The Leontief-BLS partnership: a new framework for measurement

The ongoing collaboration between Wassily Leontief and the Bureau of Labor Statistics was mutually beneficial, bringing to Leontief confirmation of the utility of input-output analysis and to the Bureau tables that remained useful for decades to come

Martin C. Kohli

"The Department of Labor," according to Wassily Leontief, "was the first government agency to take an active interest in the 'input-output' approach to the study of the American economy and the continual cooperative relationship with its Bureau of Labor Statistics has benefited our work most decisively."[1] The specifics of the Bureau's role, however, are not well known. Referring to the forecasts the Bureau made during the last year of World War II that the postwar demand for steel would be strong, contrary to the opinion of many experts, Leontief held that the accuracy of this forecast provided evidence that input-output analysis was a useful tool for decisionmakers.[2]

Although he cited this episode, Leontief never provided a comprehensive account of the Bureau's role in the development of input-output analysis, thus leaving the door open for a number of interpretations. Robert Dorfman pointed out that the Bureau's resources made it possible for the Agency to formulate and develop "very large and detailed input-output tables."[3] Tjalling C. Koopmans described the early work on interindustry economics as "initiated, developed, and stimulated largely by Leontief and given statistical expression by measurements and tabulations produced by the Bureau of Labor Statistics," thereby distinguishing between the intellectual work accomplished by Leontief and the presumably routine data gathering done by the Bureau.[4] These accounts suggest that the Bureau's relationship with Leontief was significant largely because the Agency supplied the resources needed to transform his ideas from an academic curiosity into an operational tool for policymakers.

Indeed, a closer examination shows that the Bureau did more than just supply resources. This article proposes that the Department of Labor's interest stimulated the development of tables that were more useful for policymakers than Leontief's first formulation was. While the Battelle Memorial Institute summarizes many of the key facts, it gives short shrift to the Bureau's conceptual contributions.[5]

The Bureau's work with Leontief also had a number of effects on the Agency itself. When a still-being-assembled UNIVAC computer inverted a 1947 matrix, the Bureau found itself at the vanguard of computing technology. However, neither the Battelle study nor the history of Government statistics from 1926 to 1976 by Joseph W. Duncan and William C. Shelton examined how the input-output work affected the relationships among the Bureau's programs.[6] Such an examination, undertaken in this article, shows that, as a result of its input-output work, the Bureau attempted to treat some of its measured price, quantity, and value magnitudes as part of a new framework—a consistent system of national economic accounts—and this approach revealed inadequacies in at least one BLS program.

Martin C. Kohli is an economist in the New York Office of the Bureau of Labor Statistics, New York, New York. E-mail: Kohli_M@bls.gov.

In 1953, Defense Department funding for input-output analyis dried up, and in 1954, the Bureau's work on the subject came to a halt. In 1961, the Bureau and Leontief began a second chapter in their partnership, but that story will need to be told elsewhere; this article confines itself to the developments that occurred between 1941 and 1953 and to some of their consequences.

The first input-output tables

In 1932, freshly arrived at Harvard after a brief stint with the National Bureau of Economic Research, Leontief began the unusual project of constructing a *tableau économique* for the United States. François Quesnay, the 18th-century French economist, had used his *tableau* to analyze how changes, such as an increase in spending on luxuries, would affect the net product of France and its distribution among the various French social classes. In a similar manner, Leontief used his table to demonstrate "how the outputs of various industries and the prices of their products would have reacted" to changes in parameters for industrial productivity and savings.[7] Leontief treated this demonstration of conditional reactions as a goal toward the satisfaction of which he assembled and reconciled a massive amount of information.

Having set his goal, Leontief began the journey by describing an accounting scheme that covered "all branches of industry, agriculture, and transportation [and] also the individual budgets of all private persons."[8] The key account was the expenditure and revenue account, which included all expenditures leaving, and all revenues entering, an establishment over a particular period. For the purpose of understanding the development of input-output analysis, the critical feature of Leontief's schema was that the expenditure account explicitly included "capital outlays."[9] The accounts for an industry could be derived by consolidating the accounts of the establishments within it—adding up all the purchases from and sales to other establishments. Because one industry's sales to another would be recorded as the latter's purchases from the former, the industry accounts could be represented in what we now call a transactions table. Table 1 provides part of the transactions table for 1929. Note that for any individual sector, expenditures could exceed, equal, or fall short of receipts. But for the economy as a whole, the sum of expenditures would necessarily equal the sum of receipts.

