How Revealing is Revealed Preference?

Richard Blundell UCL and IFS April 2016

Lecture II, Boston University

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  - Identifying Taste Change: tobacco
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- Selected references: all on my website:
  - Blundell, Browning and Crawford [BBC1, 2] (*Ecta* 2003, 2008)
  - Blundell, Horowitz and Parey [BHP1, 2] (*QE* 2013, *REStat* 2016)
  - Blundell, Kristensen and Matzkin [BKM1, 2] (*JoE* 2014, WP 2016)
  - Blundell, Browning, Crawford, Vermeulen [BBCV] (*AEJ-Mic* 2015)
  - Adams, Blundell, Browning and Crawford [ABBC] (*IFS-WP*, 2015)

Rationality and Revealed Preference: Introduction

- There are two key criticisms of the empirical application of revealed preference theory to consumer behaviour:
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- Modern RP analysis takes a nonparametric approach.
- To quote Dan McFadden: "parametric models interpose an untidy veil between econometric analysis and the propositions of economic theory"
- The aim of recent research is to "lift 'McFadden's' untidy veil"!

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- ▶ Particular attention is given to application to observational data: nonseparable unobserved heterogeneity and endogeneity.
- ▶ New insights are provided about the price responsiveness and the degree of rationality, especially across different income and education groups.

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  - Collective choice
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- And **'Beyond'**...
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  - Choice under uncertainty
  - Consideration sets
  - Reference-dependent choice...

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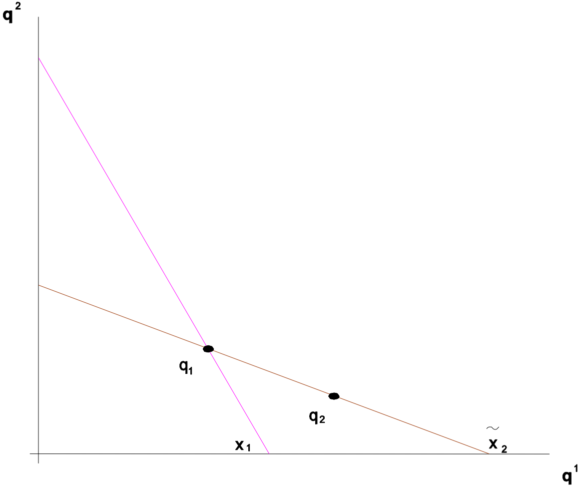
- Think through a simple RP rejection: **Figure 1a:**

Figure 1a



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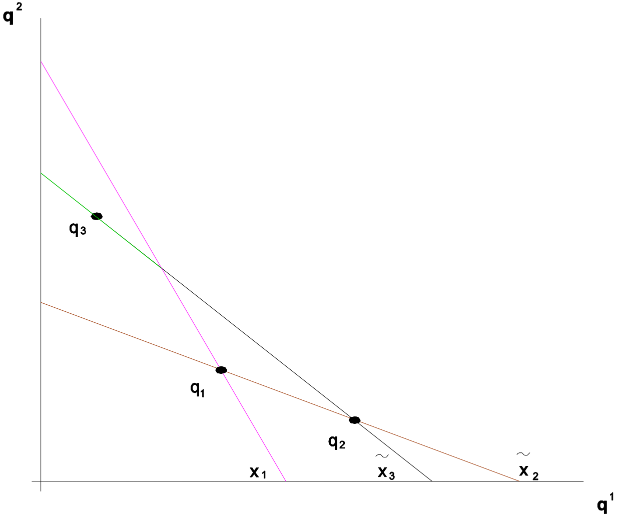

Afriat's Theorem

The following statements are equivalent:

A. there exists a utility function $u(\mathbf{q})$ *which is continuous, non-satiated and concave which rationalises the data* $\{\mathbf{p}_t, \mathbf{q}_t\}_{t=1,...,T}$.

B1. there exist numbers $\{U_t, \lambda_t > 0\}_{t=1,...,T}$ *such that*

$$U_s \leq U_t + \lambda_t \mathbf{p}_t' (\mathbf{q}_s - \mathbf{q}_t) \ \forall \ s, t \in \{1, ..., T\}$$

B2. the data $\{\mathbf{p}_t, \mathbf{q}_t\}_{t=1,...,T}$ *satisfy the Generalised Axiom of Revealed Preference (GARP).*

