Computational Economics

Stanford University
Department of Economics, Econ 288
Autumn 2000-2001
11:00 a.m. - 12:50, Monday and Wednesday

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Course Description

Objective

The objective of this course is to introduce the student to computational approaches to solving economic models. We will formulate economic problems in computationally tractable forms, and use numerical analysis techniques to solve them. We will study examples of computational techniques in the current economic literature as well as discuss areas of economic analysis where numerical analysis may be useful in future research of dynamic economic problems. The substantive applications will cover a wide range of problems including public finance, macroeconomics, game theory, mechanism design, finance, industrial organization, agricultural economics, and econometrics.

Overview

We begin with an overview of the necessary numerical analysis and approximation theory. First, we review standard numerical analysis - interpolation and approximation techniques, numerical optimization, numerical solutions to systems of nonlinear equations, quadrature formulas for numerical integration, and basic solution techniques for ordinary and partial differential equations. Second, we examine some less standard material from numerical analysis which is very useful for economic problems. That includes projection approaches to ordinary and partial differential equations as well as topics in high-dimensional integration. Third, we cover perturbation and bifurcation techniques which are useful in economics problems.

We give economic examples as we discuss numerical methods, including Nash equilibrium and general equilibrium calculations using nonlinear equation methods, and optimal incentive mechanisms using numerical optimization. We then use these methods to solve dynamic optimization problems. The techniques will be illustrated by applications to standard economic problems - particularly optimal growth, life-cycle models of consumption and savings, and portfolio management. We will then examine a variety of equilibrium problems, such as economies with taxation, intervention in commodity markets, and equilibria of dynamic games. We will develop techniques for numerical solutions to a broad range of recursive equilibrium problems.

Prerequisites

It would be useful if students are familiar with basic dynamic optimization theory, and have a good undergraduate background in mathematics. In particular, students should be familiar with linear algebra, finite- dimensional optimization theory, and linear differential equations. However, any student who is interested in the course and has passed their econometrics and theory courses will be able to follow the course.

Course Grade

Doing computation is the only way to learn computation. The course grade will be based solely on the computational exercises assigned roughly every two weeks. You will be allowed to work in groups of two or three on the exercises.

Computing Languages

Students will need to know some computational language. FORTRAN is still the primary language used in scientific computations since it offers the greatest range of packaged routines, such as NAG, IMSL, BLAS, MINPACK, HOMPACK, LAPACK, and MINOS. Students are welcomed to use other languages, such as C, Matlab, and Gauss. (No, Excel will not be adequate.) In fact, if you do not know any suitable language, I recommend that you use Matlab since it is relatively easy to learn, adequate for this course, and available on Stanford computer systems.

While the range of topics is broad, the intent of the course would be to acquaint students with the range of techniques which have been useful in economic analysis as well as expose them to others which have potential use in economic applications. I want to develop a basic understanding of numerical techniques, demonstrating their use in economic examples, show how existing techniques fit into the broader numerical literature, and point the students to potential areas of economic research which could make use of sophisticated numerical techniques.

Course Outline and Schedule

The following is the course schedule. The text is *Numerical Methods in Economics* by Judd.

I. Numerical Analysis: General Considerations - September 27

Chapters 1 and 2. General ideas of convergence rates, computational errors, error analysis.

II. Solution of Linear Equations - October 2, 4

Chapter 3. LU, QR, and Cholesky decomposition, condition numbers, Gauss-Jacobi and Gauss-Seidel methods. Applications to oligopoly and Markov chain statistics.

III. Optimization Methods - October 9, 11

Chapter 4. Search methods, bisection, Newton's method, BFGS and DFP updates. Applications to consumer demand, portfolio choice, and incentive problems.

IV. Solving Nonlinear Equations - October 16, 18

Chapter 5. Bisection methods, Newton's method, Broyden updates, Powell hybrid method, continuation and homotopy methods. Applications to general equilibrium and Nash equilibrium.

V. Interpolation and Approximation of Functions - October 23, 25

Chapter 6. Orthogonal polynomials, splines, interpolation, neural networks.

VI. Numerical Quadrature - October 30, November 1

Chapter 7, 8, and 9. Integration methods for single- and multiple-dimensional integrals. Monte Carlo simulation methods. Applications to portfolio choice and dynamic problems.

VII. Differential, Integral, and Functional Equations - November 6, 8, 13

Chapter 10 and 11. Methods for solving ordinary differential equations as well as the more complex equations arising in dynamic economic models. Applications to dynamic optimization.

VIII. Numerical Dynamic Programming - November 15

Chapter 12. Solutions to deterministic and stochastic dynamic programming problems using approximation, integration, and optimization methods. Applications to life-cycle problems.

IX. Perturbation Methods - November 20, 22

Chapter 13, 14, and 15. Taylor series approximations to find numerical solutions, linearizing, around the steady state. Applications to dynamic equilibrium models.

X. Solutions of Deterministic Dynamic Models - November 27

Chapter 16. Solution of perfect foresight models. Fair-Taylor method, shooting method, parametric path method.

XI. General Methods for Solving Rational Expectations Models - Nov. 29, Dec. 4, 6

Chapter 17. Rational expectations models, Lucas asset pricing model, Brock-Mirman growth models.