The detailed transaction tables for 1919 and 1929 contained 44 sectors, 41 of which were producing sectors. The 42nd sector was foreign trade, which consumed exports and produced imports. The inputs, or consumption, of households, the 43rd sector, produced services, which were measured in dollars. The only formal difference between households and other sectors was that the transactions table showed two types of income: wages and salaries under one subtotal and capital and entrepreneurial services under the other. The last sector was undistributed, which reflected a lack of income-expenditure accounts for wholesale and retail trade, banking and finance, nonrail transportation, and Federal, State, and local governments. This sector functioned as an accounting balance; for example, because the automobile industry produced $5,454 million worth of cars in 1929 and the other sectors absorbed $4,903 million, $551 million was charged to the undistributed sector. Undistributed charges accounted for 19.8 percent and 19.4 percent of total gross output in the 44-sector versions of the 1919 and 1929 tables, respectively, reflecting large lacunae in our factual knowledge about the economy.

The construction of the tables required data from a large number of sources, some of which Leontief documented in Appendix II of *The Structure of American Economy* and the rest of which he made available on request. In the appendix, most of the discussion focused on the tables' bottom rows, which covered labor compensation, the returns to capital and entrepreneurial services, undistributed items, and gross outlays. Industrial censuses from the Bureau of the Census provided figures on total production and, in some cases, on wages and salaries. Estimates of compensation for capital and entrepreneurial services were based on tax data from the Bureau of Internal Revenue and Simon Kuznets's pathbreaking *National Income, 1929–1932*. Gross outlays included spending on investment, estimates of which were developed using data from the Federal Reserve, Kuznets, the Bureau of Internal Revenue, the Department of Agriculture, the financial press, and other sources.[10] The data that were the most difficult to obtain were the amounts of interindustry transactions. For each manufacturing industry, the Census Bureau had a figure on the combined cost of materials, fuels, energy purchased, and contract work. In virtually every industry, Leontief needed additional information to disaggregate the Census figures on intermediate inputs.

To achieve his goal of understanding the system's behavior, in addition to the table, he needed a model. A thorough discussion of the model's features is beyond the scope of this article, but several of the model's characteristics are relevant.[11] The model began with a set of equations, one for each sector, describing, in Leontief's words, "a hypothetical state of simple reproduction which knows neither savings nor investment."[12] Each sector produced a good or service that was completely consumed by the other sectors, so that

$$\text{output of product } i - S \text{ quantities of } i \text{ consumed by other sectors} = 0. \quad (1)$$

A second model not presented here, focused on prices and stipulated that the value of a sector's output equaled the value of that sector's inputs.

To move from equation (1) to a solution for the quantities produced, one needs to make some assumptions about the relationship between a sector's output and its inputs. Leontief

Table 1. Selected interindustry transactions, United States, 1929

[In millions of dollars]

Distribution of outlays	Distribution of output (revenue)						
	...	Other iron and steel	Automobiles	...	Exports	Consumption	Total output
... ...	...	14	15	...	42	43	...
14 Other iron and steel	...	1,274	548	...	807	1,151	12,865
15 Automobiles	...	...	1,445	...	532	2,926	5,454
...	...	...	...	...	...	...	...
42 Imports	...	20	—	...	...	842	4,997
43a Wages and salaries	...	4,226	871	...	...	6,978	45,603
43b Capital and entrepreneurial services	...	1,347	496	...	...	7,175	26,194
43c Total services	...	5,573	1,367	...	...	14,153	71,797
Total outlays	...	13,667	5,734	...	5,230	75,646	251,502

NOTE: Dash indicates amounts smaller than 0.1 percent. Numbers associated with names of sectors are from Leontief's table.

SOURCE: Wassily Leontief, *Structure of American Economy, 1919–1939*, table 6.

argued that he would use a particularly simple functional form, because "the numerical values of all the parameters must be ascertainable on the basis of available statistical information."[13] In this simple form, the quantity of input *i* consumed by industry *j* equaled a unit input coefficient times the level of output; that is,

$$\text{amount of } i \text{ consumed by industry } j = a_{ij} \times \text{output of product } j, \quad (2)$$

where a_{ij} is the unit input coefficient.

Leontief, however, modified equation (2) to incorporate the fact of investment spending, embodied in his accounting data. If expenditures exceeded revenues, a sector was said to be investing. To represent this phenomenon, he introduced a sectoral savings coefficient, whose initial value was the ratio of sectoral receipts to sectoral expenditures. To complete the model of quantities, Leontief modified the input functions of equation (2) to reflect these and other factors and then substituted the modified functions into the balance equation (1). In the quantity and price models, quantities and prices were determined by the unit-input coefficients. Thus, these coefficients were the ultimate objects of Leontief's efforts at measurement, with the transaction table being an intermediate step.

