# 1 Lecture1.

1. Syllabus and Course Overview.

2. Helpful hints for graduate students.

3. Overview of topics.

# 2 Syllabus and Course Overview.

- Welcome to Economics 8681.
- Intended for Ph.D. students interested in conducting research in empirical IO.
- Focus on research frontier.
- Main goal: Facilitate student research!

We will discuss the following classes of models (estimation and applications)

1. Models of product differentiation.

2. Static games of Imperfect Competition.

3. Dynamic games of Imperfect competition.

4. Auctions.

## 2.1 Requirements.

- This class will be rather demanding.

- However, I hope that you will find the benefits will exceed the cost.

- Philosophy– last chance to be exposed to the frontier in class!

1. Read the papers **before** class.

2. There will be 3 or 4 intense empirical exercises.

-We will impliment the estimators studied in class.

-Familiarity with some programming language (e.g. Matlab, Fortran, C, Gauss. . . .)

## 2.2 Grading.

- Students will be graded on item 2 above.

- Also, students will be graded based on class participation.

- There will be no in class exams.

- Students are encouraged to work together by discussing the papers and in implementing the estimators.

- Course information can be found on my personal web page.

- Office hours are on Friday and by appointment.

- Registered students are encouraged to drop by– don't be shy!

- Don't be passive. Ask questions– this is an important part of being a good researcher.

- Good reseachers love to discuss economics.

# 3 Helpful Hints for Graduate Students.

- Objective of most graduate students– Get a Good Job/ write well cited research!

- If you want to get a job at a research university, the following two attributes will determine your level of success:

1. The quality of your job market paper.

2. Your ability to communicate in an articulate manner with other people.

- In economics departments, there is relatively more weight on the first item.

- In business schools, more weight on the second item.

**Remark.** If your first language is not English and you wish to consider the B-School or even consulting market, you should exploit available ESL resources.

-Weak oral communication skills $\Longrightarrow$ trouble with the MBA's.

-Oral communication skills also a consideration at Econ. Departments.

Things that don't matter very much in your placement:

1. Your grades.

2. Being an outstanding TA or RA.

3. Politics.

- The New Economics PhD market is a big matching market (lots of candidates with lots of schools).

- All the department can do is get other people to read your file.

- Typically, most faculty are generous in recommending students.

- However, after someone else gets your file, our ability to influence the outcome at the margin is small.

- This is true even if you believe your advisor is a "big shot".

- Economists are an independent bunch who make up their own minds about the quality of alternative candidates.

- The market is quite efficient and it is relatively rare that students are massively under or over placed.

- If they are, the market will reallocate them shortly.

## 3.1 Characteristicss of High Quality Job Market Papers in Empirical Microeconomics?

1. The authors asks an interesting and novel research question.

-The data and questions are new and of interest to your audience.

-Rehashing the same questions with not very different results from other researchers is not a good strategy.

2. The analysis is technically well executed.

-You should attempt to use state of the art methods.

-Making at least a small technical innovation in some part of the paper is a good signal to future employers (particularly at top departments).

-They want to make sure that you are capable of teaching graduate students.

-If you don't try hard technically on some part of your paper, don't expect your employers to give you the benefit of the doubt that you are technically up to speed.

-Clean identification.

3. The paper is well written and presented well.

-Remember to write your paper to a general audience of economists, not just specialists.

-Don't skip steps of logic.

-This is much, much harder than most graduate students think.

-Budget at least 6 months for writing and polishing your results.

## 3.2 Common Pitfalls.

1. Research project starts off by making a small extension to an existing, well known paper.

-Typically, if easy, but important extensions could be made the author would have done it already.

2. Technique motivates the empirical question (instead of vice versa).

-This is appropriate for a theorist, since producing purely technical papers is the domain of theorists.

-Pure econometric theory, or economic theory, is an extremely competitive field (much more so than applied work).

-Outcomes in this field have a high variance– not for the risk averse!

-When an applied economist comes up with the technique before the theory, the result is frequently that neither the theoretical innovation nor the application are very compelling.

