

## CHAPTER 2

# ALTERNATE METHODS OF ANALYSIS

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### INTRODUCTION

This chapter discusses three methods of analysis which—like process analysis—seek to predict the ability of the economy to meet desired objectives with limited resources. These three methods—namely, GNP analysis, requirements analysis and input-output analysis—together with process analysis may be grouped under the general heading of feasibility or capabilities analysis. There are some differences in the range of applicability of these methods, but each addresses itself to the following types of question: Is a particular national objective economically feasible? Are there resource limitations which will render the economy incapable of achieving its objective? What are the alternative economic targets that are feasible?

From the viewpoint of the analyst interested in practical policy development, the various methods should be judged in terms of applicability, accuracy, cost, and availability. The policy developer wants to know the types of question to which each method of analysis can be applied. Or, to state the “applicability” consideration conversely, he wants to know which of the available methods bears on his problems. “Accuracy” is concerned with whether or not the answers returned by the analysis are reasonably correct. When a method suggests conclusions counter to initial judgment, is it likely to be a true or a false oracle? If two methods of analysis were applicable to the questions at hand, and both provided equally acceptable levels of accuracy, then choice between them would properly depend on cost and availability. Here cost should include the total costs of preparing for, performing, and interpreting the results of the analysis; while availability may be thought of as the probability that any developmental work needed to make the method applicable to the specific problem at hand can be carried out without undue delay.

For each method, in turn, this chapter briefly discusses its nature and its salient characteristics with respect to applicability, accuracy, cost, and availability. We shall argue that for some problems—and for certain stages of other problems—the simplest method, GNP analysis, serves best. For other problems the more complex methods of requirements analysis, input-output analysis, and process analysis are desirable or essential. In areas where

these methods are desirable but unavailable, the gap must be filled by that always available, sometimes accurate method called judgment.

#### GROSS NATIONAL PRODUCT ANALYSIS

The annual gross national product (GNP) is the money value of goods and services produced by the economy in a year. In contrast to *net* national product, GNP does not subtract depreciation allowances from the value of production. It does, however, exclude the value of intermediate products used within the year in the process of making other goods and services. Thus GNP represents the total money value of the economy's output available to satisfy "final demands" for household consumption, government expenditures, gross fixed capital formation, net inventory changes, and net exports.

Countless questions of detail must be resolved in order to produce an operational definition of GNP: How do we distinguish maintenance expenditures—which are excluded from GNP—from capital expenditures, which are included? Should GNP include the value of the food consumed by the farm families who grew it? Should it include the value of do-it-yourself activities in which people paint, repair, or build their own homes, boats, or furniture? With relative prices and product qualities changing from year to year, how should the value of goods and services be added together to permit reasonably meaningful comparisons of GNP over time? We shall not pursue these questions. Rather, we shall speak of GNP with no more qualifications than we speak of temperature or humidity—implicitly assuming that the various questions have been answered reasonably, and the resulting statistical procedure has been carried out consistently.

A GNP analysis estimates the total gross national product required to meet a proposed economy-wide program, and compares this with the GNP which the economy is likely to have at its disposal. If the proposed use of GNP exceeds the likely supply, something has to give way. Perhaps consumption or investment objectives should be reduced, or perhaps foreign funds should be sought. Or perhaps GNP can be raised through increased labor supply, e.g., increased female participation or longer working hours. In effect, a GNP analysis adds up the bill for proposed economy-wide objectives and compares this with the value of product available to cover this bill. The objectives will have to be reconsidered if the former exceeds the latter.

Although a GNP analysis is simpler to construct than the others, it is not without its difficulties. For example, projections of the supply of GNP usually involve estimates of labor force and productivity. Both of these factors are susceptible to errors of estimate. Nevertheless, in comparison with other methods, GNP analysis is by far the least expensive and most readily available.

