a different way to nuclear physics. The differences between this group and the more familiar SU(2) are pointed out and their physical implications discussed. In such a small book, certain subjects must inevitably be omitted. In some cases, like the Lorentz group, this omission is regrettable.

In this type of presentation, there is usually the danger of sacrificing rigor and detail. It is gratifying that this is not the case in Lipkin's book. Although intended as an elementary text, *Lie Groups for Pedestrians* succeeds in imparting not only relevant facts but much of the spirit of this field of physics, and the book should be very useful to graduate students, experimental physicists, and "pedestrian" theoreticians.

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Analyzing an Industrial Economy

Input-Output Economics. WASSILY LEONTIEF. Oxford University Press, New York, 1966. 269 pp., illus. \$8.50.

It is appropriate that in his 60th year Wassily Leontief be honored by the publication of two volumes of his essays of the past 30 years. The 11-article volume reviewed here covers only one facet of his broad interests, input-output analysis.

The notion of relating, on a systemwide basis, the inputs and products of national economic activity did not originate with Leontief. The French physiocrats, headed by Quesnay, made ample use of many of the same ideas in the mid-18th century, formulating the *tableaux économiques*. In the next century, these concepts were rigorously stated in mathematical form and developed further by the Swiss Léon Walras (in *Eléments d'économie politique pure*, Lausanne, 1874). Also, important contributions to the subject were made by Russian mathematicians early in this century. But it was Leontief (himself a Russian by birth and now Henry Lee Professor of Economics at Harvard) who brought the ideas to the point of empirical fruition.

Basically, the concepts involved are extremely simple (these are expounded in three somewhat repetitive essays in the present volume, numbers 2, 7, and 8). Let superscript 58 represent constant 1958 dollars, and let F be an n-component vector of industry final demands, S an n-component column vector of gross industry outputs, $A = n \times n$ matrix of input-output coefficients whose elements a_{ij} denote the constant dollars of output of industry i required to produce a constant dollar of gross output of industry j, and I the identity matrix. Then the fundamental input-output relation in matrix notation is

$$F^{58} = (I - A)S^{58}. \qquad (1)$$

In single-equation notation, for the first industry, this is equivalent to:

$$f_1^{58} = (1 - a_{11})s_1^{58} - a_{12}\,s_2^{58} - \ldots - a_{1n}\,s_n^{58}$$

In other words, the amount delivered to final demand by the first industry is its total gross output less the amounts delivered to all industries (including itself) for use as production inputs.

Thus, to undertake input-output analysis, one needs two vectors, industry output and sales to final demand, plus a matrix (A) of technological relationships. Such data have now been compiled for the United States for 1939, 1947, 1958, and 1964. They have also been constructed for many other countries for various years. The accuracy and detail of these efforts, of course, varies greatly. For example, the 1947 U.S. input-output table has 451 industries and the 1958 table has only 86. The latter is completely consistent with the official income and product accounts, the former is not.

Also, owing to input-output conventions, industry final demand is not the same as final expenditures (consumption, investment, and so forth) in the national income and product accounts. For example, the sale of an automobile generates final demands for the manufacturing, transportation, and trade sectors. Therefore an additional translator is needed. Let G be an m-component vector of gross-national-product (GNP) component expenditures, B an $n \times m$ constant matrix of parameters where b_{ik} denotes the constant dollars of final demand required from industry i to produce a constant dollar of GNP-component expenditure k. Then

$$F^{58} = BG^{58}. \qquad (2)$$

Substituting Eq. 2 into Eq. 1 we find

$$BG^{58} = (I-A)S^{58} \qquad (3)$$

or

$$S^{58} = (I-A)^{-1}\,BG^{58}. \qquad (4)$$

This yields the amount of constant-dollar gross output directly and indirectly required from every industry, given a vector of constant-dollar GNP-component demands. The usefulness of the technique for business forecasting purposes therefore should be evident.

