Volume Title: Input-Output Analysis: An Appraisal

Volume Author/Editor:

Volume Publisher: Princeton University Press

Volume ISBN: 0-870-14173-2

Volume URL: http://www.nber.org/books/unkn55-2

Publication Date: 1955

Chapter Title: A Survey of Current Interindustry Models

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Chapter URL: http://www.nber.org/chapters/c2868

Chapter pages in book: (p. 215 - 252)

A Survey of Current Interindustry Models

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As PART of the government interindustry-research program, a 190-sector model has been developed. This has at times been referred to as a 200-sector model, thus taking into account the approximately 10 final demand sectors that have been stipulated along with the basic 190 industries. This model has been developed from some 450 detailed sector studies, which comprise the documentation for the 1947 interindustry-relations study. W. Duane Evans and Marvin Hoffenberg have discussed the 1947 study in an article in *The Review of Economics and Statistics*, and have expanded on that article in a paper prepared for this Conference.[1] Other papers prepared by the personnel of the Division of Interindustry Economics, Bureau of Labor Statistics, provide detailed documentation of the methods that were employed; these papers describe the specific construction of the sector accounts in the central structure and the derivation of the final demand accounts.

A. *Guide to Interindustry Research*

Although these papers reveal the construction of an interindustry model in all its empirical complexity, the sheer bulk of the papers will dismay all save the most energetic. For the casual reader with an interest in interindustry economics and in the techniques employed in model construction, a reader's guide to the literature would be most handy. One purpose of this paper is to provide such a guide, but the reader should expect nothing more than a summary. The true flavor of the processes involved in constructing the model can be extracted only by reading the detailed papers.

This summarization will be taken up in two parts: (1) the construction of the sector accounts—that is, the distribution of inputs and outputs within the endogenous part of the model, and (2) the derivation of the sectors of final demand. In the process of constructing the sector accounts, the sectors sharing common problems in measurement or existence of information have been grouped so

[1] W. Duane Evans and Marvin Hoffenberg's paper in this volume, "The Nature and Uses of Interindustry-Relations Data and Methods."

that groups representing manufacturing, mining, agriculture, transportation, and trade and services will be found together. The final demand sectors are the familiar ones found in the gross national product accounts—namely, households (as consumers), producers' durables, construction, foreign trade, government, and changes in inventories; however, as will appear in the subsequent discussion, these categories have been extended and modified in the actual computations.

This paper has a second purpose, which is correlative and complementary to the first. It is to show the extent to which an interindustry model can and has embraced the body of "received doctrine" that has been developed from studies in the various areas of economic analysis. These considerations open up an almost limitless range of problems, only a few of which can be explored; for example, we can consider whether the information contained in an interindustry model is consistent with microeconomic studies of the marketing pattern or cost structure for firms or industries; whether behavior equations derived from statistical time series have been adequately portrayed; or to what extent the incidence of taxes or freight charges implied in the model is plausible. In this respect, it is necessary to make a distinction between what has in fact been done in the 1947 interindustry study and what it is possible to do; it is also necessary to make a second distinction between those things that can be done easily through small adjustments in the data or techniques, and those that would require a major rearrangement of the basic structure. It is my impression that some of the criticisms raised about interindustry models qua models have their origins, at least in part, in ignorance of modifications incorporated in the 1947 study but not adequately documented. Some of these modifications will be described in this paper.

In developing the two purposes of this paper, it will be most convenient to begin with the second purpose, which has implications for the entire structure of the model, and then go on to a summarization of those papers concerned with the empirical problems involved in the collection and utilization of the data.

B. *The Framework of the 1947 Interindustry Study*

1. TRANSACTIONS TABLES AND OPERATING MODELS

In the literature on construction of interindustry or input-output models, many of the discussions have been concerned with the structure and assumptions of particular models (the 1947 interindustry model, the models of Leontief, etc.) and with the uses to which they have been put in problem solving, prediction, and the like. These discussions touch on vital points that are controversial, but in the midst of questions as to the operational validity of interindustry models, one very basic fact should be kept in mind. A gross transactions table showing the distributions of inputs and outputs (in physical and/or dollar terms) contains no implicit hypotheses as to the regularity of behavior or response of the flows; it is a neutral social accounting device for the collection of statistics. This particular aspect of interindustry models deserves some additional attention because of its importance in data collection.

The table representing gross dollar flows arranged by sectors is the basis for an interindustry study. As is by now generally known, the distributions along the rows represent the sales or revenues of a given sector divided among sales to other industries as intermediate products and sales to components of gross national product or final demand. Likewise, the distributions in the columns represent purchases of materials and services from other industries plus factor payments. In this respect a gross transactions table amplifies and elaborates the process of computing the gross national product. Conceptually, this process can be viewed as starting from the operating statement of the firm. On the revenues side appear total sales and inventory change; total sales can be further decomposed into sales to consumers, sales to government, net foreign sales, sales to other industries for investment purposes, and sales to other industries for current production purposes. On the purchases side of the account appear materials and services purchased from other industries for further processing and the factor payments of wages, interest, rent, and profits.

Since, for the entire economy, the total of materials and services purchased for further processing is equal to total sales for current production purposes, these two may be netted out of the purchases and revenues side of the account, respectively, leaving the elements of the gross national product. The logic of this account is precisely the same as the logic of the gross transactions table in an interindustry study. From the totals in the final demand columns and the value added rows, it is always possible, after making adjustments, to derive the gross national product; however, these adjustments are substantial in the case of the 1947 study.

The two items that are netted out in the calculation of the gross national product are developed in great detail in the gross transactions table. The rows and columns in the endogenous, or processing, part of the table represent these two items carried out in detail for each sector separately. A gross transactions table is thus a summary of the transactions taking place in the economy in some period of time, but one in which the "duplicative" transactions (in the national income sense) must be specified cell by cell. Not all transactions are covered, however. Financial transactions and transfers of existing assets are excluded. If the transactions table is of interest purely as a structure for social accounting, these omissions may be a disadvantage; however, the problem solving in which we are interested does not involve the construction of a theory of payments, which is the only purpose for which these omitted transactions are important.

As a structure for social accounting, a table constructed in this fashion meets the three functional criteria presented by J. R. N. Stone:[2] (1) providing a classification for transactions; (2) providing a "basis for collecting economic information"; (3) presenting detailed information on the structure of economic transactions. Furthermore, the detail on transactions in an interindustry table is much more specific with regard to sector breakdown than is usual in alternative social accounting structures, such as moneyflows analysis,[3] the structure suggested by Stone, or the accounts in the nation's economic budget.

Although the transactions table is void of theoretical implications, it is the grossest misreading of the facts to allege that interindustry models are lacking in theoretical structure. This allegation seems to stem from a confusion between "model" and "transactions table." An operating interindustry model is something more than a description of transactions. The specifics of the situation will be discussed in a moment. However, an interindustry model is capable of incorporating a wide variety of hypotheses derived from economic studies, whether on production functions, consumer or investment behavior, generalized demand functions, or the like. A number of these incorporations are considered later in this paper.

As Stone has so neatly pointed out, there are fundamental similarities in structure among interindustry models, simple Keynesian models, foreign trade transaction models, and some of the sophisti-

[2] J. R. N. Stone, "Functions and Criteria of a System of Social Accounting," *Income and Wealth Series I*, The International Association for Research in Income and Wealth, 1951, Chap. 1, pp. 7-8.

[3] Morris A. Copeland, *A Study of Moneyflows in the United States*, National Bureau of Economic Research, 1952.

cated multiplier models.[4] Their differences arise from the unique ways in which economic transactions may be considered; the transaction pie may be sliced one way to look at the relationships among productive units (firms, governments, households); another way to look at productive activities (consumption, production, investment); or a third way to look at types of transactions (on final account, transfers, duplicative, etc.). These models also differ with respect to the specification of exogenous and endogenous elements and the behavior characteristics of these elements. But it is clear that all of them, including interindustry models, contain sufficient theoretical structure to allow inferences to be drawn from the specific hypotheses introduced. Whether the inferences are "correct," that is, whether they correspond to actual behavior, is a separate issue. Consideration of it involves a study of the hypotheses and a quantitative comparison of actual and estimated values, i.e. a test of the predictive power of the model.

This paper discusses the first issue as applied to interindustry models; about the second (the test of predictive power), little can be said because (1) the results from the 190-industry model have a security classification because of certain military information; and (2) the "actuals" with which to compare them are just beginning to become available. It is fair to say that in a few specific cases the results achieved by the 190-industry model are strikingly accurate, and have occasioned a re-evaluation of estimates based purely on microeconomic studies.

