Econometric Analysis: Hausman and Leonard (2002) and Hosken et al (2011)

Class 6

Structural versus Reduced Form

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- Empirical papers can be broadly classified as:
 - Structural: Empirical specification based on a micro model: i.e. estimate parameters of a model
 - E.g. Hausman and Leonard (2002)
 - Reduced form: Explores relationship among variables without deriving the empirical specification from theory
 - E.g. Collins and Preston (1966), Ashenfelter and Hosken (2008/10), Hosken et al (2011)





Differentiated Goods & Oligopoly

- Bertrand is a common oligopoly model in empirical work
 - Ex.: cereals, automobiles, bath tissue, soft drinks
 - N firms each sells one differentiated good
 - Multi-product firms can be modeled
 - Price endogeneity: issue in estimating demand
 - Product characteristics often assumed exogenous

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- Empirical models often assume constant mc
 - Important assumption if lack cost data (usual)

Bertrand: First Order Condition

$$\pi_{j}(p_{1}, \dots, p_{N}) = p_{j}q_{j}(p_{1}, \dots, p_{N}) - C_{j}(q_{j})$$

$$\frac{\partial \pi_{j}}{\partial p_{j}} = q_{j}(p_{1}, \dots, p_{N}) + (p_{j} - mc_{j})\frac{\partial q_{j}(p_{1}, \dots, p_{N})}{\partial p_{j}} \stackrel{set}{=} 0$$

$$(p_{j} - mc_{j})\frac{\partial q_{j}}{\partial p_{j}} = -q_{j}$$

$$\frac{p_{j} - mc_{j}}{p_{j}} = -\frac{1}{\frac{\partial q_{j}p_{j}}{\partial p_{j}}q_{j}}$$

$$\frac{p_{j} - mc_{j}}{p_{j}} = -\frac{1}{\varepsilon_{j}}$$

Static Bertrand NE

•	Price vector $(p_1,, p_N)$ that solves these N equations is the NE	$\frac{p_1-c_1}{p_1}=-\frac{1}{\varepsilon_1}$
	 All firms maximizing profits: no one firm has an incentive to deviate 	$\frac{p_2-c_2}{p_2}=-\frac{1}{\varepsilon_2}$
•	Prices in data, so if estimate elasticities can find marginal costs algebraically	$\frac{p_N - c_N}{p_N} = -\frac{1}{\varepsilon_N}$

"Back out" Costs Example

- Observe $p_1 = 10$ and $p_2 = 20$
- Assume constant elasticity demand functional form; estimate $\varepsilon_{11}=-1.75$ and $\varepsilon_{22}=-1.55$
- If constant marginal costs and industry in Bertrand NE, what are each firm's costs?

$$\frac{p_1 - c_1}{p_1} = -\frac{1}{\varepsilon_1} \Rightarrow \frac{10 - c_1}{10} = -\frac{1}{-1.75} \Rightarrow c_1 = 4.3$$
$$\frac{p_2 - c_2}{p_2} = -\frac{1}{\varepsilon_2} \Rightarrow \frac{20 - c_2}{20} = -\frac{1}{-1.55} \Rightarrow c_2 = 7.1$$
What if $\varepsilon_{11} = -0.75$

Estimating Demand: Representative Consumer Approach

- Representative consumer (goods are goods)
 - Systems of demand equations
 - Aggregate data
 - Market level data: total quantity over all consumers
 - Because adding up over many consumers, quantity treated as a continuous variable
 - Est. demand parameters for system w/ regression

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 In contrast, with micro-level data on individual consumers, discrete-choice models often used

Demand system, N goods

$$q_{1} = f(p_{1}, p_{2}, \dots, p_{N}, x_{1}, x_{2}, \dots, x_{H}, \theta_{1})$$

$$q_{2} = f(p_{1}, p_{2}, \dots, p_{N}, x_{1}, x_{2}, \dots, x_{H}, \theta_{2})$$
:

 $q_N = f(p_1, p_2, \dots, p_N, x_1, x_2, \dots, x_H, \theta_N)$

- $-q_j$: Aggregate quantity purchased of Good j
- $-p_i$: Market price of Good j
- $-x_h$: A demand shifter (*H* in total)
- θ_j : Vector of demand parameters for Good j

Constant Elasticity Specification

$$\ln(q_1) = \alpha_1 + \sum_{k=1}^N \eta_{1k} \ln(p_k) + \varepsilon_1$$

$$\ln(q_2) = \alpha_2 + \sum_{k=1}^N \eta_{2k} \ln(p_k) + \varepsilon_2$$

$$\vdots$$

$$\ln(q_N) = \alpha_N + \sum_{k=1}^N \eta_{Nk} \ln(p_k) + \varepsilon_N$$

– What is η_{22} ? η_{23} ? What is α_N ?