GARP

Definition: *A dataset* $\{\mathbf{p}_t, \mathbf{q}_t\}_{t=1,..,T}$ *satisfies GARP if and only if we can construct relations* R_0, R *such that*
(i) for all t, s *if* $\mathbf{p}_t\mathbf{q}_t \geq \mathbf{p}_t\mathbf{q}_s$ *then* $\mathbf{q}_t \; R_0 \; \mathbf{q}_s$*;*
(ii) for all $t, s, u, \ldots, r, v$*, if* $\mathbf{q}_t \; R_0 \; \mathbf{q}_s$ *,* $\mathbf{q}_s \; R_0 \; \mathbf{q}_u$*, . . . ,* $\mathbf{q}_r \; R_0 \; \mathbf{q}_v$ *then* $\mathbf{q}_t \; R \; \mathbf{q}_v$*;*
(iii) for all t, s*, if* $\mathbf{q}_t \; R \; \mathbf{q}_s$*, then* $\mathbf{p}_s\mathbf{q}_s \leq \mathbf{p}_s\mathbf{q}_t$*.*

Condition (i) states that the quantities $\mathbf{q}_t$ are directly revealed preferred over $\mathbf{q}_s$ if $\mathbf{q}_t$ was chosen when $\mathbf{q}_s$ was equally attainable.

Condition (ii) imposes transitivity on the revealed preference relation R.

Condition (iii) states that if a consumption bundle $\mathbf{q}_t$ is revealed preferred to a consumption bundle $\mathbf{q}_s$, then $\mathbf{q}_s$ cannot be more expensive then $\mathbf{q}_t$.

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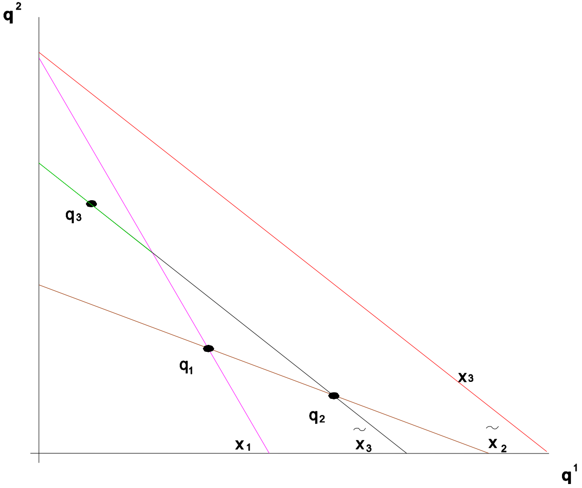

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- This result has been extended to models of collective choice, habits, ...

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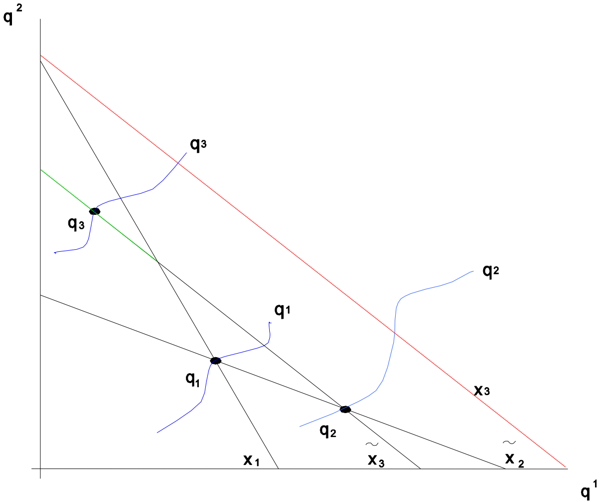
- See **Fig 1b.**

Figure 1b: Using Expansion Paths



- Given the expansion paths $\{\mathbf{p}_t, \mathbf{q}_t(x)\}_{t=1,..T}$, define intersection demands $\mathbf{q}_t(\tilde{x}_t)$ by $\mathbf{p}_0'\mathbf{q}_t(\tilde{x}_t) = \mathbf{x}_0$

- The set of points that are consistent with observed expansion paths and utility maximisation is given by the *support set*:

