

Econ 561a
Yale University
Fall 2007
Prof. Tony Smith

Syllabus for
COMPUTATIONAL METHODS FOR ECONOMIC DYNAMICS
ECON 561a

Course Objectives: Most of the dynamic models used in modern quantitative research in economics do not have analytical (closed-form) solutions. For this reason, the computer has become an indispensable tool for conducting research in economics. The goal of this set of lectures is to provide an introduction to computational tools for conducting numerical analysis of dynamic economic models.

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Office hours: Thursdays from 2:30PM to 4PM, or by appointment

Class Meetings: The course meets on Tuesdays and Thursdays from 10:30AM to 11:50AM in Room B1 (28 Hillhouse). This is a half-semester course; the last lecture is on Thursday, October 18.

Prerequisites: This course is designed for graduate students in economics who have taken first-year graduate courses in microeconomics, macroeconomics, and econometrics. No prior knowledge of either numerical methods or computer programming is assumed, but some familiarity with a programming language would prove helpful.

Texts: The lectures will be largely self-contained, but there are several good texts that provide useful complements to the material in the lectures. An especially valuable book is: *Numerical Recipes in Fortran 77: The Art of Scientific Computing, Second Edition* (Volume 1 of Fortran Numerical Recipes) by William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery (Cambridge University Press, 1992). This book, as well as its companion *Numerical Recipes in Fortran 90: The Art of Parallel Scientific Computing, Second Edition* (Volume 2 of Fortran Numerical Recipes), is available online at <http://www.nr.com>. Other useful books include:

- *Applied Computational Economics and Finance* by Mario J. Miranda and Paul L. Fackler (MIT Press, 2002).
- *Numerical Methods in Economics* by Kenneth L. Judd (MIT Press, 1998).
- *Dynamic Economics: Quantitative Methods and Applications* by Jérôme Adda and Russell Cooper (MIT Press, 2003).
- *Computational Methods for the Study of Dynamic Economies*, edited by Ramon Marimon and Andrew Scott (Oxford University Press, 1999).
- *Handbook of Computational Economics (Volume 1)*, edited by Hans M. Amman, David A. Kendrick, and John Rust (North-Holland, 1996).

Exercises: The best (and really the only) way to learn numerical methods is to use them in actual problems. Accordingly, each week of lectures will be accompanied by a set of problems for students to solve. It is highly recommended that students attempt to work these problems!

SCHEDULE OF LECTURES

Week 1

Introduction (built around some simple examples from economics, including the stochastic-growth model and a canonical consumption-savings model).

General considerations in numerical analysis: convergence, roundoff error, truncation error.

Numerical differentiation.

Root-finding in one or more dimensions: bisection, secant method, Newton's method, fixed-point iteration, Gauss-Jacobi, Gauss-Seidel, Brent's method.

Suggested readings:

Chapters 1, 5.7, and 9 in *Numerical Recipes*; Appendix 2A, Chapter 3, and Chapter 5.6 in Miranda and Fackler; Chapters 1, 2, 5, and 7.7 in Judd.

Huggett, M. (1993), "The Risk-Free Rate in Heterogeneous-Agents, Incomplete Markets Economies," *Journal of Economic Dynamics and Control* 17, 953–969.

Taylor, J.B. and H. Uhlig (1990), "Solving Nonlinear Stochastic Growth Models: A Comparison of Alternative Solution Methods," *Journal of Business and Economic Statistics* 8, 1–18.

Week 2

Minimization in one or more dimensions: golden section search, Brent's method with or without derivatives, simplex method, Newton-Raphson, variable metric methods.

Suggested readings: Chapter 10 in *Numerical Recipes*; Chapter 5 in Miranda and Fackler; Chapter 4 in Judd.

Week 3

Interpolation and approximation of functions: linear interpolation in several dimensions, cubic splines, polynomial interpolation, orthogonal polynomials.

Suggested readings: Chapters 3 and 6 in *Numerical Recipes*; Chapter 5 in Miranda and Fackler; Chapter 6 in Judd.

Week 4

Numerical integration: cubic spline integration, Gaussian quadrature, Monte Carlo integration, integration of multivariate normal densities.

Suggested readings: Chapters 4 and 7 in *Numerical Recipes*; Chapter 5 in Miranda and Fackler; Chapters 7 and 8 in Judd.

Week 5

Numerical dynamic programming: value iteration, Euler equation methods, rules of thumb, perturbation methods, parameterized expectations, linear-quadratic (first-order) and second-order methods.

Suggested readings:

Chapters 7, 8, and 9 in Miranda and Fackler; Chapters 12, 13, 16, and 17 in Judd.

