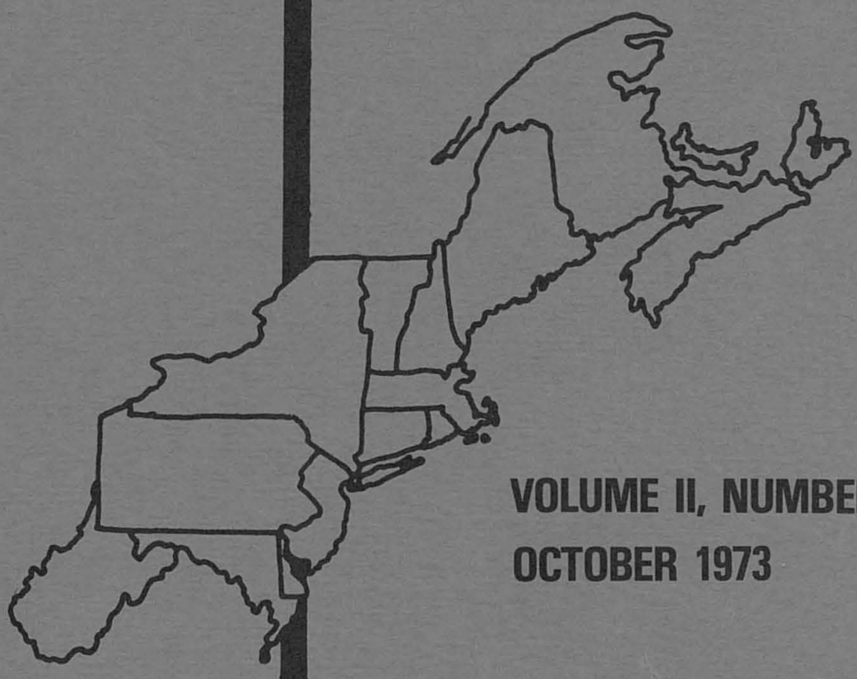
JOURNAL OF THE

Northeastern Agricultural Economics Council



VOLUME II, NUMBER 2
OCTOBER 1973

STRATEGY FOR DEVELOPMENT OF SYSTEMS ANALYTIC MODELS - A DAIRY EXPERIENCE -

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As economists our greatest contribution to policymakers 1/ is likely to stem from our ability to make conditional forecasts--conditional forecasts of the outcome of specific possible or actual courses of action on the part of (1) government policymakers, (2) participants in the economy of interest, or (3) participants in other economies. 2/ But these conditional forecasts are not easy to come by, given the present state of the arts in our profession. In the first place, we do not yet have models which include parameter estimates in which we can place a great deal of confidence. Secondly, we do not at present have models which adequately encompass the vast number of relationships and constraints characteristic of a given economic system.

This is not meant to imply that all past modeling efforts are useless and should be abandoned. On the contrary, these efforts have and likely will continue to contribute greatly to our store of knowledge about methodology as well as about the operation, function, and control of economic systems.

Nevertheless, we are far from the point at which we can become self-laudatory. The answers we now generate are often imprecise and do

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1/ In this paper we use the term "policymakers" to refer to elected, appointed, or hired government officials whose charge it is to establish and/or recommend "government" policy with respect to the organization and operation of an economic system, as well as industry personnel whose charge it is to establish industry or firm policy. We often ignore the fact that there can be policy other than "government" policy and policymakers other than "government" policymakers.

2/ See C. C. Holt. "Quantitative Decision Analysis and National Policy: How Can We Bridge the Gap?" in B. G. Hickman (ed.). Quantitative Planning of Economic Policy. Brookings 1965, pp. 252-269.

not reflect the impact of all relevant factors. Existing models are so aggregative that only a limited set of questions can be answered. Trade-offs between competing performance indicators cannot be evaluated. Before we can provide the required answers, we must take time out to formulate another model because we have failed to anticipate the relevant questions in previous models. In short, we are not yet able to provide timely, accurate, and complete information to policymakers.

