Syllabus & Course Outline

APPLIED ECONOMICS 8202
MATHEMATICAL OPTIMIZATION IN APPLIED ECONOMICS

Fall 2011

Course Description: Applications of mathematical programming techniques to economic problems are presented. Mathematical optimization concepts are reviewed; structures and economic interpretations of various models of the firm, consumer, household, sector, and economy are examined. Model building and solution techniques are illustrated using examples and computer exercises. Approaches to dynamic optimization are introduced. 3 credits.

Instructor: Jeffrey Apland, 332c Ruttan Hall
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Meeting Time & Place: 4:15-5:30, Mondays and Wednesdays; B26 Ruttan Hall.

References: A partial list of references to supplement and complement the lectures is incorporated into the course outline which follows. Assigned readings will be announced in class. Most of the references are available in Waite Library – some, marked with an asterisk (*) are on reserve. There is no required textbook. *Mathematical Optimization and Economic Theory* by Michael Intriligator is a good reference on the mathematics of optimization in the context of economic problems. Several chapters will be placed on reserve in Waite Library and will be assigned reading. Several good mathematical economics and applied math programming books are listed below. The books by McCarl and Spreen, and Hazell and Norton address many of the topics discussed in the course. Two other texts which have a bent toward empirical applications are *Model Building in Mathematical Programming* by H. P. Williams, and *Computational Economics: Economic Modeling with Optimization Software* by Gerald L. Thompson and Sten Thore. Many of the topics are also discussed in numerous operations research books. One such book, *Introduction to Operations Research* by Hillier and Lieberman, is a useful reference on a variety of mathematical and dynamic programming topics.

Throughout the course, we will discuss solutions to economic problems modeled using GAMS – the Generalized Algebraic Modeling System. Some computer exercises will be included in assignments and, if possible, we will schedule class meetings in a computer lab. Depending on prior experience and interest, we may explore other mathematical programming software such as the Excel Solver.

Grading: Final grades will be based on a mid-term examination (40%), a final examination (40%), written and computer exercises (15%), and class participation (5%).

Some Useful Reference Books:

Hazell, Peter B. R. and Roger D. Norton. *Mathematical Proramming for Economic Analysis in Agriculture*. New York: Macmillan Publishing Company. 1986.

Hillier, Frederick S. and Gerald J. Lieberman. Introduction to Operations Research. Oakland, California: Holden-Day, Inc. 1986.

Hillier, Frederick S. and Mark S. Hillier. Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets, Fourth Edition. New York: McGraw-Hill Irwin. 2011.

Intrilligator, Michael D. *Mathematical Optimization and Economic Theory*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc. 1971.

McCarl, Bruce A. and Thomas Spreen. *Applied Mathematical Programming Using Algebraic Systems*. http://agecon2.tamu.edu/people/faculty/mccarl-bruce/books.htm.

Miranda, Mario J. and Paul L. Fackler. Applied Computational Economics and Finance. Cambridge, Massachusetts: The MIT Press. 2002.

Takayama, Akira. *Analytical Methods in Economics.* Ann Arbor: The University of Michigan Press. 1993.

Thompson, Gerald L. and Sten Thore. *Computational Economics: Economic Modeling with Optimization Software.* South San Francisco, California: The Scientific Press. 1992.

Williams, H. P. *Model Building in Mathematical Programming.* Third Edition. West Sussex, England: John Wiley and Sons Ltd. 1990.

Course Outline:

I. Introduction

    A. Perspective of the Course

    B. Software for Mathematical and Dynamic Programming

    References for Section I:

* *GAMS: A User's Guide.* Chapter 2: A GAMS Tutorial, by Richard E. Rosenthal. GAMS Development Corporation, Washington DC. 2007.

* Intriligator, Michael. *Mathematical Optimization and Economic Theory.* Chapter 1, Appendix B-9.

