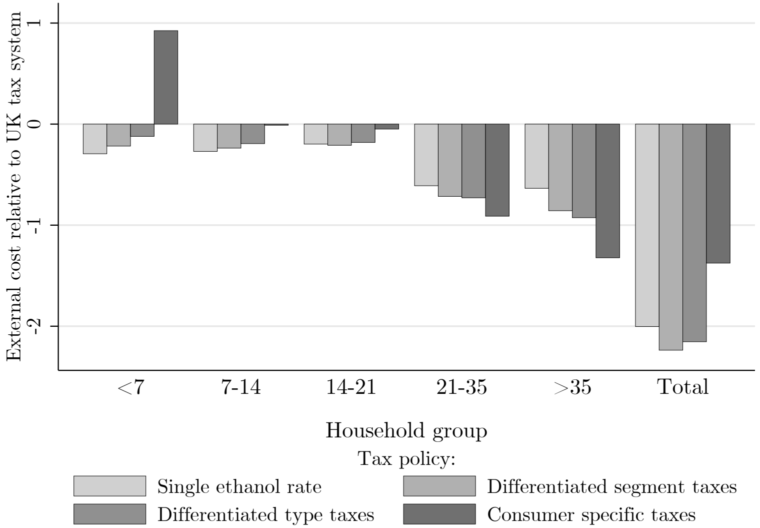
External cost by household group



Consumer surplus
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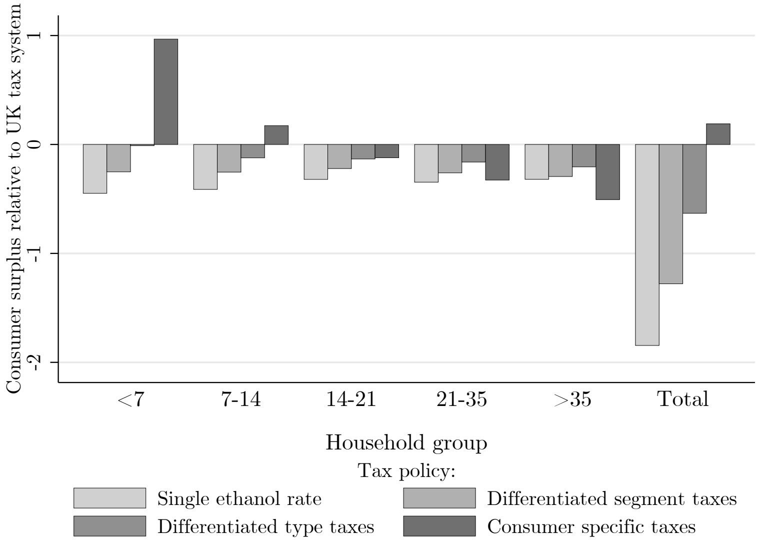
Consumer surplus by household group



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