3. Fail to produce a first draft early enough.

-The most successful candidates have a solid first draft a year before they go onto the market.

-The profession puts a high premium on polished work.

-Polishing a paper your first time out requires a considerable amount of time.

## 3.3 Helpful Hints

1. Start out simply.

-Start your project with a good question.

-Before you estimate a complicated model, examine the data using simpler techniques (e.g. a table or a regression).

-Research is a process of polishing.

2. Get started right away.

-Rough in your first draft as soon as possible with all the major moving parts.

-Gradually polish and extend your results.

-Most people squander their third year and don't make forward progress on research.

-Few people have time left to spare before the job market.

3. Attend a reading group and a seminar.

-A reading group allows you to keep up on recent research.

-If you read a paper a week for 3 years, you will know 100 papers (at least) by the time your graduate.

-A seminar allows you to see leading researchers present and discuss their work.

-Giving a clear, persuasive seminar is important in getting a job. Learn from researchers with more experience.

4. Start working with an advisor.

-You should meet with an advisor on a regular basis (weekly or bi-weekly).

-If you aren't making forward progress, you might want to see if you can find a better fit.

# 4 Overview of topics.

- The course will primarily focus on structural models.

- This is due in part to the instructor's research interests.

- Also, this is a natural way to organize the course.

# Why use structural models if people aren't rational?

- We are all aware, either from industry, or personal experience, of examples where people or firms act irrationally.

- Recent work in theory suggests that Nash equilibrium can be the result of irrational behavior.

- Evolution- survival of the fittest leads to equilibrium.

- Learning- backward looking behavior can frequently lead to equilibrium.

- If agents experience feedback causes them to improve their behavior (e.g. learning or equilibrium), the result will be equilibrium if the economy doesn't degenerate into infinite cycles.

- You can also estimate structural models where people are less than rational.

- This has a mixed track record.

- In many methods for structural estimation, a first step requires estimation of a "reduced form".

- The structural estimation boils down to a change of variables, from the reduced form to the structural parameters.

- In many cases, this change of variables is close to just identified.

- The conflict between structural and reduced form methods is not particularly intense when viewed from this perspective.

- Structural estimation just involves a relabeling of the parameters.

- IO economists increasingly spend time simulating computationally sophisticated oligopoly models.

- Like macro, computational methods are used to study models.

- Estimation is a reaonable way to choose benchmark parameter values.

- The simulations are often interesting as pieces of applied theory.

## 4.1 Differentiated Products.

- In empirical industrial organization, one of the most active areas of recent research has been estimation of demand and supply in differentiated product markets.

- Most of the markets in our empirical applications offer similar, but not identical products.

- Random utility models such as the logit, multinomial probit, etc.. are common models used to study demand in these markets.

- Benchmark random utility models have the following strucutre:

$$u_{ij} = \sum_k \beta_k x_{j,k} - \alpha p_j + \varepsilon_{ij}$$

$$\varepsilon_{ij} \text{ distributed iid}$$

- $x_{j,k}$ is a vector of characteristics for product $j$.

- $\varepsilon_{ij}$ is a household level idiosyncratic taste shock (e.g. logit, probit, GEV...).

- Each household realizes a set of choice specific taste shocks and chooses the utility maxizing alternative.

- In applications, we often work with the conditional logit model:

- Let $P(j|x)$ denote the probability that $j$ is chosen conditional on $x = (x_j)_{j=1}^J$

- In the conditional logit:

$$P(j|x) = \frac{\exp(x_j' \cdot \beta)}{\sum_{j'=1}^J \exp(x_{j'}' \cdot \beta)}$$

- With individual level data, we can estimate this model using MLE.

- This is a computationally elegant framework.

- However, this model has some limitations.

- First, the model puts quite restrictive assumptions on own and cross price elasticities.

- Calculating the own and cross price elasticites.

