Estimating Discrete Games with Many Firms and Many Decisions: An Application to Merger and Product Variety

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Note

- Previously: "Merger, Product Variety and Firm Entry: the Retail Craft Beer Market in California"

- The paper we will discuss today makes contributions to
  1. Econometrics: How to estimate games with a large set of discrete choices
  2. IO: Study the effect of merger on product variety, with an empirical example of the retail craft beer market in California
- This discussion will focus more towards the IO application, and will broadly discuss the technical contribution of the paper when introducing the supply-side estimation procedure

Overview

Research Questions

- What are the effects of merger on product varieties and firm entry in a (multi-product) industry? What is the impact on consumer surplus?

Approach: structural model + counterfactual

- Study the retail craft beer market in California
- Demand-side: BLP (will briefly describe)
- Supply-side: 2-stage model for entry and product choices **(main technical contribution)**

Why is this interesting?

- Mergers would lead to increased prices but this will encourage firm entry which mitigates the anti-competitive effects of merger
- Entrants $\implies \uparrow$ no. of products; but merged firms could $\downarrow$ product offerings; overall effect of merger is ambiguous

Retail Craft Beer Market in California

- Craft beer: multi-product industry + significant growth in variety and sales
  - Craft breweries have become popular acquisitions by large breweries → antitrust concerns
- California: largest no. of craft breweries and highest craft beer production out of all states. In 2015,
  - 462 craft breweries (12% of USA)
  - 43 million barrels of production (18% of USA)
- California law effectively allows breweries to distribute their products directly to the consumer
  - Such institutional features support assumption that firm entry and product choices are based on retail profits
- Furthermore, California provides rich demographic variation that identifies consumer tastes given the size of the state

Data and definitions

- Nielsen Retail Scanner Data (2009-2016): product, sales and prices of beers sold at major retail chains
- Nielsen Consumer Panel (2009-2016): micro-level data
- Craft beer designation collected from the Brewers Association
- Hand-collected data on identities of the owner and brewery and the location where each product is brewed
- County-level demographics taken from Census
- Market = retailer-county pair; firm = corporate owner (e.g., Boston Beer Company) which can have many products; product = brand (e.g., Samuel Adams Boston Lager)
- Nielsen data is aggregated from UPC/week level to the product/month level — each unit is a 12-ounce-12-pack equivalent and prices are aggregated using the quantity-weighted average price across weeks

Larger markets tend to have more products

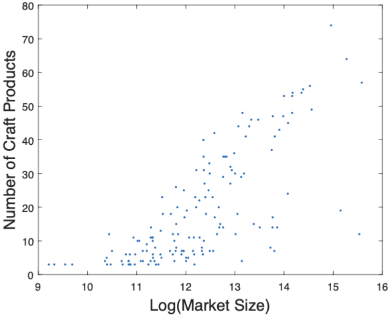


Figure 1: No. of Craft Products vs. Market Size

- Market size = average monthly alcohol sales (12-pack units) in a market $\times$ 8 (median no. of HH trips to a retail store)
- Variations in market sizes could affect profits, product choice and entry $\implies$ include product and market fixed-effects

Product Entry by Distance

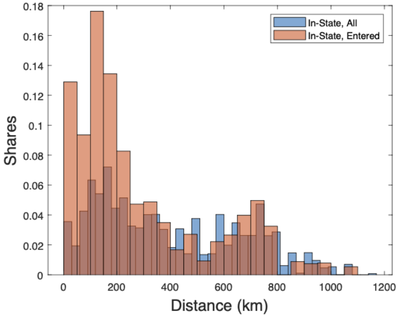


Figure 2: Distribution of Craft Breweries

- Distance-to-market could affect product entry decisions and variable profits $\implies$ control for distance in demand and marginal cost functions