Turning to the question of accuracy, we find that GNP analysis is subject to a definite weakness, but can nonetheless serve a useful function. GNP analysis, used by itself, tends to overestimate the capabilities of the economy. It fails to reject programs whose source of infeasibility is the shortage of

specific, specialized resources as distinguished from resources in general. Suppose—to take an extreme example—that an agricultural nation attempted in the course of a single year to:

- substantially reduce its output of grain, and
- increase by an equal dollar value its output of steel.

The proposed program does not involve an increased requirement for GNP—yet it is clearly infeasible. Farm land and equipment cannot be converted quickly into steel mills, nor farmers into steel workers.

GNP analysis can serve as a coarse screen, catching proposals whose general demands on resources are out of line in total. Only those proposals which pass through this coarse screen are then subject to the finer screening of the more complex methods of analysis. The more complex methods look for specialized resources which will become bottlenecks if a proposed program is implemented. Not only do they attempt to answer with greater precision the question “Can the economy achieve the specified objectives with limited resources?” but they also address themselves to such questions as “Which resources will become bottlenecks and which will be plentiful?”

Thus, in the division of labor among methods of analysis, the inexpensive coarse screen approach of GNP analysis may have to be supplemented by some finer screen method. The rest of this chapter will discuss two such methods, and the balance of this monograph is concerned with a third.

#### REQUIREMENTS ANALYSIS

A requirements analysis for, say, steel might proceed as follows:  $X$  tractors and  $Y$  square feet of industrial construction are planned (or expected) for a forthcoming period of time. The average tractor requires  $A$  tons of steel; the average square foot of industrial construction requires  $B$  tons. Add  $A$  times  $X$  plus  $B$  times  $Y$  plus, similarly, any other uses of steel to obtain estimated total requirements. Compare this with the projected steel availability to see if a “steel problem” exists. The analysis may proceed through several levels, reflecting the fact that, e.g., automobile production requires steel, steel requires pig iron, pig iron requires coke, and coke requires coal. For computational convenience the requirements for several resources may be computed simultaneously, thus avoiding the duplicate recalculation of requirements for intermediate goods which contribute ultimately to the requirement for two or more resources.

The inputs to a requirements analysis consist of estimates of resource availabilities, desired levels of final demands, and requirements coefficients estimating the inputs needed per unit of output. From these, the analysis produces a shopping list of ingredients required to support the objectives. Comparisons between requirements and availabilities help to indicate possible trouble areas.

Requirements analysis is applied in practice to problems of various scope. Under different names it is used in manufacturing analysis to estimate expected needs for men, machines, standard materials and purchased parts. The

military services use it to determine procurement quantities. At a national level it has been used, during war and peace, for tin, rubber, machine tools, blast furnace capacity, foreign exchange, and countless other potential bottle-necks. The problems of applying requirements analysis at a national level differ somewhat from those of applying it at an intrafirm level. Our concern will be with the former, broader-scope applications.

In an industry-wide steel study based, for example, on *U. S. Census of Manufactures* data, one could distinguish various mill shapes of "carbon steel," "alloy steel except stainless," and "stainless steel." But even "stainless steel" is an aggregate of many individual steels with differing applicabilities in manufacturing. Although the categories of a requirements analysis—e.g., stainless steel—are frequently discussed as if they were homogeneous commodities, in fact they are aggregates. The aggregation system of a requirements analysis in effect assigns specific goods and services to classes, and adds together the members of each class according to some criterion such as weight, volume, piece, or value. The characteristics and data requirements of each specific requirements analysis depend heavily on the aggregation system chosen. The choice of an aggregation system—whether done by design or by passive acceptance of existing categories—is the central, strategic decision in performing a requirements analysis.

Requirements analysis is not alone in its dependence upon aggregation. Aggregation is used with every practical technique of capabilities analysis at a national level. Aggregation problems constitute many, if not all, of the major problems of applying a technique. To a large extent, the differences between one technique and another may be viewed as differences in their approach to aggregation. GNP analysis, for example, represents an extreme form in which all goods and services are added together to form a single money value total. Formally, at least, GNP analysis may be viewed as a requirements analysis in which only one resource, national product, is distinguished. The cost of each good or service, then, is its requirement coefficient for GNP. Thus a GNP analysis is a requirements analysis with an extremely coarse aggregation of resources.