– How many parameters to estimate?

– What is ε_2 ? Why no other subscript?

Linear Specification

$$q_{1} = \alpha_{1} + \sum_{k=1}^{N} \beta_{1k} p_{k} + \varepsilon_{1}$$

$$q_{2} = \alpha_{2} + \sum_{k=1}^{N} \beta_{2k} p_{k} + \varepsilon_{2}$$

$$\vdots$$

$$q_{N} = \alpha_{N} + \sum_{k=1}^{N} \beta_{Nk} p_{k} + \varepsilon_{N}$$

- What is β_{22} ? β_{23} ? What is α_N ? - How many parameters to estimate?

Too Many Parameters: Dimensionality Problem (N^2)

- · More parameters to estimate, need more data
 - Impossible to estimate more parameters than observations in the data
 - Inadvisable to have very small degrees of freedom
 - A priori restrictions on demand parameters reduce size of estimation problem
 - Ex: Restrict some elasticities to be equal: $\eta_{12}=\eta_{21}$
 - Impose structure on substitution possibilities
 - Ad hoc: "for this" choice of convenience

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Endogeneity Still A Problem

- · Firms choose prices given demand
 - Price is endogenous; Firms choose it to maximize profits; Behavioral model (Bertrand)
 - Price correlated with unobserved (by researcher) demand shifters that are in the error term
- To address endogeneity (Class 5):
 - Collect more data
 - Include fixed effects
 - Instrumental variables

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Example: Bath Tissue (BT)

- Hausman and Leonard (2002)
 - Oligopoly bath tissue industry: Proctor & Gamble (Charmin), James River (Northern), Georgia Pacific (Angel Soft), Scott (Cottonelle)
 - Case study to estimate benefit of new product
 1991: Kimberly Clark (Kleenex), introduced new BT
 - Test validity of Bertrand NE assumption: compare model's prediction with actual effect of the new product in bath tissue industry





Impact of New Product

- Two effects of a new products:
 - Increased competition lowers prices of existing products (if single-product firms)
 - Bigger effect if new good is a close substitute
 - Increased variety benefits consumers who have heterogeneous preferences
 - Bigger effect if new good not a close substitute

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Production Costs

- Production technology for bath tissue:
 - High fixed costs: tissue machines major capital equipment
 - Low marginal costs: main input cost is pulp
 Pulp prices are highly cyclical ("pulp cycle")
- What cost function reasonable to assume?
- How do fixed costs affect price and output decisions?

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Data

- Scanner data provided by AC Nielson
 - Weekly data: Jan. 92 Sept. 95 (196 weeks)
 - 30 U.S. cities
 - 7 brands of bath tissue (include private label)
 - Kleenex, Cottonelle, Charmin, Northern, Angel Soft, Scot Tissue, and Private Label
 - Unit sales and average price for each city in each week for each brand
- Income by city, by week from BLS

Bath Tissue Expenditures

City	BT Total Expenditure (\$) (4/95 – 9/95)
Charlotte	\$10,308,700
Chicago	\$35,658,610
Dallas	\$21,537,900
Miami	\$22,377,420

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Product Aggregation

- Not many different brands of bath tissue, but many sizes and styles of each brand
 - Many SKU's (stock keeping unit) and UPC's (universal product code: bar code)
- To solve too many elasticity problem:
 - Aggregate up to brand level
 - Aggregate over sizes (measure 28,000 sheets)
 - Price is dollars per 28,000 sheets

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Expenditure Market Shares

	Kleenex	Charmin	Angel Soft	Scot	Private Label
Charlotte	10.0%	36.1%	11.3%	25.8%	3.2%
Chicago	10.5%	26.6%	4.4%	23.1%	8.6%
Dallas	10.7%	37.1%	10.7%	11.1%	8.4%
Miami	9.1%	38.4%	10.8%	14.4%	11.2%

Prices Per 28,000 Sheets

	Kleenex	Charmin	Angel Soft	Scot	Private Label
Charlotte	\$25.82	\$32.60	\$22.19	\$15.06	\$17.23
Chicago	\$26.01	\$30.36	\$22.43	\$14.06	\$15.73
Dallas	\$25.71	\$32.92	\$22.32	\$16.23	\$18.83
Miami	\$24.81	\$33.99	\$22.64	\$15.99	\$18.07

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KBT Rolled Out in Waves

- Kimberly Clark introduced its new product "Kleenex Bath Tissue" (KBT) in waves
 - -1^{st} wave: 17 of 30 cities introduce before 1/92
 - -2^{nd} wave: 3 of 30 cities introduce in 7/93
 - -3^{rd} wave: 10 of 30 cities introduce in 5/94
- Important because if introduced in all cities at same moment, could not conclude changes are caused by KBT's introduction

