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Book Reviews

Update on Math Programming

Mathematical Programming for Economic Analysis in Agriculture *By Peter B R Hazell and Roger D Norton New York Macmillan, 1986, 400 pp, $42 50*

Reviewed by Robert M House

Agricultural economics contains a rich tradition of mathematical programming, but until Hazell and Norton's book, there had been no thorough compendium of the most interesting developments in the past 15 years Their book is a self-contained reference to programming modeling linear programming (LP) theory and computer solution, farm modeling techniques, sector modeling techniques, and policy applications

The book blends theory and practice The discussion of farm and sector models and applications is illustrated with tableau fragments (tables containing a small rectangular block of the coefficients from a few rows and columns of an LP model) The book is aimed at the graduate student level Knowledge of intermediate microeconomics is assumed The reader should understand linear algebra and some calculus Hazell and Norton cover topics quickly and give interested readers references to more comprehensive treatments of many subjects The reference list is thorough for an intermediate text

Using a simple farm model as an example, the authors discuss the assumptions of linear programming and briefly introduce duality, Lagrangean functions, and Kuhn-Tucker conditions They illustrate ways to solve an LP problem graphically and take the obligatory walk through several iterations of the Simplex algorithm Then the discussion of farm modeling techniques begins in earnest They discuss production activities, focusing on factor substitution, input/output response relations, crop rotation, and joint products They briefly cover input and resource issues A chapter on advanced farm modeling topics introduces single and multiperiod investment, consumption, work/leisure preferences, and multiple goals

The farm modeling discussion is excellent Topics are well covered The material progresses from the simple to the more complex, and there are plenty of practical tips and real-world know-how As an introduction to farm modeling, the book is a good update of Beneke and Winterboer[1] The book focuses on farm model components that are used in sector models, it does not cover farm simulation in sufficient detail to address, for example, machinery sizing/purchase decisionmaking or financial and tax planning

The strength of Hazell and Norton's book is sector modeling The authors explain how the agricultural sector presents a multilevel decisionmaking problem That is, at an upper or sectoral level, officials make policy decisions, trying to achieve national or social objectives At the lower or microeconomic level, producers independently make individual decisions, attempting to achieve their objectives, given market, resource, technology, and policy conditions There exists no algorithm that solves the multilevel problem directly, so most sector models do not try to maximize a set of policy objectives, but focus instead on simulating how producers respond to alternative policies and other conditions Researchers analyze policy by simulating sector response under alternate policy scenarios

The treatment of sector model topics is thorough Hazell and Norton discuss the standard fare selection of representative production units, aggregation, input supply and output demand markets, regional markets, processing, and onfarm consumption They include more sophisticated topics such as departures from competitive markets and approaches to handling cross-price effects The standard sector model generally omits the response of demand to income changes and, therefore, provides only partial equilibrium impacts to policy changes Hazell and Norton explain how to link demand to income and augment a sector model to yield general equilibrium responses

There is no recipe for constructing a first-rate sector model, good modelers are competent in many areas and

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[1] Raymond R Beneke and Ronald Winterboer, *Linear Programming Applications to Agriculture* (Ames The Iowa State Univ Press, 1973)

improve their skills through practice Based on considerable experience, Hazell and Norton give us valuable insight on how to construct and validate sector models They offer tips on calculating and estimating coefficients Occasionally they make philosophical observations

> Building an applied model is a process, and the most successful models evolve through time to take into account new findings There is never a definitive version, but rather at any moment in time the model represents a kind of orderly data bank that reflects both the strengths and limitations of the available quantitative information (p. 272)

There is value in keeping models small One important lesson for model developers is that "sponsors of the effort are likely to lose interest if they have to wait 1 or 2 years for the first results " Even before a sector model is ready for use, much useful partial analysis can often be done with the assembled data

Hazell and Norton draw a small sample from the set of actual sector models to illustrate applied policy analyses The examples are organized around policy issues such as questions of comparative advantage, input and output pricing policies, and evaluation of investment project alternatives Agricultural policymaking is complicated because policies have multiple objectives One approach is to use the sector model to construct policy feasibility frontiers that show the tradeoffs among two or more objectives (such as foreign exchange and sector income) under different combinations of policy instruments