There is a real question whether we can continue to operate in this fashion and at the same time satisfy our benefactors that we are most effectively using the funds they provide. Churchman 3/, for example, observes that:

> Not only has the citizen become far more vocal, but he has also in many instances begun to suspect that the people who make the major decisions that affect our lives don't know what they are doing. They don't know what they are doing simply because they have no adequate basis to judge the effects of their decisions.
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> To many it must seem that we live in an age of moronic decision making. About all that the decision maker can do is pick on one aspect of the situation and push that as hard as possible, arguing against his enemies on the basis that they are failing to sense the true situation.

There are several reasons why this state of affairs exists. We believe the primary reason is not because of a lack of the necessary elasticities, data from which to estimate these elasticities, manpower, or expertise. Rather, we suggest the primary reason is that so far we have been unwilling to make a concerted effort to capitalize on our collective knowledge (and ignorance!) in an attempt to systematically make our individual efforts add up to produce useful and somewhere near complete packages.

It is clear that traditional literary exposition will not do. There is a severe limitation on the number and complexity of variable factors which can be taken into account--a limitation stemming from the individual's inability to handle a simultaneously all the inter-relationships of a complex system. And of course computers have obviated the necessity of relying on literary exposition alone.

Systems analysis provides us with a method of looking at the complex web of interrelationships characteristic of economic systems which could not be understood through introspection alone. A systems analytic model constitutes an abstraction of an entire economy and represents a

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3/ C. West Churchman. The Systems Approach. Dell. New York, 1968, p. vii.

collection of systems--e.g., production, assembly, processing, distribution, consumption, and regulation. If we accomplished nothing more than putting such a model together, it would be useful in providing a mechanism for understanding how the complete system works--an important contribution in its own right. But such a model also provides us with an analytical tool--that is, a tool with which (1) to calculate the outcome of the system under different circumstances (i.e., provide conditional forecasts) and (2) to indicate how the system should be redesigned so as to function more in accordance with the wishes of policymakers.

Several such attempts have been made by both general economists and agricultural economists. One of the most ambitious undertakings in recent years in agricultural economics is the so-called Hog-Pork Subsector Model financed largely by ERS but participated in by both USDA and university economists. A similar attempt is currently underway with respect to the dairy industry. The purpose of this paper is to describe the initial ideas which have gone into planning the latter effort and to suggest some considerations for future efforts. In this paper, only those questions concerning the general design of such models and the strategy involved in construction will be considered. Questions concerning estimation, verification and implementation are perhaps just as important but are beyond the scope of this paper.

POLICY FRAMEWORK

The First step in constructing a model of this nature is to decide as precisely as is possible what its purpose shall be. In this connection, Tenbergen's approach to the theory of economic policy is particularly helpful 4/. To Tinbergen there is a set of target variables 5/, a set of instrument variables, and "data." The target variables may be considered goals of the policymakers and can be fixed or flexible. The instruments are the means which the policymaker can use, manipulate or influence in order to achieve his targets. The "data" are the uncontrollable or exogenous factors characteristic of the economy. How the instruments and "data" affect the targets is conditioned by the structural relations or constraints of the system.

Finally, in addition to the targets there may be a set of side-effects or "irrelevant" variables in which the policymaker is not

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4/ J. Tinbergen. On the Theory of Economic Policy. North-Holland, 1956. See also K. A. Fox, J. K. Sengupta, and E. Thorebecke. The Theory of Quantitative Economic Policy. North-Holland, 1966, Chapter 2.

5/ More specifically, there is a welfare function which has as arguments the target variables.

primarily interested. But since both targets and irrelevant variables may constitute measures of how well the system performs and therefore should be of at least nominal concern to the policymaker, we prefer to call them collectively policy variables.

Given this general framework, one can concentrate on the policy variables or on discovering what conditions are necessary to meet certain targets 6/. One might choose, for example, to specify values for the instruments and exogenous variables, then solve the reduced form equations of the system for the resulting values of the policy variables. Proceeding in this way, one could trace the impact of various levels of the instruments. Furthermore one could examine the trade-offs between competing policy variables.