Demand Varies over Markets

- Each city is a separate market
 - No reason why demand conditions will be the same across markets
 - In fact, data shows substantial variation in prices and market shares across the 30 cities included in the data
 - Within a city, demand may change over time
- Firms can set prices in each market
 - Notice that national advertising mute on price

Two-Stage Budgeting & AIDS

- Limit parameters with two-stage budgeting
 - First Stage: Consumers choose total bath tissue expenditures (\$)
 - Second Stage: Consumers choose brands of bath tissue given their bath tissue budget
 - No substitution with goods not in second stage

• Estimate "Almost Ideal Demand System"

- 2nd order approx. (flexible functional form)

- Only 7 goods: price elasticities unconstrained

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2nd Stage: Almost Ideal Demand System (AIDS)

$$s_{int} = \alpha_{in} + \beta_i \log\left(\frac{Y_{nt}}{P_{nt}}\right) + \sum_{j=1}^{I} \gamma_{ij} \log(p_{jnt}) + Z_{nt}\theta_i + \varepsilon_{int}$$

- Indices:
- Variables in AIDS model:

- s: expenditure-based market share

- *i*: brand (1, ..., I)- *n*: city (1, ..., N)
- *t*: week (1, ..., *T*)
- Y: total BT expenditures (\$)
 P: price index (Stone Index)
- -p: average price per 28,000 sheets
- Z: month dummies and a time trend

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1st Stage: Overall Demand for BT

 $\log(u_{nt}) = \mu_n + \lambda \log(X_{nt}) + \delta \log(P_{nt}) + Z_{nt}\phi + \eta_{nt}$

• Indices:

- Variables in top stage:
- *n*: city (1, ..., *N*)
- *u*: quantity of BT *X*: income (BLS)
- -t: week (1, ..., T)
- P: price index (Stone Index)
- Z: month dummies and a time trend

Price Correlated with Error

$$s_{int} = \alpha_{in} + \beta_i \log\left(\frac{Y_{nt}}{P_{nt}}\right) + \sum_{j=1}^{l} \gamma_{ij} \log(p_{jnt}) + Z_{nt}\theta_i + \varepsilon_{int}$$
Problem

- If could control for *all* differences in demand across cities and time then price would not be correlated with error
 - What do authors do to control for some differences?
 - Possible to control for everything affecting demand across markets and time?

Price endogeneity: a very serious concern in estimating demand

- In estimating demand, expect endogeneity to lead to upwardly biased estimates of γ_{ii}
 - Ex: In markets with the strongest demand for Charmin, expect higher prices
 - Might even get a positive estimated price effect because of the endogeneity bias
 - Without instruments, parameter estimates biased: causes biased elasticity estimates and biased estimates of KBT's value, and invalidates test of Bertrand NE

Requirements: Valid Instrument

- <u>Instrumental variable</u>: A variable with the following four properties:
 - It is an additional variable that is not logically included as a direct explanatory variable
 - "Exclusion restriction"
 - Is correlated with included endogenous explanatory (RHS) variable
 - Is <u>not</u> correlated with unobservables (ε)
 - Varies over observations in data

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Good Instruments Hard to Find

- Valid instruments often difficult to find
- A lot of discussion about empirical papers centers around the validity of the instruments and whether reported parameter estimates are really consistent
 - Critics often argue that instrumental variables are not really exogenous
 - Instruments may be "weak": not very correlated with endogenous variables

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Finding Instruments

- At first glace appears that they have no available instruments in the data:
 - Only have data on price, quantity and income
 - No cost shifters available
 - "While plant-specific variable cost data for each manufacturers would be helpful, having access to such data is rare and indeed, we do not have access to such data" p. 248

Intuition for their instruments

- "To get around this problem, we attempt to utilize the panel structure of the underlying data ... we use the prices from one city as the instruments for other cities"
- "The intuition is that prices in each city reflect both underlying product costs and city-specific factors that vary over time as supermarkets run promotions on a particular product."
- "To the extent that the stochastic city-specific factors are independent of each other, prices from one city can serve as instruments for another city." p. 249

Valid Instrument? Example

- Estimate KBT's demand in Chicago
 - Need instrument for KBT's price in Chicago
- Is KBT's price in Miami:
 - Validly excluded from demand in Chicago?
 - Correlated with KBT's price in Chicago's?
 - Not correlated with unobserved factors affecting demand in Chicago?
 - Varying over time?