The relationship may, of course, be differentiated with respect to any GNP demand (defense expenditures, for example) to indicate additional output requirements from any industry. That is,

$$\partial S_i^{58}/\partial G_k^{58} = \sum_{j=1}^{n} (I-A)_{ij}^{-1}\;B_{jk}.$$

This is the kind of game that was played during World War II and in Leontief's consideration of the economic effects of disarmament (essay 9). If the national A and B matrices are segmented to reflect regional technologies and output distributions, then the impact of an arms cut can be ascertained on an industry and area basis (essay 10). (Actually, Leontief augments the matrices so as to describe flows: nationally; from local to national industries; from national to local sectors; and within local industries.)

It is also the kind of game that can be, and is, played for much present-day development planning. Given desired consumption and investment goals, a country can determine what industries it needs to develop in order to achieve its objectives. In fact, one measure of the degree of development is the density of the A matrix (essay 4). For the United States, the matrix has positive entries in nearly every cell; for the less-developed nations it is sparse, with mostly zero entries.

Thus far, we have talked only of industry output requirements. It is also possible to take account of labor and capital requirements. Let L be an $n \times n$ diagonal matrix of industry units of labor (say workers) per constant dollar of gross output and E be an n-component column vector of industry labor requirements. Then

$$E = LS^{58} = L(I-A)^{-1} BG^{58}. \quad (5)$$

Obviously this computation can also be performed by type of labor requirement, in which case L becomes a series of diagonal matrices and E (with some additional manipulation) is an $n \times p$ matrix showing the demand by industry for p labor types. Let C be an $n \times n$ diagonal matrix of industry marginal capital requirements per constant dollar of gross output, D an $n \times n$ diagonal matrix of industry average capital requirements per constant dollar of gross output, and K^* an n-component column vector of industry equilibrium capital requirements. Then

$$K^* = [(D-C) + C]S^{58} = [(D-C) + C](I-A)^{-1} BG^{58}. \quad (6)$$

Again, this computation may be performed by type of requirement. If it is assumed that the capital-requirements function is linear or that the change in final demand from some initial position is small, then the additional investment required is

$$K^* - K_o^* = C(S^{58} - S_o^{58}) = C(I-A)^{-1} B(G^{58} - G_o^{58}). \quad (7)$$

Any positive or negative actual less equilibrium discrepancy ($K_0 - K_0^*$) in the initial capital stock would, of course, also have to be added.

Applying these equations to U.S. data for 1947 leads Leontief to perhaps his most important, interesting, and controversial finding (essays 5 and 6). Others have dubbed it the "Leontief paradox." He finds that the U.S. is a labor-surplus, capital-shortage nation in that its *competitive* imports (machinery, packaged foods, and the like—minerals, coffee, and so on are *noncompetitive* imports) have a higher relative capital content, judged by U.S. technology, than its exports. This means that an increase in the supply of capital would tend to reduce, and alternatively a rise in the supply of labor to expand, the volume of foreign trade. Many reasons, of course, have been offered to explain why the U.S., with the greatest capital stock per employee of any nation, should be in this position. Leontief avers that it is due to the extremely high productivity of American labor. For another analyst, it is due to labor-protective tariffs on U.S. exports. But the true reason probably is a greater relative surplus of overseas labor. This makes it profitable to substitute foreign labor for foreign capital in processes that by U.S. standards are highly capital-intensive. For example, the manufacture and assembly of watch mechanisms overseas is done mostly by hand; domestically, more of the process is automated. In other words, the technologies employed are different.

