

# Computational Economics

## NAKE, June 2001

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### Course Description

#### Objective

This workshop introduces the student to computational approaches to solving dynamic models in both deterministic and stochastic environments. We will concentrate on how to formulate dynamic economic problems in computationally tractable forms, and use numerical analysis techniques to solve them. The substantive applications include a wide range of problems from finance, public finance, macroeconomics, game theory, mechanism design, industrial organization, agricultural economics, and econometrics.

#### Overview

We begin with an overview of basic numerical analysis and approximation theory. The first two days review standard numerical analysis – error analysis, interpolation and approximation techniques, numerical optimization, numerical solutions to systems of linear and nonlinear equations, and numerical integration. These lectures will be purely mathematical, but the methods form the basis for almost all numerical work in economics. We then use these methods to solve dynamic programming problems and rational expectations equilibrium in dynamic models. We first present projection methods and then discuss perturbation and bifurcation techniques. The final presentation ends with a discussion of how the complementary strengths of numerical methods and economic theory can work together to analyze interesting economic problems.

The lectures will focus on techniques. The methods can be applied to stochastic growth models, asset pricing models with symmetric and asymmetric information, life-cycle optimization problems, overlapping generations models, and static and dynamic games. We won't have time to examine many examples in depth but I will indicate which methods work for which kinds of problems.

The lectures will focus on simple examples of various techniques. The objective is to show the key ideas in simple contexts and then indicate where the student can read about more advanced techniques and complex applications.

#### Prerequisites

Students should be familiar with linear algebra, multivariate calculus, finite-dimensional optimization theory, and basic dynamic programming.

## Course Readings

The lectures will be based on my book, *Numerical Methods in Economics*. I will also discuss the following papers:

“Projection Methods for Solving Aggregate Growth Models,” *Journal of Economic Theory* **58** (December, 1992): 410-452.

“Asset Market Equilibrium with General Tastes, Returns, and Informational Asymmetries,” with Antonio Bernardo, *Journal of Financial Markets* **1** (1, 2000).

“Asymptotic Methods for Aggregate Growth Models,” with Sy-ming Guu, in *Journal of Economic Dynamics and Control* **21** (6) (June 1997): 1025-42.

“Perturbation Solution Methods for Economic Growth Models,” in *Economic and Financial Modelling with Mathematica*, edited by Hal Varian (New York: Springer-Verlag Publishers, 1992), pp. 80-103.

“Bifurcation Methods for Asset Market Equilibrium Analysis,” with Sy-Ming Guu, *Economic Theory* (2001).

“Computational Economics and Economic Theory: Substitutes or Complements?” in *Journal of Economic Dynamics and Control* **21** (6) (June 1997): 907-42.

Copies of Chapters 7, 8, and 12 of *Numerical Methods in Economics* and the papers are available at NAKE. Some papers are available at <http://bucky.stanford.edu>, which also contains many more papers on computational methods. My web site occasionally crashes, so if you have problems, try again.

Chapters 7 and 8 from *Numerical Methods in Economics* contain basic material. You should read them before the lectures so that we can cover that material quickly on Tuesday. Chapter 12 is more challenging. The remaining papers will be difficult to read before the lectures, and the lectures will not assume you have read them carefully. Skim them before the lectures, but do not be discouraged if you have trouble understanding them. A useful survey paper to read after the week’s lectures is

“Approximation, Perturbation, and Projection Solution Methods in Economics,” in *Handbook of Computational Economics* (North Holland, 1996).

## Course Topics and Schedule

### **I. Monday June 11:** 15.00 - 16.15

Numerical concepts: numerical errors, and convergence rates.

Linear equations: solution methods and condition numbers

Optimization: Newton's method

Nonlinear Equations: fixed-point iteration, Newton's method

Applications: general equilibrium, Nash equilibrium

### **II. Tuesday June 12:** 11.00 - 12.45

Approximation theory: Orthogonal polynomials, splines, interpolation.

Numerical integration: Gaussian quadrature, Monte Carlo integration

Numerical dynamic programming

Readings: *Numerical Methods*, Chapters 6, 7, and 12.

### **III. Wednesday June 13:** 10.45 – 12.15

Methods for solving rational expectations models

Readings: Skim Judd, (*JET*, 1990) and Bernardo and Judd (*JFM*, 2000)

### **IV. Thursday June 14:** 09.00 - 10.45

Perturbation Methods

Readings: Skim Judd and Guu (1993) and Judd and Guu (*JEDC*, 1997)

### **V. Friday June 15:** 10.45 - 12.15

Bifurcation methods for asset market analysis

Reading: Skim Judd and Guu (*ET*, 2001)

Numerical Methods and Economic Methodology

Reading: Read Judd (*JEDC*, 1997)