In a similar manner, requirements analysis may be viewed as a special case of process analysis. A process analysis can distinguish alternate ways of producing the same product. Requirements analysis aggregates these alternate productive processes into a representative activity with fixed inputs per unit of output. Thus, if a process analysis model did not distinguish alternate production activities, it would be a requirements analysis, and if it distinguished only one resource (gross national product) it would be a GNP analysis. Input-output analysis, finally, may be viewed as a form of requirements analysis using a somewhat different way of aggregating economic activity. The aggregation principles of input-output and their consequences will be discussed later in this chapter.

Thus each method of analysis has its own ground rules for aggregation. The specific aggregation system chosen within these ground rules determines the specific characteristics and data needs of the particular analysis.

The major cost involved in performing a requirements analysis is that of collecting and organizing data. Requirements analysis does not entail large calculation costs, as may be incurred for process analysis. With the available computing equipment, once the data for a requirements analysis are assembled in suitable form, calculations for even the largest analysis can be performed at a relatively small cost. With respect to the cost and availability of data, requirements analysis stands between GNP and process analysis. It needs a list of specific inputs per unit of output, as distinguished from the single money value figure which is sufficient for GNP analysis. Since requirements analysis does not develop coefficients for alternate productive processes, it can make extensive use of historical inputs and outputs to develop average requirements, avoiding (completely or in great part) the need for engineering data upon which process analysis frequently relies.

The major source of inaccuracy inherent in requirements analysis is its neglect of alternate modes of production. Often, substantially different inputs can be—and, in fact, are—used to produce the same product. Electricity can be produced by water power or, in steam electric plants, from either nuclear fuel, coal, oil, or natural gas; agricultural products can be produced using more or less fertilizer and irrigation; metals can be produced using varying ratios of scrap to ore; the same metalworking tasks can be performed on a variety of machines; and so on. A requirements analysis must attempt to estimate a typical process: e.g., the average use of nuclear fuel vs. coal vs. water power in the production of electricity. But the scarcity of one material relative to another will lead to the use of processes which conserve the one at the expense of the other. Thus, to an important extent, the use of one or another process will depend on the very shortages and surpluses that the analysis seeks to predict.

The manner in which a requirements analysis misestimates the capabilities of an economy, due to its failure to take account of substitution possibilities, depends on the aggregation system used. If two resources (e.g., lathes and milling machines) are aggregated together into the same category (e.g., machine tools) then they are assumed to be perfect substitutes for each other. If they are distinguished as different resource categories, then no substitution is assumed to exist. Thus an extremely coarse classification of resources will tend to overestimate the amount of substitution possible, and hence overestimate the capabilities of the economy. An extremely fine classification, on the other hand, will understate the amount of substitution possible between resources, and hence tend to underestimate the capabilities of the economy. In choosing an aggregation system for a requirements analysis the following dilemma must be faced: In order to anticipate bottlenecks among specific resources a fine classification is needed; but to avoid underestimating substitution possibilities a coarse classification of resources is needed.

Coal is sometimes a substitute for fuel oil, but not in all its applications; a lathe can sometimes substitute for a milling machine, but not always; aluminum and copper are competitors, but only in part of their range of applications. As a consequence, any aggregation system must be a compromise with,

rather than a solution to, the dilemma. Any attempt to completely avoid one horn of the dilemma is bound to drive the analysis to the other horn.

In principle one could circumvent this dilemma by the following process of trial and error:

Choose categories sufficiently fine to identify specific bottlenecks; estimate likely requirements; perform the analysis using these estimates; and inspect the results for bottlenecks.

Then, on the basis of this initial analysis:

Modify coefficients to reflect processes which substitute plentiful for scarce factors of production; repeat the requirements calculation and again inspect the results; make further adjustments and repeat if necessary.

This is a tedious and time-consuming procedure which must, of necessity, be stopped short of its ultimate end. Process analysis in effect accelerates this procedure by distinguishing alternate processes at the outset, and by letting automatic techniques perform the substitution of one process for another according to overall resource availabilities.

