

Leontief and the Bureau of Labor Statistics, 1941-54:  
A Unfinished Chapter in the History of Economic Measurement

By Martin C. Kohli  
Bureau of Labor Statistics  
New York NY 10011  
Kohli\_M@bls.gov

## Abstract

While Leontief's accomplishments have been recognized, his work with the Bureau of Labor Statistics occupies an uncertain position in historical accounts. Some observers have argued that the Bureau of Labor Statistics merely tabulated data in accordance with his theories. This paper evaluates such claims by examining the concepts and classifications used by Leontief and the Bureau in the early tables. It concludes that the changes made by the Bureau made possible significant measurements of the GNP and of the factor-content of international trade. Today statistical agencies continue to develop measures of prices and quantities, using the framework pioneered by Leontief.

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While Wassily Leontief's accomplishments have been justly recognized, his work with the Bureau of Labor Statistics occupies an uncertain position in historical accounts of economic measurement. Focusing on measurements made by the federal government during the period 1926 to 1976, Duncan and Shelton pointed out that the Bureau's 1947 publication of post-war employment forecasts "probably did more than any other single thing to disseminate knowledge of the concept of input-output and its usefulness," but they did not appreciate some contributions made by the Bureau (1978, p. 111). In this they had company. Koopmans (1951, Introduction) and Dorfman (1973) implied that the Bureau's relationship with Leontief was significant largely because it supplied the muscle to flesh out his ideas. Dantzig (1963) gives more credit to the Bureau, but his opinion appears to be in the minority. A closer examination of the historical record, such as that presented in Kohli (2001a and 2001b), shows that in addition to supplying resources the Bureau made several changes to the framework—the concepts and classifications—underlying Leontief's tables.

The issue involved here is not simply one of recognizing a contribution. Instead, it has to do with understanding how in the mid-twentieth century economists and statisticians improved measurements of the economy. Porter (2001), while not addressing this particular issue, raised the related question of the relative importance of, on the one hand, basic research, and, on the other, bureaucratic imperatives in the history of measurement. Porter described the champions of basic research as believing that breakthroughs in quantitative methods tend to occur first in the hard sciences and then are adopted later by social sciences. Stigler (1999) can be read as a proponent of this interpretation. For the purposes of understanding developments in the 1940s and 1950s, the issue of borrowing from hard

sciences is not so salient. Instead, the interesting contrast is between formalists, such as Trygve Haavelmo and Tjalling Koopmans, who championed probability-based techniques, and economic accountants, such as Simon Kuznets, Richard Stone, and Leontief, who developed disaggregated national economic accounts.

Porter (2001) showed that in the seventeenth and eighteenth centuries, it was difficult to distinguish administrative from scientific purposes in early efforts at economic and social quantification. He also contended, citing several of the studies in Klein and Morgan (2001), that in this respect the history of measurement in the twentieth century showed continuity with the past. Consistent with this interpretation, the story of Leontief's work with the Bureau illustrates the importance of the government's administrative needs. The federal government's commitment to assembling input-output tables regularly was in doubt until the Budget Bureau recognized its interest in having accurate measurements of national income and product. To this day, the development of the underlying industry accounts, especially in constant dollars, remains a work in progress. But this story also illustrates a more subtle interplay between economic theory and measurement, with some of the Bureau's conceptual changes having had effects on economic theory.

### 1. LEONTIEF'S *TABLEAU ECONOMIQUE* FOR 1919

In 1932 Leontief began the unusual project of constructing a *tableau économique* for the United States. François Quesnay, the eighteenth century French economist, had used his *tableau* with hypothetical numbers to analyze how changes, such as an increase in spending on luxuries, would influence the net product and its distribution between social classes. In a similar manner Leontief intended to use his theoretical scheme and table to demonstrate how prices and quantities would have reacted to changes in parameters for industrial productivity and savings (Leontief 1936). His goal, in other words, was to use the table to illustrate the theoretical notion of sectoral interdependence.

The second section of the first input-output article, with the grand-sounding title of “Fundamental Concepts,” discussed the mundane topic of accounting. As Kohli (2001b) argued, the accounting scheme offered the conceptual apparatus by which Leontief intended to use primary data to quantify the interdependence of the economy’s sectors. He proposed to consider the consequences of an accounting system that covered the economic activity of every business establishment and household. The key account was the expenditure and revenue account. The expenditure side showed the flows of commodities and services as they entered the enterprise or household during a particular period; the revenue side documented outflows of commodities and services. For the purpose of understanding the development of input-output analysis, the key feature of this conceptual schema was that the expenditure account explicitly included capital outlays (Leontief 1936). In other words the accounting scheme did not distinguish between current-account and capital-account purchases. He recognized that capital accounts existed, but they raised issues, such as depreciation, which he could not solve with his simple system of registering transactions between accounting units.

