# Agricultural Economics 637
# Production Economics and Dynamic Optimization (Part I)
# Summer 2003

**Instructor**
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**Office Hours and communication**

- Open door policy
- e-mail messages usually receive prompt response.
- If necessary, you may call me at home, but please not after 9:00.

## I. Course Objectives

- To develop an intuitive understanding of dynamic economic problems including (discrete and continuous, deterministic and stochastic).
- To understand applications of dynamic economic analysis in the areas of agricultural and natural resource economics.
- To become competent in the process of setting up and solving dynamic optimization problems, both analytically and numerically, and to understand the strengths and weaknesses of alternative methods.
- To be able to read and understand papers in which dynamic optimization plays a central role.

## II. Grading

The course grade will be determined based on an equal weighting of your performance on the two parts of AGEC 637.
The purpose of grades is to provide a signal to you, the department, the university, future employers, and others. Here is what I believe those signals should indicate for a graduate-level course:
A - Thorough understanding of the material, and demonstrated ability to apply the concepts to problems beyond the scope of the course.
B - Good understanding of the material but unclear whether the student would be able to extend the concepts beyond the course
C - Failed to achieve of the objectives noted above.
D - A lot worse than C.
F - Forgot to withdraw from the class.

That said, the critical point is how you will demonstrate these skills. Your final grade will be based on your average grade on the problem sets (35%), exam (55%), and participation (10%).

*Homeworks*: Each homework assignment will contain a mathematical or computational component and a component of interpretation. These two components will be given approximately equal weight. Hence, interpretation of the results is just as important as getting the right numbers and/or equations. The mathematical or computational component of your homeworks should be commented, that is, each important part of your analysis or computer code should be explained so that I can easily follow what you are doing. For example, an answer that consists on only a series of equations with no explanation of the objective of a sequence of equations is not acceptable. Similarly, computer programs need to be written in such a way that even someone entirely unfamiliar with the language can understand the logic of the program. In your interpretation, clarity of writing will be taken into account.

I expect your assignments to be neat, well formatted, and should be written in a manner that communicates to the reader. **Do not turn in unformatted computer printout with your homework.** Rather, your results should be in well-prepared tables or (better) figures and should be specifically referred to in your discussion of your results. All computer programs used in solving your program should be submitted electronically.

Finally, please, answer the assigned questions.

*Exam*: A two-part final exam will be given. The in-class exam will be given on July 2, to be followed by a take-home portion in which the student must write a computer program to solve a dynamic programming problem, this is due on Thursday, July 3 at 5:00 p.m.

*Extensions*: Extensions are not in the best interest of either the student or the instructor and will be granted only in special conditions related to complete surprises.

*Writing skills*: The clarity of your writing will be considered in the evaluation of your work. Spelling and grammatical errors will be penalized. Always use a spell and grammar checker before submitting typed work.

*Working with others*: Anything you hand in for this class must reflect your own understanding. On homework assignments, you may work with others, but you must understand what is finally handed in. The algebra or computer programs might be identical, but the discussion, explanation of the steps, and comments in your computer code should be written independently. It is strictly forbidden to obtain assistance from anyone else on the take-home final. It is also strictly forbidden to use computer code or homework from students who have taken this course in previous years. I've got copies of their assignments – don't try it.

## III. How to have fun and succeed in AGEC 637

To get the most out of this class and not be overwhelmed by stress, I have one simple piece of advice: plan ahead.

*Read ahead*. Complete lecture are available before each class. You should print and read the lecture notes that we will be presented in class. Since the lecture notes are available in advance, we will make best use of our time if people indicate questions that they have before class begins and I will make sure that all those questions are addressed. We will work to develop a system by which questions can be submitted before class. In addition, if there is an assigned reading, do it in advance.

*Work ahead*. Start on the problem sets as soon as possible. This will give you an opportunity to ask questions when you have time to process the answers. I am very willing to help out if you ask questions well in advance after you've made a good faith effort to find the solution, but am much more reluctant to help out when the deadline is hours away.