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- See Figures 3 a,b,c

Figure 3a: The 'Varian' Support Set with RP

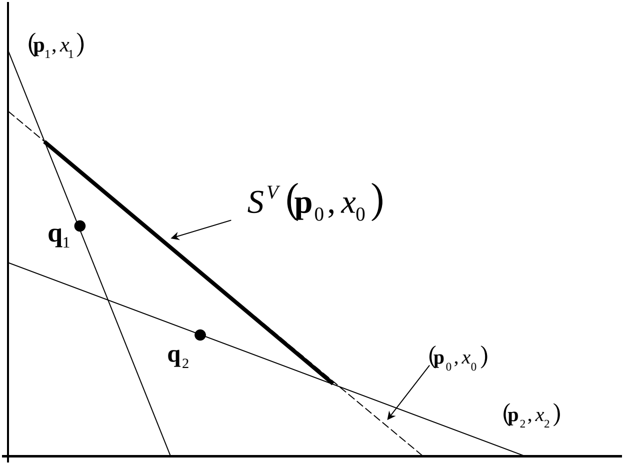


Figure 3b. Support set with Quantile Expansion Paths

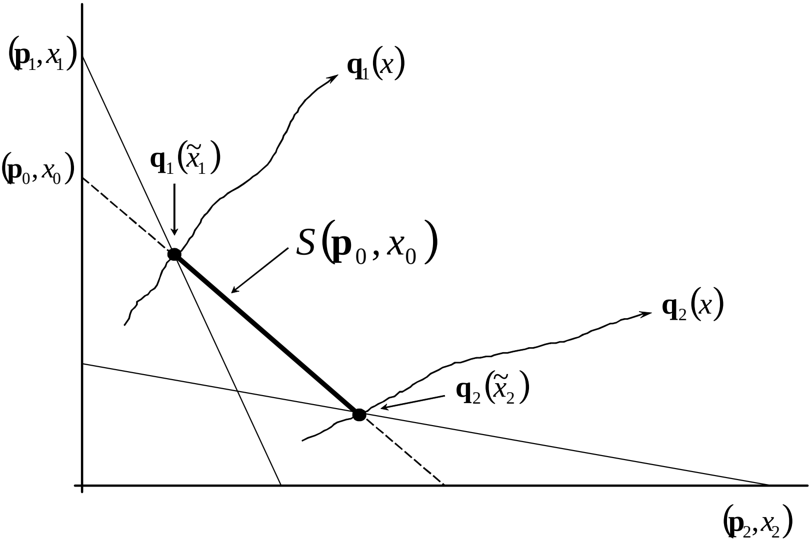
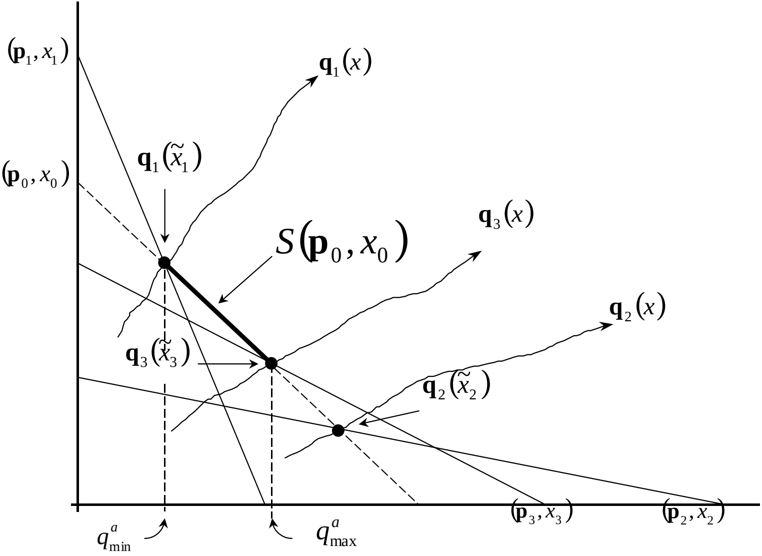


Figure 3c: Support Set with Many Markets



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- Sharp bounds under SARP are what we call *i-bounds*
- These allow us to provide sharp bounds on Welfare Measures where transitivity is essential.

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- Can also show how the approach can be extend to a life-cycle model with habit formation.

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- That is preferences are assumed take the form:

$$U_i^t\left(q_{1i}, q_{0i}\right) = v\left(q_{1i}, q_{0i}\right) + w(q_{1_i}, \varepsilon_i)$$

preference heterogeneity ε_i

- Strictly increasing and concave with positive cross derivative for w guarantees q_1 is invertible in ε.
- Note that RP consistent responses to price and income changes will be represented by a shift in the distribution of demands.

Figure 2a: The distribution of heterogeneous consumers

- Distribution of consumer tastes in a market:

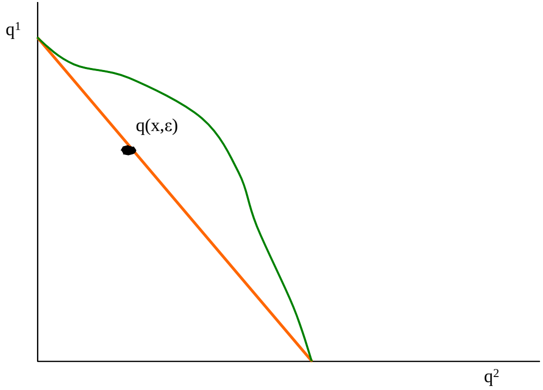


Figure 2b: Monotonicity and rank preserving changes

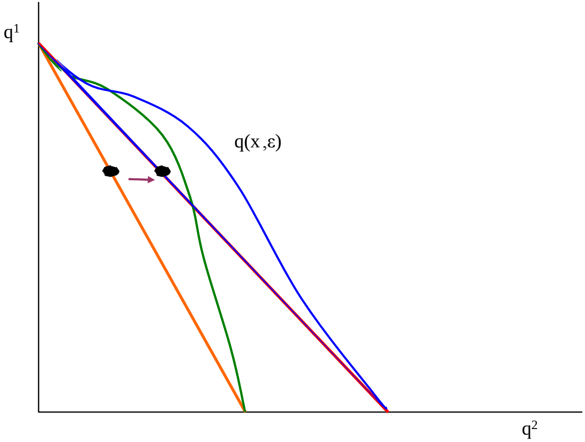
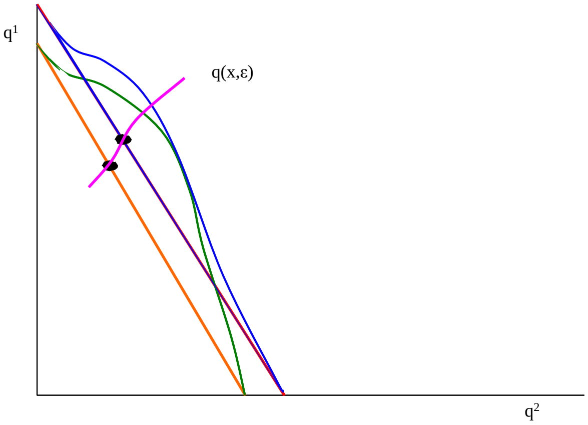


Figure 2c: The quantile expansion path



Sharp Bounds on Demand Responses

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Figure 4a. Unrestricted Quantile Expansion Paths: Food

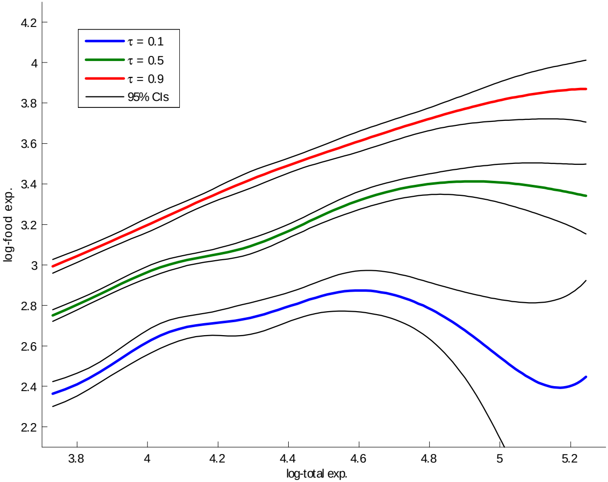


Figure 4b. RP Restricted Quantile Expansion Paths: Food

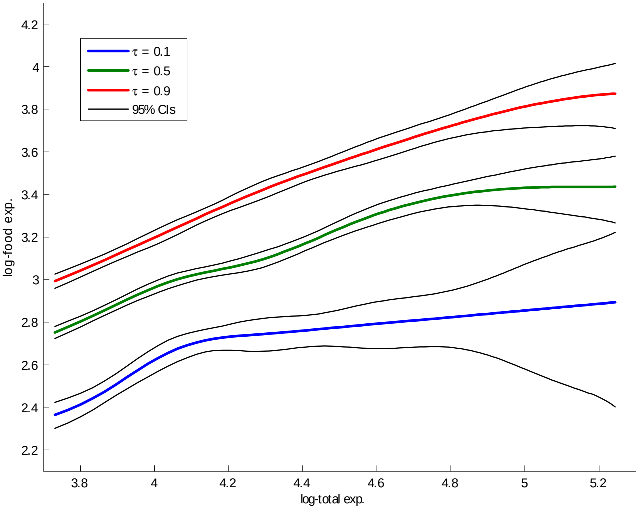


Figure 5a: Quantile Demand Bounds at Median Income and Median Heterogeneity

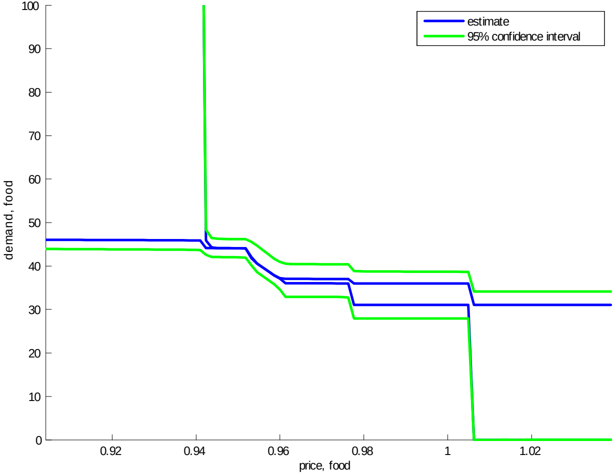
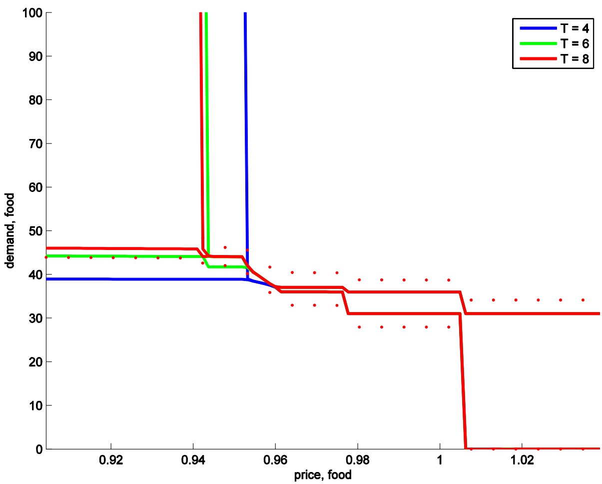


