CHAPTER 3

PROBLEMS AND POTENTIALS OF PROCESS ANALYSIS

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The experimental nature of much of process analysis, and the rapid rates at which certain contributing arts are advancing, make it hazardous to estimate the potentials and limitations of this approach. The methods discussed in Chapter 2 have been used extensively. Even the newest, input-output, has been applied more than once to the U. S. economy, and to an impressive list of other countries. In contrast, the studies in this volume generally represent first attempts of their type for the sectors covered. The most that can be claimed with certainty for the majority of these studies is that the models have been completed and have at least a familial resemblance to the industries represented. Further statements about cost and reliability are based largely on extrapolation and conjecture.

These extrapolations and conjectures, however, are central to our belief that the process analysis approach can make practical contributions to the understanding of an economy. This chapter presents these extrapolations and conjectures, at least to serve as a basis for further consideration.

APPLICABILITY: SCOPE OF ANALYSIS

In connection with process analysis applications, we shall consider two topics. In the present section, we discuss the scope of such models, and in the following section the type of decision to be influenced.

A process analysis application may cover a single industry or a group of industries. In principle, if models were available for all industries, a process analysis could cover the economy as a whole. Later, we discuss the feasibility of such all-embracing analyses. For the moment we will consider some problems of application which seem to apply most forcibly to smaller scope, industry-wide models, but in fact are equally serious as we widen the scope of the analysis.

Most of the studies in this monograph, being static in nature and covering a single industry or limited industrial complex, are closely related to the economist's "static, partial equilibrium analysis." The problems encountered in such uses of process analysis are those of any practical application of static, partial equilibrium analysis. They cluster in two groups around the phrases "static equilibrium" and "partial analysis," respectively.

The difficulty in using a static equilibrium analysis is that of interpreting its results for a world in constant change. Ideally we would prefer accurate dynamic models, thus avoiding the problems of static approximations. Thoughts concerning the construction and use of dynamic models are scattered throughout this monograph, but for the present, it is principally the static analysis which is available for application.

The details of a static model should depend upon the time horizon of the practical problem. For example, in setting up a linear programming computation, certain capacity restrictions or material availabilities, although fixed in the short run, should be regarded as expansible in the long run. There is no sharp boundary between the short and the long run. As we lengthen our view, an increasing number of resources are best treated as reproducible (or variable within limits) rather than rigidly fixed.

The major problems which arise from the "partial" nature of an analysis concern the handling of boundary conditions. Industries are connected with other industries via the products they sell or buy. In the long run, this includes equipment needed to expand capacity as well as inputs required on current account to manufacture the product. In a partial analysis (say, of a single industry) the products which the industry obtains from elsewhere can be treated either as fixed in supply, or as procurable (perhaps within limits), or as subject to a supply curve (perhaps as established in another analysis). The products which the industry supplies to other sectors can be treated as subject to fixed requirements, or salable at fixed prices or subject to a demand curve. Where there is uncertainty concerning availability or demand, several alternate levels can be explored.

Problems of boundary conditions do not disappear as we increase the scope of our analysis. When a model of industry A is combined with one of industry B to form a model of industrial complex AB, the interface between A and B is handled by formal computation, but the relations of these industries to other industries and to final demand must still be treated as boundary conditions. If all industries were combined into a single model, both the final demands for end items and the supplies of basic resources would still remain as boundary conditions to the analysis. The same options are available in treating these as are available in handling the boundary conditions of an individual industry in an analysis of smaller scope. For problems in which interrelations between industries play a crucial part, a multi-industry model may prove essential. One danger with such broader scope models is that the details concerning boundary conditions will perhaps not be considered with the same care as can more easily be given them in the smaller analyses.

Applicability: Type of Decision

Now we turn to the type of decision which can be influenced by a process analysis model, and comment on the apparent ability of such models to prescribe manufacturing procedures as well as to identify bottlenecks and to judge overall feasibility.

For its own use at least, a process analysis calculates the best method by which objectives may be achieved. In principle, one could use this solution to prescribe detailed production plans. In some cases, the analysis might contribute usefully to the choice of methods of production. In other cases, however, such an attempt to specify production details would be more likely to hurt than to help the economy.

In the case of complex industries in highly developed countries (e.g., U. S. metalworking, with thousands of heterogeneous establishments producing partially overlapping sets of products), any attempt to use the results of an industry-wide model to prescribe detailed operations would probably be detrimental. In an analysis of such industries, the categories of men, materials, equipment, and productive processes must be coarse aggregates. The industrial engineer with a knowledge of the particular circumstances of his establishment can better plan the allocation of his resources on the basis of analyses of narrower scope.

The desirability of a division of labor between broad-scope and narrower-scope analysis is not peculiar to either a market economy or a planned economy. In a market economy, broad-scope analysis is required to judge the feasibility and estimate the impact of major government actions, e.g., in the areas of military preparedness, regional unemployment, or agricultural policy. Problems of implementing these policies are passed on—in part through the government organization, in part through the market mechanism, in part through the business organizations of individual firms—to those responsible for specific production decisions. In a centralized economy, over-all programs must similarly be supplemented by detailed plans of smaller scope. The principal difference is in the channels of communication between the broad and narrow planning activities, and in the incentives at some of the stages of this process.