Demand: random coefficients model / BLP

- The (indirect) utility function of household i in market m from product j in month t is

$$\begin{aligned} u_{ijmt} =& (\sigma_0 \nu_i + \kappa_0 y_i) + (\alpha + \kappa_\alpha y_i) p_{jmt} + X_{jm}' \beta \\ & + \sigma^{ale} \nu_i^{ale} x_j^{ale} + \sigma^{lager} \nu_i^{lager} x_j^{lager} + \sigma^{light} \nu_i^{light} x_j^{light} \\ & + \sigma^{import} \nu_i^{import} x_j^{import} + (\sigma^{craft} \nu_i^{craft} + \kappa^{craft} y_i) x_j^{craft} \\ & + \bar{\xi}_j + \bar{\xi}_m + \bar{\xi}_t + \xi_{jmt} + \varepsilon_{ijmt} \end{aligned}$$

- X_{jm} are a vector of indicators to control for distance between brewery to market
- σ-terms measure dispersion in unobserved tastes (ν); κ-terms capture interaction between income (y) and tastes for characteristics (x)
- FEs are included for products ($\bar{\xi}_j$), market ($\bar{\xi}_m$) and month ($\bar{\xi}_t$)
- ε_{ijmt} is i.i.d. Type 1 EV shock

Supply: 2nd stage / Marginal Costs

- In each month t, firm n sets prices p_{jmt} for products $\mathcal{J}_{nm\tau}$ in a Bertrand-Nash environment
- The 2nd stage profit maximization problem is:

$$\max_{p_{jmt}} \ \pi_{nmt} = \mathbb{E} \sum_{j \in \mathcal{J}_{nm\tau}} (p_{jmt} - mc_{jmt}) D_{jmt}(p_{jmt}, p_{-jmt})$$

  where the marginal cost is decomposed into:

$$mc_{jmt} = \bar{\omega}_j + \bar{\omega}_m + \bar{\omega}_t + \gamma X_{jm} + \omega_{jmt}$$

  and the expectation $\mathbb{E}$ is w.r.t $(\xi_{jmt}, \omega_{jmt})$
- Given this structure, follow BLP and invert MCs from the FOCs for the optimal prices (from demand model)

Supply: 1st stage / Fixed Costs

- At the start of each year τ (subscripts dropped), firm n chooses the set of products $\mathcal{J}_{nm}$ that they want to sell in market m:

$$\max_{\mathcal{J}_{nm} \subseteq \mathcal{J}_n} \pi_{nm}(\mathcal{J}_{nm}, \mathcal{J}_{-nm}) - C_{nm}(\mathcal{J}_{nm})$$

  where $\mathcal{J}_n$ denotes an exogenous set of potential products that firm n can select; $\pi_{nm}(\cdot) = \sum_t \pi_{nmt}$

- Fixed costs are assumed to be separable by products and shocks are assumed to be additive:

$$C_{nm}(\mathcal{J}_{nm}) = \sum_{j \in \mathcal{J}_n} Y_{jm} \cdot \left(c(W_{jm}, \theta) + \zeta_{jm}\right)$$

  where Y_{jm} is an indicator for product j in market m, W_{jm} is a vector of cost covariates, and $\zeta_{jm} \sim N(0, \sigma_m^2)$

Instruments

- ξ_{jmt} is the unobserved demand shock specific to a product $\times$ market $\times$ month combination
- Use monthly global barley prices (input prices) interacted with beer types (ale, lager, light, import, craft) as IVs for price
- Interactions account for heterogeneity in input use by beer type

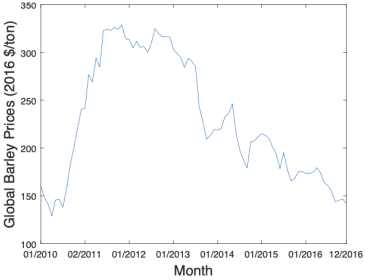


Figure 3: Monthly Variation in Global Barley Prices

Micro-moments

1. $\mathbb{E}(\sum_{t=1}^{12} q_{it} | \sum_{t=1}^{12} q_{it} \geq 1) \rightarrow \sigma_0$ for total beer purchased