*Work in groups*: I encourage you to help each other. Asking another student for help will usually benefit both of you. However, there are limits to this. First, be considerate of other students' time. If you are asking questions because you procrastinated, then the student who worked hard for many hours is under no obligation to help you. Moreover, help that is only one-way is pathway to failure. If you find that you're always on the receiving end of the advice line, then you need to start worrying. The way to address this is with the next assignment, get started well in advance and ask me for help, then you can provide assistance to your classmates. Finally, work you turn in must reflect your own understanding. *Turning in work that you have copied from another student that you do not understand is **plagiarism** and is a very serious offense*. See the discussion about this in section II above.

## IV. Class home page

The class homepage is located at http://agecon.tamu.edu/faculty/woodward/637/. Notes, problem sets and other information relevant to the course will be available there. I will provide notes for each lecture on the web site at least 48 hours prior to each class. If for some reason I fail to post the notes at that time, I will supply printed copies in class.

## V. Prerequisites

It will be assumed that you have a very strong understanding of calculus (constrained optimization and integration), linear algebra and fundamental principals of probability and statistics. You must also be comfortable with the basic microeconomic results of consumer and producer theory. Previous exposure to differential equations would be helpful, but is not assumed. Econometrics 669 satisfies the prerequisite requirements.

## VI. Computer programming

The use of computers is central to applied economic analysis and will play a major role in this course. The only way to learn a foreign language is by practicing. The same rule holds for programming languages. I believe that you should look at each course you take as an opportunity to learn a new language. The more languages you "speak", the more flexibility that you have as you try to solve a problem. On the other hand, learning a language can be time consuming and get in the way of learning

the economic concepts that are the focus of the course. So you must balance the associated benefits and costs based on your own interests, time constraints and talents.

We will have four computer labs during which students I will be available to assist in the use of programming languages that will be used to complete the homework assignments. Except for students that are taking only the dynamic optimization part of 637, these labs will be optional.

All of the computer homework assignments can, at least in theory, be completed using any one of a number of programs including GAMS, Fortran, Gauss, Matlab, or Visual Basic. Some of the problems could even be solved in Excel or other spreadsheets. You may use any acceptable program to complete the assignments for this course. However, the default language for the course will be Visual Basic. I can provide a compiler and support for anyone who wishes to use Fortran. We will have several sessions in which we spend some time working in the computer lab. There are a number of books that will help you learn to program using the book by Albright noted below.

**VII. Outline of the course** (This outline is substantive, not sequential)

A. Nature of Dynamics

B. Optimal control theory
   1. Derivation of optimal control necessary conditions, Hamiltonians
   2. Finite horizon problems
   3. Infinite horizon problems
   4. Economic Interpretation
   5. Bang-bang and most-rapid-approach-path solutions to optimal control
   6. Stochastic optimal control (Ito calculus)

C. Dynamic Programming
   1. Deterministic DP
   2. Stochastic DP
   3. Infinite horizon problem and convergence
   4. Case studies

D. Dynamic programming in planning, management and positive analysis
   1. Extension of DP using Markov Process Principles
   2. Using DP in econometric analysis

**VIII. Texts**

The following are optional texts and should be available at the book store. I would ***not*** recommend buying all of these books as the cost would be excessive and there is some repetition. You are welcome to look at my copies of these books before making a decision. For the nuts and bolts of numerical dynamic programming, the best available references are, in my opinion, the chapter by Rust (*Handbook of Computational Economics*, on reserve at in the reference lab) and a few chapters of the book by Judd.

Albright, S. Christian. 2001. *VBA for Modelers: Developing Decision Support Systems with Microsoft Excel*. Pacifica Grove, CA.: Duxbury:

Judd, Kenneth L. 1996. *Numerical Methods in Economics*. Cambridge, Mass.: The MIT Press. ($55) [An excellent overview of state-of-the-art methods - a useful reference book]

Kamien, Morton I. and Schwartz, Nancy Lou. 1991. *Dynamic Optimization : The Calculus of Variations and Optimal Control in Economics and Management*. New York, N.Y. : Elsevier. [A very good references for optimal control]

Leonard, Daniel, and Ngo Van Long. 1992. *Optimal Control Theory and Static Optimization in Economics*. New York: Cambridge University Press. [Very well written introduction to optimal control]