Process analysis and requirements analysis are closely related, as is illustrated by the discussion of the metalworking industries in Part IV of this monograph. Data and procedures are presented in Part IV for a requirements analysis assuming fixed inputs of various kinds of men, machines, and materials per unit output of each metalworking industry. After this, data and procedures for analyzing a certain source of substitution possibilities are presented, plus suggestions concerning the analysis of another source of substitution. The requirements analysis serves as an immediately available technique to which information concerning alternate processes can be added, as appropriate and available.

In itself, without the addition of alternate process information, requirements analysis serves to identify potential trouble areas. In some cases the apparent bottlenecks are not bottlenecks at all. The economy would take care of the shortage naturally, by substituting plentiful for scarce resources. In other cases the bottlenecks are real; the timing and level of objectives should in fact be reconsidered in light of possible infeasibilities. By spotlighting possible trouble areas for further investigation, requirements analysis supplies a valuable service beyond that provided by GNP analysis.

#### INPUT-OUTPUT ANALYSIS

A difficult problem of requirements analysis is that of estimating total requirements as distinguished from direct requirements. For example, the production of electricity, say to light homes, requires coal; but the production of coal itself requires electricity, whose production in turn requires more coal; and so on ad infinitum. To make matters worse, the production of both coal and electricity have other requirements whose demands ramify through the

economy, further augmenting the total requirements by electricity for coal. In the usual requirements analysis, indirect requirements are, after a point, accounted for by some rule-of-thumb procedure. An example of such a procedure would be to add together direct requirements, second order requirements, and third order requirements of each end item for a particular resource; see what fraction ( $X$ ) of a particular year's use of this resource is thus explained; account for the rest by multiplying ( $1/X$ ) times the sum of first, second, and third order requirements to form estimates of total requirements. Insofar as the fourth + fifth + sixth + . . . order requirement is not proportional to the first + second + third order requirement, the procedure is subject to error. The possible magnitude of this error depends on the extent to which first, second, and third order requirements account for the demands for the resource.

Input-output<sup>1</sup> approaches the problem of estimating total requirements through the use of a complete model of the economy. It classifies business establishments into an exhaustive set of industries and estimates the direct requirements by each industry for each other industry's output. These inter-industry demands are arrayed in a square table with industries listed across the top and down the side. With this table (plus the assumption of fixed inputs per unit output) standard mathematical techniques can be used to answer questions such as "How much gross coal production is required to produce an extra one million dollars' worth of electricity, net of all intermediate inter-industry requirements?"

As a theoretical matter, the notion of a complete input-output table dates back at least as far as the eighteenth century economist Quesnay. As a practical matter, the construction of an input-output table, in the sense used here, begins with the pioneering work of Wassily Leontief carried out during the 1930's and published in 1941. Subsequently—with electronic computers to trace through the consequences of ever larger systems, and with Leontief's work to demonstrate the feasibility of such an approach—various input-output tables have been built, including a 190-industry model of the United States economy for 1947.

Two forms of interindustry models are generally distinguished. The "closed model" (as first used by Leontief) includes households as an industry with inputs of consumption goods and outputs of labor. The "open model" (Cornfield, Evans, and Hoffenberg, 1947) does not include a household industry but treats demands by households as fixed requirements to be met by the economy. Also treated as fixed are the requirements for other components of "final demand" including government purchases, gross private capital formation, net inventory changes, and net exports. With respect to sectors other than households and other final demands, open and closed models can be identical. For problems of feasibility analysis, the open model is generally the more convenient.

In principle, an input-output analysis could use physical units of measure such as weight, volume, or count. In practice, however, dollar values have

<sup>1</sup> Sometimes referred to as interindustry analysis.

been used almost exclusively. Thus the classic statement of procedure for estimating coefficients for interindustry requirements, expressed here for the closed model, is as follows:

Each "industry" (including households) is treated as a single accounting entity—comparable to a "country" in official foreign trade statistics—with sales entered on one side of its trading account and purchases on the other. As in the trade between countries the sales of one industry are the purchases of another. Entering the sales and purchase accounts of all the separate industries in one large table we get a comprehensive view of the structure of the national economy as a whole.<sup>2</sup>

From this table of purchases and sales the direct requirement coefficients are calculated by dividing sales from industry  $i$  to industry  $j$  by the gross output of industry  $j$ .

