SIMULTANEOUS PRODUCTION AND MARKETING DECISIONS OVER TIME: DISCUSSION

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Discrete stochastic programming (DSP) was developed by Cocks and Rae about 20 years ago, but has not been widely used in empirical applications by our profession. Of the limited amount of empirical research that has used this technique, the majority have focused on farm production problems. Thus, it was quite useful to see Lambert extend the application of this technique to a joint production-marketing decision problem.[1]

The purpose of Lambert's paper was to demonstrate how DSP can be applied to a production and marketing problem faced by cow/calf producers assuming a three stage decision environment. Lambert's paper is a case study of this technique which explains the steps involved in constructing the model and interpretation of the results. My discussion will be more general in that I will present a brief description of DSP models and will discuss several issues which are frequently associated with them. Lambert's application will be used in discussing some of the issues that are addressed.

The development and application of risk programming models (e.g., quadratic programming (QP) (Freund; Markowitz), minimization of absolute deviations (MOTAD) (Hazell), safety first (Roumasset; Benito), and game theoretic (McInerney) models) have made a significant contribution to applied decision analysis. Yet there are several limitations inherent in many of them with respect to farm applications as Lambert points out. First, risk is usually captured by modeling only the objective function coefficients as stochastic coefficients (e.g., net revenue activities), while parameters in the constraint set are usually treated deterministically. In reality, however, resource availability and requirements in the constraint set may be an equally important source of risk to the farmer, e.g. supply of field time. Second, these models usually assume a static, nonsequential decision process. Farm production and marketing decision making, however, is usually an adaptive process involving a sequence of decisions over time. Because they are nonsequential, such models implicitly assume an information structure of complete knowledge of the past, present, and future stages of the planning process. Consequently, there is no method for modifying decision variables as new information is received over the planning horizon.

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[1]For another joint production-marketing application of DSP to a crop farm, see Kaiser (1985) and Kaiser and Apland (1986).

Lambert discusses how DSP is capable of overcoming some of these limitations. DSP can be thought of as a programming formulation of a decision tree. Like a decision tree, the DSP model is characterized by: a) a sequence of discrete decision dates (stages), b) a set of decision variables or acts for each stage, c) a number of random events (states of nature) for each stage, and d) a logical representation of the flow of information (information structure) among the various stages in the decision process. These models are sequential since decisions made in any stage are influenced by plans implemented in past stages and the outcome of random events that have occurred in previous stages. For example, in Lambert's application, the rancher's selection of marketing strategies at time t not only depends upon his knowledge of prices in this period, but also on past decisions made at times t-1, t-2,..., as well as the occurrence of random states of nature that have influenced the outcomes of these decision.

The formulation of the DSP problem depends upon assumptions regarding the flows of information to the decision maker, i.e., the information structure. While not explicitly stated, Lambert assumes that the rancher has complete knowledge of the past and present, which means that at time t, the agent has complete knowledge of events that occurred in stages t, t-1, t-2,..., but only has probabilistic knowledge of events in stages t+1, t+2, etc. It should be noted that DSP models are quite flexible in handling other types of information structures as well. Rae (1971(a)) specified two additional categories of information structures: complete knowledge of the past, and incomplete knowledge of the past. In many decision problems, combinations of these three classes of information structure may be appropriate and DSP models may accommodate such mixed structures.

The main advantage of modeling decision problems in a DSP framework is that it conforms quite well to how decisions are actually made. This is particularly true in agricultural applications where decisions are typically made throughout the year rather than at one point in time. Compared with deterministic mathematical programming techniques, e.g. QP and MOTAD models, DSP more accurately approximates resource usage and availability because it allows for a larger number of states of nature to be considered. This technique also explicitly recognizes the irreversibility of the decision process, i.e. previous decisions cannot be changed when making current decisions. Finally, unlike deterministic models, DSP provides optimal solutions corresponding to each state of nature specified in the decision environment, which should be more useful to farmers in updating decisions throughout the planning process. In Lambert's paper, the optimal contingency plans correspond to stage 2 decisions, which depend upon the occurrence of random events in stage 1 as well as on price expectations on stage 3 events.

The most common reason cited for its limited use in empirical research is that while it conceptually conforms well to how farm decisions are actually made, the size of the programming matrix becomes extremely large for even modestly complex problems (King and Oamek). For example, a k stage s state of nature problem has k^s decision nodes. If each of these decision nodes contains n variables and there are c constraints on these decisions, then there will be nk^s variables and ck^s constraints in the programming matrix (Featherstone, Preckel, and Baker). Because the programming matrix of DSP problems becomes considerably large with even modest increases in the number of stages and states, it is important that the model is centered on the most critical sources of risk in the decision. For example, Lambert divides the decision process into a three stage problem with nine joint events. Obviously the size of this problem is very manageable. Indeed, Lambert could have easily expanded the number of states of nature in stages 2 and 3. With the use of a matrix generator, one could imagine 100 joint events on the price states of nature, which would represent a more realistic depiction of the price risk faced by these producers.

There are several ways to handle dimensionality problems. One way to reduce the size of the DSP matrix is to eliminate decision alternatives judged to be non-optimal prior to solving the model. For instance, optimal decision variables from a model of a subproblem or from a previous study could be used in the larger model to reduce the number of activities. Random variables not critical to the problem or adding little risk can be modeled deterministically to reduce model size. In Lambert's example, production risk was ignored presumably because price risk was judged to be of greater importance. Another way to reduce the size of the DSP matrix is to first formulate the model with the greatest level of detail in the first stage (or stages) decisions and less emphasis on more distant stages. After solving the model, later stages may be re-modeled in greater detail using the results of the initial model. This type of process implies that later stages decisions may be revised on a "rolling" or "adaptive planning" basis, reflecting the results of the initial stage(s) model (Anderson, Dillon, and Hardaker).

Although dimensionality is an important concern, it is becoming less of a barrier to implementing DSP models due to recent advances in mathematical programming software and hardware. New linear and nonlinear packages are capable of handling much larger programming problems than earlier software. MINOS is a case in point. As a result, implementation of DSP to more empirical problems may be done with lower costs and fewer sacrifices in realism than was the case before. Also, with the development of GAMS-MINOS, the cost of having to develop a matrix generator for each problem no longer exists since this software has a general matrix generator built in.

While not used a great deal, it is useful to point out that there have been a number of applications of DSP to farm problems in addition to Lambert. DSP models have been used to: analyze growth of farm firms (Johnson, Tefertiller, and Moore), examine production decisions for vegetable producers with random weather conditions (Rae, 1971(b)), find optimal fertilization strategies (Tice), study the economic feasibility of crop residue production (Apland), analyze the investment decision of on-farm grain drier (Klemme), examine alternative weed management technologies (Obrien), and evaluate alternative marketing and government program participation strategies for grain farmers (Kaiser and Apland). Most of these studies have successfully dealt with the issue of dimensionality. The point is that the argument that these models are too big to use is becoming less and less convincing. As a result, hopefully more analysts will consider DSP in farm production and marketing decision problems.

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