Alternatively, he may choose to input to the system desired values of the policy variables, then solve the system for the level of the instruments necessary to meet specified targets. In this way, policymakers could be provided with suggestions as to the conditions necessary to meet specified targets.

Policy Variables

If one is successful in isolating (or more appropriately anticipating) the relevant policy variables, he will probably be successful in formulating a useful model. This set of variables will dictate in large part the shape of the model.

To develop a realistic list of policy variables for the economy under study, it will be helpful to consider what are likely to be the relevant issues facing this economy in the foreseeable future. As an example, the following list has been developed for the dairy industry 7/:

1. What would be the impact of alternative methods for pricing milk and dairy products?

2. What would be the impact of alternative methods of sharing the proceeds of Class I sales among producers in different areas or of different types?

3. What is likely to be the impact of the growth and changing role of dairy cooperatives?

6/ We assume here that certain mathematical properties of the system necessary for a solution can be met (see Fox et. al. op. cit.).

7/ This list is not intended to be complete nor is it intended to imply any priorities.

4. What are likely to be the impacts of pollution control regulations imposed on producers and processors?

5. Where will milk production be located in the future and what will be the impact of changes in the structure and location of milk production?

6. How large will dairy product processing facilities be in the future, where will they be located, and what will be the impact of these changes on the dairy industry?

7. What is likely to be the future structure of demand for dairy products and the impact of changes in demand (e.g., increased demand for cheese and low-fat items)?

8. What will be the impact of supply control legislation and of restrictive (FTC) legislation affecting processing firm operations?

9. What will be the impact of altering national policy with respect to importing and exporting dairy products?

From this list of issues, it is clear that information about several different variables is needed before we can be of much service to policy-makers. The following constitutes a fairly comprehensive list of policy variables for the dairy industry:

A. Producer-related variables.

1. Number of cows in each region.

2. Milk production per cow in each region.

3. Grade A and Grade B milk production in each region.

4. Size distribution of dairy farms in each region.

5. Capital and labor use on dairy farms in each region.

6. Beef production by the dairy industry.

7. Cost of milk production on farms in different regions.

8. Net income of dairy farmers by size of dairy herd in each region.

9. Pollutants produced.

B. Processor-retailer related variables.

1. Wholesale and retail margins by product by region.

2. Size distribution of processing firms by region and by type and ownership of firm.

3. Net income of processing firms by size and type and region.

4. Production and inventories of dairy products by region.

5. Capital and labor use of processing firms by region.

6. Excess capacity of processing firms by region, by season, and by type of firm.

7. Pollutants produced.

C. Consumer related variables.

1. Consumption of dairy products by region.

   a. Store sales.

   b. Institutional sales.

   c. School lunch and food stamp sales.

2. Retail prices of dairy products.

D. Government related variables.

1. Purchases of dairy products.

2. Storage costs.

3. Administrative costs of federal order and support programs.

E. Foreign trade related variables.

1. Exports of dairy products.

2. Imports of dairy products.

Policy Instruments

The policy instruments are taken to include those things which are or can be decided by the regulatory authorities or by firms in the industry. In the dairy industry, they include:

1. Support price level.

2. Pricing rules or strategies.

   a. Formula pricing.

   b. Component pricing.

   c. Classified pricing.

3. Procedures for pooling milk.

4. Order consolidation.

5. Welfare programs.

   a. Food Stamp.

   b. School Lunch.

   c. Donations.

6. Incentives for change encouraged or dictated (i.e., pollution control, increased productivity, anti-trust activity, etc.).

7. Advertising and promotion.

8. New technological developments in production, processing, and transportation.

9. Foreign trade restrictions and incentives.

Exogenous Variables

The model should also be responsive to changes that occur outside the system and which are not brought about by the regulatory authority. These variables will affect the policy variables and may dictate in part what actions are needed to achieve certain targets. Exogenous variables for the dairy industry include:

1. Shifts in the location of feed production.
2. Technological developments in the feed industry and in genetics.
3. Opening of new alternatives (farm and nonfarm) to dairy production.
4. Changes in the supply of and costs of farm labor.
5. Weather.
6. Changes in the demand for farm land (e.g., pressure for urban expansion).