Figure 5b: Estimated 'Sharp' Demand Bounds as More Markets are Added



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- ▶ Can use Slutsky inequalities for continuous prices, as in the work on Gasoline demand with Joel Horrowitz and Matthias Parey, *QE* and forthcoming *REStat*.

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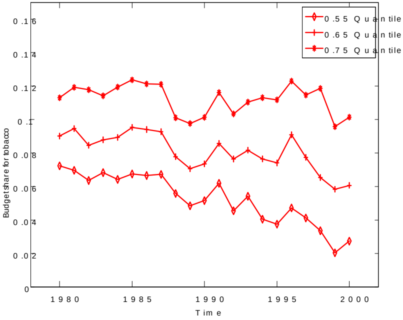
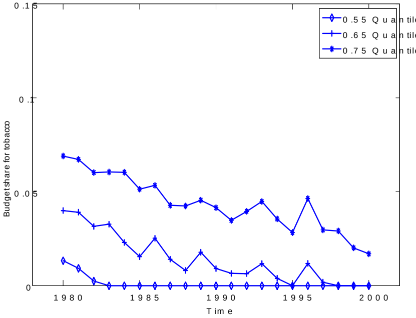
- We also consider how tastes evolve across different education strata. Do tastes change differentially across education groups?

Taste changes and prices

UK Budget shares for Tobacco: Quantiles



(a) Low Education



(b) High Education

Taste Change

- Consumer i's maximisation problem can be expressed as:

$$\max_{\mathbf{q}} u^i(\mathbf{q}, \alpha_t^i) \text{ subject to } \mathbf{p}'\mathbf{q} = x$$

where $\mathbf{q} \in \mathbb{R}_+^K$ denotes the demanded quantity bundle, $\mathbf{p} \in \mathbb{R}_{++}^K$ denotes the (exogenous) price vector faced by consumer i and x gives total expenditure.

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- Using this framework we derive RP inequality conditions that incorporate minimal perturbations to individual preferences to account for taste change.

Marginal utility (MU) perturbations

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- Characterising taste change in this way yields the temporal series of utility functions:

$$u^i(\mathbf{q}, \boldsymbol{\alpha}_t^i) = v^i(\mathbf{q}) + \boldsymbol{\alpha}_t^{i\prime}\mathbf{q}, \text{ where } \boldsymbol{\alpha}_t^i \in \mathbb{R}^K.$$

- Under this specification, $\alpha_t^{i,k}$ can be interpreted as the taste shift in the marginal utility of good k at time t for individual i.

- The theorems below imply this specification is not at all restrictive.

Afriat conditions

- For individual i we seek the Afriat inequalities that would allow us to rationalise observed prices $\{\mathbf{p}^1, ...\mathbf{p}^T\}$ and quantities $\{\mathbf{q}^1, ...\mathbf{q}^T\}$.
- We can '*good* 1 *taste rationalise*' the observed prices and quantities if there is a function $v(\mathbf{q})$ and scalars $\{\alpha_1, \alpha_2, ...\alpha_T\}$ such that:

$$v(\mathbf{q}^t) + \alpha_t q_1^t \geq \psi(\mathbf{q}) + \alpha_t q_1$$

for all $\mathbf{q}$ such that $\mathbf{p}^t\mathbf{q} \leq \mathbf{p}^t\mathbf{q}^t$.

Afriat conditions

Theorem: The following statements are equivalent:

1. Individual observed choice behaviour, $\{\mathbf{p}_t, \mathbf{q}_t\}_{t=1,...,T}$, can be good-1 rationalised by the set of taste shifters $\{\alpha_t\}_{t=1,...,T}$.

2. One can find sets $\{v_t\}_{t=1,...,T}$, $\{\alpha_t\}_{t=1,...,T}$ and $\{\lambda_t\}_{t=1,...,T}$ with $\lambda_t > 0$ for all $t = 1, ..., T$, such that there exists a non-empty solution set to the following inequalities:

$$\begin{aligned} \left(v\left(\mathbf{q}^t\right) - v\left(\mathbf{q}^s\right)\right) + \alpha_t\left(q_1^t - q_1^s\right) &\leq \lambda_t\left(\mathbf{p}^t\right)'\left(\mathbf{q}^t - \mathbf{q}^s\right) \\ \alpha_t &\leq \lambda_t p_t \end{aligned}$$

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- These inequalities are a simple extension of Afriat (1967).
- When they hold there exists a well-behaved base utility function and a series of taste shifters on good-1 that perfectly rationalise observed behaviour.