II. Overview of Mathematical Programming

    A. The Mathematical Programming Problem -- Terms and Concepts, the Weierstrass Theorem and the Local-Global Theorem

    B. The Classical Programming Problem and the Method of Lagrange

    C. Nonlinear Programming and the Kuhn-Tucker Conditions

    D. The Linear Programming Problem

        1. Primal and Dual Problems, Kuhn-Tucker Conditions

        2. The Simplex Algorithm

        3. Degeneracy, Sensitivity Analysis and Ranging

    E. Special Classes of Mathematical Programming Problems

        1. Problems with Integer Variables

        2. Quadratic Programming

        3. Approximation of Nonlinear Programming Problems Using Linear Programming

    References for Section II:

* Apland, Jeffrey. "The Approximation of Nonlinear Programming Problems Using Linear Programming." Staff Paper P86-2, Dept of Agricultural and Applied Economics, Univ of Minnesota.

* Intriligator, Michael D. *Mathematical Optimization and Economic Theory.* Chapters 2-5.

McCarl, Bruce A. and Hayri Önal. "Linear Approximation Using MOTAD and Separable Programming: Should It Be Done?" *American Journal of Agricultural Economics.* February 1989, pp. 158-166.

III. Firm-Level Applications of Mathematical Programming

    A. Formulation of Economic Problems as Linear Programs

        1. The Blending Problem

        2. The Transportation Problem and Variants

    B. A Linear Programming Model of the Firm

        1. Model Structure, Kuhn-Tucker Conditions and an Example

        2. Comparison of the LP Model with the Neoclassical Model of the Firm

    C. Modeling Farm Production

        1. A Corn and Soybean Farm

        2. Extensions and Applications

    D. Applications of Integer Programming

    E. An Overview of Risk Programming

        1. The Mean Variance and MOTAD Risk Programming Models

        2. Discrete Stochastic Programming

        3. Other Risk Programming Models

    F. Multiple Objective Programming

References for Section III:

Anderson, Jock R., John L. Dillon and Brian Hardaker. *Agricultural Decision Analysis.* Iowa State University Press, Ames, Iowa, pp. 197-202 and 207-212.

Apland, Jeffrey. "The Dynamics of Beef Cattle Production: Model Formulation, Application and an Example." *North Central Journal of Agricultural Economics.* July 1985, pp. 21-31.

* Apland, Jeffrey, Robert N. Barnes, and Fred Justus. "The Farm Lease: An Analysis of Owner- Tenant and Landlord Preferences Under Risk." *American Journal of Agricultural Economics.* Aug 1984, pp. 376-384.

Apland, Jeffrey and Steven Cornelius. "The Effects of Porcine Somatotropin on Swine Feed Costs." Staff Paper P90-10, Dept of Agricultural and Applied Economics, Univ of Minnesota, February 1990.

* Apland, Jeffrey and Grant Hauer. "Discrete Stochastic Programming: Concepts, Examples and a Review of Empirical Applications." Staff Paper P93-21, Dept of Agricultural and Applied Economics, University of Minnesota, September 1993.

* Apland, Jeffrey, Bruce A. McCarl, and Timothy G. Baker. "Crop Residue Supply for Energy Generation: A Prototype Application to Midwestern U.S.A. Grain Farms." *Energy in Agriculture.* Nov 1981, pp. 55-70.

Apland, Jeffrey, Bruce A. McCarl, and William L. Miller. "Risk and the Demand for Supplemental Irrigation: A Case Study in the Corn Belt." *American Journal of Agr Economics.* Feb 1980, pp. 142-145.

Baker, Timothy G. and Bruce A. McCarl. "Representing Farm Resource Availability Over Time in Linear Programs: A Case Study." *North Central J of Agricultural Economics.* January 1982, pp. 59-68.

Baumol, William J. "Activity Analysis in One Lesson." *AER.* December 1958, pp. 837-873.

* Boisvert, Richard N. and Bruce A. McCarl. "Agricultural Risk Modeling Using Mathematical Programming." A.E.Res. 90-9, Department of Agricultural Economics, Cornell University.

Brandao, Elizabeth, Bruce A. McCarl and G. Edward Schuh. "Predicting the Impact of New Cropping Practices upon Subsistence Farming: A Farm Level Analysis in Brazil." *Western Journal of Agricultural Economics.* December 1984, pp. 329-341.

Candler, Wilfred and Michael Boehlje. "Use of Linear Programming in Capital Budgeting with Multiple Goals." *American Journal of Agricultural Economics.* May 1971, pp. 325-330.