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National Advertising

- As are many consumer goods, bath tissue is advertised nationally
 - Primarily through television commercials
 - Cha-Cha-Cha Charmin!
 - Do not advertise price, but try to build brand loyalty by advertising a favorable brand-image
- Does national level advertising undermine validity of using prices in one city as an instrument for price in another city?

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Own Price Elasticity Estimates (at sample averages)

	Kleenex	Charmin	Angel Soft	Scot	Private Label
Kleenex	-3.29 (0.10)				
Charmin					
Private Label					

Interpretation of -3.29? Point estimate statistically significant?

Can we infer that the demand for Kleenex is inelastic?

Own Price Elasticity Estimates (at sample averages)

	Kleenex	Charmin	Angel Soft	Scot	Private Label
Kleenex	-3.29 (0.10)				
Charmin					
Private Label					-1.69 (0.07)

Does -1.69 seem too inelastic? Authors argue that they aggregated a lot of products into this category: more aggregation in general means lower elasticity.

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Own & Cross Price Elasticity Estimates (at sample averages)

	Kleenex	Charmin	Angel Soft	Scot	Private Label
Kleenex	-3.29 (0.10)	0.68 (0.09)			
Charmin					
Private Label					

Interpretation of 0.68? Point estimate statistically significant?

Can we infer that Kleenex and Charmin are substitutes?

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Own & Cross Price Elasticity Estimates (at sample averages)

	Kleenex	Charmin	Angel Soft	Scot	Private Label
Kleenex	-3.29	0.68	0.21	0.09	0.02
	(0.10)	(0.09)	(0.08)	(0.06)	(0.05)
Charmin	0.26	-2.29	0.26	0.28	0.08
	(0.03)	(0.04)	(0.03)	(0.02)	(0.02)
Private	0.02	0.23	0.15	0.01	-1.69
Label	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)

Which is the closest substitute for Kleenex? Worst?

Infer that the worst substitute is not a substitute at all? Is this plausible?

Estimated Price-Cost Margins (average for last 6 months of data)

	Kleenex		
Min.	8.9%		
Median	25.1%		
Max.	38.5%		

Why is there variation?

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Estimated Price-Cost Margins (average for last 6 months of data)

	Kleenex	Charmin	Angel Soft	Scot	Private Label
Min.	8.9%	31.8%	4.3%	19.7%	38.7%
Median	25.1%	44.4%	26.7%	54.8%	62.5%
Max.	38.5%	52.5%	50.0%	75.7%	83.0%

Which brands are associated with greater market power?

Are the relative magnitudes of the estimates consistent with expectations considering branding?

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Rough Check Using Elasticity Estimates

	Kleenex	Charmin	Private Label
Kleenex	-3.29	0.68	0.02
	(0.10)	(0.09)	(0.05)
Charmin	0.26	-2.29	0.08
	(0.03)	(0.04)	(0.02)
Private	0.02	0.23	-1.69
Label	(0.07)	(0.08)	(0.07)
1 0.20	1	0.4.4	0.50

 $-\frac{1}{-3.29} = 0.30 \qquad -\frac{1}{-2.29} = 0.44 \qquad -\frac{1}{-1.69} = 0.59$

How to roughly check internal consistency of results?

Is Bath Tissue in Bertrand NE?

- Paper has two main goals:
 - Estimate consumer benefit from introduction of a new bath tissue product (KBT)
 - See paper for estimates
 - Empirically test whether the static Bertrand model is appropriate to model firms' behavior in the bath tissue industry
 - Idea is to compare observed impact of KBT's introduction with the impact predicted by model

Price Effects of KBT Introduction						
Brand	Direct Estimate	Indirect Estimate (Bertrand NE)	t-stat			
Cotton- elle	-8.2% (1.3%)	-3.6% (0.3%)	3.4			
Charmin	-3.5% (0.9%)	-2.8% (0.1%)	0.7			
Northern	-2.3% (0.8%)	-3.4% (0.2%)	1.4			
Angel Soft	-3.5% (0.6%)	-2.4% (0.3%)	1.6			
Scot	-0.6% (0.5%)	-1.5% (0.4%)	1.3			
Private Label	-3.8% (0.9%)	-0.7% (0.7%)	2.7			

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Looking Ahead

- Dry-run presentation Tuesday, 11:10 1:00
 - Team 1: Presentation is complete and practiced
 - Bring completed "Team Presentation Outline and Checklist" and "General Presentation Skills Rubrics"
 - Non-presenters: you do <u>not</u> have class on Tuesday
- Everyone, be ready for participation on Thursday (Q&A and written participation)
- Assignment #3 due Tues, Oct. 31 by 4:00
 Economics Reception, 150 St. George, main floor