Finally, the last variant of input-output techniques expounded in this volume concerns itself with prices and their components, wages, profits, taxes, and so on (essay 3). This enables one to analyze inflationary effects. Let P_F be an n-component column vector of industry final-demand price indexes, $1958 = 1.0$. Now, multiply both sides of Eq. 3 by P'_F (the transpose of P_F, that is, a row vector):

$$P'_F\, BG^{58} = P'_F\, (I-A)S^{58}. \quad (8)$$

But, the sum of columns of B must be 1, since a dollar of real GNP-component expenditures must result in a total of a dollar of real final demand:

$$\sum_m G^{58} = \sum_n F^{58}.$$

That is, the columns of B are also appropriate weights for combining industry final-demand price indexes into GNP-component price indexes, P_G (an m-component column vector). Then,

$$P'_F\, B = P'_G. \quad (9)$$

Therefore, if Eq. 9 is substituted into Eq. 8,

$$P'_G\, G^{58} = P'_F\, (I-A)S^{58}. \quad (10)$$

Now, it is fruitful to expand the industry price terms into their various elements. Three additional definitions are needed. Let Z be an n-component column vector of industry profits in current dollars per constant dollar of gross output, M an n-component column vector of industry value added other than profits and labor compensation in current dollars per constant dollar of gross output, and W an n-component column vector of industry labor-compensation costs in current dollars per unit of labor. Therefore

$$Z' = P'_F - P'_F A - M' - W' L. \quad (11)$$

This says that an industry's profits are the residual of price less the cost of inputs from other industries less other value-added items such as taxes and capital consumption allowances, less labor compensation—all per constant dollar of gross output. (Multiplying by output, S^{58}, of course yields total amounts.)

Equation 11 can be solved for industry prices:

$$P'_F = (Z' + M' + W' L)\, (I-A)^{-1}. \quad (12)$$

Equation 12 indicates that an industry's price depends on unit value added in its own and all other industries. This relationship may, of course, be differentiated to get the change in any price with respect to a change in any value added. The latter may come about either through a shift in its price (for example, hourly wage rates, W) or its real quantity (say, manhours, L) per constant dollar of gross output.

The next step is to substitute Eq. 12 into Eqs. 9 and 10. This yields the prices of GNP components as a function of industry unit value added:

$$P'_G = (Z' + M' + W' L)\, (I-A)^{-1} B, \quad (13)$$

and current dollar GNP as a function of unit value added and constant dollar gross output,

$$P'_G\, G^{58} = (Z' + M' + W' L)S^{58}. \quad (14)$$

That is, the impact on the price of any good or service and total current dollar GNP of an increase in industry wage rates or profits is given by Eqs. 13 and 14.

Other useful permutations of input-output analysis can also be developed. These include, first of all, using different A and B matrices for each year so as to reflect the impact of technological changes. Projections of the coefficients of the matrices would counter the objections of critics of the system who say that it must always be out of date because it takes several years to compile the actual data. Such tables have now been forecast for the U.S. through 1970 and form the basis for Department of Labor estimates of 1970 industry output and employment.

Next, the analysis can be made dynamic to reflect production lead times and the availability of beginning-of-period inventories. Such a model is presently being used by the Office of Emergency Planning to program mobilization of resources in the event of destruction of U.S. cities and factories by nuclear attack.

There is a difficulty with input-output analysis, however, that has not been met. Technically speaking, the technique only provides a zero-order approximation to the structure of the economy. It says, in essence, that all factors of production must be used in fixed proportions; there is no continuous substitution between capital and labor as a result of shifting input prices and changing technology. Nevertheless, for many purposes, input-output is the best initial approximation of the structure of industry (taken as whole) currently available. Leontief has devoted a lifetime to the technique. Its wide adoption in the United States and abroad speaks for itself as a measure of his achievement.

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Old Hats in the Technology Gap

The Integration of Technologies. LESLIE HOLLIDAY, Ed. Hutchinson, London, 1966. 167 pp., illus. 30s.

If there is such a thing as a "technology gap" between Britain and the United States, this book helps explain (unintentionally) why such a gap might exist. Nearly every chapter provides evidence of the backwardness of British technological education and practice as compared with American, of British social attitudes which militate against the exploitation of a scientific technology, and of a tendency to follow behind American leadership in new methodologies and in approaches to scientific-technological problems.

