INNOVATIONS AND PROGRAMMING TECHNIQUES FOR RISK ANALYSIS: DISCUSSION

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The topic assigned to Professor McCarl, "Innovations and Programming Techniques for Risk Analysis," is very broad. Professor McCarl, with contributions by Professors Reid and Tew, has taken a useful approach in developing the paper. By emphasizing mathematical programming techniques, the focus is narrowed considerably. Then, by concentrating on innovations in mathematical programming solution techniques and risk modeling, the focus is narrowed further. Even so, the authors cover a wide range of important mathematical programming techniques and innovations. The reference list contains articles in more than twenty different journals, ranging from the *American, Southern*, and *Western Journal of Agricultural Economics* to *Operations Research, Management Science, Econometrica, Journal of the Royal Statistical Society*, *Journal of Political Economy*, *American Economic Review*, and others. Some innovations are covered in considerable detail while others are mentioned briefly. Had all topics been discussed in detail, a very long manuscript would have emerged. Such a manuscript would be very useful, however.

One of the primary contributions of the paper is its emphasis on nonlinear programming as a useful tool in risk analysis. The authors argue correctly that the existence of nonlinear programming algorithms such as MINOS removes much of the motivation to use MOTAD approximations in risk analysis. The DEMP formulation discussed by Professor McCarl, and applied by Lambert and McCarl, appears to be a flexible and powerful tool for risk analysis. The DEMP model has the advantage of using a utility of wealth function which can exhibit increasing, decreasing, or constant risk aversion with increasing wealth. The requirement that the decision maker be everywhere risk averse limits the approach relative to stochastic efficiency analysis, but not relative to quadratic programming.

The DEMP model maximizes the summation of the utility of wealth for various states of nature weighted by the probability of those states of nature. The constraint set contains the objective function values under each state of nature. McCarl argues that use of the explicit objective function values for each state of nature does not embody distributional assumptions other than that the distribution of outcomes is truly represented by the empirical distribution contained in the model. Neither the empirical distribution contained in the

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model nor the utility of wealth function is discussed in much detail. How well the empirical distribution represents the true distribution of outcomes may depend upon sample size and other considerations which are not discussed.

The application of the DEMP model presented by Lambert and McCarl in the *AJAE* gives one a better appreciation for potential uses of the model. In this analysis, the objective function is quasi-convex and maximization of this formulation leads to a global maximum for utility of wealth. Quasi-concavity requires a monotonically increasing function such that the marginal expected utility of wealth is positive everywhere. The results of this analysis are generated for a two activity portfolio model under the assumptions of quadratic, cubic, negative exponential, and power utility functions and normal, uniform, and triangular distributions of uncertain outcomes. The results are quite logical in that increasing risk aversion leads to increases in the proportion of the less risky asset in the optimum solution. However, even with the DEMP model, portfolio selection is said to be sensitive to the specific level of initial wealth, to the form of bivariate distribution of returns and to the functional form of the utility function. These concerns sound somewhat familiar to those of us who have attempted to generate risk efficient farm plans using other types of programming formulations, such as quadratic programming and MOTAD. Solution sensitivity is a problem, of course, for linear programming models and simulation models, so that one cannot be unduly critical on this point.

Professor McCarl also indicates that the DEMP model can handle sequential or nonsequential problems as well as uncertainty in technical parameters independently and/or jointly within the model structure. If the number of decision stages for key variables is large, one can visualize a very complex model structure which would be difficult and/or expensive to solve.

The authors discuss a number of other mathematical programming innovations, including stochastic programming with recourse, a modification of discrete stochastic programming; the approach used by Wicks and Guise to handle technical coefficient uncertainty in a MOTAD-like framework; Paris' EV model which simultaneously depicts right-hand side and objective function coefficient risk; Tauer's target MOTAD approach; the lower partial moment model presented by Atwood; and, others. Each model has advantages and disadvantages, and each may be the best model to use for a specific type of risk analysis.