The question then arises as to what one can do with the two models. Leontief wanted to demonstrate how the relative prices and quantities would respond to variations in the industry productivity and savings parameters. Deploying his formidable powers of analysis, he was able to derive formulas and calculate the values of quasi elasticities for both 1919 and 1929, showing how the systems of prices and quantities would, in theory, respond.

In 1941, Harvard University Press published Leontief's first input-output articles, supplemented with additional material, as *The Structure of American Economy, 1919–1929*. As Dorfman noted, the first tables "established that even at that time statistical resources and computational facilities were adequate to make the construction of input-output tables a practical enterprise."[14] Nonetheless, the quantity model had little connection with the dominant economic concern of the 1930s: the Great Depression. Nor did the model have any policy levers, such as tax and spending variables. One could suggest that the industry savings parameters depended on tax and spending policies, but even if the model were extended in this direction, it would determine only relative quantities, which had little apparent interest to policymakers.

The BLS-produced table for 1939

In 1941, Commissioner of Labor Statistics Isador Lubin requested $96,500 from Congress to fund the first year of a study of the economic effects of demobilization. The assignment was given to Donald Davenport, who had recently left Harvard, where he had known Leontief, and had joined the Bureau's Postwar Division. Later that year the Bureau hired Leontief, opened an office of its Postwar Division in Cambridge, Massachusetts, and began work on a 95-sector table for 1939.

In 1944, Leontief published a transactions table for 1939, which differed in several ways from its predecessors. The first difference was that the 11-sector version stated that its source was the "United States Department of Labor, Bureau of Labor Statistics, Employment and Occupational Outlook Branch, Postwar Division." Richard Stone and others identified the 1947 table as the first official table, but Leontief and several of his collaborators recognized the priority of the 1939 table.[15]

Other differences between the table for 1939 and its predecessors can be attributed to the former's different purpose. The article presenting the table began with a question: "How

will the cessation of war purchases of planes, guns, tanks, and ships—if not compensated by increased demand for other types of commodities—affect the national level of employment?"[16] This was a what-if question of the general type that Leontief's model was intended to answer. However, the specifics of the question could not have been answered with the earlier tables and model.

To begin with, the question assumed that labor was measured not in dollars, as it had been in the earlier tables, but in employee years. Using data from the industrial censuses, the 1939 table provided consistent values of output and employment by sector. Because, at the time, the Bureau benchmarked its survey of payroll jobs to those censuses, the employment figures in the table were consistent with figures from the payroll series.

A second difference concerned the selection of sectors worthy of interest. The problem posed by Leontief required taking government spending, or at least the military portion of it, as exogenous. In the 1919 and 1929 tables, government had been lumped, along with trade, finance, and nonrail transportation, into the undistributed sector; in the 1939 table, it stood alone in the 11-sector version that Leontief published, and it was also alone in the 43-sector version included in the Bureau's unpublished study on postwar employment.[17] Data on government purchases came from a 1939 Bureau study of Federal contracts and a study by the Temporary National Economic Committee. The 1939 table also improved on its predecessors by breaking out trade as a separate sector. Even with the inclusion of these additional sectors, 15 percent of gross output was still charged to the undistributed account.

Another change concerned the representation of investment. In his first book, Leontief had pointed out the theoretical relationship between the transactions table and the national income accounts. Following up on this idea, the Bureau sought to reconcile its transactions table with those same accounts. Marvin Hoffenberg, who had the responsibility for this work, realized the desirability of moving capital-account purchases out of the transactions table. As W. Duane Evans and Hoffenberg would point out, there was no a priori reason why the ratio of investment spending to output would be stable.[18] For example, to produce more bread, a bakery would need more flour, but not necessarily more ovens. Thus, the 1939 table had an investment column, which showed how much of an industry's output was purchased for domestic private investment, and a row, which would have shown depreciation if the data had been available. After removing investment spending and taking into account changes in inventories, the Bureau sought to impose the constraint that the value of output (the row sum) equaled the value of inputs (the column sum), although data limitations prevented the achievement of this goal in all industries.