Benitez-Silva, H., G. Hall, G. Hitsch, G. Pauletto, and J. Rust (2000), “A Comparison of Discrete and Parametric Approximation Methods for Continuous-State Dynamic Programming Problems,” manuscript (www.econ.yale.edu/~econ681/cefbcn.html).

Christiano, L.J. and J.D.M. Fisher (2000), “Algorithms for Solving Dynamic Models with Occasionally Binding Constraints,” *Journal of Economic Dynamics and Control* 24, 1179–1232.

Coleman, W.J. II (1990), “Solving the Stochastic Growth Model by Policy Function Iteration,” *Journal of Business and Economic Statistics* 8, 27–29.

Kim, J., S. Kim, E. Schaumburg, and C.A. Sims (2003), “Calculating and Using Sec-

ond Order Accurate Solutions of Discrete Time Dynamic Equilibrium Models,” manuscript (www.princeton.edu/~sims/#gensys2).

Schmitt-Grohé, S. and M. Uribe (2004), “Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function,” *Journal of Economic Dynamics and Control* 28, 755–775.

Smith, Jr., A.A. (1991), “Solving Stochastic Dynamic Programming Problems Using Rules of Thumb,” Queen’s University Discussion Paper No. 816.

Uhlig, H. (1999), “A Toolkit for Analysing Nonlinear Dynamic Stochastic Models Easily,” in: *Computational Methods for the Study of Dynamic Economies*.

Week 6

Computation of dynamic equilibrium models with heterogeneous actors.

Suggested readings:

Aiyagari, S.R. (1994), “Uninsured Idiosyncratic Risk and Aggregate Saving,” *Quarterly Journal of Economics* 109, 659–684.

Bachmann, R. (2007), “Understanding Jobless Recoveries: A Tale of Two Margins,” manuscript (<http://pantheon.yale.edu/~rb328/jobmarketpaper.pdf>).

Den Haan, W.J. (1997), “Solving Dynamic Models with Aggregate Shocks and Heterogeneous Agents,” *Macroeconomic Dynamics* 1, 355–386.

Guvenen, M.F. (2003) “A Parsimonious Macroeconomic Model for Asset Pricing: Habit Formation or Cross-Sectional Heterogeneity?” manuscript (www.econ.rochester.edu/guvenen/guvenen.htm).

Huggett, M. (1993), “The Risk-Free Rate in Heterogeneous-Agents, Incomplete Markets Economies,” *Journal of Economic Dynamics and Control* 17, 953–969.

Huggett, M. (1996), “Wealth Distribution in Life-Cycle Economies,” *Journal of Monetary Economics* 38, 469–494.

Khan, A. and J.K. Thomas (2002), “Nonconvex Factor Adjustments in Equilibrium Business Cycle Models: Do Nonlinearities Matter?” *Journal of Monetary Economics* 50 331–360.

- Khan, A. and J.K. Thomas (2003), “Inventories and the Business Cycle: An Equilibrium Analysis of (S,s) Policies,” manuscript (www.econ.umn.edu/~jkt/).
- Krusell, P. and A.A. Smith, Jr. (1997), “Income and Wealth Heterogeneity, Portfolio Selection, and Equilibrium Asset Returns,” *Macroeconomic Dynamics* 1, 387–422.
- Krusell, P. and A.A. Smith, Jr. (1998), “Income and Wealth Heterogeneity in the Macroeconomy,” *Journal of Political Economy* 106, 867–896.
- Krusell, P. and A.A. Smith, Jr. (1999), “On the Welfare Effects of Eliminating Business Cycles,” *Review of Economic Dynamics* 2, 245–272.
- Krusell, P. and A.A. Smith, Jr. (2002), “Revisiting the Welfare Effects of Eliminating Business Cycles,” manuscript (www.econ.yale.edu/smith/revisit.pdf).
- Midrigan, V. (2006), “Menu Costs, Multi-Product Firms and Aggregate Fluctuations,” manuscript (<http://homepages.nyu.edu/~vm50/multiproductfirms.pdf>).
- Ríos-Rull, J.V. (1999), “Computation of Equilibria in Heterogeneous-Agent Models,” in: *Computational Methods for the Study of Dynamic Economies*.
- Telmer, C., K. Storesletten, and A. Yaron (2001), “Asset Pricing with Idiosyncratic Risk and Overlapping Generations,” manuscript (bertha.gsia.cmu.edu/telmerc/research.html).
- Thomas, J.K. (2002), “Is Lumpy Investment Relevant for the Business Cycle?” *Journal of Political Economy* 110, 508–534.