Thus, for complex sectors within highly developed countries, the chief use of industry-wide analyses consists of cost and feasibility estimates and general notions of shortage and surplus. Detailed planning decisions can and should be delegated.

The situation is very different in the case of a new industry in a less developed country. There an industry-wide analysis may encompass little more than would an establishment-wide or a firm-wide analysis within a highly developed country. In the chemical plant location study in Chapter 6, for example, the problem is to locate one, two, or at most five, plants of each of two types in the entire Latin American region. From an "industry-wide" analysis of such a nature, one could hope for reasonable prescriptions concerning detailed investment decisions.

Accuracy and Testing

A process analysis model can be viewed as a complex hypothesis which, like hypotheses in the physical sciences, has implications concerning observable phenomena. The natural hope is that process analysis models can be tested by methods analogous to those of the physical sciences. Although the experimental methods of physics and chemistry are not available, the checking of theory against fact as in astronomy or meteorology seems appropriate. Towards this end are the tests reported in Chapters 4, 5, and 9.

It is important to realize some of the limitations inherent in such tests. Our remarks, however, are not intended to discourage testing. Checks of the model against recent history serve, if for no other purpose, to catch gross errors such as misplaced decimal points or reversed algebraic signs. Although they do not provide the level of confidence we would desire, their contribution is in an area where otherwise we have next to nothing.

The difficulty with historical testing of models is twofold: First, it is possible for an extremely inaccurate, untrustworthy model to do well at such tests. (We do not mean "do well" accidentally, one time, but do well consistently even though the model is of little use as a policy guide.) Second, it is possible for an extremely useful model to perform quite poorly.

In order to illustrate the possibility that a poor model can perform consistently well in tests against history, consider the following highly simplified example. Suppose that there are two products, a and b, and two limited resources, A and B. One unit of a can be produced only by using a unit of A; a unit of b can be produced only by using a unit of B. The model, however, incorrectly assumes that either a unit of A or one of B may be used to produce a, and that the same is true for b. In this case the production possibilities, in fact, are given by the region $OACB$ in Figure 1, whereas the model would assert that the entire region $OA'B'$ is attainable. If the economy is efficient it will produce C, and a historical test will vindicate the model. Suppose that the model was used to form policy decisions, and that plans were made requiring the product mix represented by C'. This mix could not be achieved by the economy since the only feasible points are those in $OACB$. If the economy remained efficient, C would be produced (perhaps disrupting plans based on C'). If, forgetting about the original plans to produce C' and the failure of the economy to accomplish this goal, we performed a test by history,

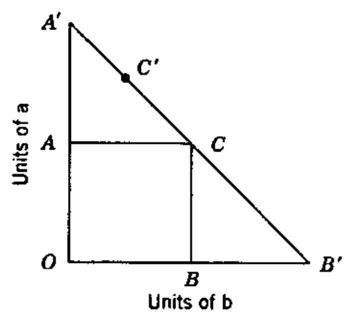

FIGURE 1

we would again find that the performance of the economy was consistent with the model.[1]

This example illustrates the possibility that a model can be quite useless for policy evaluation and yet score well according to the test of history. The converse may also be true. For example, in connection with requirements analysis, we have already noted that judgment may be used in an iterative fashion to modify the original model. Even though the initial model may fail the test of history, it nevertheless contributes to the general process of arriving at valid conclusions.

Cost and Availability of Broad-Scope Models

In principle, the process analysis approach permits a more accurate description of economic alternatives than do the alternate approaches discussed in Chapter 2. This superiority is merely academic, however, unless process analysis models can be developed and used economically. The studies in this monograph illustrate the feasibility of the process analysis approach in single industries. Now we turn to a more speculative issue concerning the feasibility of broader-scope (multi-industry and economy-wide) models.

We divide this question into two parts, the first concerned with computation, and the second with model building and data collection. In effect we ask: Is it possible, at reasonable cost and in a reasonable time, to formalize technological relations which characterize much or all of the economy? Can data be obtained to supply the parameters of such models? Can the consequences of such models be derived for problems with important economy-wide ramifications?

Computation

The art of linear programming has evolved rapidly, and gives ample evidence of a continued rapid evolution. Statements concerning computing costs become obsolete quickly. For example, in 1959 computing limitations restricted the size of linear programming models to 250 equations. By 1961—only two years later—a general-purpose linear programming code had run several 500-equation problems, and was capable of handling systems of up to 1000 equations. Without going beyond well-established principles (but by taking advantage of the special structure of large process analysis matrices), a code could be developed for handling systems with thousands of equations.

Linear programming is not applicable to all process analysis models. For example, in some instances involving economies of scale, it may be desirable to make use of integer programming optimization methods. In extremely complex cases (e.g., multisector spatial models involving sequential decisions over

[1] We may, however, be led to somewhat greater confidence in a test by history if the relative implicit prices within the model (the slope of $A'C'CB'$) check reasonably well with the historical market prices. Such a test is described by Manne, pp. 40–42.

time in the face of uncertainty), there may exist no economical techniques for optimization. For such problems, simulation has proved useful.

