Simulation

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APPLICATION OF OPTIMIZATION TO MACRO-ECONOMIC SIMULATION MODELS

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A number of macro-economic simulation models of the U.S. agricultural economy have been developed over the past two decades. These models have generally been used to address "what-if" types of questions in a deterministic and/or stochastic mode. One such policy simulator is the National Agricultural Policy Simulator (POLYSIM) (Ray and Richardson). POLYSIM like a number of other computerized simulation models can be optimized by using a Numerical Optimization procedure.

An optimization option has been added to the POLYSIM model by incorporating a Numerical Optimization Technique (Richardson and Ray). The simulation model is relatively large, containing about 215 endogenous variables and 110 exogenous variables. (The computer code for the model is written in FORTRAN and consists of about 1,550 statements.)

POLYSIM is a partially disaggregated macro model of the U.S. agricultural economy with the following crop and livestock categories: feed grains, wheat, soybeans, cotton, cattle and calves, hogs, sheep and lambs, chicken, turkeys, eggs, and milk. The impacts on the supply, utilization and prices of these commodities and on total farm incomes, consumer expenditures for food and government farm program costs can be simulated with the model. Policy instruments the user may change are: target prices and resulting deficiency payments, loan rates, CCC buy-and-sell criteria, acreage allotments, voluntary and mandatory set-aside acreages, per-acre payment schedules for voluntary set-aside, program participation rates, and acreage or production quotas.

Policy insturments selected as control variables for the optimization

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study are loan rates, target prices and voluntary diversion levels for feed grains (corn, sorghum and oats), wheat and cotton. Optimal values for the policy variables were selected annually for a 4 year planning horizon, resulting in 20 seperate control variables for each policy instrument. To reduce the cost of optimizing the model, realistic boundaries were imposed on each of the policy instruments. For example the first year's loan rate for wheat was constrained to be between \$2 and \$3/bu. and the fourth year's loan rate was constrained to be between \$2 and \$3.25/bu. The use of such boundary constraints reduces the area over which the optimization routine must search and thus reduces the number of times that the simulation model must be solved.

The objective function used for the study includes the variables thought to be important to taxpayers, farmers and consumers when formulating farm policy decisions. Specifically, the variables in the function are: net farm income_t, consumers' total expenditures for food_t, total income support payments to farmers_t, total CCC interest and storage costs_t, and the ending year stocks_t of feed grains, wheat and cotton. Parameter weights for the variables in the objective function were developed using Rausser and Freebairn's three-stage approach and are not purported to be the true values but illustrative values that demonstrate the technique. The specification of the objective function caused the optimization routine to maximize net farm income and net income for livestock producers subject to the penalties incurred as the cost of food and government farm programs passed their respective baseline trojectories.

Overall the optimization routine sought to maximize the value of the objective function by selecting alternative values for the policy instruments in years 1 thorugh 4. The optimization routine selected values for the relevant policy instruments, simulated the POLYSIM model for 4 years, evaluated the objective function and re-selected values for the policy instruments.

Actual values for the policy instruments were used as one of the starting points for the rountine, thus reducing the cost of optimization somewhat. To insure that the rountine searched over the entire response surface for the global maximum, the remaining starting values (N+1 -1) were selected at random from their range of relevant values.

The types of policies simulated were: I-a price and income support program, II-a price and income support program with voluntary acreage diversion, III-a price support and voluntary acreage diversion program with a grain reserve provision, and IV-a price and income support program with voluntary acreage diversion and increased export demands for feed grains, wheat and cotton in year 1. The results of the optimization routine were checked throughly and were found to be realistic with respect to constraints on the policy variables, the variables included in the objective function and the structural equations in the model.

Box's "Complex" algorithum was selected to optimize the POLYSIM model since the policy variables obviously should be constrained to realistic values and the procedure has been used successfully to optimize large-scale simulation models in the Chemical and Industrial Engineering fields (Adelman and Steven, Friedman and Pinder, Keefer, Mitchell and Kaplan, Umeda et.al., and Swann).

In application the optimization routine generally located an optimum solution in 600 to 700 iterations, thus the model had to be solved (and the objective function evaluated) about 1,000 times per run. Each policy (I-IV) was solved several times, using different starting values to insure that the rountine had located the global maximum, resulting in a total cost of about $150 per analysis.

Problems encountered in this research effort were the following: (1) specification of parameters weights on the variables in the objective function,

(2) specification of the boundary constraints on the policy variables. Very few problems were encountered in modifying the POLYSIM model to operate as a part of the optimization routine.

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