Welcome to the ICE12 Summer Workshop

Initiative for Computational Economics

Sponsored by

University of Chicago
Argonne National Laboratories

UC Computation Institute
Becker Friedman Institute
Economics Research Center
Graduate Program, Chicago Booth School of Business

July 16, 2012

Why ICE?

- Computational technologies are exploding in their ability to analyze scientific and mathematical problems in every science.
- Economics is different: In the opinion of an applied mathematician at MIT, "Economists will soon be so far behind they will not be able to catch up."
- The computational approach has enormous potential for economic analysis, but very little is being exploited.
- The Initiative for Computational Economics is working to change this.

Attitude of Economics Towards Numerical Methods

- "Nothing in numerical analysis would be useful in economics" - October, 2009, declaration to an audience of applied mathematicians by the head of a leading Economics Department.
- "[A new professor] can easily learn computation after he finishes his thesis" - comment on why an offer was made to a job candidate who understood nothing about his computations (and blamed his advisors).
- Very few economics departments offer their students serious training in computational methods.
- A sample of what is taught in an actual "course":
  - Use the simplest possible methods.
  - Use methods that are as transparent as possible (i.e., methods for which the computer code reflects as closely as possible the economic structure of the problem).
  - Watch the computations as they proceed.
  - Use one-dimensional algorithms as much as possible.
  - Avoid black boxes.

Conventional Wisdom versus ICE12

- You will see many computational ideas you never saw before
- Many of these ideas will contradict what you have been "taught"
- The elite economics journals put no value on bringing methods from the numerical analysis literature to economics; in fact, such work is "not research" according to Journal of Econometrics and Econometrica.
- But, economists know little about numerical analysis
- Therefore, you can use state-of-the-art numerical methods to solve economics problems as long as you are quiet about it

Optimization Methods

- CW: There have been no advances in optimization algorithms in the past 45 years that.
- ICE12: Todd Munson, author of the best CGE software available (presented in his University of Wisconsin Computer Science PhD thesis), and winner of a Presidential Early Career Award for Scientists and Engineers in 2006, will survey the literature on numerical optimization.

Optimization Software

- CW: Stay with simple methods, motivated by economic intuition; stay away from "magical black boxes"
- ICE12: A box ceases to be black when you open your eyes and turn on the lights, which we will help you do in our software tutorial sessions.

CW: Estimation of Games: January, 2007

Econometrica, Vol. 75, No. 1 (January, 2007), 1–53

SEQUENTIAL ESTIMATION OF DYNAMIC DISCRETE GAMES

unique vector P, but a set of vectors. In this case, the MLE can be defined as

$$\hat{\theta}_{\text{MLE}} = \arg\max_{\theta\in\Theta}\left\{\sup_{P\in(0,1)^{N|X|}} Q_M(\theta, P) \text{ subject to } P = \Psi(\theta, P)\right\}. \tag{26}$$

This estimator can be shown to be consistent, asymptotically normal, and efficient. However, in practice, this estimator can be extremely difficult to implement. Notice that for each trial value of θ, we have to compute all the vectors P that are an equilibrium associated with θ and then select the one with the maximum value for $Q_M(\theta, P)$. Finding all the Markov perfect equilibria of a dynamic game can be very difficult even for relatively simple models (see McKelvey and McLennan (1996)). Note also that with multiple equilibria, the number of evaluations of Ψ for different values of P increases very importantly. These problems motivate the pseudo likelihood estimators we develop in the following subsections.

CW: Estimation of Games: September, 2007

Econometrica, Vol. 75, No. 5 (September, 2007), 1331–1370

ESTIMATING DYNAMIC MODELS OF IMPERFECT COMPETITION

BY PATRICK BAJARI, C. LANIER BENKARD, AND JONATHAN LEVIN[1]

both conceptually and computationally.