2. $\mathbb{E}(\sum_{t=1}^{12} q_{it}^{f} | \sum_{t=1}^{12} q_{it}^{f} \geq 1) \rightarrow \sigma^{f}$ where f = (ale, lager, light, import, craft)

3. $\mathbb{E}(\sum_{t=1}^{12} q_{it}^{f} | \sum_{t=1}^{12} q_{it}^{craft} \geq 1)$ for the taste correlation between craft and other types of beer

4. $\frac{\mathbb{E}(\sum_{t=1}^{12} exp_{it} | y_i \in \mathcal{I})}{\mathbb{E}(\sum_{t=1}^{12} q_{it} | y_i \in \mathcal{I})}$, the average expenditure on beer among each income-group $\rightarrow \kappa_{\alpha}$

5. $\mathbb{E}(\sum_{t=1}^{12} q_{it}^{craft} \geq 1, y_i \in \mathcal{I}) \rightarrow \kappa^{craft}$

6. $\mathbb{E}(\sum_{t=1}^{12} q_{it} | \sum_{t=1}^{12} q_{it} \geq 1, y_i \in \mathcal{I}) \rightarrow \kappa_0$

Product Portfolio Choice

- Let $\Delta_j(Y_{-jm}, X_{nm}) \equiv$ incremental change in firm n's expected variable profit when j is included, and define

$$\underline{\Delta}_j(X_{nm}) \equiv \min_{Y_{-jm}} \Delta_j(Y_{-jm}, X_{nm})$$
$$\overline{\Delta}_j(X_{nm}) \equiv \max_{Y_{-jm}} \Delta_j(Y_{-jm}, X_{nm})$$

where Y_{-jm} denotes firm n and rivals' decisions on other products; and X_{nm} is a vector of observable firm & market covariates

- The change in fixed cost from adding product j is

$$\underbrace{\theta_1 craft_j + \theta_2 instate_j \cdot craft_j + \theta_3 instate_j \cdot craft_j \cdot size_m}_{c(W_{jm}, \theta)} + \zeta_{jm}$$

Bounds for Conditional Choice Probabilities

- Let Y_{jm} denote the equilibrium choice of product j in market m; the conditional choice probability is bounded as follows:

$$
\begin{aligned}
&\Pr\Big(\zeta_{jm} < \underline{\Delta}_j(X_{nm}) - c(W_{jm},\theta)\Big)\\
\leq\ &\Pr\Big(Y_{jm} = 1 | X_{nm}, W_{jm}\Big)\\
\leq\ &1 - \Pr\Big(\zeta_{jm} > \overline{\Delta}_j(X_{nm}) - c(W_{jm},\theta)\Big)
\end{aligned}
$$

- Assumption: if product j is observed, then $Y_{jm} = 1$ is **not** a dominated strategy after ζ_{jm} is realized $\implies$ bounds for $\Pr\Big(Y_{jm} = 1 | X_{nm}, W_{jm}\Big)$, where the LB is such that $Y_{jm} = 1$ is a dominant strategy and the UB is such that $Y_{jm} = 1$ is not a dominated strategy

Moment Inequalities

- Following the bounds on the conditional choice probabilities, construct moment functions:

$$L(Y_{jm}, X_{nm}, W_{jm}, \theta, \sigma_\zeta) = F_\zeta\left(\underline{\Delta}_j(X_{nm}) - c(W_{jm}, \theta)\right) - \mathbb{1}\left(Y_{jm} = 1\right)$$
$$H(Y_{jm}, X_{nm}, W_{jm}, \theta, \sigma_\zeta) = \mathbb{1}\left(Y_{jm} = 1\right) - F_\zeta\left(\overline{\Delta}_j(X_{nm}) - c(W_{jm}, \theta)\right)$$

- Which gives the conditional moment inequalities:

$$\mathbb{E}[L(Y_{jm}, X_{nm}, W_{jm}, \theta, \sigma_\zeta) | (X_{nm}, W_{jm})] \leq 0$$
$$\mathbb{E}[H(Y_{jm}, X_{nm}, W_{jm}, \theta, \sigma_\zeta) | (X_{nm}, W_{jm})] \leq 0$$