- Let $\eta_{jk}$ denote elasticity between j and k.

$$\begin{aligned}
\eta_{jk} &= \frac{\partial \text{Pr(i chooses j)}}{\partial p_k} \frac{p_k}{\text{Pr(i chooses j)}} \\
&= \begin{cases} -\alpha p_j (1 - s_j) \text{ if } j = k \\ -\alpha p_k s_k \end{cases}
\end{aligned}$$

- Second, prices are assumed to be exogenous in the model above.

- BLP noticed that in some previous studies, even with microdata, researchers had estimated "upward sloping" demand curves.

- They conjecture this was because the researchers don't observe all relevant product characteristics.

- Also, heterogeneity only enters through the i.i.d. $\varepsilon_{ij}$.

- In practice, consumers probably have different marginal valuations for product characteristics.

- Berry (1994), BLP (1995), Nevo (2001), Petrin(2002), etc... examine models of the form:

$$u_{ij} = \sum_k \beta_{i,k} \log(x_{j,k}) + \xi_j - \alpha_i \log(y_i - p_j) + \varepsilon_{ij}$$

$$(\beta_i, \alpha_i) \sim F(d_i; \theta)$$

$$E(\xi_j | z_j) = 0$$

- $x_{j,k}$ is a vector of characteristics for product $j$.

- $\xi_j$ is a scalar characteristic observed to the consumer, but not the economist.

- $\varepsilon_{ij}$ is a household level idiosyncratic taste shock (e.g. logit, probit, GEV...).

- $(\beta_i, \alpha_i)$ are random coefficients from a parametric distribution which depend on a vector of household level demographics $d_i$.

- This model generalized the logit and multinomial probit by allowing for product characteristics that are seen by the consumer, not the economists, $\xi_j$.

- Omiting this factor will lead to price elasticities that are biased (often severrly) towards zero.

- Intuition- much of what consumers are paying for is not included in our data sets.

- If we don't account for everything consumers are buying, they don't appear to be very price sensitive.

- The inclusion of random coefficients, $(\beta_i, \alpha_i) \sim F(d_i; \theta)$ allows for more flexibility in substitution patterns.

- We will study how to estimate BLP and some of its extensions.

- These include non-parametric versions of this model and models with an explicit supply side.

- We will also discuss Bayesian approaches.

# 5 The model

- Illustrate with a simple entry example.
- Generalization of simple conditional logit.
- Key point- a game is a simple fixed point.

## 5.1 Entry Example.

- Data on a cross section of markets.
- Entry by Walmart and/or Target.
- Markets $t = 1, ..., T$ and firms $i = 1, 2$
- Let $a_{i,t} = 1$ denote entry and $a_{i,t} = 0$ denote no entry.
- $DIST_{it}$ is distance from headquarters
- $POP_t$ is population of market $t$

- The profit of firm $i$ is:

$$u_{it} = POP_t \cdot \alpha + DIST_{it} \cdot \beta + 1\left\{a_{-i,t} = 1\right\} \cdot \delta + \varepsilon_{it}$$
if $a_{i,t} = 1$

$u_{it} = 0$ if $a_{i,t} = 0$

- $\varepsilon_{it}$ is private information

- $\sigma_i(a_{i,t} = 1|POP_t, DIST_{1t}, DIST_{2t})$ is probability that $i$ enters market $t$.

- In a Bayes-Nash equilibrium, agents make best response to $\sigma_i(a_{i,t} = 1)$

- Therefore, $i$'s decision rule is:

  $a_i = 1 \Leftrightarrow POP_t \cdot \alpha + DIST_{it} \cdot \beta + \sigma_{-i}(a_{-i} = 1) \cdot \delta + \varepsilon_{it} > 0$

- Equilibrium two equations in two unknowns ($\sigma_1(a_1 = 1)$ and $\sigma_2(a_2 = 1)$):

$$\sigma_1(a_1 = 1) = \frac{\exp(POP_t \cdot \alpha + DIST_{it} \cdot \beta + \sigma_2(a_2 = 1) \cdot \delta)}{1 + \exp(POP_t \cdot \alpha + DIST_{it} \cdot \beta + \sigma_{-i}(a_2 = 1) \cdot \delta)}$$

$$\sigma_2(a_2 = 1) = \frac{\exp(POP_t \cdot \alpha + DIST_{it} \cdot \beta + \sigma_1(a_1 = 1) \cdot \delta)}{1 + \exp(POP_t \cdot \alpha + DIST_{it} \cdot \beta + \sigma_1(a_1 = 1) \cdot \delta)}$$

- Estimation is in two steps.