2. THE IMPACT ON FEDERAL STATISTICS

The construction of a gross transactions table for an interindustry model requires accurate detailed information on the consumption of materials and the distribution of outputs sector by sector. Important sources of information have been the federal censuses of manufactures, business, and mineral industries. Although the coverage of the censuses is extremely broad, their basic arrangement does not provide an integrated picture of transactions among sectors. Furthermore, although the *Census of Manufactures* is supplemented by an *Annual Survey*, starting in 1949, and the *Census of Mineral Industries* is supplemented by the information contained in the *Minerals Yearbook*, the most recent censuses are by now ancient history; for example, no census of mineral industries has been conducted

[4] J. R. N. Stone, "Simple Transaction Models, Information and Computing," *The Review of Economic Studies*, 1951-1952.

since 1939, no census of manufactures since 1947, and no census of business since 1948.

Input-output analysis requires more and better data on transactions. The deficiencies in the censuses were very quickly apparent to the working groups, and in an effort to correct these deficiencies and to improve the federal statistical program, recommendations were made for changes in the proposed 1953 censuses. The Bureau of Labor Statistics has worked with the Bureau of the Census to expand coverage of statistics on the consumption of specific supplies and materials by each industry. They made suggestions for improvement in the *Census of Business* and the *Census of Mineral Industries.* The Inter-Industry Analysis Branch of the Bureau of Mines worked on recommendations for improving the coverage of statistics in the mineral industries and for making these statistics more consistent with the definitions and coverages of those collected by the Bureau of the Census. Other groups in the interindustry program made specific recommendations covering individual industries.

In the *Census of Manufactures: 1947*, approximately complete coverage on consumption was obtained for only 61 materials. In addition, limited coverage was obtained on a second group of 75 materials. From its detailed listings of the distribution of inputs and outputs for individual industries, the Bureau of Labor Statistics compiled a comprehensive list of products for which it would be desirable to have detailed data on consumption. In the final analysis many of these products had to be eliminated from consideration because they did not meet certain minimum criteria for coverage established by the Bureau of the Census. These minimum criteria are expressed in terms of (1) a specified minimum total dollar value consumed by manufacturing industries, (2) a specified minimum percentage of total supply accounted for by manufacturing consumption, and (3) a specified minimum average dollar consumption per consuming establishment. For product lines within each product class, special criteria of importance are applied. If only partial coverage on the consumption of an item is desired, roughly the same criteria have been applied, but with a relaxation of restrictions; for product classes that are of strategic importance for defense or other purposes, there may be more liberal interpretations. The strictness of these criteria limits the number of transactions or product classes that can be included within the coverage of a census of manufactures. Nevertheless, within this working framework the Bureau of Labor Statistics was able to make recommendations for the complete coverage of approximately 100 product lines and partial or specific coverage for 700 product lines. From their analyses it was also possible to make recommendations as to product breakdowns or combinations most easily reportable and most useful for industry analysis. These recommendations, if adopted for the future, will result in some extension of the number of transactions or types of products covered in the *Census of Manufactures*, and will be of direct benefit in the derivation of input patterns in a transactions table. Equally important are the benefits that will accrue from consistent handling of transactions that cut across the subject matter of other censuses, such as the *Census of Mineral Industries*.

The Bureau of Labor Statistics also made detailed recommendations for changes in the *Census of Business*. For the trade and service industries, the *Census of Business* was particularly deficient in its lack of information on margins by type of business and class of customer. For the usual interindustry study, gross output in the trade and service industries is measured by margins. Consistency with this definition was made even more difficult by the fact that retail and wholesale trade establishments frequently engaged in manufacturing operations as well as providing distributive services. Drugs and food products are frequently packed or processed by wholesalers; furniture stores, furriers, and feed stores are examples of retail businesses that frequently engage in some type of manufacturing. In these areas, information is most needed on the cost of goods sold, or on gross operating expenditures, to permit the estimation of margins (i.e. gross output) for each kind of business. The recommendations on costs have been in the direction of standardizing the transaction definitions; those on distribution of output have been in the direction of a clarification of customer classes.

The statistics of the mineral industries pose special problems. It has been usual in these industries to collect the data primarily on a product basis rather than on an establishment basis, as is done in the *Census of Manufactures*. Sometimes, it is easy to aggregate product information to approximate an industry classification, but frequently it is not. For many purposes a product basis is the only rational one, since an industry definition such as "nonferrous metals, not elsewhere classified," which includes manganese, tin, tungsten, and a dozen other metals, is a catchall with very little operational significance. Although output or shipment figures may be collected on a product basis, information on wages and salaries, cost of materials, etc., is usually collected on an establishment basis, thus further complicating the rationalization of the statistics.

Inasmuch as the interindustry models so far constructed are being used for mobilization planning purposes, the metals are of strategic importance, and the distribution of use of each of them by consuming product (or industry) is a prime requisite. This information would in itself be extremely valuable in an approach to priorities and allocations, yet the use patterns as presented in the *Minerals Yearbook* are usually incomplete and much too aggregative. As a start in the right direction, the Inter-Industry Analysis Branch reviewed the report forms issued by the Bureau of Mines and made numerous suggestions for expansion of the information on consumption of mineral products. In order to integrate more fully the statistics on mineral industries with those contained in the censuses of manufactures and business, the Standard Industrial Classifications used in the latter have been adopted wherever possible in the lists of consumers on Bureau of Mines report forms.

Although a number of recommendations for changes in governmental statistical reporting have been made, not the least of the contributions has been a move to regularize existing reporting programs, to obtain greater precision of definition of terms, and to introduce a greater degree of consistency and integration among data sources. There is a bias in the federal censuses in favor of "value added" measurements; the bias is in accord with national income accounting requirements, but the basic economic unit of measurement is the transaction. While the recommendations made by interindustry working groups may not be adopted immediately, there is a reorientation in favor of the transaction as the basic unit of account. For the purposes of a truly descriptive social accounting system—and for economic research in general—this reorientation is very promising.

3. USE OF THE MODEL IN PROBLEM SOLVING

An interindustry study does not, of course, stop with the construction of a gross transactions table. It is intended to be something more than a structure on which to record economic transactions. It is intended, in short, that it be used as a problem-solving device. The part of an interindustry model represented by a gross transactions table is structurally nonoperational; it is a descriptive device for social accounting. In order to transform it to an operational model, additional assumptions must be incorporated either in the form of structural or technological relationships or in the form of statistical behavior functions. There is no sharp line of distinction to be drawn between these two types of relationships, and an interindustry operational model usually includes both.

Generally speaking, two assumptions are necessary in order to transform the gross transactions table into an operationally significant model for problem-solving purposes. Assumption 1: inputs can be functionally related to the output of that industry. This requires making some assumption about the form of the production function. In the interindustry models computed to date, it has been assumed that each input is a linear homogeneous function of the output of the industry that consumes it. Assumption 2: in an open interindustry model (the only kind with which we are now concerned) there are some deliveries of products to sectors outside the system; that is, some sectors may be designated as exogenous or final demand sectors. Since both of these assumptions have been called into question in a number of different ways, it will be useful to describe how some of the difficulties have been met in the construction of the 190-industry model and how some others may be met in the construction of future models.

A wide variety of criticism has been leveled at the simple form of the production function used in interindustry models. At various times it has been alleged that: (a) The coefficients are not invariant with regard to scale as is assumed in the models. This may be interpreted to mean that *none* of the coefficients behaves in this way or that *some* do not. (b) The input pattern for any industry is not independent of the bill of goods as is assumed in the models; substitutability among inputs does occur. A distinction should be made here between the substitutions induced by relative price changes and those that are the result of structural or technological change. (c) If the product mix of an industry changes, then its input pattern may be expected to change, and fixed coefficients do not accurately reflect this phenomenon. This is simply another aspect of the problem of substitutability among inputs and perhaps should be blanketed in with (b) above. The criticism stems from the fact that in an interindustry model each industry includes only one productive process. Since the criticisms are usually based upon an appeal to empirical fact, they have been listed separately here. (d) The coefficients in an interindustry model are based only upon a single sample from the data, that is, the year for which the transactions table was originally constructed. Ronald W. Shephard[5] suggests a transformation of an interindustry model to a system of simultaneous stochastic equations that utilizes time series on individual variables and in which the coefficients are derived by (limited information) maximum likelihood estimates or linear approximations to them.

In a paper of this length it is not possible to examine in detail all of these criticisms and to assign them a proper weight of relevance to an interindustry model, but some brief comments seem to be required. At the very least it is possible to point out some of those devices that have been "built in" the 190-industry model to meet specific criticisms. And a few more general comments are perhaps also in order.