A simulation analysis does not find an optimum policy. Rather it evaluates proposed policies under various contingencies. On the basis of initial simulation runs, new proposals may be devised and in turn tested by further runs. The evaluation of alternate proposals may be less desirable than would be the development of an optimum strategy; but for models beyond the range of optimization techniques such evaluation is preferable to implementing vast programs without prior testing, or to testing programs with models which seriously misrepresent the technological possibilities.

Despite the rapid progress in optimization techniques and simulation, computation capabilities remain a scarce resource. They constitute an important consideration in formulating economy-wide models. Depending upon the particular policy application, spatial, temporal, or technological details will be emphasized and others suppressed in order to fit within a computational budget. There remains great value in finding more economical computing methods to increase the analyst's ability to freely explore problems of economic capability.

Model Building and Data Collection

In the present section we discuss requirements for building economy-wide process analysis models. Of the three alternative approaches described in the preceding chapter, input-output is the most demanding of time and resources. We will be particularly concerned with comparing the demands of this approach, as a benchmark, with those of process analysis.

Process analysis models built for individual industries (or closely related industrial complexes) can have value in themselves. Examples of such sector studies are noted throughout this monograph. The sector studies do not individually make excessive demands on time and resources. They require an effort roughly comparable to that of a Ph.D. dissertation. The building of a one-sector model should lie well within the resources of any agency charged with responsibility for analyzing the capabilities of that sector.

Once the individual sector studies exist, multisector models can be obtained at relatively low incremental cost. If we include the time and resources needed to build the individual sector models, the requirements for an economy-wide process analysis model are substantially greater than those of a detailed input-output table. On the other hand, if we include just the incremental cost of combining sectors, the cost of an economy-wide process analysis model is only a small fraction of that of input-output.

A vast amount of information concerning productive processes is publicly available. The analyst's chief job is that of selection and aggregation. Insofar as needed data are not in the public domain, our own experience has been that managers are generally quite cooperative in supplying information for a scientific cause—provided that the nature of the information is clear, that it is readily available within their files, and that its confidential nature is carefully respected. Generally, the information needed for process analysis is more readily available than that needed for input-output. In running a business, it is not necessary to be able to classify sales and purchases by census categories, but it *is* necessary for someone to know what materials and resources are used and what products are produced by manufacturing operations.

Increasingly, techniques such as linear programming and simulation are being applied at an intrafirm level, e.g., to problems of equipment selection and plant operation. Such intrafirm models present both data and relationships in a form particularly suited to the needs of the process analyst.

Some sectors or aspects of the economy do not readily lend themselves to technological analysis. This is particularly characteristic of such service industries as retailing, advertising, and banking. The inputs to these sectors should probably be handled as boundary conditions of a process analysis.

Technological relationships are neither ageless nor universal. Productivity coefficients should be updated with time, and new processes and products added as they become important. In extrapolating from one country to another, coefficients must be modified to reflect, e.g., the average age of equipment in a given category, or the average skill and experience of labor in the performance of labor-paced tasks.

There is nevertheless a substantial degree of transferability of technological models in time and place. For an industry-wide model, the list of processes employed by the economy changes slowly. The updating of production coefficients (which should be done periodically for all models) is a much easier task, more subject to delegation and routine procedures, than is the original model building.

The transfer of models of technology from one country to another is most easily accomplished in the case of equipment-paced processes, although adjustments may have to be made to reflect differences in equipment age and efficiency. For labor-paced processes, further adjustments may have to be made to account for differences in work habits and experience between one region and another. Also, because of radical differences in the capital-labor availability ratio, productive processes may be relevant for one country but not for another. Nevertheless, as illustrated in Chapter 16 for Mexico, experience thus far suggests that the existence of models for one country is a great aid in the construction of models for similar industries elsewhere.

For previously unexplored sectors, process analysis models should not be mass-produced. They require an individual or a team familiar with detailed technological relationships and the types of models by which these relationships can be portrayed. Even for such an individual or team the construction of a model may be a time-consuming research activity subject to the unpredictability that research is generally expected to have.

The development of process analysis models can, nevertheless, be encouraged and assisted. For example, funds for Ph.D. candidates who wish to write dissertations in this area would help attract interested graduate students. A central clearinghouse for studies and data could help answer questions such as, "Now that I am done with my study, what should I do with the worksheets or punched cards of data which I no longer need but which may be valuable to someone in the future?" or "Has anyone already done a study in a particular area? If so, where is it published? And how can I get his final (and perhaps intermediate) data in a machine-sensible form?"

Considering the value of individual sector studies, and the nominal cost of multi-sector models once the sectors have been analyzed, the long-run prospects for broad-scope process analysis seem quite bright. But what about the short run? If no process analysis models existed at all, the policy planner would be well advised to use some form of requirements analysis on those proposals which passed the coarse screen GNP test. Insofar as process analysis models do exist, he can introduce greater technological detail in areas which he feels germane to the problem at hand. Each addition to our stock of reliable sector models makes it more likely that the policy planner will be able to represent satisfactorily those parts of the economy which play a critical role in his practical problem.