Miranda, Mario J., and Paul L. Fackler. 2002. *Applied Computational Economics and Finance.* Cambridge, Mass.: MIT Press. [excellent applied text. The authors use Matlab to solve a wide range of problems]

## IX. Acknowledgments

In developing the material for this course I will draw on numerous sources and I want to give the authors credit. I always attempt to indicate the source of material, though can only do this ex post when the material leads to homework problems. As a disclaimer, I claim the discovery of none of the material covered in the course. If you are unsure of the source for the material that I am presenting, simply ask and I will normally gladly provide the necessary citation, at least after the problem set has been handed in. Unpublished sources that I will be drawing on include:

Karp, Larry. Lecture notes on Methods of Dynamic Analysis and Control. University of California, Berkeley

Provencher, Bill. Lecture notes on Dynamic Resource Economics. University of Wisconsin – Madison.

## X. Students with disabilities

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact the Department of Student Life, Services for Students with Disabilities in Room 126 of the Koldus Building so your professor can best accommodate your needs. The phone number is 845-1637.

## XI. Readings

A lengthy list of articles in the field of dynamic optimization is available in the complete version of this syllabus, available from the class home page. To avoid wasting paper, it is not reproduced here.

**Selected dynamic reading list**. This list has been derived from a number of sources and should be thought of as a resource which you can use to extend your knowledge of dynamic optimization. Papers that are assigned as reading will be available in the reference lab.


Androkovich, Robert A. and Kenneth R. Stollery. 1994. A Stochastic Dynamic Programming Model of Bycatch Control in Fisheries. *Marine Resource Economics* 9(1):19-30.

Arrow, Kenneth J. and Anthony C. Fisher. 1974. Environmental Preservation, Uncertainty and Irreversibility. *Quarterly Journal of Economics* 88:312-319.

Aronsson, Thomas, Per-Olav Johansson and Karl-Gustaf Lofgren. 1997. *Welfare Measurement, Sustainability and Green National Accounting*. Edward Elgar Publishing: New York.

Bellman, R.E. 1957. *Dynamic Programming*. Princeton, NJ: Princeton University Press.

Bellman, R.E. and S.E. Dreyfus. 1962. *Applied Dynamic Programming*. Princeton, NJ: Princeton University Press.

Bernardo, Daniel J. 1989. A Dynamic Model for Determining Optimal Range Improvement Programs. *Western Journal of Agricultural Economics* 14(2):223-34.

Bertsekas, Dimitri P. 1987. *Dynamic Programming : Deterministic and Stochastic Models.* Prentice Hall.

Brazee, R. and R. Mendelsohn. 1989. Timber harvesting with fluctuating prices. *Forest Science* 34:259-372.

Brito, Dagobert and Michael D. Intriligator 1987. "Stock Externalities, Pigovian Taxation and Dynamic Stability," J. Pub. Econ. 33:59-72.

Brock, W.A. and L.J. Mirman. 1972. "Optimal Economic Growth Under Uncertainty: The Discounted Case." *Journal of Economic Theory* 4:479-513.

Burt, O.R. and J.R. Allison. 1963. "Farm Management Decisions With Dynamic Programming." *Journal of Farm Economics* 45:121-37.

Chakravorty, Hochman, and Zilberman. 1995. A Spatial Model of Optimal Water Conveyance. *Journal of Environmental Economics and Management*

Chatterjee, Bishu, Richard E. Howitt and Richard J. Sexton. 1998. The Optimal Joint Provision of Water for Irrigation and Hydropower. *Journal of Environmental Economics and Management* 36:295-313

Chavas, Jean-Paul. 1996. On the Economic Rationality of Market Participants: The Case of Expectations in the U.S. Pork Market. Unpublished manuscript. Department of Agricultural and Applied Economics, University of Wisconsin-Madison.

Chavas, J.-P., J. Kliebenstein, and T.D. Crenshaw. 1985. "Modeling Dynamic Agricultural Production Response: The Case of Swine Production." *American Journal of Agricultural Economics* 67:636-46.

Chiang, Alpha C. 1991. *Elements of Dynamic Optimization*. McGraw Hill

Clark, C.W. 1976. *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*. New York: John Wiley and Sons.