The development of data for a large input-output analysis can require tens of thousands of man-hours. The 190-industry analysis of the U. S. economy, for example, required the estimation of thousands of coefficients. Most of these coefficients were not readily found in available statistics but had to be constructed from various sources, sometimes with the aid of rule-of-thumb estimation procedures. Computing costs for tracing out total requirements from the direct requirements, although not negligible, were small compared to the costs of constructing the basic table.

Because of the time required to collect and organize data for a complete interindustry table, "availability" is more of a problem with input-output than with GNP analysis or the usual requirements analysis. The development of a large input-output matrix should be viewed as a major construction project which is not to be rushed to answer some urgent policy question but is to be built carefully to serve many uses through the course of time.

#### INPUT-OUTPUT ANALYSIS (CONTINUED)

We shall note two general sources of inaccuracy to which input-output analysis is subject. The first concerns the existence of alternate methods of production. The second concerns the way in which "industry output" and "inter-industry flows" are used as basic categories of analysis. Since the former problem area—the existence of alternate methods of production—was discussed previously, it can be dispensed with quickly in the present section. The nature and consequences of inaccuracies introduced through the other source will be discussed in some detail. Despite such inaccuracies in input-output analysis, the table itself—i.e., the basic tabulation of historical inter-industry sales and purchases—is a valuable source of data concerning industrial activity. The basic table is tedious and expensive to develop, but so is much of the worthwhile economic data at our disposal.

In a preceding section we discussed difficulties of requirements analysis resulting from its failure to distinguish alternate methods of production. Radi-

<sup>2</sup> Leontief (1951), p. 4. For an introduction to input-output, we also recommend Chenery and Clark (1959).

cally different methods of production exist for many goods and services. The choice of production method depends on relative scarcities of alternate resources, and hence average requirement coefficients depend on the very shortages and surpluses to be predicted. This consideration, already noted for requirements analysis, applies equally to input-output with its assumption of fixed interindustry flows per unit of output.

Input-output is also subject to inaccuracies due to the way in which it makes use of "industry output" and "interindustry flows." For concreteness, we shall illustrate the general nature of these inaccuracies by means of examples drawn from the 190-industry matrix of the United States in 1947. (See Evans and Hoffenberg, 1952.) Difficulties such as those illustrated below have been recognized by a number of analysts who have applied input-output to practical problems. To circumvent these difficulties, various special procedures have been introduced into particular input-output analyses. Our discussion cannot do justice to these various ways of not quite doing input-output. In the examples and generalizations below, we will be dealing essentially with the classical input-output formulation as characterized in the last section. Afterwards, we shall briefly argue our preference for a process analysis approach rather than supplementing input-output with ad hoc procedures.

Suppose that industry I sells to industries X, Y, and Z, and that it purchases from A, B, and C. In tracing out total requirements, the input-output procedure assumes that the proportions among the output of A, B, and C purchased by I to produce output destined for X is the same as those proportions purchased by I to produce output destined for Y or Z. This assumption can cause substantial distortion in estimates of total requirements.<sup>3</sup>

For example, the Non-Ferrous Foundries industry casts both aluminum parts (e.g., for aircraft) and brass parts (e.g., for plumbing fixtures). In tracing out total requirements, input-output analysis assumes that the proportions of aluminum, copper, and zinc in the castings purchased by the Aircraft industries are the same as the proportions purchased by the Plumbing Fixtures and Fittings industry. The Non-Ferrous Foundry industry is treated as if it receives materials destined for different end items, combines them into a homogeneous mixture, and sends this mixture to each purchaser of non-ferrous castings.