It should be realized at the outset that in an interindustry model it need only be assumed that there is *some* functional relationship between the input and the output of the industry. The form of the functional relationship may be very simple, as in current interindustry models, or it may be more complicated. The actual form of the production function incorporated in the model should be determined, not by an a priori persuasion of the relevance of a particular functional form, but by statistical or technological demonstration.

The results of a first test of the behavior of coefficients are available. Burgess Cameron[6] used data on Australian manufacturing industries to test the form of production functions. His conclusions, while tentative, are quite interesting. Both the labor input coefficients and the materials coefficients tended to be of simple linear form. They seem to be relatively constant over short periods of time, and some are constant over long periods. There is very little indication of substitutions among inputs; relative price changes seem to have little effect. On the whole, Cameron concluded, the evidence pointed to production functions of a rather simple form. Future studies of production functions will provide additional information on which to form judgments as to functional forms.

The assumption of a linear and homogeneous production function does have the virtue of simplicity; it simplifies both the calculations and the conceptual problems in the collection and processing of the data. It may be argued further that a more complicated function can be adequately represented by a polygon, which is the result of a series of linear calculations. Production functions that are linear

[5] Ronald W. Shephard, "A Survey of Input-Output Research," processed, Rand Corporation, *P-309*, July 17, 1952.

[6] Burgess Cameron, "The Production Function in Leontief Models," *The Review of Economic Studies*, 1952-1953.

but nonhomogeneous can be most easily accommodated in the current models. The constant term in the equation can be transferred to the bill of goods, since it represents a level of input use not associated with the level of output, and that part of the input that bears a direct relationship to the level of output can be incorporated in the model as a coefficient.

The building-in of linear and nonhomogeneous relationships may become more important as we move in the direction of a partial closing of the model. The household row and column might be moved from the exogenous or final demand sector of the chart into the processing sectors. From productivity studies we expect that the input of labor to various industries is poorly represented by linear and homogeneous relationships. This is particularly true if we are including both production and nonproduction workers in the calculations. In this case, estimates can be made from productivity studies of the number of nonproduction workers historically employed in the industry; this part can be transferred back to the final demand sector. The number of production workers employed can then be represented by a fixed coefficient that is retained in the model. In the household column it is perhaps even more serious to have fixed consumption coefficients. Instead, consumption functions may be derived representing the purchases by households from each of the industries in the table; the constant terms in the equations can then be transferred to a new household column in the final demand sectors and the coefficients representing marginal propensities to consume retained in the endogenous sector of the chart.

The same sort of process can be repeated if it is desired to move inventories or private investment from final demand into the processing sector of the chart. One part of inventories might be regarded as autonomously determined, while another part might be associated with output levels in the industry. As for private investment, the part represented by replacement might very well be regarded as a function of the level of output, while net or new investment is given autonomously. In both of these cases there would be a split in the sector—one part would remain among the processing sectors of the chart and one part would be in final demand. Furthermore, there is nothing to prevent the use of negative quantities in the autonomously given sectors. In the case of inventories, such a negative quantity would act as a constraint on the build-up of inventories caused by having a part of inventories determined by output levels. It would then be necessary to supplement the analysis with a stipulation of the stocks of goods in existence prior to the initial period of the computation of the model.

The process just described is similar to one of the techniques currently being employed in interindustry work. In the use of the 190-industry model in the analysis of mobilization problems, input lead times have been associated with each of the coefficients. The input lead time in this case is the reciprocal of the inventory turnover period, so that it represents the average length of time goods are in inventory before being utilized in the production process. Consequently, with these input lead times fixed, a rise in the output level of industries requires a proportionate increase in inventories. If, in the inventory column in the bill of goods, negative quantities are inserted to indicate depletions of inventory, the depletions act as a constraint on the build-up of inventories occasioned by the use of the fixed input lead times.

The above discussion refers only to the methods by which nonhomogeneity may be introduced into the production function, thus permitting a split between an amount to be determined autonomously and an amount that fluctuates with the level of output. In addition, there are methods that, though complicated, can be used to take account of changes in the coefficients themselves in response to changes in the bill of goods. One way in which this may be done is to divide the bill of goods into increments and to compute the output levels associated with each increment separately. Those coefficients that change as output levels increase can be altered in each computation. In order to compute the total activity levels associated with a given bill of goods in one period, it is necessary to have a series of matrices in which some of the coefficients are unchanged but in which some vary as each increment is added to output. Change in some coefficients in the column and not in others thus reflects changing proportions of factor use, so that the model does in fact represent the phenomenon of rising marginal cost. The difficulties entailed by such a procedure should not, however, be underestimated. There must be bases for dividing the bill of goods into increments and, above all, the estimated changes in coefficients must be firmly grounded in technical or statistical relationships.

4. COEFFICIENT VARIABILITY AND THE FLEXIBILITY OF THE MODEL

The problem of factor substitution and coefficient variability may be looked at in another way. It has been argued that the assumption of a linear and homogeneous production function in interindustry models strictly implies that all factors are perfect complements and that the marginal productivity of any single factor is necessarily zero. Paul A. Samuelson[7] has demonstrated that, although many different processes of production exist in the market, the industry, in its attempt to reach a "most efficient" combination of resources, finally adjusts to one single combination of resources, which is the only one actually observed. In his paper "A Review of Input-Output Analysis," Carl Christ has objected to this characterization because it applies only to the case in which there is one single scarce factor, when in fact there may be many. The scarce factor is usually assumed to be labor, but natural resources are also scarce. Shephard[8] further argues that Samuelson's theorem applies only to *real* inputs, whereas in an interindustry model the industries are conglomerations of products and processes that represent special problems in aggregation.

Christ's criticisms are serious but not necessarily disabling. It is possible to argue "as if" there were only the single scarce factor—labor. The scarcity of other resources does not necessarily react on firm and industry in the ways that labor scarcity may. An appeal may be made to the usual economics of the firm for theoretical support, although in final analysis the appeal must be to the fact of industry behavior. The alternative is to construct a straight linear programing model in which the supplies of the several scarce factors are explicitly stated.

As for Shephard's criticism, it is true that in the 190-industry model the industry sector is, in many cases, an aggregate of processes or of more finely classified industries. Various criteria may be applied in performing the aggregations; it would not be maintained that all criteria are satisfied by the aggregations that have been made. (a) Industries that represent a vertical aggregation have been combined in the 190-industry model. It can be demonstrated that no bias is introduced by such a combination. (b) Industries with "similar" input patterns may also be combined. (c) An aggregated industry whose output presents approximately a constant output mix is still a third type of combination. The constancy of output mix can be tested by looking at a time series of the ratios of output of the constituent industries that have been aggregated; if

[7] Paul A. Samuelson, "Abstract of a Theorem Concerning Substitutability in Open Leontief Models," in *Activity Analysis of Production and Allocation*, Tjalling C. Koopmans, editor, Wiley, 1951, Chap. VII.

[8] *Op. cit.*

these ratios remain approximately constant, the aggregation can safely be made, since the ratios of inputs would also remain approximately constant. Some criteria that may be applied to the problem of aggregation are so strict as to negate any action whatever.[9] In the absence of proof to the contrary, it would appear that the three criteria above provide a valid basis for applying the theorems on substitutability to these industries.

There are reasons for expecting that problems of aggregation will prove manageable in interindustry models. In a time-phased model (such as the 190-industry model) in which lead times are associated with each coefficient, different coefficients may be introduced for each period of time. This may be done for a number of reasons, one being an estimated change in the product mixes of an industry aggregate. Second, "truncated" models may be used in which some industries preserve their identities while others are very extensively aggregated. Oskar Morgenstern and Thomson M. Whitin have found that the inverse coefficients of the nonaggregated and of the "truncated" models are surprisingly similar (both absolute and percentage differences small).[10] Consequently, the generated output levels for a given bill of goods will also be similar. The "errors" may thus be relatively insignificant.

Furthermore, if the coefficients for an industry group are known to be poor, as in "nonferrous metals, not elsewhere classified," which includes manganese, cobalt, nickel, and many other critical materials, a separate submodel may be used. In the case of the critical materials, the Inter-Industry Analysis Branch, Bureau of Mines, is using a linear programing model in which each critical material is listed separately; the "coefficients" of inputs of critical materials to consuming products, such as alloy steels, are determined from metallurgical experience, and the "program elements" (required outputs) that activate the linear programing model are taken from the interindustry model.[11] These "program elements" are the generated output levels for the relevant industries associated with a given final demand. Since the "feedback" effects of changes in outputs of critical materials are small, they may be ignored. In this

[9] M. Hatanaka, "Note on Consolidation within a Leontief System," *Econometrica*, April 1952.