With government and investment represented explicitly, the 1939 table, unlike Leontief's earlier tables, had estimates of all four of the components of the product side of GNP. In 1942, the Department of Commerce released its first estimates of the product side. Perhaps because these were not well documented, Hoffenberg's reconciliation concerned only the income aspect. The Bureau's estimates indicated that households received $61.2 billion in income from businesses and $10 billion from government, for a total of $71.2 billion. The Bureau noted that the Commerce Department's estimate was $400 million, or 0.6 percent, less, because of different treatments of contingency reserves, bad-debt allowances, and inventory revaluations.[19]

Measuring interindustry flows led the Bureau into new types of statistical work. As Joseph P. Goldberg and William T. Moye noted, the Bureau's traditional way of operating was to conduct voluntary surveys, in which employers or households were asked more or less directly about strikes, labor conditions, prices paid, or quantities purchased. Schedules were checked for internal consistency, but not for consistency with values for an industry.[20] In the 1930s, many BLS surveys covered only selected parts of the economy. For example, the Wholesale Price Index, which later became the Producer Price Index, covered less than half the value of the products produced by the mining and manufacturing sectors.[21] In the case of constructing a transaction table, the Bureau employed a classification system that covered the entire economy. After defining total industry output and input and determining their values, the primary problem was to disaggregate purchases of intermediate inputs, subject to a set of accounting constraints. This is essentially a problem of inferring economic transactions from noneconomic data. The documentation for the 1939 table provides some examples: to estimate the use of coal by the trade, services, and housing sectors, for instance, the staff assumed that coal consumption would be proportional to the square footage of the areas that needed to be heated, and then they developed estimates of the square footage in the three sectors.[22] Moreover, while BLS staff could improvise inferences for specific cells, the double-entry character of the table required that all of these measurements be consistent with each other.

The Bureau's first applications

Leontief's 1944 article provided the tools for analyzing the effects on employment of alternative bills of goods, but it did not actually perform such an analysis for specific alternatives. As the Battelle study documented, the first such analysis occurred in 1944, when the War Production Board approached the Bureau about forecasting postwar employment. Using the 1939 table and the Board's assumptions about decreases in war spending and increases in personal consumption, the Bureau produced its first set of comprehensive and consistent projections of employment by industry.[23] Around the same time, the Bureau created a 20-sector table for Germany, using the U.S. table and a highly confidential German

census of production. The Office of Strategic Services used this table to guide its efforts to cripple the German economy; later, the table was used to analyze the issue of German reparations. These were apparently the first occasions on which government agencies applied Leontief's model to specific problems.

In 1945, as the Battelle study noted, the Office of War Mobilization and Reconversion asked the Bureau to examine the postwar demand for capital goods. Many people believed that, with the end of the war, the economy could slump into depression again. Because tanks, battleships, and other military goods were steel intensive, it seemed likely that the steel industry would suffer significant unused capacity. With the 1939 table, the Bureau had data on the steel intensiveness of consumer durables, such as motor vehicles, and construction. Assuming pent-up demand for construction, the Bureau concluded that the wartime increase in steel capacity might not prove adequate in the postwar years. This study, however, was not intended for public use.

The Bureau's first published application of input-output analysis was undertaken to explore the extent to which international conditions could contribute to the achievement of full employment in the postwar years.[24] Author Jerome Cornfield's immediate goal was to understand the direct and indirect connections between actual exports and industrial employment. He found that the largest numbers of jobs that were directly dependent on exports were in the metal fabrication, motor vehicles and industrial equipment, and fuel and power industries, while the largest numbers of jobs that were indirectly dependent on exports were in trade, transportation, and business and consumer services. One of the more striking features of Cornfield's 1945 *Monthly Labor Review* article is that imports and their relationship to domestic employment are not mentioned at all! A year later, Leontief revisited the issue of trade and employment in considerably more detail.[25] He introduced a distinction between competitive imports (which had domestically produced counterparts) and noncompetitive imports (which did not), although this distinction did not play a role in the analysis.

The Bureau's first comprehensive projections of output and employment by industry for the public examined whether, under plausible assumptions, the economy would achieve full employment in 1950. Cornfield, Evans, and Hoffenberg coauthored a 1947 *Monthly Labor Review* article that made assumptions about demand from households, about investment, about government, and about the rest of the world and then, using an input-output table to determine a consistent set of outputs, projected whether the levels of output would produce full employment. They declared, "No unconditional forecasts. . .are presented at any place in the text"; instead, their purpose, they said, was "to investigate the logical consequences of these assumptions" about demand and other data.[26] This method of constructing scenarios based upon observed parameter values is consistent with Leontief's methodological beliefs discussed earlier.