- Estimate $\widehat{\sigma}_i(a_i = 1|POP_j, DIST_{1j}, DIST_{2j})$ using a "flexible" method.

- We let $L(\alpha, \beta, \delta)$ denote the pseudo likelihood function defined as:

$$L(\alpha,\beta,\delta) = \prod_{t=1}^{T}\prod_{i=1}^{2}\left(\frac{\exp(POP_t\cdot\alpha+DIST_{it}\cdot\beta+\widehat{\sigma}_{-i}(a_{-i}=1)\cdot\delta)}{1+\exp(POP_t\cdot\alpha+DIST_{it}\cdot\beta+\widehat{\sigma}_{-i}(a_{-i}=1)\cdot\delta)}\right)^{1\{a_{i,t}=1\}}$$

$$\left(1-\frac{\exp(POP_t\cdot\alpha+DIST_{it}\cdot\beta+\widehat{\sigma}_{-i}(a_{-i}=1)\cdot\delta)}{1+\exp(POP_t\cdot\alpha+DIST_{it}\cdot\beta+\widehat{\sigma}_{-i}(a_{-i}=1)\cdot\delta)}\right)^{1\{a_{i,t}=0\}}$$

- Maximize psuedo-likelihood to estimate $\alpha, \beta, \delta$.

- Extensions:

- More general games.

- Identification.

- Unobserved heterogeneity- market specific fixed effects.

# 6 Dynamic Games.

- IO economists have recently become quite interested in the identification and estimation of dynamic games.

- In these models, the data generating process is usually assumed to be similar to Erickson and Pakes.

- Each time period, firms play a standard oligopoly model (e.g. Bertrand in a differentiated product market).

- Firms make entry/exit decisions.

- Firms also make an investment decision.

- Notation.

- Assume discrete state space and discrete action space (for convenience only).

- Agents: $i = 1, ..., N$

- Time: $t = 1, ..., \infty$

- States: $\mathbf{s}_t \in S \subset R^G$, commonly known.

- Actions: $a_{it} \in A_i$, simultaneously chosen.

- Transitions: $P(\mathbf{s}_{t+1}|\mathbf{a}_t, \mathbf{s}_t)$.

- Discount Factor: $\beta$ (known to econometrician).

Objective Function: Agent maximizes EDV,

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t u_i(\mathbf{a}_t, \mathbf{s}_t). \tag{1}$$

# Equilibrium.

- Concept: Markov Perfect Equilibrium [MPE]
- Strategies: $\sigma_i : S \to A_i$.
- Recursive Formulation:

  $$V_i(\mathbf{s}|\boldsymbol{\sigma}) = u_i(\boldsymbol{\sigma}(\mathbf{s}), \mathbf{s}) + \beta \int V_i(\mathbf{s}'|\boldsymbol{\sigma}) dP(\mathbf{s}'|\sigma(\mathbf{s}), \mathbf{s})$$

- A MPE is given by a Markov profile, $\sigma$, such that for all $i$, $\mathbf{s}$, $\sigma_i'$

$$V_i(\mathbf{s}|\sigma_i, \boldsymbol{\sigma}_{-i}) \geq V_i(\mathbf{s}|\sigma_i', \boldsymbol{\sigma}_{-i})$$

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- A first (naive) idea is to estimate dynamic games using FIML.

- That is, we fix the parameter value and compute the equilibrium to the model.

- We use the equilibrium to generate a likelihood function.

- See Rust (1994) for an example of this approach.