MODEL CONSTRUCTION

Too often, economists develop models that emphasize a single performance indicator. Pure mathematical programming models typically fall into this category. Such models would generally not qualify as systems analytic models and, as has been implied above, can produce misleading or at least incomplete results. By the same token, it would be heroic indeed to attempt to build a model of the dairy industry, say, that would encompass every single policy variable listed in the preceeding section. Some compromise seems warranted.

The ideal, of course, would be to build a single model that would include all policy variables--and perhaps this is a goal toward which to work. However, we suspect it is both wishful thinking and unnecessary in most instances. In the first place, the resulting model is likely to be so large as to be unnecessarily unwieldy even on modern-day computers. Furthermore, once the basic structural system which includes a few major policy variables is solved, we see no reason why other policy variables cannot be examined via "side analyses." For example, in the dairy model we may be particularly interested in returns from dairy farming by regions and by size of farm. But this information can be derived from a model that is solved independently of the basic price-allocation model. How much of this can be done will depend to a large extent on the nature of the model as conceived--i.e., its recursive versus its interdependent nature.

Models with which to conduct these "side-analyses" may be constructed by different individuals or teams. Nevertheless this work must be coordinated so that eventually all such models can in a meaningful way be tied together and so that trade-offs between competing performance indicators can be realistically examined.

Choice of Algorithm

At some point early in the design of the model, one must decide upon the algorithm or combination of algorithms he is going to use. Since one of the objectives of systems analysis is to examine a set of performance indicators, the concept of "maximization" must be viewed in many dimensions as opposed to a single dimension. This means that traditional mathematical programming methods must be abandoned.

One alternative is to utilize an algorithm for handling several objective functions simultaneously. Unfortunately there are no efficient algorithms yet available for solving such problems although progress is being made 8/.

A second approach would be to quantify the welfare function and apply readily available algorithms to maximize welfare. The difficulties here are well-known (i.e., establishing the weights of the welfare function), but we suggest it is not an impossibility 9/. Frish 10/ and Holt11/ argue rather strongly for this approach and suggest some ways of implementing it. Louwes et. al. 12/ utilized this approach in a limited way

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8/ A. M. Geoffrion, J. S. Dyer, and A. Feinberg. "An Interactive Approach for Multi-Criterion Optimization, With an Application to the Operation of an Academic Department." Management Science 19:4:357-368, Dec. 1972.

9/ Indeed we have often attached weights implicitly by omitting certain policy variables from consideration altogether.

10/ R. Frish. "Selection and Implementation: The Econometrics of the Future," in Pontifica Academia Scientiarium. The Econometric Approach to Development Planning. Study Week held at Vatican City, October 1963. Rand McNally. 1965, pp. 1197-1204.

11/ Op. Cit.

12/ S. L. Louwes, J. C. G. Boot, and S. Wage. "A Quadratic Programming Approach to the Problem of Optimal Use of Milk in the Netherlands." JFE 45:309-317, May 1963.

to determine the optimal use of milk in the Netherlands. Van Eijk and Sandee 13/ and Fromm and Taubman 14/ have used this approach in quantitative policy models for national economies. By proceeding in this way, we may be able to contribute a great deal more to the decision making process than we otherwise could.

Finally, we can construct a model that does not have an objective function at all and be satisfied with producing conditional forecasts by straight-forward algebraic methods. Most likely this is what we should plan to do in the initial stages at least. The disadvantages of this approach are that (1) we may never know or be able to discover the "best" policy, and (2) we may eventually inundate the policymaker with so many conditional forecasts that he can't sort through the maze so as to make a sound decision.