Cocks, K.D. "Discrete Stochastic Programming." *Management Science.* Sept 1968, pp. 72-79.

Dillon, Carl, Bruce A. McCarl and J. W. Mjelde. "Biophysical Simulation in Support of Crop Production Decisions: A Case Study in the Blacklands Region of Texas." *Southern J of Agr Econ.* July 1989, pp. 73-86.

* Dorfman, Robert. "Mathematical or Linear Programming: A Nonmathematical Exposition." *American Economic Review.* December 1953, pp. 797-825.

Hardaker, J. Brian, Sushil Pandey and Louise H. Patten. "Farm Planning Under Uncertainty: A Review of Alternative Programming Models." *Rev of Marketing and Agr Economics* 59(1991):9-22.

Hazell, Peter B. R. and Roger D. Norton. *Mathematical Programming for Economic Analysis in Agriculture.* Chapter 5: Risk in the Farm Model.

* Lee, Sang M. and Laurence J. Moore. "Optimizing Transportation Problems with Multiple Objec-tives." *AIIE Transactions.* December 1973, pp. 333-338.

* Naylor, Thomas H. "The Theory of the Firm: A Comparison of Marginal Analysis and Linear Pro-gramming." *Southern Economic Journal.* January 1966, pp. 263-274.

Olson, Kent D. and Vernon R. Eidman. "A Farmer's Choice of Weed Control Method and the Impacts of Policy and Risk." *Review of Agricultural Economics.* January 1992, pp. 125-137.

Rae, A. N. "An Empirical Application of and Evaluation of Discrete Stochastic Programming in Farm Management." *American Journal of Agricultural Economics.* November 1971, pp. 625-638.

Rae, A. N. "Stochastic Programming, Utility and Sequential Decision Problems in Farm Management." *American Journal of Agricultural Economics.* August 1971, pp. 448-460.

Tauer, Loren W. "Target MOTAD." *American Jour of Agricultural Econ.* Aug 1983, pp. 606-610.

IV. Market, Sector and Economy Level Applications of Mathematical Programming

    A. Modeling Market Equilibrium as a Mathematical Programming Problem

    B. A Single-Commodity Trade Model and Extensions

    C. Sector Models with Exogenous, Price Responsive Input Supply and Output Demand Functions, and Endogenous Input Demand and Output Supply

References for Section IV:

"Agricultural Sector Modeling." Siegfried Bauer and Wilhelm Henrichsmeyer, Editors. Proceedings of the 16th Symposium of the European Association of Agricultural Economists, April 14-15, 1988. Bonn, FRG. Wissenschaftsverlag Vaul Kiel KG, 1989.

* Apland, Jeffrey and Hans Andersson. "Optimal Location of Processing Plants: Sector Modeling Considerations and an Example." *Review of Agricultural Economics.* September 1996.

* Apland, Jeffrey, Bo Öhlmér and Lars Jonasson. "Economic Analysis of Agricultural Technologies and Policies: The Sector Modeling Approach". Report 71, Swedish University of Agricultural Sciences, Department of Economics; Uppsala, Sweden; 1994.

* Brännlund, Runar, Rolf Färe and Shawna Grosskopf. "The Cost of Environmental Regulation: A Programming Approach." Umeå Economic Studies No. 332, Univ of Umeå; Umeå, Sweden; 1993.

Chang, Ching-Cheng, Bruce A. McCarl, James W. Mjelde and James W. Richardson. "Sectoral Implications of Farm Program Modifications." *American J. of Agr. Economics.* Feb 1992, pp. 38-49.

Coble, Keith H., Ching-Cheng Chang, Bruce A. McCarl and Bobby R. Eddleman. "Assessing Eco-nomic Implications of New Technology: the Case of Cornstarch-Based Biodegradable Plastics." *Review of Agricultural Economics.* January 1992, pp. 31-43.

Duloy, J. and R. Norton. "Prices and Incomes in Linear Programming Models." *American Journal of Agricultural Economics.* November 1975, pp. 591-600.

Graubner, Marten, Alfons Balmann, and Richard J. Sexton. "Spatial Price Discrimination in Agricultural Product Procurement Markets: A Computational Economics Approach." *American Journal of Agricultural Economics* 2011 93: 949-967.

