DISCUSSION: USE OF BIOPHYSICAL SIMULATION IN PRODUCTION ECONOMICS

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Musser and Tew cover much territory in their effort to "review the current use of biophysical simulation in production economics and to evaluate the potential of biophysical simulation as a methodology." Four general topics are addressed: (1) definition and description of biophysical simulation; (2) survey of current use of biophysical simulators; (3) behavioral theory as it relates to the use of biophysical simulation; and (4) uses of biophysical simulators. They conclude that "the use of biophysical simulators is accelerating" and that "the primary area of application is to provide input-output data when dynamic, risky, input decisions are prevalent." Two major disadvantages of biophysical simulation were identified. First, cooperation of other agricultural scientists is essential for development and use of these models. Second, existing biophysical simulation models encompass relatively few decision variables.

Musser and Tew's conclusion that the primary advantage of biophysical simulators is to provide input-output data for dynamic, risky production problems appears appropriate. This discussion will focus on: (1) refining the definition and conceptual framework underlying biophysical simulation and illuminating the implications of this conceptual framework for potential uses of the methodology: (2) outlining the need for, nature of, and potential for interdisciplinary cooperation in applying this methodology; and (3) the implied relationship between behavioral theory and biophysical simulation.

One additional point of information that may be of interest is that an international survey of economic-ecological models was recently completed (Braat and van Lierop). The survey was conducted by the Institute for Environmental Studies, Free University of Amsterdam in coöperation with and supported by the International Institute for Applied Systems Analysis, Laxenburg, Austria. Over 100 models were identified and a three part report is currently being completed.

CONCEPTUAL BASIS OF BIOPHYSICAL SIMULATION

Musser and Tew define a biophysical simulator as "a complex mathematical model of some process with explicit attention to biological and/or physical determinants of agricultural production." They relate biophysical simulators to production functions using Dillon's general formulation:

$$(1)\ Y = f(X_1,X_2,\ldots,X_n;\ X_{n+1},\ldots,X_k;\ X_{k+1},\ldots,X_m),$$

where Y is the output; $X_1,\ldots,X_n$ are the input decision variables; $X_{n+1},\ldots,X_k$ are the predetermined input variables; and $X_{k+1},\ldots,X_m$ are the uncertain input variables.

This formulation explicitly recognizes environmental influences through the inclusion of $X_{k+1},\ldots,X_m$. The dynamic aspects of production are included by segmenting the production period into T time periods and rewriting equation (1) as:

$$(2)\ Y = f(X_{1t},X_{2t},\ldots,X_{nt};\ X_{n+1},\ldots,X_k;\ X_{(k+1)t},\ldots,X_{mt}),$$

where X_{it} is a $T \times 1$ vector, $t = 1,2,\ldots,T$. The problem is that this formulation encompasses the same limitations that lead to development of biophysical simulation models in the first place. Many agricultural production problems are characterized by a complex system of stochastic, time-dependent processes. Production is not generally a single process as Musser and Tew's definition suggests. Representing these systems with a continuous, single-valued, twice differential, point function is a "black box" that is likely to be rejected by biological scientists if not by fellow economists.

An alternative is to make use of the Georgescu-Roegen theory of production which starts with the concept of an elementary process and builds to the production function. The concept of elementary processes is quite familiar and fundamental to biological and physical scientists and provides an excellent foundation for communicating and building an economic theory of production. Every production system is a

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system of elementary processes. Mathematically, the "production function" can be represented as a functional relationship from a set of functions to one function:

$$(3)\ Q(t) = F[R(t), I(t), M(t), W(t); L(t), K(t), H(t)],$$

where: Q(t) represents the flow of output over time, R(t) represents the flow of natural resources over time (rainfall, solar radiation), I(t) represents the flow of materials (seed, chemicals), M(t) represents the flow of maintenance inputs (lubrication and repairs), W(t) represents the flow of wastes (wear on equipment, and environmental pollutants), L(t) represents the land services, K(t) represents the machinery services and H(t) represents labor services.