[10] Oskar Morgenstern and Thomson M. Whitin, "Aggregation and Errors in Input-Output Models," Logistics Research Project, George Washington University, undated.

[11] Frederick T. Moore, *An Application of Linear Programming to the Determination of Requirements for Critical Materials Used in Alloy Steels*, Item 20, Inter-Industry Analysis Branch, Bureau of Mines, Feb. 4, 1953.

way problems of coefficient variability and substitutability among these materials are both being attacked, and the flexibility of the interindustry model is greatly enhanced.

In addition to the problems of factor substitutability, there are problems induced by time and technological or structural change. If an interindustry study is constructed from data based upon a single year, as is the case in the 1947 interindustry study, and if the table of coefficients (or inverse elements) is to be used for solving problems referring to later years, the course of known technological changes may have altered coefficients in the intervening period so far as to make the use of them highly suspect. A table of coefficients constructed from 1947 data does not adequately represent conditions in 1951 or 1954. If the coefficients are to be used, they have to be revised to represent conditions existing as of the date of the problem. It might be argued that what is really required is the construction of a whole new table of transactions and coefficients, but this should not be necessary unless it is felt that the technical and structural changes are general throughout all industries. The alternative is to pinpoint those industries that are undergoing significant changes in input patterns and to revise the coefficients for these industries alone. That is the procedure that has been utilized in the 190-industry model.

5. MEASURING COEFFICIENT CHANGES

Three major industry areas were finally selected for coefficient revision: (1) the energy industries—coal, petroleum, natural gas, coke, and electric power; (2) three important metals—steel, copper, and aluminum; (3) synthetic fibers. The coefficients in the energy industry rows are known to be changing as a result of several factors. First, a rapid substitution of one type of energy for another is occurring in a number of areas; for example, in the railroad industry diesel locomotives are taking the place of coal locomotives, and in commercial and house heating there is a trend toward petroleum and natural gas and away from coal. Second, in many consuming industries there is a definite trend toward greater efficiency in the use of energy. Third, some industries are becoming more energy intensive, particularly in the use of electric power.

The Inter-Industry Analysis Branch, Bureau of Mines, made detailed studies of each of the energy industries to determine how and in what areas the coefficients are changing. Technical and other information was utilized to produce "indexes of change" for each coefficient for a series of years. The coefficients in the 1947 study can then be multiplied by the indexes of change to obtain new coefficients to represent conditions in a current, or in a future, year. The indexes of change combine the effects of greater efficiency in use and of substitutions that are taking place. In some cases energy coefficients in the table were written down to zero, and requirements for energy in these areas were transferred to the bill of goods. Fuels for household and commercial use were estimated in this manner. Btu's consumed were correlated with disposable personal income; then, on the basis of a detailed cross-sectional study prepared by the Bureau of Mines,[12] fuel requirements were split among the energy industries and distributed seasonally by quarters.

The way in which energy required by the railroad industry was handled furnishes an example of the flexibility that can be achieved in the use of the model. Diesel locomotives are replacing coal locomotives as fast as they can be delivered. Delivery schedules for diesel locomotives are known for the current period and for several years in the future; from these data, and from data on the capacity of diesel locomotives, estimates were prepared of diesel oil requirements by the railroad industry. Estimates were also prepared for the energy requirements for electric locomotives and fuel oil locomotives. The requirements for diesel, fuel oil, and electric power were expressed in Btu terms. These Btu requirements were then converted to coal equivalent Btu's, and by applying the price per Btu of coal to the converted figures, a value figure was obtained. This figure was inserted as a negative final demand against the coal industry; it represents the value of coal that would be required to move the traffic that in fact will be hauled by oil, diesel, and electric locomotives. Likewise, the input of coal into the railroad industry was raised to a level corresponding to total locomotive fuel requirements. The effect of these two changes accurately reflects the substitutability among fuels as the output of the railroad industry changes. A fixed amount of traffic, based on the rate of dieselization, is estimated outside of the model. The residual traffic is met by pressing into service coal locomotives. Consequently, by this procedure a change in input coefficient and factor substitutability are accounted for in the model. It is a demonstration that with ingenuity

[12] W. H. Lyon and D. S. Colby, "Production Consumption and Use of Fuels and Electric Energy in the United States in 1929, 1939, and 1947," *Report of Investigations 4805*, Bureau of Mines, October 1951.

there are ways of accommodating these problems in an interindustry study.

An alternative method for handling the energy industries might be briefly described. Instead of having the usual energy industries in the model, we might construct a synthetic "Btu industry." Inputs from this industry to consuming industries could be represented in physical terms. The model would then generate a requirement from this industry purely in terms of Btu's. As a side calculation it would then be possible to estimate the percentage of the total to be supplied by coal, petroleum, natural gas, etc. In order to get the "feedback" effects of these energy industries on the rest of the economy, additional bills of goods would be constructed for petroleum, coal, natural gas, etc. based upon the input pattern to these industries separately, and a final solution would be achieved through iteration.

Coefficients for steel, copper, and aluminum were revised from 1947 to 1951 conditions on the basis of statistical report forms collected under the Controlled Materials Plan. Tabulations were made of the consumption of these metals, industry by industry, and new coefficients were computed on the basis of the compilations. The new coefficients were then inserted into the model. As a result of the changes made in the three metals and in synthetic fibers, 172 cells in the matrix were changed. As a result of the work on the energy industries, 767 changes were made.

Coefficient variability may be approached in yet another way in appraising the structure of the model. The question might be asked: If a group of coefficients vary (perhaps as a result of substitutions in the input pattern for a single industry), how significant will the effects be on the activity levels of the industries in the model? The question might have been alternatively framed to make it a consideration of the effects of errors in the coefficients; differences between the "true" and the observed coefficients might occur as the result of inexact data, aggregation, or the like. The question has been framed generally enough to cover both situations.

The Inter-Industry Analysis Branch, Bureau of Mines, undertook to study the effects of coefficient variability in the 190-industry model. A question was raised in roughly the form indicated above. In order to get answers to this question, two things had to be decided: (1) What size(s) of coefficient change should be considered?; (2) how should a "significant" change in activity levels be defined? In order that a liberal allowance be made, it was assumed that coefficients might change by 100 per cent. Since we wish to consider only those coefficient changes that increase activity levels, thus putting a greater strain on the economy, we considered only the effects of a doubling of the coefficients.

Defining a "significant" change in activity levels poses a somewhat more difficult problem. Since the models are being used in mobilization analysis, increased requirements from some industries will be more important than from others. A mobilization plan would never be regarded as infeasible because of a lack of capacity in advertising, hotels, or banking and insurance. Therefore, different levels of significance were assigned to the industries on an arbitrary basis; for each industry, significance was measured in terms of a minimum percentage change in output; the figures for some selected industries are: steel, 5 per cent; primary copper, 3 per cent; construction and mining machinery, 5 per cent; metal stampings, 10 per cent; banking and insurance, 100 per cent.

Now let us assume that the coefficients in column k of the matrix have been changed. It can then be demonstrated that the percentage change in the output level of industry i, resulting from these changes, is given by the formula

$$\frac{\overline{X}_i - X_i}{X_i} = \frac{X_k}{X_i}\left[\frac{\sum_{j=1}^{n} b_{ij}d_{jk}}{1 - \sum_{j=1}^{n} b_{kj}d_{jk}}\right]$$

in which $\overline{X}_i$ = the activity level of the ith industry after the change
X_i = the ith industry's output before the change
X_k = the activity level of the kth industry before the change
b = inverse element
d = algebraic change in the coefficients in column k.

We might have used this formula in our calculations. On the left-hand side of the equation, we would insert the critical percentage figure for each industry; the old activity levels (X_i, X_k) and the inverse elements (the b's) are known. It is then possible to determine all those coefficient changes (the d's) that affect the activity level by as much as, or more than, the critical level assumed. However, since the amount of computation involved in the use of this formula is considerable, a simplified version was employed. Instead of considering a whole column of changes at once, each coefficient was considered separately. If only one element in the matrix is changed, say the element in the hth row and kth column, the formula reduces to

$$\frac{\overline{X}_i - X_i}{X_i} = \frac{X_k}{X_i}\left(\frac{b_{ih}d_{hk}}{1 - b_{kh}d_{hk}}\right)$$

with the symbols having the same meanings as before. In studying one coefficient at a time, we are necessarily involved in a *ceteris paribus* assumption about the behavior of the other coefficients. As such, the application of the simplified formula has a limited use. (In actually carrying out these computations, a number of refinements were introduced, which will not be discussed here; the effect of these refinements was, if anything, to provide a more strict test of the coefficients.)