- The rest of the estimation procedure follows Chernozhukov, Chetverikov & Kato (2019) for inference based on conditional moment inequalities

Estimation of Bounds

- Too computationally costly to solve directly for $\underline{\Delta}_j(X_{nm})$ and $\overline{\Delta}_j(X_{nm}) \implies$ solving for the min and max of expected change in profit over all possible values of Y_{-jm}, with $2^{|Y_{-jm}|}$ possible values and having to solve a BLP model each time to get prices and invert MC
- Instead, understand that the variable profit function is a linear function of and is decreasing in the entry decisions of other products because all products are substitutes
- So $\underline{\Delta}_j(X_{nm})$ and $\overline{\Delta}_j(X_{nm})$ can be approximated by:

$$\underline{\Delta}_j(X_{nm}) \approx \Delta_j\big((1,\dots,1), X_{nm}\big)$$
$$\overline{\Delta}_j(X_{nm}) \approx \Delta_j\big((0,\dots,0), X_{nm}\big)$$

Demand-side Estimates (1/2)

Unobserved	σ_0	0.00	Income Effect	κ_0	-2.15
Heterogeneity		(0.02)			(0.02)
	σ^{ale}	1.98		κ^{craft}	1.08
		(<0.01)			(0.02)
	σ^{lager}	0.89		κ_α	0.15
		(<0.01)			(<0.01)
	σ^{light}	2.67			
		(<0.01)			
	σ^{import}	2.14	Price Coefficient	α	-2.26
		(<0.01)			(0.03)
	σ^{craft}	2.44			
		(<0.01)			
	$\rho^{\text{craft-light}}$	-0.28			
		(<0.01)			

Note: Standard errors are in parentheses.

Figure 4: Estimates of Indirect Utility Parameters

- σ-terms show significant dispersion in unobserved consumer heterogeneity
- High-income HHs are less likely to purchase beer; those that purchase beer are less price sensitive and prefer craft beer

Demand-side Estimates (2/2)

		Craft			Main	
Craft	-10.09	0.14	0.02	0.01	0.01	0.01
	0.22	-9.52	0.02	0.01	0.01	0.01
	0.04	0.03	-9.16	0.01	0.03	0.01
Main	<0.01	<0.01	<0.01	-5.87	0.04	0.67
	<0.01	<0.01	<0.01	0.08	-6.81	0.08
	<0.01	<0.01	<0.01	0.68	0.04	-5.88

Figure 5: Own-price & Cross-price Elasticities

- There is more substitution within the craft group than substitution across craft and non-craft groups

Supply-side Estimates (1/2)

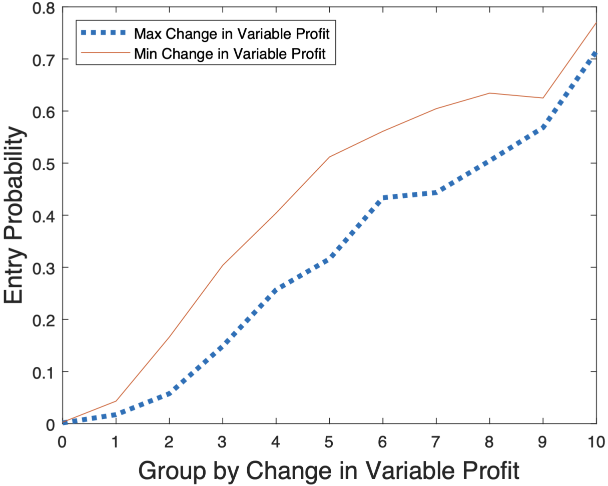


Figure 6: Entry Probability vs. $[\underline{\Delta}_j(\cdot),\overline{\Delta}_j(\cdot)]$

Supply-side Estimates (2/2)

Craft (θ_1)	[229.14, 1093.24]
In State$\times$ Craft (θ_2)	[-387.82, 208.18]
Market-size specific fixed cost (θ_3)	
Small market	[308.95, 938.33]
Medium market	[1027.77, 1468.10]
Large market	[3325.71, 4177.69]
Market-size specific std. dev. (σ_ς)	
Small market	[0.00, 522.79]
Medium market	[679.41, 863.25]
Large market	[2511.65, 3424.06]

Note: Estimates in 2016 US dollars.