There are several implications of this conceptual framework as the foundation for biophysical simulation models. First, an understanding of the underlying biological and physical processes is essential for model building. However, this understanding provides a much stronger foundation for evaluating the results and formulating recommendations. Second, the stochastic aspects of natural resources flows are explicitly modeled. This provides the opportunity to evaluate various sources of production risk. Third, the timing aspect of input applications is explicitly modeled allowing analysis of dynamic input decisions such as irrigation scheduling or pest management. Finally, however, it is important to recognize that the functional relationship is mathematically less tractable than the neoclassical production function. As a result, simulation analysis coupled with various search algorithms are normally used to analyze decision alternatives rather than analytical derivation of the "optimal" input levels. Given this conceptual framework, it should not be too surprising to discover that the vast majority of applications of biophysical models have addressed dynamic, stochastic production problems with simulation techniques.

Conceptually, however, application of biophysical simulators are not limited to these types of problems. Fundamentally, all biophysical simulation does is generate the production response surface which is necessary for all empirical production research. Decisions on whether biophysical simulation is the appropriate method of obtaining this response surface will depend on the nature of the problem being studied and the alternative costs of obtaining the necessary response surface information.

INTERDISCIPLINARY ASPECTS OF BIOPHYSICAL SIMULATION

Musser and Tew mention four basic steps in simulation—investigation, model translation, model specification, and validation. These steps are essentially identical to any research process and roughly translate as—know your problem, use appropriate theoretical constructs to model the problem, obtain data to accurately specify the model, and validate your results. What distinguishes this research process for biophysical simulation models from other problems is that the first three steps are primarily the domain of biological and physical scientists unless one is very familiar with carbohydrate partitioning, leaf expansion, respiration, and transpiration. The agricultural economist's primary concerns should be: (1) how to appropriately use these models in research; (2) how to communicate the advantages of biophysical simulation to experimental scientist colleagues; and (3) how to serve as integrator or facilitator in bringing together various types of scientists to build these models.

Several points need to be raised relative to the latter two concerns. First, experimental scientists are not going to participate in developing these models unless they understand why they are needed, how they can contribute, and how participation will enhance their research programs. Second, development of process level growth models requires sophisticated and often expensive basic research. Third, this type of interdisciplinary research is fraught with most of the same problems as other interdisciplinary production research with two exceptions. First, the process theory/production system conceptual framework is superior to the traditional neoclassical theory as a paradigm for communication. Second, a formal mathematical model provides a focal point for integrating the various pieces of research. Chances of getting cooperation in building biophysical simulation models may be much greater than getting the data necessary to estimate the traditional neoclassical production functions of the last 30 years.

RELATIONSHIP BETWEEN BEHAVIORAL THEORY AND BIOPHYSICAL SIMULATION

Musser and Tew digress from the primary subject and discuss behavioral theory (Simon) as it relates to the use of biophysical simulation models. The reason given for the digression is that "most of the standard paradigms seem to have fundamental problems as a general approach to production economics." Although elaboration on the nature of these fundamental problems was not provided, the constructs of behavioral theory were used to argue that: (1) prescriptive research is not very useful to decisionmakers; (2) partial analyses may be more appropriate and useful than complex, comprehensive analyses; and (3) providing information on the nature of the choice set and its relationship to quantifiable goals is more useful than identification of "optimal" plans.

While behavioral theory may be very useful, its acceptance or rejection is not germane to the appropriateness of biophysical simulation as a research methodology. Since many biophysical simulation models are mathematically intractable, simulation of various options in the choice set and provision of information about the relative impacts of these options on various quantifiable goals is an attractive approach. However, it does not preclude specification and optimization with respect to a well-defined objective function if the analyst is so inclined.

Finally, the issue of partial versus comprehensive analysis, though interesting, is no more an issue with respect to biophysical simulation than it is with traditional neoclassical production function analysis. In fact the potential for process-level growth models to integrate the effects of multiple stresses is tremendous. For example, researchers at Florida have an operational soybean growth model that includes two species of weeds, three insect species and water stresses (Wilkerson et al.).

CONCLUSIONS

Biophysical simulation is an alternative methodology for estimating production response surfaces. A clear understanding of the underlying conceptual basis will facilitate appropriate applications of the methodology and increase the likelihood of obtaining the required interdisciplinary cooperation. Biophysical simulation has a clear advantage over other methodologies for empirical analyses of dynamic, stochastic production problems. Furthermore, agricultural economists will likely be much more successful in getting the necessary cooperation from other discipline scientists to build these models than in getting the data necessary to estimate traditional neoclassical production functions. Finally, although the constructs of behavioral theory are consistent with biophysical simulation, they are not germane to the acceptance or rejection of biophysical simulation as an appropriate methodology.

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