Model Building by Stages

We seldom have enough information to cope with all details in the initial stages of model building. Some details will only be learned as we become more familiar with the data and as we conduct experiments with the model. For example, what is the appropriate level of spatial and product aggregation or what is the appropriate functional form for the demand equations? How much detail should be ignored because it is empirically intractable or would not warrant the expense of including it?

A sensible procedure seems to be to begin with a relatively simple model, then add more detail at later stages. In the dairy effort, for example, we have begun with a basic supply-demand model which has sufficient constraints built in to approximate reality in a broad or macro sense. It has limited normative capabilities and by no means includes all policy or instrument variables outlined above.

There are several advantages in operating in this fashion. First, it assures that _a_ model is developed and available at all times--it will not answer all of the questions we may like to ask it nor will it answer these questions as precisely as we would like but it is available for generating a limited amount of information. Furthermore, it is available so that administrators can point to some accomplishment--a not unimportant consideration since what we are talking about is not a shortrun research project.

13/ C. J. Van Eijk and J. Sandee. "Quantitative Determination of an Optimum Economic Policy." _Econometrica_ 27:1-23, January 1959.

14/ G. Fromm and P. Taubman. _Policy Simulations With An Econometric Model_. Brookings 1968.

Second, by starting with a relatively simple model and progressing to more complicated ones, we are not as apt to lose sight of the trees for the forest. This has two dimensions--model construction and model testing. Every effort must be made to see that all components of the model are sufficiently detailed and constructed so they are related in a logical and consistent manner. Also, we are likely to find it to our advantage to be able to test out each component of the system on progressively more complex models.

Finally, by progressing in this manner, we will force ourselves to build the model in such a way that it can easily be added onto, revised, and updated. Model formulation is critical but not independent of refinement and testing. Models must be subjected to whatever tests are available to guard against internal inconsistencies or logical errors. "In economics, as in medicine, autopsies can and should be a major learning devise 15/". Halter et. al. 16/ have suggested a useful conceptual scheme for viewing the modeling process as an iterative problem solving effort in which feedback loops between modeling, estimation, and experimentation are a prominent feature.

Organization Required

The individual who has the required knowledge of an entire economic system to put together a model of the type we have been discussing is rare indeed. Even rarer is the individual who has this expertise and is also sufficiently versed in estimation techniques and general computer technology to accomplish the task. Some sort of a task force is necessary.

The mere mass collection of research talent (in government agencies such as USDA, public and private research institutes, and regional research committees) will not ensure the proper vehicle, particularly if the "right" talent is absent. What is needed first and foremost is someone who can provide strong leadership. New ideas must be generated and pursued, special talents must be called in as they are needed regardless of institutional affiliation, existing data generation methods must be understood and new data sources pursued or developed, the work of all individuals (again regardless of institutional affiliation) participating in the project must be coordinated so that all pieces eventually fit together.

15/ Zvi Griliches. "The Brookings Model Volume: A Review Article," Rev. Econ. and Stat. 50:215-34, May 1968.

16/ A. N. Halter, M. L. Hayenga, and T. J. Manetsch. "Simulating a Developing Agricultural Economy: Methodology and Planning Capability," AJAE 55:272-284, May 1970.

IMPLICATIONS

Constructing a systems analytic model is not a simple task. Several different types of expertise are needed including general knowledge of the system under study, knowledge of statistical and nonstatistical methods of estimation and verification, and knowledge of computer capabilities and programming. Furthermore, it is not a shortrun research project--the effort will have to proceed in stages, some of which will involve updating, some of which will involve verification, and some of which will involve adding detail.

The payoff of such efforts can only be surmised and will, of course, depend on the success of the efforts. Certainly our basic knowledge of the system should be increased and we should be in a better position to participate actively in the policy decision-making process. One side benefit will likely be in the area of specifying more precisely our future data needs, and thus we should be able to provide input to such committees as the AAEA Committee on Economic Statistical 17/.

17/ J. T. Bonnen, J. Hildreth, G. Judge, G. Tolley, and H. Trelogan "Our Obsolete Data Systems: New Directions and Opportunities" AJAE 54:5:867-875, Dec. 1972.