Figure 7: Interval Estimates of Fixed Cost Parameters

- Higher fixed cost for craft breweries
- Larger markets have higher fixed costs and larger shocks

Scenario

- Simulate a merger where the largest non-craft macro brewery acquires the three large craft breweries in California
- Merged firm accounts for 44% of craft beer sales in 2016 (similar concentration in the overall beer market)
- Number of firms, prices, product varieties (and later fixed costs) are allowed to adjust:
  - CF1. (i) Entrant effects (ii) Product effects (iii) Price effects
  - CF2. (ii) Product effects, (iii) Price effects
  - CF3. (iii) Price effects
- Total product variety effect ($= CF1 - CF3$) decomposed into change in products from entrants ($= CF1 - CF2$) and change in products from incumbents ($= CF2 - CF3$)

Aggregate Post-Merger Outcomes (1/2)

Average Change Per Market			Aggregate Change Across Markets		
(1)	# of firms	[-2.93, -2.82]	(10)	quantity (1000)	[-266.94, -251.57]
(2)	# new entrants	[0.02, 0.14]	(11)	craft	[-249.76, -230.46]
(3)	# of products	[-0.86, -0.33]	(12)	craft, merging firms	[-301.64, -283.55]
(4)	merging firms	[-0.90, -0.49]	(13)	consumer surplus ($1000)	[-639.00, -602.81]
(5)	non-merging incumbents	[0.02, 0.08]	(14)	craft beer profits ($1000)	[97.95, 111.07]
(6)	new entrants	[0.02, 0.14]	(15)	merging firms	[24.78, 27.68]
(7)	average price ($)	[0.00, 0.00]	(16)	total surplus ($1000)	[-533.03, -504.86]
(8)	craft products ($)	[0.04, 0.07]	ΔCS decomposition ($1000)		
(9)	craft, merging firms ($)	[0.13, 0.15]	(17)	due to variety change	[-155.43, -106.54]
			(18)	due to entry	[6.85, 26.09]
			(19)	due to incumbent product adj.	[-164.55, -123.48]

Notes: Rows (1)-(9) on the left report the weighted average changes, where the simulated expected changes in each market are weighted by the market size. Rows (10)-(19) on the right report the total changes, where the simulated expected changes are summed across markets. We report the range of estimates across the vectors of fixed cost parameters sampled from their 95% confidence set.

Figure 8: Weighted Average Changes with no Fixed Cost Reductions

Aggregate Post-Merger Outcomes (2/2)

Average Change Per Market			Aggregate Change Across Markets		
(1)	# of firms	[-2.95, -2.93]	(10)	quantity (1000)	[-213.04, -127.44]
(2)	# new entrants	[0.00, 0.03]	(11)	craft	[-190.51, -99.72]
(3)	# of products	[0.00, 1.43]	(12)	craft, merging firms	[-229.06, -122.52]
(4)	merging firms	[-0.04, 1.42]	(13)	consumer surplus ($1000)	[-512.79, -320.01]
(5)	non-merging incumbents	[0.00, 0.01]	(14)	craft beer profits ($1000)	[89.96, 145.94]
(6)	new entrants	[0.00, 0.03]	(15)	merging firms	[26.77, 103.40]
(7)	average price ($)	[0.00, 0.01]	(16)	total surplus ($1000)	[-422.83, -174.07]
(8)	craft products ($)	[0.07, 0.10]	ΔCS decomposition ($1000)		
(9)	craft, merging firms ($)	[0.14, 0.19]	(17)	due to variety change	[-16.52, 176.26]
			(18)	due to entry	[0.59, 7.25]
			(19)	due to incumbent product adj.	[-23.77, 175.67]

Notes: this table reports the results when we take into account potential reductions in fixed costs when a craft brewery is acquired by a macro brewery. Rows (1)-(9) on the left report the weighted average changes, where the simulated expected changes in each market are weighted by the market size. Rows (10)-(19) on the right report the total changes, where the simulated expected changes are summed across markets. We report the range of estimates across the vectors of fixed cost parameters sampled from their 95% confidence set.