Having stated these reservations and having no major disagreements with the McCarl paper, I will use the rest of my allotted time to make a couple of other points. We have spent considerable time on models which deal with annual decisions in a risky environment. We have modeled risk often using historical data to generate variance-covariance matrices of gross margins or net returns. Many contributions have been made to the methodology of performing whole farm analysis under risk. However, often the results of these whole-firm analyses have been less than robust. Risk efficient farm plans often have not corresponded closely with producer actions. Variations in the risk aversion coefficient have been used to generate a set of farm plans said to be risk efficient. Alternatively, deviations between actual and risk efficient farm plans have been used to infer the risk aversion coefficient. Often these analyses have been conducted using models which, because of historical data limitations, have few activities and constraints. Perhaps we have expected the risk aversion coefficient to explain more of producers' actions than it is capable of explaining. As we expand our risk research with increased emphasis on sequential models, on models in which time is involved in an essential way, on models in which the control function is an important part of the analysis, on models which integrate production marketing and financial risk responses, subjective assessments will become more important than those based on historical data. Furthermore, risk aversion will likely become less important in explaining variations in the results of the analysis.

We see evidence of these phenomena in recent literature. In a study reported in the *AJAE*, Lee, Brown, and Lovejoy studied the adoption of reduced tillage practices under risk. The authors were uncertain whether one should elicit the farmers' subjective beliefs about the effect of reduced tillage practices on the income distribution or whether an objective income distribution could be used in the analysis. One result of their study was that a carefully constructed objective income distribution could not match farmers' subjective income distributions. That is, farmers were considerably more optimistic (had higher means and lower variances in the subjective income distribution) than reflected in the objective income distribution based on historical data. When they used both the subjective and objective income distributions, mean expected income predicted adoption of reduced tillage practices as well as did mean-variance or second degree stochastic dominance. When the objective income distribution was used, mean-variance outperformed second degree stochastic dominance. Only when the subjective income distribution was used did second degree stochastic dominance perform the best. They suggest that possibly the objective income distributions are poor proxies for farmers' subjective income distributions.

Risk aversion has been suggested as a reason for a number of practices used by farm operators. For example, farmers are said to wish to avoid low chances of a very large crop loss due to pests, and risk aversion is often suggested as a reason for the use of high levels of pesticides on the average (Pingali and Carlson). A similar line of reasoning is used to suggest risk aversion as an explanation for intensive irrigation practices in arid regions of the country (Harris and Mapp). Other examples could be cited also. However, in addition to risk aversion, decisions on input use are also based on the decision maker's subjective assessments of the marginal productivities of the inputs. Pingali and Carlson argue that errors in farmers' estimates of productivity of pesticides could result from uncertainty about the levels of pest populations or uncertainty about the effectiveness of pest controls. They argue further that to model behavior in an uncertain environment we must distinguish between how farmers perceive the random events they face and their aversion to remaining in a risky state. In a similar fashion, decisions to schedule irrigations in accordance with plant needs are based on farmers' subjective assessments of the marginal productivity of irrigation water at various times during the growing season in addition to their overall risk attitude. Errors in subjective assessment of the productivity of an input may be as important as risk aversion in explaining farmer actions. One would expect that as farmers learn, as might be captured in a recursive model, errors in subjective assessments would decrease and input use would adjust toward levels that are optimum with perfect knowledge. In fact, Buccola, in a study on risk preferences and short-run pricing efficiency, found that market information mitigates subjectively perceived risk and diminishes the differences between risk averse, risk seeking, and risk neutral choices.

A certain portion of our research effort needs to be directed to models which can accommodate uncertainty of resource use, sequential decisions during the growing season, and uncertainty with respect to the technical coefficients. Modeling the feedback and adaptive control parts of the problem is difficult with mathematical programming and perhaps can be accomplished more effectively using simulation models. When the problem is cast in the light of a multi-year analysis where production, marketing, and financial relationships interact, the advantages of simulation over mathematical programming are increased.

In summary, the more realistic and meaningful our risk analysis becomes, the less it will rely on historical data and objective probabilities and the more it will rely on subjective assessments by the decision maker. These subjective assessments will relate not just to the distribution of outcomes but to the impact of variations in input use on outcomes. As recursive decisions and dynamics are included in risk analysis, risk aversion will become less important in explaining variations in production, marketing and financial decisions. As Professor McCarl indicates, a number of recent innovations in mathematical programming solution techniques will permit these models to be used increasingly as the complexity and realism of our analyses increases. However, simulation models have numerous advantages in incorporating these complexities into economic analysis.

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