One reason for this is the perceived difficulty of incorporating information from a dynamic equilibrium into an estimation algorithm. Research on dynamic competition (e.g., Ericson and Pakes (1995), Pakes and McGuire (1994, 2001), Gowrisankaran and Town (1997), and Benkard (2004)) has shown that computing an equilibrium for even relatively simple industry models is all but prohibitive. For models with the complexity usually required for empirical work, the situation is even bleaker. Even with advancing computer technology, computing equilibria over and over, as would be required in a typical estimation routine, seems out of the question. Moreover, dynamic games often admit a vast multiplicity of equilibria. This multiplicity greatly complicates the application of estimators that require computing equilibria and then matching these equilibria to observed data.

CW: Estimation of Games: 2012

Econometrica, Vol. 80, No. 3 (May, 2012), 1019–1061

THE COSTS OF ENVIRONMENTAL REGULATION IN A CONCENTRATED INDUSTRY

BY STEPHEN P. RYAN[1]

Previous work, such as Benkard (2004), has shown that maximum-likelihood approaches to estimating the parameters of dynamic models can be computationally demanding, due to the necessity of having to solve for an equilibrium at every guess of the parameter vector. Furthermore, the presence of multiple equilibria requires the econometrician to both compute the set of all possible equilibria and to specify how agents decide on which equilibrium will be played in the data, as in Bajari, Hong, and Ryan (2010).[21]

ICE12 Structural Estimation

- CW: Econometrica and Econometric Society dogma declares that estimation requires solving for all solutions for all parameter values examined by procedure.
- ICE12: Prof. Che-Lin Su will show you how to use modern optimization methods to compute efficient estimators for both dynamic choice problems and dynamic games, and show that ES dogma contradicts well-known numerical mathematics.

Dynamic Programming

- CW: It is difficult to write DP code that is stable, efficient, and accurate, particularly for multidimensional problems.
- ICE12: It is easy to do this for concave problems once you learn a little math.

Dynamic Games

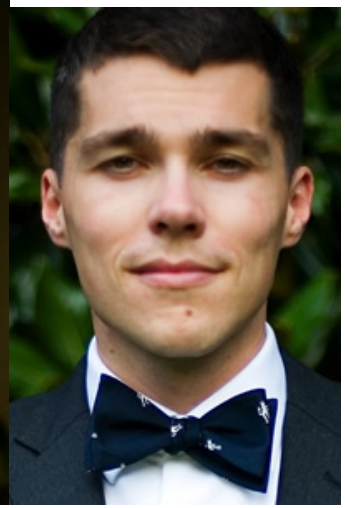
- CW: Finding feedback equilibria (a.k.a. MPE) is very difficult.
- ICE12: Life is always hard if you use only Gauss-Jacobi and Gauss-Seidel methods. Karl Schmedders will show you how to use complementarity methods to solve dynamic games, even ones where players occasionally hit constraints such as zero output or zero investment.

Dynamic Supergames

- CW: It is difficult to find all Nash equilibria of a dynamic game.
- ICE12: Sevin Yeltekin will present methods for solving dynamic games.

Computer Resources

- CW: It is difficult to use parallel systems.
- ICE12: Greg Thain will demonstrate Condor, a distributed computing system developed at the University of Wisconsin, and Philip Blood, from the Pittsburgh Supercomputing Center will introduce you to XSEDE. Eric Aldrich will show examples of GPUs applied to economics problems.



Polynomial Equations

- CW: There are no closed-form solutions for polynomial systems of equations
- ICE12: Karl Schmedders and Felix Kubler will demonstrate tools from algebraic geometry that allow you to solve polynomial systems of equations.

Numerical Integration

- CW: It is not tractable to accurately compute multidimensional integrals with numerical quadrature; you must use Monte Carlo
- CW: Monte Carlo integration is good enough for econometrics
- CW: Asymptotic theory is valid in modern demand estimation
- ICE12: Our answer is *BS!* Ben Skrainka.