The occasion for this volume is an essay competition, sponsored by Shell Chemical Company in collaboration with the British Association for the Advancement of Science, on the central theme of linking individual technologies together to provide a common body of theory and techniques which might be applied to diverse industrial problems. The essay contest was instituted in 1965, to run for seven years, and the book presents a selection of the entries already submitted, plus several other essays bearing on the same theme. The hope of the sponsors is that publication of these examples will stimulate interest in the problem of the integration of technologies.

None of the authors represented in this collection doubts that there is a problem, namely, that the various technologies have become too specialized and that this overspecialization is preventing technological progress. The basic assumption of the essay contest is that the narrow specialization of the technologies must be overcome by searching for some common threads among them. The only essayist who deals with this basic assumption is Stephen Toulmin, whose stimulating essay "Science and our intellectual tradition" attempts to trace historically the trends toward specialization and the more recent trends toward re-integration of the sciences. Although he does not frame his argument in terms which are relevant to the essay contest, he does raise questions regarding the nature of our scientific knowledge and its technological application. He claims that the change from Athenian (speculative) to Alexandrian (technological) emphases in science involved a failure of intellectual nerve, which prevented Greek science from becoming modern science until "Ionian confidence" was revived in the 17th century. This begs the question of whether the Athenians could have gone farther on pure speculation, and it denigrates what most historians regard as the great achievements of Greek science which occurred during the Hellenistic period. Is it really true, as he asserts, that the mainspring of scientific progress has been philosophical? And if this is so, why does he downgrade our contemporary space science? Insofar as it is a scientific rather than a political or military effort, it has its *raison d'être* in attempting to answer those major questions to which Toulmin thinks all science should address itself.

Most of the 15 essays are written by engineers, and they show the inferiority complex which British engineers feel before "pure" scientists and humanists. There is almost a whining quality about their essays, which deplore the snobbish attitude of the scientists and humanists toward the technologist, the lack of support for technological education in Britain, and the inability of engineers to make themselves effectively heard in Britain. The solutions offered for these problems and for the overspecialization of technologies are likely to seem truisms or naive or "old hat" to most American scientists and engineers.

More than one author points out the importance of education in integrating the technologies. What kind of education? One in engineering fundamentals, which resembles closely the engineering science curriculum introduced in many leading American institutions of technology almost a decade ago.

To some of the essayists, it is the communications problem that is foremost. Alex L. Marshall (Chapter 7) stresses the need for simplicity of language to allow communication between technologies, and his positive suggestion is a technological newspaper—"A bulletin which is easily assimilated . . . no article longer than 500 words, journalese, headlines even" (a technological *Reader's Digest* perhaps?). Edward Manougian (chapter 10) pleads for a common language for the technologies, and, not surprisingly, he finds this in what is already a common language for scientists and technologists, namely, mathematics.

Leslie Walter Boxer (chapter 3) calls for a team approach, but he is contradicted by Alfred M. Prince (chapter 8), who calls for "hybrid vigour": instead of having individuals from different disciplines working together, Prince feels that it is better to have different disciplines within one individual. His concrete proposal is to give fellowships to outstanding individuals within certain disciplines to enable them to get training in a second or third discipline.

There is also the call for new methodologies to achieve the integration of technologies. The enthusiasm of D. M. Jamieson (chapter 9) for general systems research is equaled by the enthusiasm of Arnold Reisman (chapter 13) for operations research, which he claims can be useful in solving all technological problems. Reisman provides a model taken from his doctoral dissertation, which is now in the process of being refined; as presented in his model, operations research seems a barrier to integration rather than a means for achieving it.

The two most meaningful essays, for they cite specific cases where integration has already been achieved in certain technologies, are those by Leslie Holliday, director of the Carrington Plastics Laboratory, and John Hearle of Manchester University. Both their chapters deal with concrete advances made in materials sciences. Perhaps the clue to the integration of the technologies is that it must emerge from the technological developments themselves rather than be imposed artificially or mechanically.

Where does the evidence for the technology gap show in all this? It shows in the fact that virtually all the recommendations, presumably new or at least not fully tried and developed in Britain, are already fairly well established in the United States. And it is