With the listing of the critical figures for percentage changes in output levels, industry by industry, and assuming a 100 per cent change in the coefficients, a study was made of the coefficients in the 190-industry model. The study revealed only 320 coefficients whose change would be significant to the activity levels of the 190 industries in the model. As would be expected, a number of the coefficients were significant for more than one industry; the 320 coefficients affected the output levels of the industries in their own row and in addition affected the activity levels of 422 industries outside of their own row. Thus, including the repetitions, 742 significant coefficients were chosen by this procedure. Table 1 shows a distribution of the industries according to the number of significant coefficients. The maximum number of coefficients affecting any one industry was 24; these applied to the iron ore industry.

TABLE 1

Distribution of the 190 Industries According to the Number of Significant Coefficients

Number of Coefficients Appearing	*Number of Industries*
0–4	134
5–9	41
10–14	8
15–19	5
20–24	2
Total	190

Source: Unpublished research, Bureau of Mines.

If these results may be taken as a first approximation, the worst of the fears as to the effects of coefficient variability perhaps may be allayed. In comparison to the total number of coefficients in the model, a relatively small number of significant ones has been chosen by this procedure. It would be possible to take them one by one and to determine, on technical or other bases, the probability of their variation. The serious limitation in this procedure is the *ceteris paribus* assumption. A number of small coefficients, no one of which is significant by itself, might all vary simultaneously, thus producing a significant change in the output level of one or more industries. Since a pattern of simultaneous variation in a number of coefficients is to be expected, a next step in this problem should be aimed at evaluating the effects of such simultaneous changes.

C. *Data Problems and Methodology in Constructing the Interindustry Transactions Table*

The construction of the transactions table in an interindustry study involves the mass handling of statistical materials, in the course of which many decisions of a conceptual and practical nature must be made. In order to summarize these developments, the discussion will be centered about three major problem areas: (1) The problem of operational definitions. Problems in this area include the choice of an industrial classification system, the definition of gross output, and, on a more basic level, the definition of a transaction. (2) The problem of measurement and reconciliation. Here are included the problems of deciding at what point to take measurements, the disentangling of transactions, and the reconciliation, for example, of the information contained in the distributions along the rows as contrasted with the distributions along the columns. (3) The problem of statistical imputation. This problem arises, at least in part, from the fact that statistical detail on transactions among sectors is missing and must be "pieced together" from whatever sources are available within the limits prescribed by a given control total. It is this "piecing together" that Morgenstern is questioning when he suggests that the zero cells in a gross transactions table may not in fact be zeros but very small quantities.[18] These three problem areas are not mutually exclusive but overlapping; nevertheless, by dis-

[18] Oskar Morgenstern, discussion of paper by Wassily Leontief, "Input-Output Relations," in *Proceedings of a Conference on Interindustry Relations Held at Driebergen, Holland*, Netherlands Economic Institute, 1953.

tinguishing them, some of the important problems can be emphasized.

In the gross transactions table the distribution of inputs and outputs in the intermediate or processing sectors may be considered separately from the preparation of the final demand sectors. The line of demarcation between intermediate and final sectors is not a hard and fast one; sectors may be transferred out of the one and into the other, if desired; however, the final demand columns correspond to the components of the gross national product, so that there are some special problems in this area. The processing sectors will be considered separately from the final demand sectors.

1. THE PROCESSING SECTORS

As finally constituted the interindustry model had 190 industries; however, initially the classification system was kept rather flexible, and data were collected on a more detailed basis. Originally, data were collected on (approximately) a 450-industry basis. Transactions for these industries were distributed along rows and columns; distributive margins to trade, etc., were determined, and those transactions that could not be immediately identified were assigned to an "undistributed" row and column. In future studies this basic 450-industry classification can be utilized; however, for analytical purposes aggregation to the final 190-industry classification was carried out.[14]

In this process several definitions of "industry" were adopted. Many industries could be represented as a group of semihomogeneous establishments. Most of the manufacturing industries are set up on this basis; this classification was dictated by the form in which the data appear in the *Census of Manufactures*. The establishment basis for classifying industries breaks down when applied to other areas. In agriculture, for example, it was more meaningful to make the classification in terms of products (e.g. meat animals, poultry and eggs, etc.).[15] The mining industries were also defined on a product basis, but these coincided with traditional industry definitions.[16] The trade and service industries were defined in terms of

[14] Philip M. Ritz and Gabriel G. Rudney, "General Explanations of the 200 Sector Tables," *The 1947 Interindustry Relations Study*, Bureau of Labor Statistics Report 33, June 1953.

[15] Philip M. Ritz, "Agriculture," in "Input-Output Analysis: Technical Supplement," National Bureau of Economic Research, Multilithed, 1954.

[16] Jack Faucett, "Mining," in the supplement to this volume, as cited.

the distributive or service functions that they perform.[17] These definitional problems are significant primarily because of the way they affect the measurement of gross output in each of the industries.

The measurement of gross output in the models is clarified if we use an illustration. Let us suppose that industry 1 produces a primary product, A_1, and a secondary product, B_1; and industry 2 produces a primary product, B_2, and a secondary product, A_2. Gross output for these industries might now be measured in several different ways. On a strict industry basis, the output of industry 1 would be $A_1 + B_1$; and of industry 2, $A_2 + B_2$. The chief difficulty with this definition, so far as it may be applied in a model, is that the demands generated are primarily for products; a second difficulty is that most statistical sources showing shipments are on a product basis. The *Census of Manufactures* has data on the shipments of products from wherever made, with little or no reference to the producing industries from which the shipments originated. For product A in our example above it is not possible to distinguish between shipments that arise in industry 1 and those which arise in industry 2. For these reasons the strict industry definition was not used in the models.

An alternative would be to use a product definition of gross output. In this case the output of industry 1 in the example would be $A_1 + A_2$; and for industry 2, $B_1 + B_2$. There are some definite advantages in using product definitions. Input coefficients computed on a product basis are apt to be more stable than those computed on an industry basis; therefore, several of the criticisms about the production function are nullified. Production functions for products are more meaningful than for industries. Problems such as the estimation of requirements for critical materials would also have been simpler if product definitions had been used. However, there are also difficulties here. The Standard Industrial Classification, which the *Census of Manufactures* follows, refers to establishments. The "cost of materials" collected in the census would have been relatively useless in determining input coefficients if product definitions had been used; the input structures could have been determined only by reference to engineering and technical literature. Trying to establish cost breakdowns among products soon becomes as difficult as trying to establish industry breakdowns, so little is gained in terms of classification. Moreover, since input coefficients would be derived directly from the technical literature, there would be no

[17] Gabriel Cherin, "Services and Financial Intermediaries," in the supplement to this volume, as cited.

way of knowing whether all transactions of goods and services in the economy had been accounted for.

There is a conceptual difficulty in using product definitions that turns on the problems of control and response. When an interindustry model generates required outputs, the behavior of firms or establishments is involved. Control of the production process and response to changes in demand are functions of these organizational units. In mobilization analysis these functions may be vital to the solution of a problem, so that establishment identity would have to be preserved.

The definition of gross output finally adopted in the interindustry model was a compromise between the two just mentioned. The output of industry 1 was defined as $A_1 + B_1 + A_2$; and for industry 2, $A_2 + B_2 + B_1$. A_2, the secondary product of industry 2, appears in the chart as a fictitious sale to industry 1, and is distributed along the row as part of the output of industry 1. Imports that are competitive with the primary product of industry 1 have been treated in the same way; instead of being distributed directly to consuming industries, these imports are "transferred" to industry 1 in a single "sale" by that industry.

The definition of industry output that emerges is made up of several parts: (1) actual production in the industry of primary and secondary products; (2) competitive imports; (3) production of the product primary to this industry that is a secondary product of another industry. The latter two parts are designated as "transfers." Throughout the 1947 study, these "transfers" have been used. The use of them simplifies the allocation of outputs along the row. Consider the alternative of distributing the sales or shipment of products separately for primary products and the "transfers-in." Information would be needed on whether a purchasing industry normally buys from a primary producer or from a producer to whom the product is secondary. These marketing arrangements are not hard and fast; purchasers vary their procedures. If input coefficients were computed on these transient marketing arrangements, there would be every reason to believe that they would be highly unstable. The Bureau of Labor Statistics chose the most useful method in what is admittedly a most difficult conceptual area. In any event, separate matrices of the "real" flows and the fictitious "transfers" are available and may be used if desired.

For some industries the problem of defining gross output was a somewhat simpler task. In agriculture and mining, gross output could be measured in physical product terms and then converted to values by multiplying by unit prices. For those industries defined as "activities," gross output was measured as either gross receipts or margins. In these cases also, activity meant "activity wherever performed" and secondary activities were excluded; however, only rarely were the secondary activities "transferred out," as was done in the case of secondary products. By definition the activity was simply that of rendering some productive service.