Auctions

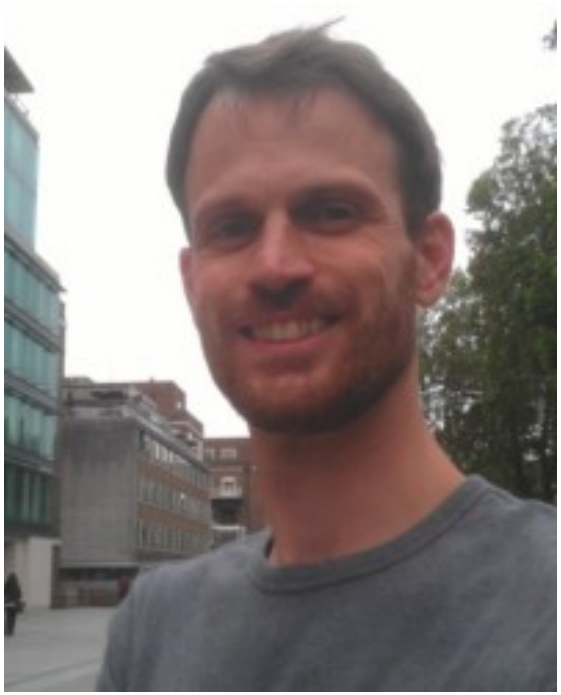
- CW: It is not tractable to solve auctions with heterogeneous bidders.
- ICE12: Harry Paarsch will describe stable and reliable methods to solve auctions.

Solving Rational Expectations Models

- CW: "It is reasonable to work with first order perturbations." – Larry Christiano
- CW: A macroeconomist told me that lack of IQ is a reason why he used poor numerical methods
- ICE12: Serguei Maliar offers an alternative to log-linearization that is globally valid and simple to implement

Theorems versus Computation

- CW: Theorems are better than computational approaches to a problem
- ICE12: Colin Rowat will show a computational approach that proves theorems.



Integrated Assessment Models for Climate Change Issues

- CW: It is beyond the "scientific frontier" to compute DSGE models with several goods - EPA and DJA
- ICE12: Yongyang Cai will describe DSICE, a DSGE extension of DICE with one year time periods, and no time travel for CO2.

Why is ICE12 at Chicago?

- The University of Chicago is about doing research.
- The University of Chicago, its partners, and the speakers have provided *all* the funding for *all* ICE workshops.

Why Chicago Economics?

- The Chicago tradition in economics is to do economics, using whatever tools are necessary.
  - If supply and demand curves suffice, then use them.
  - If you need to formulate a problem as a fixed point in L_∞ then learn the necessary functional analysis - Lucas
  - If you have a problem with censored data, then develop novel econometric methods - Heckman
  - If you can't find cute closed-form solutions to dynamic incentive problems, then compute - Townsend
  - If you want to explore alternatives to full rationality, then study and extend robustness theory - Hansen
- The University of Chicago has made a long-term commitment to give their students the training in computational methods they need in their economic research
- ICE is its way of sharing that expertise with the general economics community.

Why Argonne National Laboratories?

- Argonne Labs has an excellent center for computational research.
  - Computational mathematicians at Argonne are among the world's leading experts on the kind of computational tools that are most valuable for economists.
  - Scientists at Argonne are interested in working on problems in economics.
- What is the Computation Institute?
  - The Computation Institute helps stimulate collaboration between scientists at Argonne Labs and faculty and students at the University of Chicago.
  - An excellent example of this is CIM-EARTH, an effort to combine the expertise in economics and computation at Argonne and UC to create the next generation of models for assessing issues related to climate change

What are you going to do?

- Lectures: Learn basic numerical methods and see them applied to economics problems.
- Software Tutorials: Learn how to use powerful software tools and apply them to economic problems.
- Projects: You will form groups of four or five, formulate an economics problem and solve it using the tools presented here.
- Offce hours: Individuals may schedule appointments with speakers to discuss their own research.
- Seminars: Presentations by economists who are using computational tools.

- Have fun
  - Eat, drink, and be merry
    - Goose Island on Tuesday night, July 17
    - Friday night, July 20, TGIF at Pub
    - A conference dinner on Friday, July 27.
  - See Chicago (July 21-22)
    - Art Institute
    - Architectural Boat Trips
    - Top of the Hancock Tower (not the building-formerly-known-as-Sears)
    - See Sue ... at the Field Museum
    - See the only U-boat captured in battle ... Museum of Science and Industry
    - Many other possibilities