Conrad, Jon M. and Colin W. Clark. 1987. *Natural resource economics: notes and problems*. New York: Cambridge University Press. (a useful applied text with some nice examples in resources)

Dixit, A.K. 1992. *Optimization in Economic Theory, 2nd Ed*. Oxford: Oxford University Press.

Dorfman, R. 1969. "An Economic Interpretation of Optimal Control Theory." *American Economic Review* 59:817-31.

Dreyfus, Stuart. 2002. Richard Bellman on the Birth of Dynamic Programming. *Operations Research* 50(1):48-51.

Eckstein, Z. 1984. "A Rational Expectations Model of Agricultural Supply." *Journal of Political Economy* 92:1-19.

Eckstein, Z. 1985. "The Dynamics of Agricultural Supply: A Reconsideration." *American Journal of Agricultural Economics* 67:204-14.

Epstein, L.G. and S.E. Zin. 1989. "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework." *Econometrica* 57:937-970.

Fair, R.C. and J.B. Taylor. 1983. "Solution and Maximum Likelihood Estimation of Dynamic Nonlinear Rational Expectations Models." *Econometrica* 51:1169-85

Gill, P.E., W. Murray, and M.H. Wright. 1981. *Practical Optimization*. New York: Academic Press.

Glauber, J.W., P.G. Helmberger, and M.J. Miranda. 1989. "Four Approaches to Commodity Price Stabilization: A Comparative Analysis." *American Journal of Agricultural Economics* 71:326-337.

Goodwin, T.H. and S.M. Sheffrin. 1982. "Testing the Rational Expectations Hypothesis in an Agricultural Market." *Review of Economics and Statistics* 64:658-67.

Griffin, R.C. 1987. Environmental Policy for Spatial and Persistent Pollutants. *Journal of Environmental Economics and Management* 14:41-53.

Hansen, L.P. and T.J. Sargent. 1980. "Formulating and Estimating Dynamic Linear Rational Expectations Models." *Journal of Economic Dynamics and Control* 2:7-46.

Harper, Jayson K., James W. Mjelde, M. Edward Rister, Michael O. Way and Bastiaan M. Drees. 1994. Developing Flexible Economic Thresholds for Pest Management Using Dynamic Programming. *Journal of Agricultural and Applied Economics*; 26(1):134-47.

Hartwick, John M. 1990. Natural Resources, National Accounting and Economic Depreciation. *Journal of Public Economics* 43:291-304.

Hotelling, H. 1931. "The Economics of Exhaustible Resources." *Journal of Political Economy* 39:137-175.

Judd, K.L. 1992. "Projection Methods for Solving Aggregate Growth Models." *Journal of Economic Theory* 58:410-52.

Judd, Kenneth L. 1997. Computational Economics and Economic Theory: Substitutes or Complements? *Journal of Economic Dynamics and Control* 21:907-942.

Kennedy, J.O.S. 1986. *Dynamic Programming: Applications to Agriculture and Natural Resources*. New York: Elsevier Publishers.

Ko, Il-Dong, Harvey E. Lapan and Todd Sandler, 1992. "Controlling Stock Externalities, Flexible versus Inflexible Pigovian Corrections," *Eur Econ Rev* 36:1263-1276.

Knapp, Keith C. and Lars J. Olson. 1996. Dynamic Resource Management: Intertemporal Substitution and Risk Aversion. *American Journal of Agricultural Economics* 78(4):1004-1014.

Krautkraemer, Jeffrey A., G.C. van Kooten and Douglas L. Young. 1992. Incorporating Risk Aversion into Dynamic Programming Models. *American Journal of Agricultural Economics* 74(4):870-78.

Kreps, D.M. and E.L. Porteus. 1979. "Dynamic Choice Theory and Dynamic Programming." *Econometrica* 47:91-100.

Levhari, D. and L.J. Mirman. 1980. The great fish war: An example using a dynamic Cournot-Nash solution. *Bell Journal of Economics* 11:322-334.

Lucas, R.E. Jr. 1976. Econometric Policy Evaluation: A Critique . In K Brunner and A.H. Meltzer eds., *The Phillips Curve and Labor Markets*, 19-46. Amsterdam: North-Holland.