A surprising result

- We can then show, under mild assumptions on the characteristics of available choice data, that we can always find a pattern of taste shifters on a single good that are sufficient to rationalise any finite time series of prices and quantities:

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  Definition: There is 'perfect intertemporal variation' (PIV) in good 1 if $q_1^t \neq q_1^s$ for all $t \neq s = 1, ..., T$.

  Theorem: Given observed choice behaviour, $\{\mathbf{p}^t, \mathbf{q}^t\}$ for $t = 1, \ldots T$ where good-1 exhibits PIV, one can *always* find a set $\{v_t, \alpha_t, \lambda_t\}$ with $\lambda_t > 0$ for all $t = 1, ..., T$, that satisfy the Afriat inequalities.

- PIV is sufficient for rationalisation but not necessary.

Taste changes as price adjustments

- We can reinterpret the rationalisability question as a 'missing price problem'.
- We can find scalars $\{v_1, ...v_T\}$, positive scalars $\{\lambda_1, ...\lambda_T\}$, and a weakly positive taste-adjusted price vector, $\{\widetilde{\mathbf{p}}^t\}_{t=1,..,T}$, such that

$$v(\mathbf{q}^t) - v(\mathbf{q}^s) \geq \lambda_t (\widetilde{\mathbf{p}}^t)' (\mathbf{q}^t - \mathbf{q}^s)$$

  where

$$\widetilde{\mathbf{p}}^t = \left[p_1^t - \alpha_t/\lambda_t, \mathbf{p}_{\neg 1}^t\right].$$

- We refer to α_t/λ_t as the *taste wedge*.
- The change in demand due to a positive taste change for good 1 $(\alpha_t > 0)$ can be viewed as a price reduction in the price of good 1.
- This provides a link between two of the levers (*taxes and information*) available to governments.

Recovering taste change perturbations

- Given the no rejection result, we can always find a non-empty *set* of scalars that satisfy the Afriat conditions.
- Pick out values $\{v_t, \alpha_t, \lambda_t\}_{t=1,\dots T}$ that solve:

$$\min \sum_{t=2}^{T} \alpha_t^2 \text{ subject to the Afriat inequalities}$$

- This a quadratic-linear program.
- Minimizing the sum of squared α's subject to the set of RP inequalities ensures that the recovered pattern of taste perturbations are sufficient to rationalise observed choice behaviour.
- With $\alpha_1 = 0$, we interpret $\{\alpha_t\}_{t=2,\dots,T}$ as the minimal rationalising marginal utility perturbations to good-1 relative to preferences at $t = 1$.
- Can also impose more structure on the evolution of taste change over time. For example, monotonicity: $\alpha_{t+1} \leq \alpha_t$.

Empirical Strategy

- Our empirical analysis uses data drawn from the U.K. Family Expenditure Survey (FES) between 1980 and 2000.
- The FES records detailed expenditure and demographic information for 7,000 households each year.
- It is not panel data so we follow birth-cohorts of individuals stratified by education level.

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- Separately by birth cohort and by education group $E^i \in \{L, H\}$.
- We use a quantile control function approach to correct for the endogeneity of total expenditure.
- We recover shifts in the distribution of demands and ask what are the minimal perturbations to tastes that maintain the RP inequalities at each particular quantile.

Results

- Minimal virtual prices along each birth cohort's SMP path τth quantile and education group E are recovered as:

$$\widehat{\pi}_t^{E,\tau} = p_t^1 - \frac{\widehat{\alpha}_t^{E,\tau}}{\widehat{\lambda}_t^{E,\tau}}$$

The "taste wedge", $\widehat{\alpha}_t^{E,\tau} / \widehat{\lambda}_t^{E,\tau}$ represents the change in the marginal willingness to pay for tobacco relative to base tastes.

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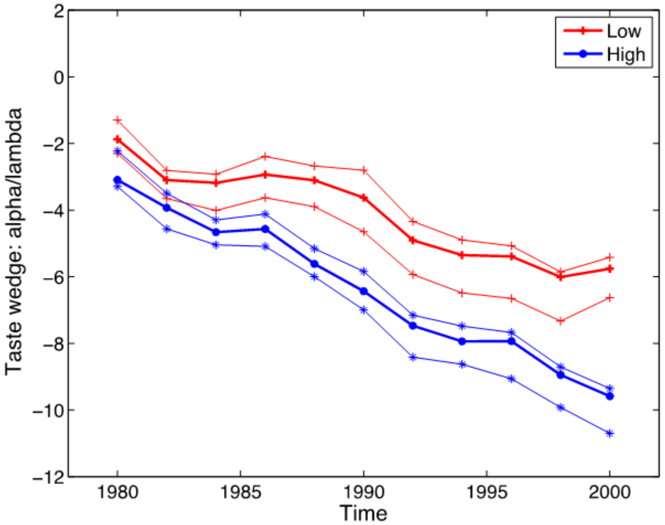
3. The taste change trajectories for light and moderate smokers in the high education cohort are similar.
4. Education is irrelevant for explaining the evolution of virtual prices amongst heavy smokers.