The importance of this example depends on three points:

*First: In a case such as the above the input-output procedure introduces substantial inaccuracies in the estimates of indirect requirements.* In 1954,<sup>4</sup> for example, the Aircraft industries actually purchased \$49 million worth of aluminum and aluminum-base castings vs. \$4 million worth of copper and copper-base castings. The Plumbing Fixtures and Fittings industry, on the other hand, purchased \$.5 million of aluminum and aluminum-base castings vs. \$14 million worth of copper and copper-base castings. For these two, and

<sup>3</sup> On this point, see also S. B. Noble (1960), especially p. 408.

<sup>4</sup> We use 1954 rather than 1947 figures here since statistics on castings purchased by the Aircraft Equipment n.e.c. industry are more complete for the later year.

for a number of other<sup>5</sup> large purchasers of nonferrous castings, the assumption of equal proportions is untenable.

*Second: This difficulty cannot be avoided by a more detailed industrial classification.* Manufacturing industries are collections of establishments. Interindustry flows are the sums of purchases by establishments in one industry from establishments in another. Since many establishments cast both aluminum and brass, no matter how finely we classify establishments into industries—even if we let each establishment be an industry in itself—brass for plumbing fixtures will appear to end up in aircraft, and aluminum for aircraft will end up in plumbing fixtures.<sup>6</sup>

*Third: The Non-Ferrous Foundry industry is not alone in having this effect on the estimation of indirect requirements.* Similar distortions are caused by any industry which supplies a service performed on a variety of materials on behalf of a variety of consuming industries. Examples include Iron and Steel Forging, Metal Stamping, Metal Coating and Engraving, Machine Shops, and Screw Machine Products.

Input-output analysis is frequently combined with the notion of industry capacity. The input-output analysis predicts gross production required from various industries. By comparing these gross required outputs with the available capacities, potential bottlenecks are identified. This procedure encounters difficulties when industries can, in effect, borrow capacity from each other. Such borrowing of capacity is particularly common among the metalworking industries, which fabricate and assemble metal parts for a great variety of military, household, and industrial durable goods. Skills and equipment needed to perform the tasks of one of these industries typically overlap with those required for other such industries. Many shops regularly or occasionally produce parts destined for commodities of other metalworking industries. It is for such reasons that we find, according to the U. S. input-output table for 1947, that 9 cents' worth of Motor Vehicles, 1.8 cents' worth of Aircraft and 1 cent's worth of Motorcycles and Bicycles were directly "required" to

<sup>5</sup>The following examples present millions of dollars' worth of purchases of aluminum and aluminum-base castings vs. copper and copper-base castings (the data presented in that order) for some 4-digit census industries which consume large amounts of nonferrous castings and show a large discrepancy from the proportionality assumption. High aluminum consumers: Domestic Laundry Equipment (12.7, .1), Electric Appliances (10.1, .1), Metal Doors, Sash and Trim (4.7, .1), Internal Combustion Engines (21.8, 1.5); High copper consumers: Valves and Valve Fittings, except Plumbing (2.2, 22.8), Power Transmission Equipment (1.7, 5.7), Pumps and Compressors (4.4, 13.0).

Source: *U. S. Census of Manufactures, 1954*, Table 1B, pp. 210-238.

<sup>6</sup>This discussion is based upon (a) the definition of industry used by the *U. S. Census of Manufactures* and (b) the definition of interindustry flow used by Leontief (1951). One modification of these conventional definitions is to segregate the purchases and sales of establishments by product line, thereby departing from the establishment basis of classification. Since nonferrous foundry establishments have labor and equipment which may be used interchangeably for the casting of both brass and aluminum, the use of this product line classification would raise problems of the sort discussed immediately below for the metalworking industries.

make \$1 worth of Locomotives; that 7 cents' worth of Motor Vehicles and at least 1 cent each of Aircraft, Ships, and Railroad Equipment were required to make Motorcycles and Bicycles.

Whether or not it is combined with the notion of industry capacity, the input-output procedure is inadequate here for at least two reasons. First, it fails to analyze the capabilities of one such industry to supplement another. Second, it assumes that since 1.8 cents' worth of Aircraft is required directly for Locomotives, a proportionate share of everything that went into Aircraft should also be incorporated into Locomotives. The effect is similar in nature, though less in amount, to the mixing of flows that occurred through intermediate industries such as forges, foundries, and machine shops.