Figure 9: Weighted Average Changes allowing for Fixed Cost Reductions

Heterogeneous Outcomes by Market Size (1/3)

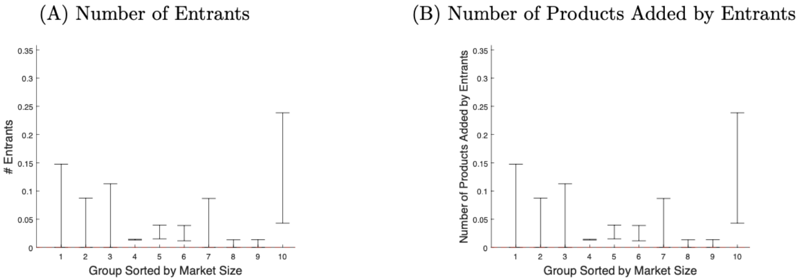
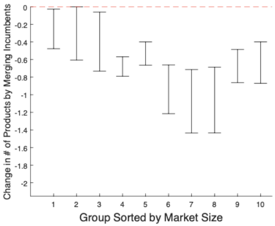


Figure 10: Number of Entrants and New Products from Entrants

Heterogeneous Outcomes by Market Size (2/3)

(C) Change in the Number of Products by Merging Firms



(D) Change in the Number of Products by Non-merging Incumbent Firms

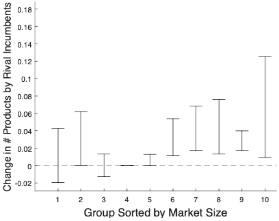


Figure 11: Δ No. of Products by Merging and Non-Merging Firms

Heterogeneous Outcomes by Market Size (3/3)

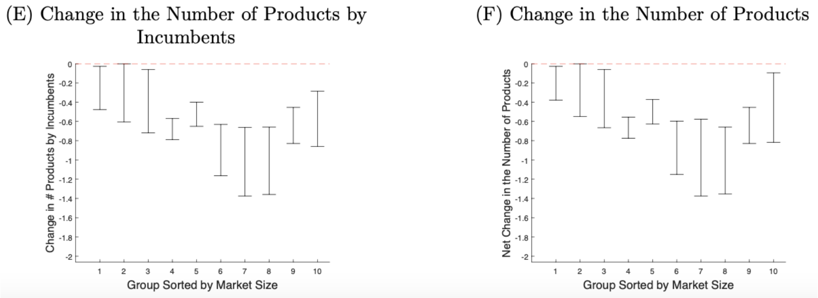


Figure 12: Net Effects on No. of Products

Key Findings

- Firm merger in a multi-product market can lead to entry and product variety effects
  1. Merged firms raise prices and reduce product variety, reducing consumer surplus; also find a larger reduction in product variety if the merging firms have more market power
  2. New products by entrants and non-merging firms in response to merger would increase consumer surplus
- From the simulation with the retail craft beer market in California, the entry effect (2) is small and does not completely offset the negative effect (1) of the merger
- Merger effects are heterogeneous across markets, with larger markets more likely to experience an increase in products from entrants and non-merging firms

Concluding Remarks

- Main contribution: new approach to entry games (into a multi-product market) that involve a large set of discrete choices
  - Construct bounds for the entry probability of each product — one-dimensional and tractable to compute
  - Do not require equilibrium selection rules or solving the full game
- Model has relevant application to IO: study changes in product variety due to merger
  - Would have liked to see the model applied to an actual merger (which occurred in the data) in addition to the simulation