Taste wedges for light smokers



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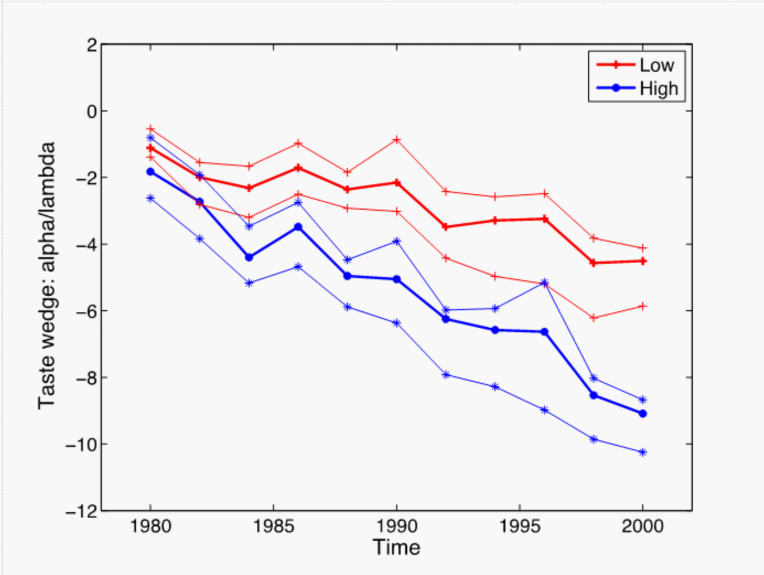
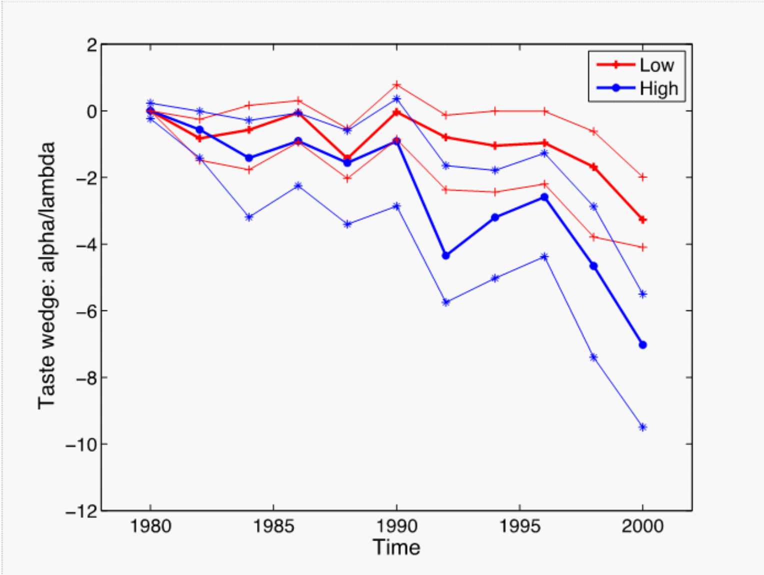


Taste wedges for heavy smokers



Results: relaxing separability through conditional demands

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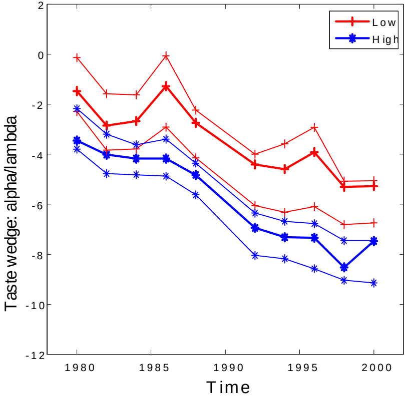
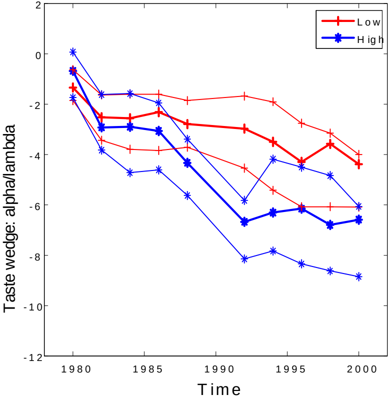
- We partition the set of observations into "light" and "heavy" drinkers depending on whether an individual is below or above the median budget share for alcohol.
- The significant difference by education group in the evolution taste change for light and moderate smokers is robust to non-separability.
- 95% confidence intervals on virtual prices and the taste wedge are disjoint across education groups for all cohorts except for the "heavy smoking"-"heavy drinking" group. Effective tastes for this group evolved very little for both education groups.