Miranda, M.J. and G.D. Schnitkey. 1995. "Estimation of Dynamic Agricultural Decision Models: The Case of Dairy Cow Replacement." *Journal of Applied Econometrics* 10:41-56.

Miranda, M.J. and J.W. Glauber. 1993. "Estimation of Dynamic Nonlinear Rational Expectations Models of Primary Commodity Markets with Private and Government Stockholding." *Review of Economics and Statistics* 75:463-467.

Miranda, M.J. and P.G. Helmberger. 1988. "The Effects of Price Band Buffer Stock Programs." *American Economic Review* 78:46-58.

Miranda, M.J. and P.W. Fackler. 2000. *Lecture Notes in Computational Economic Dynamics.* Manuscript, The Ohio State University.

Mjelde, James W., Steven T. Sonka, Bruce L. Dixon and Peter J. Lamb. 1988. Valuing Forecast Characteristics in a Dynamic Agricultural Production System. *American Journal of Agricultural Economics* 70(3):674-84.

Provencher, Bill. 1995. Structural Estimation of the Stochastic Dynamic Decision Problems of Resource Users: An Application to the Timber Harvest Decision. *Journal of Environmental Economics and Management* 29:321-338.

Provencher, Bill. An Investigation of the Harvest Decision of Timber Firms in the South-East United States. *Journal of Applied Econometrics* 10:S57-S74.

Rosen, S. 1987. "Dynamic Animal Economics." *American Journal of Agricultural Economics* 69:547-557

Rust, J. 1987. "Optimal Replacement of GMC Bus Engines: An Empirical Model of Harold Zurcher." *Econometrica* 55:999-1033

Rust, J. 1988. "Maximum Likelihood Estimation of Discrete Control Processes." *SIAM Journal of Control and Optimization* 26:1006-1024.

Rust, J. 1992. "Estimation of Dynamic Structural Models, Problems and Prospects: Discrete Decision Processes." In C. Sims ed., *Advances in Econometrics 6th World Congress,* 119-170 . Cambridge: Cambridge University Press.

Rust, J. 1993. "Structural Estimation of Markov Decision Process." In D.L. McFadden ed., *Handbook of Econometrics Vol. 4*. New York: North-Holland.

Rust, J. 1994. "Numerical Dynamic Programming in Economics." In H. Amman, D.A. Kendrick, and J. Rust eds., *Handbook of Computational Economics*, *Vol. 1,* 619-722. New York: North-Holland.

Rust, John. 1996. Numerical Dynamic Programming in Economics. In H. Amman, D. Kendrick and J. Rust (eds.), *Handbook of Computational Economics*. New York: North Holland.

Smith, Vernon L. 1972. Dynamics of Waste Accumulation: Disposal Versus Recycling. *The Quarterly Journal of Economics*, 86(4):600-616.

Stokey, Nancy L. and Lucas Robert E. 1989. *Recursive Methods in Economic Dynamics*. Harvard Univ. Press.

Taylor C. Robert (editor). 1993. *Applications of dynamic programming to agricultural decision problems*. Boulder: Westview Press.

Taylor, C Robert; Burt, Oscar R. 1984. Near-Optimal Management Strategies for Controlling Wild Oats in Spring Wheat. *American Journal of Agricultural Economics* 66(1):50-60.

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.

Vande Kamp, Philip R. and Harry M. Kaiser. 2000. “Optimal Temporal Policies in Fluid Milk Advertising.” *American Journal of Agricultural Economics* 82(2):274-86.

van Kooten, G. Cornelis, Douglas L. Young and Jeffrey A. Krautkraemer. 1997. Safety-first Approach to Dynamic Cropping Decisions. *European Review of Agricultural Economic* 24:47-63.

Wilen, James E. 1985. Bioeconomics of Renewable Resource Use, In A.V. Kneese and J.L. Sweeney (eds.) *Handbook of Natural Resource and Energy Economics, vol. I.* New York: Elsevier Science Publishers B.V.

Wirl, Franz 1994. "Pigouvian Taxation of Energy for Flow and Stock Externalities and Strategic, Noncompetitive Energy Pricing," *Journal of Environmental Economics and Management*. 26:1-18.