AAE 760
Dynamic Natural Resource Economics
Syllabus

Fall 1999
T,Th 11:00-12:15

Provencher
330 Taylor Hall

As reflected in the recent literature, to a large extent current research in resource economics involves either optimal control or dynamic programming. This reflects the importance of the temporal aspects of resource allocation. With these observations in mind, I have two objectives for Ag Econ 760. First, to provide students with the training required to read the journals concerning the temporal aspects of resource allocation, including *Land Economics*, *JEEM, Natural Resources Modeling, Water Resources Research*, and *Forest Science*. And second, to provide students with a sufficient understanding of control theory and dynamic programming to bring these methods to their own work.

The upshot is that the course is fairly methods-oriented, and not topically organized, as one might expect. We will not examine the "classic" articles in resource economics. Rather, the course uses several approaches to provide students with a good understanding of optimal control theory and dynamic programming as they apply to resource economics. The first approach is to read and discuss articles that elucidate and illustrate the application of dynamic methods in resource economics. The second is to develop several proofs for theorems/results that are fundamental to optimal control theory and dynamic programming. Although these proofs are somewhat tedious, they throw light on what would otherwise be "little black boxes". The third approach is to solve optimal control and dynamic programming problems via analytical and/or numerical methods.

Home Page for the Course
The home page for the course is http://aae.wisc.edu/aae760/. I plan to have all lecture notes available on the course page by the evening before class. You should download a copy of the notes before each class. Do not download the notes sooner; during the course of the semester I modify them as necessary.

Texts
The course does not follow any single text. I provide you with lecture notes that I believe are sufficient to do the work for the course. Nonetheless, it's nice to see the material presented in several different ways, so I will provide supplementary readings. Chiang is a good introductory text for optimal control theory, though it does not cover dynamic programming. Conrad and Clark is another text with an emphasis on the application of optimal control to natural resources management. Kamien and Schwartz is a good reference for optimal control theory, and of the texts listed, this is perhaps the best one to get if you plan to use optimal control in your work. Kennedy

is a good introduction to dynamic programming, but very expensive. Chapters 4 and 7 in Leonard and Van Long are very good introductions to optimal control theory.

Chiang, “Dynamic Optimization”, 1991.
Conrad and Clark, “Natural Resource Economics”, 1991.
Kamien and Schwartz, “Dynamic Optimization”, 1991.
Kennedy, “Dynamic Programming”, 1986.
Leonard and Van Long, “Optimal Control”, 1992.

Problem Sets & Exams

Three problem sets comprise 45% of the course grade; the remainder of your grade is based on a final project. The problem sets are the heart and soul of the course. This is where you really figure out how to analyze dynamic resource problems. In general the problem sets can be quite difficult and time consuming, so *do not* wait to the last minute to complete them. The problem sets are graded on a pass-plus/pass/fail basis; each day past the deadline your grade is docked ½ a letter grade. You can work together on the problem sets, but be warned: in my evaluation of your final project I will include what it –and our discussions of it –reveals about your understanding of material developed in the problem sets.

The final project will require you to find a parameterized dynamic optimization problem in the recent (last 10 years) literature, and solve it numerically to verify (or perhaps contradict) the results reported in the paper. I will have more to say about this later in the semester. Here’s this year’s tentative line-up:

Problem Set 1:

- Capital Growth Problem (solve analytically using optimal control)
- Mineral Spring Problem (solve analytically using optimal control)
- Integrate the Normal PDF (numerical)
- Capital growth problem (solve numerically using optimal control)
- Groundwater extraction problem, due to Feinerman and Knapp, *AJAE 1984* (solve numerically using optimal control)

Problem Set 2:

- Capital growth problem (solve numerically using DP)
- Pesticide application problem due to Regev et al., *JEEM* 1983 (solve numerically using DP)

Problem Set 3:

- Deterministic timber harvesting problem (solve numerically using dynamic programming)
- Stochastic timber harvesting problem, due to Brazee and Mendelsohn, *Forest Science 1988* (solve numerically using dynamic programming)

Final Project: TBA

Computer Programming

Solving parameterized dynamic decision problems usually requires that the analyst write a substantial amount of primary code. This means that either you must be familiar with a programming language that you can use to write solution algorithms, or you are willing to learn a language this semester. In the past I have taught the basics of FORTRAN programming "on the fly". This year I will spend the second lecture teaching those of you interested the basics of writing and running FORTRAN programs. Those of you who would rather use some other language, such as GAUSS or MATLAB, are welcome to do so, but be forewarned that I do not know these packages, so you are on your own if your programs bomb out.

Course Summary

I. Optimal Control Theory

- Hamiltonian conditions
  - Optimality condition
  - Adjoint equation
  - State equation
  - Boundary conditions
  - Transversality conditions

- Link between Terminal conditions and Transversality conditions
  - Free endpoint problems
  - Free terminal time problems
  - Problems with a salvage function

- Current vs. Present value representations of the Hamiltonian conditions

- Proof of the necessary conditions

- Economic interpretation of necessary conditions

- Discussion of sufficiency

- Phase diagrams
  - Paths satisfy the "main" Hamiltonian conditions
  - Boundary and transversality conditions determine the optimal path

- Bang-bang and MRAP control problems

- Solution methods
  - Backwards sweep algorithm
    - Uses information in the necessary conditions
  - Constrained nonlinear optimization
    - Does not use info in the necessary conditions
  - Nonlinear optimization over a terminal (transversality) condition
    - Uses info in the necessary conditions

II. Dynamic Programming

- Solving a control problem via DP

Bellman's equation as a static problem

DP analogs to the Hamiltonian conditions

Infinite horizon vs. Finite horizon problems

Introduction to dynamic noncooperative games

Certainty equivalence in a DP setting

Proof that the solution to Bellman's equation is the solution to the infinite horizon problem

Proof of convergence of the successive approximation algorithm

Policy iteration to solve an infinite horizon problem

Linear Programming to solve an infinite horizon DP problem

Solution of DP problems via successive approximation
- Rounding
- Linear interpolation
- Chebychev Polynomials

Solution of DP problems via the equilibrium conditions

ML estimation of DP problems

III. Problems examined in class/homeworks/exams

Water conveyance problem (canal problem)
Groundwater problem (Brown and Deacon)
Groundwater problem (Feinerman and Knapp)
Capital growth problem (analytical vs. numerical solutions)
Irreversibility problem (from Kennedy code supplied in class)
Deterministic vs. stochastic timber harvest problem
Animal feeding/harvest problem
Pest resistance problem
Optimal storage under uncertainty (Miranda's rational expectations problem)
Classic fisheries management problem (MRAP illustration)
Mineral springs problem (analytical exercise)