For theoretical purposes, individual establishments were not the ideal unit of analysis. Instead the theoretically relevant unit was a homogeneous industry, “homogeneity being defined in terms of (a) identity of products and (b) qualitative and quantitative similarity of cost structure of the firms” within the industry (Leontief 1936, p. 20). By consolidating the accounts of establishments it was possible to create industry accounts. Since one industry's sales to another would be recorded as the latter's purchases from the former, the industry accounts can be arrayed in what we now call a transactions table. Table 1 provides part of what Leontief titled “Quantitative Input and Output Relations in the Economic System of the United States, 1919.”

[Insert Table 1 about here.]

One of the distinctive features of the table is that the value of an industry's output was not necessarily equal to the value of its inputs. Because Leontief included capital-account spending, an industry that was increasing its capital stock would show expenses greater than receipts, while if an industry was disinvesting (or saving), its expenses would be less than receipts.

As Leontief's praise of Quesnay and the table's title suggest, one of his favorite ways of characterizing the economy was as a system—a set of interdependent sectors that formed a complex whole. The systematic character of the economy had, I believe, an implication for what Leontief thought was a desirable attribute of economic measurements. When he praised a *tableau économique* as “an internally consistent, quantitative” representation of the economy (Leontief et al., 1953, p. v), he showed the value he attached to consistency. The double-entry character of the accounting system assured that the recorded transactions of each sector were consistent with those of every other sector, and that the tabulated characteristics of the whole, such as total expenditures and total receipts, could be derived from measurements for the parts.

The detailed transaction tables for 1919 contained 44 sectors, 41 of which were industrial sectors. The forty-second sector was international trade. As Table 1 shows, its row recorded the distribution of its product, which was imports, while the column recorded its inputs, which were exports. Leontief recognized that to treat trade as a sector was to use geography, rather than product homogeneity, as a classifying principle. The inputs, or consumption, of households, the forty-third sector, produced services, which were measured in dollars, as Table 1 illustrates. 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 another.

## 2. ECONOMIC THEORIES AND ECONOMIC MEASUREMENTS

Leontief and Koopmans, another Nobel Laureate, offered contrasting visions of a desirable relationship between economic theories and measurements. Koopmans considered theory building to be solely a matter of deriving interesting conclusions, using logic and mathematical techniques, from a small number of postulates. With a formalist's pride, he regarded the body of neoclassical theory as "an impressive and highly valuable system of deductive thought, erected on a few premises that seem to be well-chosen approximations to a complicated reality" (1957, p. 142).

For him empirical work was a separate activity, with which the theorist as theorist did not need to be concerned. His own empirical work focused on measurement errors and identification conditions and remained largely at the methodological level (Christ and Hurwicz 1987). His sharpest pronouncements on empirical methodology came in his 1949 review of the National Bureau of Economic Research study on business cycles by Burns and Mitchell. Although he mentioned an absence of economic theory in that study, the stinging part of his criticism was that Burns and Mitchell had not used probability-based inference procedures. Morgan (1990) interpreted his attack and the reaction of the National Bureau of Economic Research as evidence of a probabilistic revolution in econometrics inspired by the work of Trygve Haavelmo.

Stigler (1999, ch. 10) presented a position on the theory-measurement relationship in the social sciences similar to that of Koopmans. Stigler's argument is based on a contrast between astronomy and the social sciences. The differences in methodology between the physical and the social sciences have generated an enormous literature, including for example Kuhn (1977) and Porter (2001). For my purposes, the interesting feature of Stigler's argument is the role of theory. According to Stigler, in astronomy theory defines the objects of inference. By contrast, in the social sciences, which generally lack the ability to do controlled experiments, a statistical model defines the objects of inference—typically the parameters of a conditional expectation. Measurement in the social sciences need not have much connection at all with theory, and that is simply the way the world is.

Leontief would not have agreed. His different view of the theory-measurement relationship was implicit in his first presentation of an input-output theoretical scheme. This began with a set of equations (not shown here), one for each sector, describing, as in Quesnay's model, a hypothetical state of simple reproduction. Each sector produced a good or service,  $X_j$ , which was consumed by the different sectors. A second set of equations focused on prices, and stipulated that the value of a sector's output equaled the value of the inputs. Both of these equation sets functioned as equilibrium conditions: they described an ideal state towards which the economy was assumed to tend. These two sets of equations could be found in Walrasian models of general equilibrium.