The Bureau of Labor Statistics had a choice between measuring transactions in purchasers' prices or in producers' prices. The methodological issues involved in choosing one of them have been described elsewhere.[18] In the 1947 study, the gross transactions between industrial sectors are expressed in producers' prices. This has the virtue of counting the "spread items" (difference between purchasers' and producers' price) only once. The "spread items," which represent margins on sales for distributive functions, are allocated to the appropriate trade and service industries. Thus, the margins are an effective measure of the productive activity of these industries. The Bureau of Labor Statistics had to decide a method for allocating these margins to the appropriate sales figures. At times, information on specific costs, such as transportation charges, could be used, but in general (except for broad trade categories) the total spread items were allocated to sales proportionately to value. If a sale to industry 1 was twice that to industry 2, the allocation of margins to 1 (i.e. purchases by 1 from trade and service industries) was twice that for 2.

The basic document in the preparation of the gross transactions table is the industry report. There are several logical steps in the preparation of these reports: (1) securing measures of gross output and of gross input for the industry; (2) on the basis of readily available control totals (e.g. cost of materials as published in the *Census of Manufactures*), getting a preliminary allocation of gross output and gross input among broad categories in the table, such as distinguishing between shipments to final demand and to the processing sectors; (3) using any available published statistics, unpublished statistics of Federal or private agencies, or judgment of experts, completing the allocation of inputs and outputs by individual industries; (4) "peeling off" the marketing charges for each cell so

[18] Evans and Hoffenberg, in this volume.

as to get the value of the spread between purchasers' and producers' values (the marketing charges include rail, air, water, truck, and pipeline transportation, warehousing and storage, retail and wholesale trade margins, and excise taxes); (5) finally, reconciling the distributions for this industry with those calculated for the other industries.

The first step was to get an estimate of gross output for the industry. In the manufacturing industries the analysts could start with the shipment figures from the *Census of Manufactures*, but shipments had to be adjusted for inventory changes of the finished product in order to arrive at a gross output figure. If inventories of finished products increased during the year, shipments would be less than gross output, and an adjustment would have to be made accordingly. Estimates were also made of secondary product transfers from other industries and of competitive imports. For the transportation industries, regulatory agencies such as the Interstate Commerce Commission collect information on operating revenues, which, after minor adjustments, were taken as the measure of gross output. For other industries, notably trade, figures representing 1947 gross margins were unavailable, and it became necessary to build up a measure of gross output starting with sales data from the *Census of Business: 1948* and to apply to them control margin rates by type of business derived from a variety of sources, including the *Statistics of Income.*

Even in those cases for which a census figure was available as a starting point, modifications had to be made in the data.[19] Manufacturing operations carried on by retail or wholesale trade establishments were added to the output of the appropriate manufacturing industry. This particularly affected the food processing industries. Government manufacturing operations similar to commercial industries (such as the Government Printing Office) were lumped with the latter. Finally, some adjustment had to be made for industries not covered by the censuses. Logging was not included in the *Census of Manufactures*, and its output had to be estimated separately and incorporated in the study.

Once the gross output and gross input figures were fixed, the next step was to allocate inputs and outputs by specific industries. Two approaches were available here. The gross transactions table might

[19] Philip M. Ritz and Harry Schulman, "Industry Reports: Manufacturing Methodology." *The 1947 Interindustry Relations Study*, Bureau of Labor Statistics Report 10, March 1953.

have been built up row by row by a commodity flow or marketing analysis; or the table might have been built up by attention to the input or cost structure of the industries. Actually, both of these were used since they provided checks upon each other. Usually the analyst could start with an estimate of the cost of materials, supplies, fuels, etc., from one of the censuses, ICC reports, etc. In the mining industries it was necessary to get an estimate of total cost of materials by applying the ratio between total cost and value of output, as determined from the *Census of Mineral Industries: 1939*, to the value of output for 1947; however, some more recent data were usually available. Since, in many instances, the gross output figures for the industry had been augmented by government manufacturing operations or manufacturing operations carried on in trade establishments, the cost-of-materials figure had to be increased to reflect these additions to output. Usually the individual inputs were increased in the same proportion by which output had been increased. This assumes, of course, that the input structures are the same for both parts.

In final form each industry report is made up of at least three tables.[20] The tables summarize all the information on distributions of inputs and outputs, values of products shipped (in both producers' and purchasers' prices), values of spread items, transfers-out, and internal reconciliation of these items for the industry. Table I is a summary of transactions; it is the "balance sheet" for the industry report. On the one side appears the detail on total inputs to the industry (cost of materials and nonmaterial charges) and transfers-in by industry. The sum of these is gross input. On the output side are total production by the primary industry, including direct allocations, transfers-out of secondary products, and inventory changes in finished products. These items plus transfers-in (which are counted as part of output) add to gross output. The two sides of the account balance.

Table II is on inputs to the primary industry. The inputs are listed by industry and, wherever possible, physical quantities are preserved together with the producers' and purchasers' prices. Table III is the distribution of outputs. Total primary product shipments plus marketing charges add to one control total. These shipments are then allocated to final demand and processing sectors. In special

[20] Philip M. Ritz and Gabriel G. Rudney, "Industry Reports: General Explanation," *The 1947 Interindustry Relations Study*, Bureau of Labor Statistics Report 9, March 1953.

sections of the table the distributions of miscellaneous receipts and transfers-out are shown.

Each of the tables is bulwarked by references to the sources from which the data were derived, so that the industry reports are a complete report on the transactions in which the industry has engaged. Aside from their obvious applications to transaction tables of an interindustry study, the reports are valuable basic documents for other types of economic research.

The major contribution of the industry reports is perhaps in bringing together all the diverse statistical sources, expert opinions, etc., which bear upon the specific details of the distribution patterns for inputs and outputs. By the very nature of the problems, standardized methods of analysis were inapplicable. The extent and depth of the data varied from one industry to the next; and the extent of "patching" that had to be done varied accordingly. It is impossible to present a cross section of the sources used for all industries in the model, but some idea of their variety may be realized from a review of those used for the manufacturing industries.[21]

The *Census of Manufactures: 1947* was the single most important source of information. From it information on the consumption of fuels and purchased electric energy was obtained in sufficient detail to identify these specific fuel components; consumption data for certain metal mill shapes and forms and for rough and semifinished castings were also obtained. The latter information provided important inputs for the metal-consuming industries. The product detail in the census was very useful in distributing both inputs and outputs, but a number of gaps still remained.

The census publication *Facts for Industry* supplemented the census information and provided specific information on distributions of output for certain industries. Studies prepared by the Bureau of Agricultural Economics were invaluable in making estimates of inputs of agricultural commodities to the food processing industries, and the *Minerals Yearbook* provided similar information for the mineral processing industries.

Two special surveys provided inputs to the major metalworking industries and to the glass industries. For the Munitions Board the Bureau of the Census sampled approximately 1,700 metalworking establishments to get consumption of materials and supplies. A second special survey by the Bureau of the Census for the Bureau of

[21] Jack Alterman and Morris R. Goldman, "Manufacturing," in the supplement to this volume, as cited.

Labor Statistics obtained similar information from 77 plants in the glass industries. Together, these two surveys furnished the bulk of the information on inputs in these two major areas.

A simple listing of other sources used will convey some idea of the coverage of the data: Tariff Commission reports, "Summaries of Tariff Information" and "Synthetic Organic Chemicals," for information on commodity imports and the production of synthetic organic chemicals; the Forest Service, Department of Agriculture, report, "Wood Used in Manufacturing," on wood inputs; trade publications, such as the *Yearbook of the American Bureau of Metal Statistics*, *Petroleum Facts and Figures*, etc., for output and input information in those specific industries; engineering and chemical process handbooks for technical information on flows.

The story of data uses and sources is the same for all industries. Entries were made in the cells only after what may be accurately described as an exhaustive search of sources. Even so, gaps did appear and judgment had to be applied to the distributions. In the final analysis the industry reports had to be checked one against the other to reconcile the estimates. In the case of major discrepancies the data were resurveyed, expert opinions were solicited, and a final adjustment was made.

Three "dummy" industries are among those industries listed in the original compilation of the 1947 transactions study. They are: "waste products—metal," "waste products—nonmetal," and "stock pile of by-products." The sale of a specified important by-product was allocated directly to the by-products column rather than distributed to purchasers in the same manner as other products. These by-products included hides, cottonseed, coke oven gas, and others. Sales of these products are auxiliary to the main productive activity of the industry, so that in computing input coefficients these industries were eliminated. There is good reason for not including the distribution of these products in the structure represented by the input coefficients. To take the classic economic example of joint products—hides and meat—an increased demand for shoes in the model would generate larger requirements for meat animals and meat packing, if the coefficients included the distribution of hides. Increased scrap requirements by steel would generate a still larger output of steel, and so forth.