Taste Wedge Results: Conditional Quantiles (Moderate Smoker)

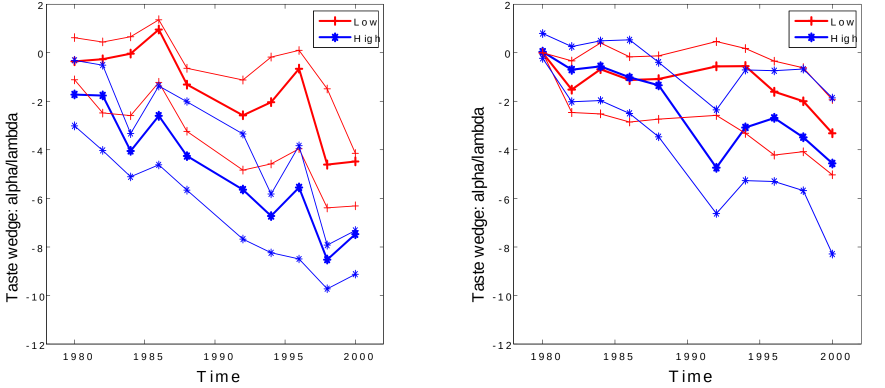


Light Drinker



Heavy Drinker

Taste Wedge Results: Conditional Quantiles (Heavy Smoker)



Light Drinker   Heavy Drinker

Characterising Taste Change

- In this final part of the lecture we have shown how to develop an empirical framework for characterising taste change that recovers the minimal intertemporal (and interpersonal) taste heterogeneity required to rationalise observed choices.
- A censored quantile approach was used to allow for unobserved heterogeneity and censoring.
- Non-separability between tobacco and alcohol consumption was incorporated using a conditional (quantile) demand analysis.
- Future work will use intertemporal RP conditions to recover the path of λ_t.
- *Systematic* taste change was required to rationalise the distribution of demands in our expenditure survey data. Statistically significant educational differences in the marginal willingness to pay for tobacco were recovered; more highly educated cohorts experienced a greater shift in their effective tastes away from tobacco.

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- Extend to a life-cycle model with habit formation.

Extra Slide 1: Life-cycle Planning and Habits

- Allow for short memory in tobacco consumption such that the base utility function depends on lagged quantity of good 1:

$$v^t = \psi\left(\mathbf{q}, q_1^{-1}\right) + \mu_t q_1$$

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- Following Browning (1989) and Crawford (2010), embed this felicity function in a standard lifecycle planning framework.

$$\max_{\{\mathbf{q}^t\}_{t=1,\dots,T}} \sum_{t=1}^{T} \beta^{t-1} \left\{ \psi\left(\mathbf{q}^t, q_1^{t-1}\right) + \mu_t q_1^t \right\}$$

s.t.

$$\sum_{t=1}^{T} \boldsymbol{\rho}_t' \mathbf{q}_t = A_0$$

for discounted prices $\boldsymbol{\rho}_t$.

Extra Slide 2: Taste Change

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Definition: Consumer i's choice behaviour, $\{\mathbf{p}_t, \mathbf{q}_t^i\}_{t=1,...,T}$, can be "taste rationalised" by a utility function $u^i(\mathbf{q}, \boldsymbol{\alpha}_t^i)$ and the temporal series of taste parameters $\{\boldsymbol{\alpha}_t^i\}_{t=1,...,T}$ if the following set of inequalities is satisfied:

$$u^i(\mathbf{q}, \boldsymbol{\alpha}_t^i) \leq u^i(\mathbf{q}_t^i, \boldsymbol{\alpha}_t^i)$$

for all $\mathbf{q}$ such that $\mathbf{p}_t'\mathbf{q} \leq \mathbf{p}_t'\mathbf{q}_t^i$.

- In words, observed behaviour can be rationalised if an individual's choice at t yields weakly higher utility than all other feasible choices at t when evaluated with respect to their time t tastes.

Extra Slide 3: Taste changes for one good

- Begin with intertemporal separability (*no habits*), individual preferences in period t (individual subscript i is suppressed) are represented by:

$$u^t(q_1, q_2, ...q_K) = v(q_1, q_2, ...q_K) + \alpha_t q_1$$

- The function $v(q_1, q_2, ...q_K)$ is a time invariant base utility function which is strictly increasing and concave in quantities.
- The term $\alpha_t q_1$ is a taste shifter for good 1 in period t.
- Normalisation: $\alpha_1 = 0$ so that the baseline preferences $v(\mathbf{q})$ are for period 1.
- Show these individual utility function satisfies single crossing in $(\mathbf{q}, \alpha)$ space.