On the one hand, the input coefficients from the 1939 table, modified to incorporate expected changes in technology, along with the assumed final demands, generated 34.4 million private nonagricultural jobs, somewhat less than the 39.0 million that would have assured full employment. On the other hand, this level of employment was greater than many people had feared it would be. BLS economists then considered output levels for several products measured in physical units—tons of steel ingots, thousands of tractors, kilowatt hours of electricity—at full employment and found that in most cases the required level exceeded previous peaks. This was true not only for consumer goods, but also for steel and other commodities "commonly regarded as the sinews of war."[27] According to Battelle, the Bureau's projections, "alone among postwar predictions," did not foresee a depression, and their correctness greatly enhanced the standing of input-output analysis in the upper echelons of the Federal Government.[28] Leontief noted that the accuracy of the sectoral output forecasts impressed decisionmakers in large industrial companies, such as Western Electric.[29]

The 500-sector study and price indexes

By 1947, Evans had decided that the 1939 table needed to be updated. In the same year, Marshall Wood became chief of the Planning Research Division of the Air Force. Interested in techniques for coordinating the Air Force's training and materials procurement activities, he had the Bureau's input-output work included in an Air Force initiative known as Project SCOOP (Scientific Computation of Optimum Programs).[30]

With the resources of the Pentagon behind it, the Bureau assembled a staff of 50 to 75 people to compile the 1947 table. The Council of Economic Advisers, the Budget Bureau, and the National Security Resources Board formed a joint advisory committee that helped coordinate work across agencies.[31] The Air Force also supplied funds to the Census Bureau, in order to obtain more detailed information on materials manufacturing, and to Leontief, who, in 1948, launched the Harvard Economic Research Project, which carried out input-output-related research. Using BLS data, as well as data from other sources in the private and public sectors, Leontief's staff assembled a matrix of capital coefficients. The capital coefficients for construction were based on a BLS study of the industry,[32] and where industry studies were not available, the staff used commodity flowsheets developed by the Bureau.[33]

The result of the coordination among agencies and the abundant resources was an unprecedented level of detailed information—on 450 industrial and 50 autonomous sectors, which were reduced to 37 and 5, respectively, in Leontief's first published version of this new table.[34] The undistributed account declined to a mere 3 percent of gross output, a significant improvement over the 1939 table.

The Bureau also made several conceptual changes. One of these concerned international trade. As net exports were recognized as a component of GNP, it was natural to add to the final demand quadrant columns for exports and imports of goods and services that had domestic counterparts. Imports that had no domestically produced rivals had a separate row.[35] The classification of the competitive imports by industry allowed Leontief, in a pioneering study, to compute how much labor and capital would have been absorbed if the demand for these imports had been met by domestically produced goods.[36] The study raised a number of issues about the status of the Hecksher-Ohlin theory of international trade that are beyond the scope of this article. Suffice it to say that, until imports were classified in this manner, it was not possible to measure how trade influenced the employment of factors.

A second change concerned secondary products—commodities that fall outside the scope of the industry in which the establishment is classified. Evans and Hoffenberg dealt with these in several ways. When the industrial censuses did not provide enough detail to identify the type of commodity, the value of the products was charged to the unallocated sector. In other cases, the Bureau created "transfers"—fictitious sales—from the industry that produced the secondary product to the industries that were the primary producers of the commodities. This treatment had the effect of inflating the value of gross output. As Evans and Hoffenberg conceded, that was not a satisfactory solution. Nonetheless, the fact that they addressed the problem directly and admitted the problematic nature of the transfers set the stage for the eventual solution.[37]

During the development of data for construction, it became apparent to the Bureau that data on output from the Department of Commerce were not consistent with the volumes of materials consumed. As a result, the Bureau raised its estimate of construction output from $24.8 billion to $28.7 billion, a difference of 16 percent.[38] The Commerce Department data also were used in the national income accounts. According to Ezra Glaser, an official with the Office of Statistical Standards of the Budget Bureau (now the Office of Management and Budget), the reconciliation of the input-output table with the national income accounts revealed serious gaps and omissions in ocean transportation and services, as well as construction.[39]

In 1953, the Defense Department stopped funding the Bureau's input-output work, but the reconciliation issue did not disappear. In 1956, the Budget Bureau asked the National Bureau of Economic Research (NBER) to review the U.S. national income accounts. In its report, the NBER's National Accounts Review Committee recognized that input-output tables served as a tool for identifying deficiencies in the aggregated figures. Specifically, the committee asserted, "It was the work on the 1947 input-output table which pointed more conclusively than anything else to the shortcomings of the current construction statistics and gave impetus to the drive for improving these statistics."[40] That drive, which the committee endorsed, was one of the reasons it gave for recommending that the Federal Government resume the work of developing the tables.