Since this type of stimulus is essentially unrealistic, the industries were eliminated; however, it was still necessary to account for the output of these industries. The procedure adopted was to add to intraindustry sales (the diagonal cells) the amounts of by-products produced by each industry. The value of hides was added to the intraindustry entry for meat animals. By doing this the 1947 proportions of by-products to principal products of the industry were frozen into the structural relationships. Then, for the generated output of meat animals associated with a given bill of goods, the value of hides can be easily calculated by using the 1947 proportions. At the same time the determination of output levels is not affected by the by-product adjustments.

In interpreting the industry reports, differences of opinion can of course arise over the judgment applied to a particular case, the credibility of statistical material, or the handling of a conceptual problem. Attacks on the credibility of statistical materials frequently boil down to differences in definitions of the quantities or values measured. Where more than one source was available, more than one was used. If, on the one hand, some zero cells ought actually to contain a small entry, it can be demonstrated, on the other hand, that within limits these errors do not materially affect the results. The Bureau of Labor Statistics has started the publication of the industry reports, and the interested reader can check these procedures for himself.

2. THE FINAL DEMAND SECTORS

In an open interindustry model, the final demand sectors are those that are estimated autonomously or independently of the processing sectors. As indicated in the first section of this paper, there need be no hard and fast distinction between final demand sectors and processing sectors. Accounts may be moved out of the former and into the latter if it is felt that their behavior can be adequately represented by a set of fixed input coefficients. These are movements in the direction of "closing" the model since fewer of the accounts are stipulated autonomously. Similarly, parts of the processing sectors may be transferred to the final demand sectors, as was done in the case of the energy industries.

A full discussion of the final demand sectors in the 190-industry model should distinguish between the construction of the 1947 figures and those forecast for future years as part of the analytical use of the model. For 1947 the Bureau of Labor Statistics was faced with the problem of deriving detailed industry figures that in sum could be checked against totals supplied by the (historical) national income statistics. For future years the GNP and all of its components had to be estimated, after which the details were derived. In making the forecasts of GNP and components for future periods, work of the Council of Economic Advisers was available, but these estimates were modified somewhat in the light of special information on relationships among categories of expenditure that had been developed by the interindustry working groups.

Conceptually, the final demand sectors in the interindustry model are similar to those in the gross national product accounts, but in practice, some transactions that cannot be considered as final consumption have been charged to final demand sectors in the interindustry model; therefore, the scope of the final product in the model is broader than the gross national product.[22] If an attempt is made to approximate GNP from the final demand sectors, by summing consumption plus investment plus government expenditures, the resulting figure will be larger than the actual GNP by the amount of these extra transactions. Nevertheless, the national income accounts furnish the starting point for constructing final demand in the model. The breakdowns of consumption and investment expenditures furnish control totals for the individual industry figures; for example, the value of consumer durable goods is a control on the individual industry shipments of these products to consumers. At a final stage of the work, the National Income Division and the Bureau of Labor Statistics cooperated on a statistical reconciliation of the charges against the household and investment sectors as carried in the two kinds of accounts. In estimating final demands (both civilian and military) for future periods, the control totals were especially important in the investment and consumption (or households) sectors.

The household column in the 1947 study followed many of the national income strictures on the measurement of consumption expenditures. Basically, the column shows allocations for personal consumption plus personal taxes. The imputed cost of food produced and consumed by farm families is included, as are imputed rents. However, maintenance construction on residences is charged to the rental "industry" and not to households. As in the national income accounts, the purchase of new residential construction is considered

[22] Sidney A. Jaffe, "Final Demand Sectors," and Sydney S. Netreba, "The Bill of Goods for Interindustry Analysis," in the supplement to this volume, as cited.

as part of investment and not as consumption expenditure. Likewise, 30 per cent of new passenger cars privately acquired were assumed to be purchased for business use and were allocated to the investment account rather than to households.

Some of the charges made to the household sector would normally not be accounted as final consumption. Business travel expense is one such expenditure; although partly incurred in the course of business activities, for purposes of interindustry analysis all business travel expenses have been charged against households. Furthermore, the entire output of hotels, eating and drinking places, and banking and life insurance was allocated to households. Undoubtedly, some of the output of these industries is purchased by industry as a business service, and hence should be considered as an intermediate product. However, the allocation adopted does little violence to requirements estimates, since the major element of cost in these industries is wages and salaries, with only small requirements for material inputs; therefore, there will not be any substantial underestimation of materials by allocating all of the output of these industries to the household sector.

In an interindustry model the whole complex of financial industries, such as banking, insurance, etc., poses special problems. If, as is true of an interindustry study, it is "real" output levels that are to be measured, the inclusion of the output of financial industries in the structure is actually anomalous. Changes in their output (measured as receipts) reflect changes in the velocity of money and not necessarily changes in "real" output for the economy. Although they are an integral part of the structure of payments in the economy, they may possibly be omitted from the structure of output and employment. The procedure of having them sell all their output to households is really a recognition of this fact.

In the 1947 study, the household row includes more than direct payments to households for productive activities. The factor payments of wages, interest, rent, and profits might be shown separately; actually, rent is shown as a payment to a fictitious rental industry, which is defined on functional, rather than conventional, grounds. The household row actually includes wages and salaries, interest, entrepreneurial income, and corporate profits (after taxes), plus some minor items. Conceptually, these factor payments might have been allocated differently. Essentially, the logic behind this allocation is that ultimately these are claims of individuals. This does not obscure the fact that the immediate disposition of them may be different from the ultimate disposition. Corporate profits may be retained or paid out as dividends. The impact on expenditure patterns will be different depending on the distribution of profits between these two. The same sort of analysis applies to interest and entrepreneurial incomes, and to certain of the other factor payments included in the household row.

There are, in addition, some nonfactor payments included in the household row. The most significant of these are capital consumption allowances (depreciation) and transfer payments. There is little question of the propriety of allocating transfer payments directly to households; they are normally so paid. There is much less reason for including capital consumption allowances in the household row.

As a matter of fact, the household row is a conglomerate of all the so-called "value added" payments, with the exception of payments to foreign trade. As a very rough first approximation, this lumping of payments in the household row may be acceptable. Estimates were available on each of the component payments, which were ultimately lumped together; however, it is apparent that this is not one of the strongest areas of the interindustry model, not because of a deficiency in measurement and data, but because interindustry models are as yet weak theoretically in these areas. If there is to be an attempt to formulate reasonable hypotheses for a theory of income distribution and expenditure, for a theory of investment, or for price analyses, better means must be found to account for these payments. While the total figure in any cell in the household row may adequately measure the amount available for distribution to claimants, it would not be maintained that individual payments, such as profits or interest, are structurally related to output levels by any fixed coefficient. There are logical methods by which labor inputs can be incorporated in the model, but other factor payments are at present only allocable in total.[23]

In the household sector of the model, it would appear most natural to estimate consumer expenditures by reference to some consumption function. In simple econometric models, a single consumption function usually suffices. In the interindustry model, consumption functions were used in estimating household expenditures for 1951-1954. Based upon the experience of 1929-1939, 46 to 50 consumption

[23] See Frederick T. Moore and J. Petersen, "An Interindustry Model of Utah," Bureau of Mines, June 1953.

functions were derived for 8 different groups of consumer durable goods, for 5 groups of consumer nondurables, and for services. Each consumption function represents a correlation of expenditures for one major group with several behavior-determining variables; the consumption function for clothing and footwear contains, as independent variables: per capita disposable personal income; the Bureau of Labor Statistics apparel price index as a per cent of the cost-of-living index; consumer expenditures for durables; and population sixty years of age or older as a per cent of total civilian population.[24] Similar consumption functions were derived for each of the other major groups of products. In using the consumption functions for making estimates of consumption in future periods, adjustments were made for products that would probably be in short supply in the projected period.

After consumption expenditures for each major group of products were estimated, expenditures for individual products within the group were based upon percentage distributions derived from historical experience. It should be noticed that the use of these fixed percentage distributions tends to make the estimates for one period a scalar multiple of the estimates for another period; thus, the shifts among products incident to a change in income may not be adequately represented in the estimates that have been made. Intensive work is being undertaken currently in the Bureau of Labor Statistics and at Harvard University to improve this area.

The investment sector of final demand includes separate accounts for producers' durable equipment, construction, and inventory changes, plus an additional category of miscellaneous charges to capital formation that was necessary in order to account for special categories of charges.