Risk is a major concern, it is the topic of separate chapters in each of the book's sections on farm, sector, and policy analysis Hazell and Norton discuss risk in terms of expected utility, and they offer several approaches to modelling risk mean variance (E, V), mean standard deviation (E, σ), and MOTAD (minimum of total absolute deviation) Sector-level risk modeling receives thorough treatment Hazell and Norton present both price and revenue expectations models of risk, and they describe how objective function formulations will differ in each case

The risk discussion is essentially the current state-of-the-art in farm-sector modeling I have used the same techniques, and they leave much to be desired Researchers on risk, such as Newbery and Stiglitz[2] and Weiss[3] have demonstrated that there are major problems with the mean-variance formulations of decision-making under uncertainty Some risk modelers have addressed these concerns Lambert and McCarl, for example, proposed a direct expected utility maximization (DEMP) formulation which has "fewer controversial assumptions."[4] Improved applied techniques for modeling risk have not yet been widely adopted

One aspect of the book that strikes me as being less forward-looking than it should be is the emphasis on linearization There is a historical reason for this shortcoming Although Enke and Samuelson in the early fifties devised a way to formulate spatial competitive equilibrium as a problem of maximizing producer and consumer surplus, some 20 years passed before practical linear programming formulations of the problem were published Regional models had yielded only approximate solutions, and they required cumbersome iterative procedures There was a breakthrough in 1973, when Duloy and Norton published an efficient linear approximation formulation with which some problems could be accurately solved with commonly available LP solvers[5] A small flood of farm-sector models followed that employed this technique However, the grid linearization innovation now influences model formulation more than it deserves Excellent large-scale, nonlinear solvers such as Minos[6] have been available to mathematical programmers since 1977, but Hazell and Norton dismiss nonlinear solutions (p 3) and focus their energy on how to linearly approximate inherently nonlinear relationships At one time these formulations were a necessity, but now it is simpler and more straightforward to solve most nonlinear relations directly in math programming models It is true that solving a nonlinear problem sometimes requires more computer time than solving the linear approximation to it, but computer time becomes less expensive every year And, with current solvers, as problem size and the number of nonlinear functions expand, the nonlinear solver may give out and a linear approximation route may become the only feasible approach However, the nonlinear approach is simpler, is more straightforward to formulate, helps keep our models small, and is quite workable for most problems In the Economic Research Service, we routinely solve the USMP Regional Agricultural Model with several hundred nonlinear variables Using grid linearization would add several hundred equations and well over 1,000 variables to this model

[2] David M G Newbery and Joseph E Stiglitz, *The Theory of Commodity Price Stabilization* (Oxford Clarendon Press, 1981)

[3] Michael D Weiss, *Conceptual Foundations of Risk Theory*, TB-1731 (U S Dept of Agr, Econ Res Serv, 1987)

[4] David K Lambert and Bruce A McCarl, 'Risk Modeling Using Direct Solution of Nonlinear Approximations of the Utility Function," *American Journal of Agricultural Economics* (Vol 67, No. 4, Nov 1985), pp 846-52

[5] John H Duloy and Roger D Norton, "CHAC, A Programming Model of Mexican Agriculture," *Multi-Level Planning Case Studies in Mexico*, ed Louis M Goreaux and Alan S Manne (Amsterdam North-Holland Publishing Co., 1973), pp 291-337

[6] Bruce A Murtagh and Michael A Saunders, *Minos 5 0 Users Guide*, Technical Report SOL 83-20 (Stanford, CA Systems Optimization Laboratory, Dept of Operations Research, Stanford Univ , Dec 1983)

The book is an important update on advances in farm and sector mathematical programing practice since 1970 The treatment of most topics such as risk, grid linearization, and cross-price effect formulation is traditional, which is no surprise because Hazell and Norton were often the theoretical and/or applied innovators and they established the traditions I must criticize the book mildly because it covers less than it ought to Its emphasis is on agricultural sector modeling that grew out of work of the Development Research Center of the World Bank in the seventies Work outside this tradition is sometimes ignored For example, the formidable difficulties of estimating coefficients of risk aversion are recounted, but Paris' suggestions on estimating risk aversion parameters from historical data are overlooked [7] But I am willing to forgive such modest failings because of what the book does cover and because it is so well written I found it rewarding to read, and I strongly recommend it

[7] Quirino Paris, "Revenue and Cost Uncertainty, Generalized Mean Variance, and the Linear Complementarity Problem," *American Journal of Agricultural Economics* (Vol 61, No. 2, May 1979), pp. 268–75

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