The final difficulty to be discussed occurs when two or more joint products result from the same process. The way this can affect the analysis of economic capabilities may be illustrated by the case of coke production.

The Coke and Products industry produces coke (mostly for blast furnaces) as its main product, and basic organics (for the chemical industries) as a by-product. Suppose there were a fall in the demand for steel. This would reduce the demand by Steel for Blast Furnace output; reduce the demand by Blast Furnaces for Coke output; and thus, according to an input-output matrix based upon purchases and sales, release Coke industry capacity for use by the Organic Chemicals industry. But this implication is opposite in direction from what may be expected in fact. Since basic organics are a by-product of coke production, the reduced production of coke would *reduce* the by-products available for the chemical industries. The chemical industry would either have to use alternate sources of raw materials or reduce its production. Thus, according to a purchase-and-sales analysis, additional "Coke Oven Capacity" would be made available by the fall in steel production, whereas in fact the flow of organics from coke ovens to the chemical industry would be reduced.<sup>7</sup>

To a certain extent, difficulties such as the above can be circumvented without giving up the appearance of an input-output table. The problem of alternate methods of production, for example, can be handled by trial-and-error procedures similar to those described in connection with requirements analysis. The problem discussed in connection with the foundry, forge, stamping, and machine shop industries can be handled by treating the primary metal purchases of such industries as if they were direct purchases by the end item producer.

In some cases, it would be extremely difficult to characterize accurately an aspect of technology within an input-output framework. The sharing of capacity between metalworking industries, for example, could be handled by means of "conversion coefficients" which showed the extent to which the capacity of one industry could be converted to another. Such coefficients would still fail to characterize properly the possibilities for reducing output

<sup>7</sup> An important instance of joint products will arise in multiperiod models of economic development. By investing in durable capital equipment, we obtain a sequence of joint products: capacity available for use during more than one time period.

in one set of industries to supply equipment and labor needed in another set. A more satisfactory approach is to explain the sharing of capacities in terms of the kinds of transferable resources used by these industries.

To many, the attractiveness of the input-output approach is that it permits the construction of a complete model of the economy without requiring an understanding of countless technological relationships. After  $N$  industries have been chosen,  $N^2$  coefficients can be delegated to a data collection team. Data may not be immediately available, but at least the team has a well defined objective: "Find or estimate the amount sold from industry  $i$  to industry  $j$  during the specified year for each  $i$  and  $j$ ."

We have argued above that various supplementary procedures must be used if the implications of such an analysis are not to be completely unreasonable. A serious difficulty with the input-output approach is that it provides no systematic way for seeking out those aspects of technology which require such special handling. Frequently input-output matrices are constructed and used without regard to such pitfalls. Sometimes these pitfalls are revealed through obviously absurd implications of the analysis. Other times pitfalls are found when someone looking at technology asks "What would happen if these technological relationships were forced into the input-output form?" There is no guarantee, however, that such ad hoc finding and patching of difficulties will not leave equally serious problems undetected.

#### SUMMARY

Gross national product analysis serves as a coarse screen to reject grossly infeasible programs. It does not detect programs whose infeasibility is due to excessive demands for particular specialized resources.

Requirements analysis compares the demands and supplies of specialized resources. Its chief drawback is its failure to account for alternate modes of production. Despite this difficulty, it can serve a valuable function in pointing out possible trouble areas.

Input-output is a form of requirements analysis which addresses itself particularly to the question of estimating total requirements—both direct and indirect. Input-output analysis fails to account for alternate methods of production. Additional difficulties in its use for capabilities analysis arise from the way in which it uses interindustry sales and purchases as the basic source of data.

Process analysis may be viewed as a generalization of requirements analysis which allows alternate modes of production to be distinguished wherever these are deemed important. Cost, availability, accuracy, and applicability characteristics of process analysis will be discussed in the next chapter.

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