The work done on the construction account is an excellent example of the contribution interindustry economics has made so far to current statistics. For 1947 the official Department of Commerce–Department of Labor series on new construction combined with the Department of Commerce series on maintenance and repair showed total construction expenditures of $24.8 billion. For most purposes, including national income accounting, the official series has been accepted without question. Yet analysis of the construction account turned up a number of serious deficiencies; in several cases the

[24] Beatrice Vaccara, "Estimates of Consumer Expenditures for the Emergency Model," Bureau of Labor Statistics, Unpublished Memorandum, Jan. 21, 1952.

official series seriously understated actual expenditures. In one account, private industrial building, the official estimate had to be raised because the basic data had not been adjusted sufficiently to compensate fully for undercoverage of projects, understatement of valuations, omission of architectural and engineering fees, and omission of "force account" operations.[25] Deficiencies of like kind were turned up in other subcategories of construction. The effect of the corrections made in the construction account was to raise the total by almost $4 billion. Of greater importance is the fact that the deficiencies in the original estimating procedures and sources of data have been brought to the attention of others and a number of improvements have been introduced.

In the original compilation of the account, 50 subcategories of construction were distinguished; in later analyses, these were condensed into 26 categories. In terms of the single construction account, the distribution of inputs adds to the value put in place during the year; in the 1947 study, new construction as a category was distinguished from maintenance construction, and input patterns were presented for both. In the distribution of outputs, maintenance construction, which is current expense, was charged directly to each of the consuming industries; new construction, which is a capital account expenditure, was allocated directly to the investment sector and to the two government sectors.

The producers' durable account posed one of the more difficult problems. Some "equipment" appears in the construction account, and in many such cases it is difficult to determine the proper allocation among accounts of different kinds of equipment. It is dangerous, for example, to rely too heavily upon the "character" of the product, since in one industry the product may be considered a current item and in another a capital item; in most industries wire is accounted a current expense item, but in the telephone industry it appears as a capital item. In the 1947 study, the inputs to the producers' durable account were essentially determined by commodity-flow analysis by type of product. Department of Commerce statistics on the shipments of producers' durable equipment by commodity group were helpful. These were supplemented by special surveys of the metal-consuming industries and of the telephone industry.

If all transactions in the economy in 1947 were to be summarized in tabular form, capital transactions would have been measured

[25] David I. Siskind, "Construction," in the supplement to this volume, as cited.

along with current transactions. A capital transactions matrix would supplement the flow transactions matrix. The Bureau of Labor Statistics aggregated all capital transactions into one sector, however, which was determined by the aforementioned analysis of the shipments of capital goods industries and by a corresponding analysis of expenditures on plant and equipment in 1947.

In making estimates of producers' durable equipment for future periods, a number of improvements have been introduced. Replacement investment has been distinguished from new or net investment and a separate estimate made of it for each industry individually. The estimates of replacement investment are essentially based upon the capital coefficients for each industry and the "useful life" of different types of equipment as determined from the Bureau of Internal Revenue *Bulletin F*. Net investment in producers' durables, in specific industries such as steel, aluminum, copper, petroleum, railroads, and electric power, has been determined by applying the programed increases in capacity to their respective capital coefficient structures, thus deriving requirements for specific types of equipment.

Although the producers' durable account in the 1947 study is represented by a single column vector, for future models it would be most useful to have a matrix of capital flows to match the matrix of current flows. By doing so, the actual capital transactions among industries would be pinpointed for more careful analysis. As a digression, it should be remarked that only the capital *flows* are of interest; the *coefficients* to be derived from such a table would be relatively meaningless, since they would not necessarily represent the unit capital requirements of the industry resulting from a given increase in demand. On a technical level, a matrix of capital flows, unlike a matrix of current flows, could not be expected to balance.

In the gross transactions table for 1947, the inventory sector provides the balancing item between production and consumption. If production was greater than consumption for an industry in 1947, the balancing item is an addition to inventory. Inventory changes have also been distinguished to show those occurring in the producing sector and those in all other sectors. A further qualification is that the changes refer only to finished goods and not to goods in process.

In the model, inventory changes are carried in four columns. Two show either additions to, or depletions of, finished product by the primary producing industry. Since these figures are on a net basis, an entry appears in one of the columns but not in both; however, for the other sectors inventory changes have not been netted out, so that both additions to and depletions of the product may have occurred. The total change in inventories in a given industry is the algebraic sum of the entries in the four columns.[26]

In the operational use of the model for some problem-solving purposes, inventories have been handled in quite a different fashion. No specific predictions of inventory behavior as a final demand account have been made; in an attempt to get a partially dynamic model, input lead times have been associated with each of the coefficients. As described in the first section of this paper, the input lead times are reciprocals of the inventory turnover period, and represent the average amount of time that goods spend in inventory before emerging in production. The use of these fixed input lead times means that inventories are uniquely related to output levels in the model. This is, no doubt, an unsatisfactory treatment of the problem; some of the more realistic alternatives have already been briefly described. In current work, additions to or depletions of inventory are being specifically included in final demand.

Since inputs and outputs are not purely domestic in origin or destination, the interindustry model includes a foreign trade sector, which appears in final demand. Allocations of products to the foreign trade column represent exports; imports appear as purchases from the foreign trade row. This account includes not only material goods but also "invisible items." The net expenditures of United States citizens abroad appear as purchases by the household sector from the foreign trade sector. Net remittances to foreign countries, and operations of private relief organizations and United States business branches abroad, are treated in the same manner. Since all imports, with a few exceptions, such as coffee, tea, cocoa, and jute, were considered to be "competitive" with domestically produced products, all such imports are allocated directly to the domestic industries that produce the product and are distributed as output through these industries.

Import and export statistics on a detailed commodity basis were compiled from Bureau of Census information. In these tabulations approximately 3,000 commodities were included on exports, and approximately 5,000 on imports.[27] These had to be allocated to the

[26] Ritz and Rudney, "General Explanations of the 200 Sector Tables," as cited.

[27] See Netreba, *op. cit.*, and Philip M. Ritz and Murray Weitzman, "Foreign Trade in the 1947 Interindustry Study," in the supplement to this volume, as cited.

appropriate producing industries, foreign and domestic port value; transportation and miscellaneous shipping charges determined; and the resulting values posted to the appropriate accounts. Although both these commodity accounts and the "invisible items" were included in the foreign trade sector, there was no attempt to approximate a balance of payments. Capital movements and flows of gold were excluded from the account.

In the government sector, there was some difficulty in sticking to a current account basis in making the estimates. On the whole, however, the handling of this sector in the interindustry model is consistent with the national income accounts. As noted previously, those operations of government that are similar to private industry have been combined with their private counterparts; for example, the RFC tin and rubber plants and the Government Printing Office were combined with the respective private industries. The interpretation of the government rows and columns is fairly straightforward. The rows represent total revenues of the governmental units. The columns show government outlays for goods and services including new construction.

Two of the more interesting problems arising in the government sector are the incidence of taxes and the handling of transfer payments. Excise taxes are treated as part of the spread between purchasers' and producers' prices. With a few important exceptions (notably that excise taxes need not be paid on goods for export), these taxes are allocated proportionally to the size of the transactions. Since excise taxes are normally charged on the manufacture or sale of a product, the method of handling them in the model corresponds with normal practice; however, the incidence of the tax is assumed to be on the initial purchaser, since, if the product is incorporated as part of another product, it is not possible in the model to trace the shift of the excise tax on the original product to a later purchaser. General sales taxes are charged directly to households, and all other taxes are charged directly to the industries responsible for payment. In general, in an interindustry model a shift in the tax to the first purchaser can be shown, but any further shifts are lost.[28]

Transfer payments are handled in several different ways in the model. Interest on the national debt appears in the form of a transfer payment from the government sector to households. Shipbuilding

[28] Irving H. Licht, "Government," in the supplement to this volume, as cited.

subsidies and some of the agricultural subsidies affect the market price of the commodities to which they apply; the portion of the value of output represented by the subsidy is treated as a purchase by government. Municipal railroad deficits appear as a negative input from government to that industry. Similar adjustments have been made for certain other types of transfer payments.

As a final word on these sectors, one point might be emphasized. Final product in the interindustry sense does not match exactly the national income definition. A reconciliation of the two approaches has been made, however. The GNP derived from the final demand sectors in the 1947 model will be found to be higher than the Department of Commerce estimate. This may be explained in part by undercoverage of the official series, as in construction, but the difference is also due to conceptual dissimilarities in the handling of specific items of expenditure. If it were desirable to do so, the GNP in the interindustry model could be reduced to conform to the Department of Commerce estimate.