The National Accounts Review Committee also revisited a second issue that BLS input-output work had raised: the construction of price indexes for the output of industries. Attempting to examine the relative stability of the economic structure of the United States, Leontief and others had taken 1 year's vector of final demand and used an earlier year's matrix to compute predicted levels of output for the later year.[41] To carry out this exercise, the bill of goods for the later year needed to be expressed in the prices of the earlier year, which were the basis of the calculated coefficients. Bills of goods were measured as the products of industries. To facilitate this adjustment, in 1953 the Bureau recoded quotations from its wholesale price program to create for the first time indexes of producer's prices by detailed industry.[42] The Bureau did not publish these indexes, however, perhaps because of problems with their scope. Commenting on an evaluation of forecasting exercises, Glaser stated, "[T]here are no very satisfactory price indexes for [the] output of many industries. Current wholesale price data are for products, and in many industries the weighted aggregate of covered items is a small fraction of the total value of production."[43] In 1957, the National Accounts Review Committee, and in 1961, another NBER committee, headed by George Stigler and focused on price indexes, voiced similar concerns and recommended the development of a comprehensive set of industry price indexes.[44]

Even in their early and imperfect forms, these indexes would turn out to have important uses for the Bureau. In 1955, the Bureau presented the first series on the real output and the productivity of production workers in manufacturing.[45] As price indexes for other sectors became available, the Bureau was able to publish additional measures of sectoral productivity.

The Bureau also established links between the industry-based input-output framework and its measures of consumer expenditures. The consumption data in the input-output table were based on the commodity-flow method, which, in effect, treats consumption as a residual. With such a treatment, it is desirable to have some independent estimates of the composition of consumption spending. Thus, in the early 1950s, the Bureau recoded the results of its 1935–36, 1941, and 1950 surveys of consumer expenditures to be consistent with the input-output table and adjusted the prices so that all of the surveys were expressed in 1947 dollars.[46]

A new framework for measurement

According to the accounts of Dorfman and Koopmans cited earlier, the Bureau was important in the development of input-output analysis because it secured the resources for the de-

tailed 1947 table. The Bureau did indeed play that role; however, the passage quoted from Leontief at the beginning of this article referred to the "*continual* cooperative relationship [he had] with the Bureau" [my italics] as providing decisive benefits, suggesting that, by 1953, the Bureau was playing an ongoing role in developing input-output analysis. A reexamination of the historical record supports Leontief's contention by documenting two additional contributions the Bureau made.[47]

In the first of these contributions, the Bureau's wartime projections demonstrated that input-output analysis had important applications for government policymakers. Leontief's first application, calculating the effects of improvements in productivity on relative prices and quantities, had little interest outside academia. By contrast, the Bureau's conditional forecasts of postwar employment aroused significant interest. The rough accuracy of these forecasts depended on the assumptions about final demand, as well as assumptions about labor productivity, so that the input-output technique was not by itself sufficient. But without the 1939 table, it would not have been possible to quantify the effects of increased demand for construction and consumer durables on industrial output and employment.

The Bureau's second contribution consisted of a series of conceptual refinements. The most important of these was Hoffenberg's decision to take capital-account transactions out of the interindustry portion of the table. This move had the obvious effect, suggested, but not stated, by the Battelle study, of facilitating the reconciliation of the input-output table and the national income accounts, which in turn led to indisputable improvements in the accounts. The second major conceptual refinement was treating competitive imports as subtractions from final demand, classified according to industries that produced rival products. This way of classifying imports, along with the compilation of capital requirements by industry, made possible Leontief's pathbreaking studies of the factor content of U.S. trade.

Commenting on the methodological views of Koopmans, who treated the compilation of data as the observation of independently existing facts, Leontief argued that the variables in a typical model could be measured only "through an intricate system of basic definitions, classifications, and rules of measurement."[48] He then held out a rosy scenario in which "an apt set of basic definitions" led to an "effective theoretical formulation," which in turn permitted "sharper observations."[49] One can argue that the development of input-output analysis illustrates that dynamic: the progressive refinement of classifications by Leontief and his collaborators, including Cornfield, Evans, and Hoffenberg, along with the work of others, made possible more detailed models that spurred new measurements.

