Welcome to the ZICE 2015 Workshop

Zurich Initiative for Computational Economics

Why ZICE?

- 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 (very well-acquainted with economists) 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 Zurich Initiative for Computational Economics is working to change this.

Attitude of the Ruling Elite in Economics Towards Numerical Methods

- "If I don't get the answers implied by economic intuition, I change the code": statement by a professor in a seminar
- Very few economics departments offer serious training in computational methods.
- A sample of what is taught in an actual "course":
  - Use the simplest possible methods.
  - Use methods where 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 ZICE 2015

- You will see computational ideas you never saw in your economics courses
- Many of these ideas will contradict what you have been "taught"
- Elite economics journals put no value on bringing modern numerical methods to economics; in fact, such work is "not research" according to Journal of Econometrics and Econometrica.
- But, this can be good news for you
  - Your competition, *particularly the American-trained competition*, knows 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. Editors and referees won't ask; you don't tell. Just do economics.

Optimization Methods

- CW: There have been no advances in optimization algorithms in the past 50 years.
- ZICE 2015: Todd Munson, author of the best CGE software (from his **University of Wisconsin** CS PhD thesis), and winner of a Presidential Early Career Award for Scientists and Engineers in 2006, will survey the literature on numerical optimization.

Optimization Methods

- ZICE 2015: Stefan Wild will speak on optimizing noisy functions

Optimization Software

- CW: Stay with simple methods, motivated by economic intuition
- CW: Stay away from "magical black boxes"
- CW: Numerical software is unreliable

ESTIMATION OF RANDOM-COEFFICIENT DEMAND MODELS:
TWO EMPIRICISTS' PERSPECTIVE
Christopher R. Knittel and Konstantinos Metaxoglou
Rev. Econ. and Stats (2013) (a Harvard journal)

Abstract—We document the numerical challenges we experienced estimating random-coefficient demand models as in Berry, Levinsohn, and Pakes (1995) using two well-known data sets and a thorough optimization design. The optimization algorithms often converge at points where the first- and second-order optimality conditions fail. There are also cases of convergence at local optima. On convergence, the variation in the values of the parame-

ZICE 2015

- Knittel and Metaxoglou's results
  - exploited sloppy stopping rules
  - typical of economists' attacks on the use of standard numerical methods
- A box ceases to be black when you open your eyes and turn on the lights.
- We introduce you to good software; expand your universe beyond what is available in Matlab
- We will show you how to use the software
  - You can always tell the solver to spit out wrong answers (and even get a paper published with the results!)
  - We show you how to use solvers so that they solve your problem

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]

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]

ZICE 2015 Structural Estimation

- CW: Econometrica (ECTA) dogma declares that estimation requires finding all solutions for each parameter vector.
- ZICE 2015: Prof. Che-Lin Su will show how to use modern optimization methods to avoid this problem.
- FACT: ECTA dogma ignores fact that Ragnar Frisch – founder of Econometrica – made an oft-cited contribution to modern optimization methods.

Dynamic Programming

- CW: It is difficult to write DP code that is stable, efficient, and accurate, particularly for multidimensional problems.
- CW: If you want to solve a stochastic DP problem with three periods and seven states in twelve days, you need to give $750,000 to an MIT professor.
- Fact: If you hire a talented Chinese grad student, Yongyang Cai, and pay him slave wages, he can solve the same problem in a couple of hours.
- ZICE 2015: We have solved nine-dimensional stochastic dynamic optimal growth problems
  - over a 600 year horizon
  - solving 300 billion optimization problems
  - with two-digit accuracy for the policy functions
  - in a few hours

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: Bakhvalov (1959) proved that there is a curse of dimensionality in integration
- ZICE 2015: Learn some math
  - There are many methods for integration of "nice" functions that are a lot better than flipping coins.
  - Bakhvalov (1959) proved
    - Section 1: there is a curse of dimensionality for C^0 functions
    - Sections 3, 5: there is no curse for C^2 functions
  - Radical idea: *read* the papers you cite!
  - Computing BLP estimates is much easier if you use classical quadrature.

Approximation

- CW: It is not tractable to accurately approximate multidimensional functions.
- ZICE 2015: Learn about modern methods of approximation

Auctions

- CW: It is not tractable to solve auctions with heterogeneous bidders.
- ZICE2015: Harry Paarsch will describe stable and reliable methods to solve auctions.

Solving Rational Expectations Models

- Engineering:
  - CW (<1940): "Linear approximations of Navier-Stokes equations are good enough for bridge design"
  - Reality (>1940): linear approximations are *not* good enough; see Wikipedia page about Tacoma Narrows bridge
- Macroeconomics
  - CW: "It is reasonable to work with first order perturbations."
  - CW: "We can manage US monetary policy using models solved on EViews"
  - ZICE 2015:
    - Log-linearization is a bad way to design bridges or economic policy.
    - We will introduce you to methods that are globally valid and simple to implement

Hardware for Economists

- CW (according to the Chairman of a "top" department):
  - "Laptops are sufficient for economics"
  - "If you are giving a presentation in a couple of days, you won't get the results from large-scale hardware because you have to submit the work to a job queue."
  - Implication: If you are the kind of student who starts a term project a day before it is due, then you have a future in macroeconomics.

Hardware for Scientists

- ZICE 2015: Olaf Schenk will talk about supercomputing, the third leg of modern scientific research.

Why is ZICE 2015 at Zurich?

- Felix Kubler and Karl Schmedders

Why Should Economists Learn These Methods?

- Our attitude is that economists should use whatever tools are necessary to economics
  - Economists spend too much time today on computational problems
    - Step one: Come up with a nice idea
    - Step two: Spend an enormous amount of time and effort figuring out a way you can use Matlab to solve your problem on your laptop
    - Step three: Change Matlab code until you get answers you expect
    - Step four: Publish paper that readers cannot replicate
  - Applied and computational math approach
    - Find what kind of math problem expresses your problem.
    - Identify best computational algorithms and software for the problem, and use them.
    - We want to free up your time and mind to focus on your economics ideas!

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.
- Offce hours: Individuals may schedule appointments with speakers to discuss their own research.
- Seminars: Presentations by economists who are using computational tools.
- Friday night: Zeughauskeller - great schweinshaxe, ribs, paprika sausage, swords, armor, artillery, ...

After ZICE 2015

- We hope that you will use the tools you learn here to do serious economics.
- Keep in touch