# Why is it hard to estimate games using brute force FIML?

1. How do we write the likelihood function when there are multiple (or no!) equilibrium?

2. It can take days to compute the equilibrium to dynamic games even once.

3. Likelihood functions may not satisfy conditions for regular asymptotics.

4. Games are often underidentified.

# Recent approach: Two-Step Estimator.

1. First step, estimate reduced form policy functions and law of motion for state variables.

- This is not always possible, but it is computationally simple when feasible.

2. Find preference/profit parameters that rationalize observed actions.

- It turns out that we can estimate, with a low computational burden, models that take weeks to simulate once.

# 7 Auctions.

- Consider the first price auction with private values.

- In the model, there are $i = 1, ..., N$ symmetric bidders with valuation $v_i$ for a single and indivisible object.

- Valuations are iid with cdf $F(v)$ and pdf $f(v)$.

- In the auction, bidders simultaneously submit sealed bids $b_i$.

- Bidder $i$'s vNM utility is

$$u_i(b_1, ..., b_n, v_i) \equiv \begin{cases} v_i - b_i & \text{if } b_i > b_j \text{ for all } i \neq j \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

- Let $\pi_i(b_i; v_i)$ denote the expected profit of bidder $i$ where $\phi$ is the inverse of the bid function:

$$\pi_i(b_i; v_i) \equiv (v_i - b_i)F(\phi(b))^{N-1}. \qquad (2)$$

- The first order condition for maximizing expected profits (2) implies that

$$v = b + \frac{F(\phi(b))}{f(\phi(b))\phi'(b)(N-1)} \ . \qquad (3)$$

- This looks hard to deal with.

- Guerre, Perrigne and Vuong (2000) propose an alternative approach.

- The econometrician observes $t = 1, ..., T$ independent replications of the auction described above.

- For each auction $t$, the econometrician observes all of the bids $b_{i,t}$.

- The object that GPV wish to estimate is $F(v)$.

- Let $G(b) = F(\phi(b_i))$ denote the equilibrium distribution of the bids.

- If we substitute $G(b)$ into (**??**) allows us to write expected utility as:

$$(v_i - b_i)G(b_i)^{N-1}.$$

The first order conditions can now be written as:

$$(v_i - b_i)\,(N-1)\,g(b_i) - G(b_i) = 0 \tag{4}$$

$$v_i = b_i + \frac{G(b_i)}{(N-1)g(b_i)} \tag{5}$$

- Let $\widehat{G}$ and $\widehat{g}$ denote estimates of $G$ and $g$

- we can form an estimate $\widehat{v}_{i,t}$ of bidder $i$'s private information $v_{i,t}$ in auction $t$ by substituting these terms into (5):

$$\widehat{v}_{i,t} = b_{i,t} + \frac{\widehat{G}(b_{i,t})}{(N-1)\widehat{g}(b_{i,t})} \tag{6}$$

To summarize, the estimator proposed by GPV:

1. Given bids $b_{i,t}$ for $i = 1, ..., N$ and $t = 1, ..., T$, estimate the distribution and density of bids $\widehat{G}(b)$ and $\widehat{g}(b)$.

2. Compute $\widehat{v}_{i,t}$ for $i = 1, ..., N$ and $t = 1, ..., T$ using equation (6). Use the empirical cdf of the $\widehat{v}_{i,t}$ to estimate $F$.

- This idea turns out to be quite general.

- The distribution of bids can be used to recover private information even in multiple unit auctions or auctions with dynamics.

- These estimators have been applied to offshore oil drilling, procurement, electronic commerce and treasury bill markets.

- There are still some interesting research questions left, however, particularly in the common values case.

# 8 Next Time.

- Read Nevo "A Practitioner's Guide to Estimation of Random Coefficients Logit Models of Demand," Journal of Economics & Management Strategy, 9(4), 513-548, 2000.

- Also read Petrin "Quantifying the Benefits of New Products: The Case of the Minivan," Journal of Political Economy, 110:705-729, 2002.