The Bureau's input-output work also had indirect effects on how the Agency measured the economy. Before working with Leontief, the Bureau had used a variety of different classifications for its surveys of employment, wages, prices, and expenditures. By developing input-output tables, it acquired a comprehensive framework that required consistency and linkages between the different classification systems. More specifically, the Bureau expanded the collection of wholesale prices and produced its first, albeit imperfect, Producer Price Indexes by industry. □

Notes

ACKNOWLEDGMENT: Solidelle Wasser sparked this project, researched much of it, and commented on several drafts. Marvin Hoffenberg provided insights from the invaluable perspective of a participant. Estelle Leontief graciously permitted access to the Leontief papers in the Pusey Library at Harvard. I owe an important reference to Karen Polenske. Ronald Kutscher steered me away from a factual mistake. John L. Wieting and Diane Nilsen offered me several editorial suggestions, while Lillian Kohlreiser assisted with the research. A longer version of this article, titled "Leontief and the Bureau of Labor Statistics, 1941–53: Developing a Framework for Measurement," was presented at the History of Political Economy Workshop on the Age of Measurement at Duke University in April 2000.

[1] Wassily Leontief, "Preface," in Wassily Leontief, Hollis B. Chenery, Paul G. Clark, James S. Dusenberry, Allen R. Ferguson, Anne P. Grosse, Robert N. Grosse, Mathilda Holzman, Walter Izard, and Helen Kistin, *Studies in the Structure of the American Economy* (White Plains, NY, International Arts and Sciences Press, 1953), p. 5.

[2] Wassily Leontief, "Input-Output Economics," *Scientific American*, October 1951, pp. 15–21. See also Wassily Leontief, "Input-Output Analysis," in *Encyclopedia of Materials Science and Engineering* (Oxford, U.K., Pergamon Press, 1985). Both articles are reprinted in Leontief, *Input-Output Economics*, 2d ed. (New York, Oxford University Press, 1986).

[3] Richard Dorfman, "Wassily Leontief's Contribution to Economics," *Swedish Journal of Economics*, December 1973, p. 437. See also Richard Stone, "Where Are We Now? A Short Account of the Development of Input-Output Studies and Their Present Trends," in United Nations Industrial Development Organization, *Proceedings of the Seventh International Conference on Input-Output Techniques* (New York, United Nations, 1984).

[4] Tjalling C. Koopmans, "Introduction," in Tjalling C. Koopmans, ed., *Activity Analysis of Production and Allocation: Proceedings of a Conference* (New York, John Wiley and Sons, 1951), p. 3.

[5] Battelle Memorial Institute, *Interactions of Science and Technology in the Innovative Process: Some Case Studies* (Columbus, OH, Columbus Laboratories, 1973).

[6] Joseph W. Duncan and William C. Shelton, *Revolution in United States Government Statistics, 1926–1976* (U.S. Department of Commerce, 1978).

[7] Wassily Leontief, *The Structure of American Economy, 1919–*

1939, 2d ed. (White Plains, NY, International Arts and Sciences Press, 1951), p. 5. In his *History of Economic Analysis* (New York, Oxford University Press, 1954), pp. 241–42, Joseph A. Schumpeter pointed out the methodological affinity between Quesnay and Leontief, declaring that Leontief's work, "entirely different though it is from Quesnay's in purpose and technique, nevertheless revived the fundamental principle of the *tableau* method."

[8] Leontief, *Structure*, p. 11.

[9] *Ibid.*, p. 12.

[10] *Ibid.*, pp. 223–44.

[11] For a more detailed discussion of how Leontief's model changed, see Martin C. Kohli, "Leontief and the Bureau of Labor Statistics, 1941–53: Developing a Framework for Measurement," paper presented at the History of Political Economy Workshop on the Age of Measurement at Duke University, April 2000.

[12] Leontief, *Structure*, p. 35.

[13] *Ibid.*, p. 37.

[14] Dorfman, "Leontief's Contribution."

[15] Those identifying the 1947 table as the first official table include Stone, "Where Are We Now?" and Adam Rose and William Miernyk, "Input-Output Analysis: The First Fifty Years," *Economic Systems Research*, June 1989, pp. 229–71. Leontief bestowed the distinction on the 1939 table in "Input-Output Analysis," in John Eatwell, Murray Milgate, and Peter Newman, eds., *The New Palgrave: A Dictionary of Economics* (New York, The Stockton Press, 1987). For the views of Leontief's former collaborators, Karen Polenske and Anne Carter, see Karen R. Polenske and Jiri V. Skolka, "Introduction," in Polenske and Skolka, eds., *Advances in Input-Output Analysis* (Cambridge, MA, Ballinger, 1976), and Anne P. Carter and Peter Petri, "Leontief's Contribution to Economics," *Journal of Policy Modeling,* Spring 1989, pp. 7–30. Stone may have overlooked the 1939 table because the Bureau never published it. A 1942 letter from Davenport to Leontief discussed a planned two-volume Government Printing Office publication of the table, with the second volume consisting of documentation of the data for particular industries. For reasons that remain unknown, this plan was never carried out. The 1939 table was included in the Bureau's unpublished study on full employment.