Hagerman, Amy D., Bruce A. McCarl, Tim E. Carpenter, Michael P. Ward and Joshua O'Brien. "Emergency Vaccination to Control Foot-and-Mouth Disease: Implications of its Inclusion as a U.S. Policy Option." *Applied Economics Perspectives and Policy.* 2012 34:119-146.

Hamilton, Scott, Bruce A. McCarl and Richard Adams. "The Effect of Aggregate Assumptions on Environmental Impact Analyses." *American J Agr Econ.* May 1985, pp. 407-413.

Hazell, Peter B. R. and Roger D. Norton. *Mathematical Programming for Economic Analysis in Agriculture.* Part Two: The Sector Model.

Howitt, Richard E. "Positive Mathematical Programming." *Am J Agr Econ.* May 1995, pp. 329-342.

* Jonasson, Lars and Jeffrey Apland. "Frontier Technologies and Inefficiencies in Programming Sector Models: An Application to Swedish Agriculture." *European Rev of Agr Econ.* 24(1997): 109-131.

Magrath, William B. and Loren W. Tauer. "New York Milk Supply with Bovine Growth Hormone." *North Central Journal of Agricultural Economics.* July 1988, pp. 233-241.

McCarl, Bruce A. "Cropping Activities in Agricultural Sector Models: A Methodological Proposal." *American Journal of Agricultural Economics.* November 1982, pp. 768-772.

McCarl, Bruce A. and Thomas H. Spreen. "Price Endogenous Mathematical Programming as a Tool for Sector Analysis." *American Journal of Agricultural Economics.* February 1980, pp. 87-102.

Mérel, Pierre, Leo K. Simon, and Fujin Yi. "A Fully Calibrated Generalized Constant-Elasticity-of-Substitution Programming Model of Agricultural Supply." *American J of Agric Economics* 2011 93: 936-948.

Norton, Roger D., and Gerhard W. Schiefer. "Agricultural Sector Programming Models: A Review." *European Review of Agricultural Economics.* 1980, pp. 229-264.

Setia, Parveen and Steven Piper. "Effects of Soil and Agricultural Chemicals Management on Farm Returns and Ground Water Quality." *Review of Agricultural Economics.* January 1992, pp. 65-80.

Shei, Shun-Yi and Robert L. Thompson. "The Impact of Trade Restrictions on Price Stability in the World Wheat Market." *American Journal of Agricultural Economics.* November 1977, pp. 628-638.

Spreen, Thomas H. and Takashi Takayama. "A Theoretical Note on Aggregation of Linear Programming Models of Production." *American Jour of Agricultural Econ.* Feb 1980, pp. 146-151.

Takayama, T. and G. G. Judge. "Spatial Equilibrium and Quadratic Programming." Journal of Farm Economics. February 1964, pp. 67-93.

Takayama, T. and G. G. Judge. Spatial and Temporal Price and Allocation Models. North-Holland Publishing Co., London.

Tanyeri-Abur, Aysen, Bruce A. McCarl, Ching-Cheng Chang, Ronald D. Knutson, E. Wesley F. Peterson and Keith H. Coble. "An Analysis of Possible U.S. Sugar Import Policy Revisions." *Review of Agricultural Economics.* May 1993, pp. 255-268.

V. Validating Mathematical Programming Models

    A. Alternative Approaches to Validation

    B. Design of Validation Experiments

    Reference for Section VI:

    Hazell, Peter B. R. and Roger D. Norton. *Mathematical Programming for Economic Analysis in Agriculture.* Chapter 11: Construction and Validation of Sector Models.

  * McCarl, Bruce A. and Jeffrey Apland. "Validation of Linear Programming Models." *Southern Journal of Agricultural Economics.* December 1986, pp. 155-164.

VI. An Overview of Dynamic Optimization

    A. Characteristics of Dynamic Problems.

    B. The Calculus of Variations

    C. Dynamic Programming

    References for Section VI:

    "Applications of Dynamic Programming to Agricultural Decision Problems." C. Robert Taylor, Editor. Westview Press, Boulder Colorado. 1993.

  * Intriligator, Michael. *Mathematical Optimization and Economic Theory.* Chapters 11-12.