[16] Leontief, *Structure*, p. 139.

[17] *Full Employment Patterns, 1950* (Bureau of Labor Statistics, unpublished and undated).

[18] W. Duane Evans and Marvin Hoffenberg, "The Interindustry Relations Study for 1947," *Review of Economics and Statistics*, May 1952, pp. 97–148.

[19] *Full Employment Patterns.*

[20] Joseph P. Goldberg and William T. Moye, The *First Hundred Years of the Bureau of Labor Statistics* (U.S. Department of Labor, 1985); see especially pp. 12–13.

[21] *BLS Handbook of Methods,* Bulletin 2490 (Bureau of Labor Statistics, 1997).

[22] *Full Employment.*

[23] Battelle, *Studies.*

[24] Jerome Cornfield, "Employment Resulting from United States Exports, 1939," *Monthly Labor Review*, July 1945, pp. 37–38.

[25] Wassily Leontief, "Export, Imports, Domestic Output, and Employment," *Quarterly Journal of Economics,* February 1946, pp. 171–93. Reprinted in Leontief, *Structure.*

[26] Jerome Cornfield, W. Duane Evans, and Marvin Hoffenberg, "Full Employment Patterns, 1950: Part 1," *Monthly Labor Review,* February 1947, pp. 163–90; quote from p. 164.

[27] Jerome Cornfield, W. Duane Evans, and Marvin Hoffenberg, "Full Employment Patterns, 1950: Part 2," *Monthly Labor Review,* March 1947, pp. 420–32; quote from p. 427.

[28] Battelle, *Interactions*, p. 8–8.

[29] Leontief, "Input-Output Analysis"; also in *New Palgrave.*

[30] Battelle, *Interactions.*

[31] Evans and Hoffenberg, "Study for 1947."

[32] *Postwar Capacity and Characteristics of the Construction Industry*, Bulletin 779 (Bureau of Labor Statistics, 1944).

[33] Robert N. Grosse, "The Structure of Capital," in Leontief et al., *Studies*.

[34] Leontief, "Input-Output Economics."

[35] This was how international trade was treated in the detailed tables. In the table published in Evans and Hoffenberg, "Study for 1947," international trade was still represented by one row for imports and one column for exports.

[36] Wassily Leontief, "Domestic Production and Foreign Trade: The American Capital Position Reconsidered," *Proceedings of the American Philosophical Society*, September 1953, pp. 332–49.

[37] Later tables, produced by the Commerce Department's Office of Business Economics, showed the use and the make of commodities by industry. This solution was proposed by Richard Stone and Alan Brown, *A Programme for Growth*, vol. 1, *A Computable Model of Economic Growth* (London, Chapman and Hall, 1962).

[38] Evans and Hoffenberg, "Study for 1947."

[39] Ezra Glaser, as cited in Battelle, *Interactions.*

[40] *The National Economic Accounts of the United States: Review, Appraisal, and Recommendations* (National Bureau of Economic Research, 1958), p. 146.

[41] See Leontief, "Output, Employment."

[42] For the method of constructing the indexes, see W. Duane Evans and Marvin Hoffenberg, "The Nature and Uses of Interindustry-Relations Data and Methods," in Conference on Research on Income and Wealth, *Input-Output Analysis: An Appraisal: Studies in Income and Wealth,* vol. 18 (Princeton, NJ, Princeton University Press, 1955). Goldberg and Moye, *First Hundred Years*, identify the year of the first industry price indexes as 1953.

[43] See Ezra Glaser, "Comment," in Conference, *Input-Output Analysis: An Appraisal.*

[44] For the NBER committee's recommendations, see National Bureau of

Economic Research, *Review, Appraisal*, p. 61. As regards the role of the Stigler Committee, see Goldberg and Moye, *First Hundred Years*, p. 199.

[45] *Trends in Output per Manhour and Manhours per unit of Output—Manufacturing, 1939–53*, Report 100 (Bureau of Labor Statistics, 1955).

[46] Elizabeth Gilboy, "Consumption in Input-Output Analysis," in Tibor Barna, ed., *The Structural Interdependence of the Economy: Proceedings of an International Conference on Input-Output Analysis* (New York, John Wiley & Sons, 1957).

[47] The longer version of this article also contends that the Bureau prompted Leontief to develop a theoretical model that was more useful for policymakers. (See Kohli, "Leontief and the Bureau.")

[48] Wassily Leontief, "The State of Economic Science," *Review of Economics and Statistics*, May 1958, pp. 103–6.

[49] *Ibid.*