The third set of equations concerned behavioral relationships—the technologies used in production and the pattern of household consumption. Leontief posited that the quantity of input  $i$  consumed by sector  $j$ , depended on the sector's output and a technical or direct input coefficient,  $a_{ij}$ :

$$x_{ij} = a_{ij}X_j \tag{1}$$

This functional form attracted criticism from economists, who favored forms that allowed for substitution. Leontief recognized that his colleagues preferred more general functional forms, but these typically involved parameters that could be estimated only with regression models—an approach that Koopmans and the Cowles Commission were advocating. Leontief contrasted the methods of “indirect statistical inference” with what he called “direct observation” (Leontief et al. 1953, p. 7). By the latter term he meant facts “observed by someone else rather than the economist” and “usually described in ordinary, everyday language or in the technical language, not of economics, but of some other discipline” (Leontief 1954, p. 54). The belief that reliable measurements are built not solely on sophisticated statistical technique but rather on systematic, direct observation as well is one of the recurring themes of Leontief's career, as Kohli (2001b) documented.

To return to the treatment of production in the original scheme: Leontief justified the fixed-coefficient form of equation (1) on methodological grounds, declaring that “the numerical values of all the parameters must be ascertainable on the basis of available statistical information” (1936, p. 37). He did not deny that as a matter of fact some production technologies allowed for substitution. Instead, lacking direct observations of alternative technologies, he shaped his theoretical scheme according to his judgment about the reliable measurement of the parameters.

### 3. OVERCOMING THE LIMITATIONS OF LEONTIEF’S ORIGINAL CONCEPTS

In April 1941, before the United States officially entered the war, the Bureau of Labor Statistics requested \$96,500 from Congress to fund a study of the economic effects of demobilization. Donald Davenport, who had recently left Harvard, where he had known Leontief, had joined the Bureau, and he believed that an approach to the problem could be found in Leontief’s recently published book (Battelle Memorial Institute 1973). The Bureau quickly hired Leontief, opened an office in Cambridge, Massachusetts, and began work on a 95-sector table for 1939. By 1943 the Bureau’s staff had completed one version of the table, and the work was winding down. Senior managers had to decide whether they wanted to continue to support the project.

They turned to Jerome Cornfield, then working in the wholesale price division. During his career Cornfield made several remarkable contributions to economic and social measurements in the United States. Cornfield was familiar with Jerzy Neyman’s work on probability sampling, and in 1941 he developed a two-stage sample design for a family expenditure survey—one of the federal government’s first uses of probability sampling. He discussed a form of the linear programming problem with George Dantzig, who was a Bureau employee before he went to the Air Force and developed the simplex algorithm. Later, after Cornfield left the Bureau for the National Institutes of Health, he published one

of the pioneering studies on the relationship between smoking and lung cancer (Duncan and Shelton 1978). In 1974 he became the president of the American Statistical Association. The March 1982 supplement to *Biometrics* contains the proceedings of a memorial symposium that celebrated his accomplishments. In 1944, however, he reviewed the input-output work for the Bureau's top managers. He concluded that Leontief's technique was "a useful tool. . . a coherent point of view" (Cornfield 1964, p. 3). The word "coherent" indicates, I believe, Cornfield's preference for measurements that were internally consistent and that showed parts adding up to wholes.

Leontief (1944) published a transactions table for 1939, which differed in several ways from its predecessors. 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?" (Leontief 1944, p. 139). This was a what-if question of the general type that Leontief's theoretical scheme was intended to answer. However, because of data and conceptual limitations, Leontief could not have used the first tables and the original scheme to answer this particular question.

This question concerned the effects of government spending. In the 1919 and 1929 tables government had been consigned, because of a lack of data, to the undistributed sector. As an analytical category, government did not exist. In the 1939 table it stood alone in the 11-sector version that Leontief published and in the 43-sector version included in Bureau's unpublished study (n.d.), which was apparently completed in 1946. Even with the inclusion of government and trade, 15 percent of gross output was still charged to the undistributed account.

A second difference concerned the units of measurement. The question assumed that labor was measured not in dollars, as it had been in the first tables, but in employee years. This change marked a significant departure from the monetary measures Leontief had used in his first *tableaux*. Leontief also developed an open model with inhomogeneous equations, in contrast to the earlier closed model with its homogeneous equations. The open model was

similar to the Keynesian model of income determination: in both exogenous spending determined the level of output. With the open model and labor measured in physical units, it was possible to analyze how changes in exogenous variables could influence employment.

A third change concerned the underlying conceptual scheme. Leontief (1936) had pointed out the theoretical relationship between the transactions table and the national income. Under what he called “static conditions,” meaning no savings and no investment, the national income, which was the sum of the entries in the household sector’s row, equaled the national product, which was the sum of the sector’s column entries. Following up on this idea, the Bureau sought to reconcile its 1939 transactions table with the national income accounts, which now included investment in the national product. Marvin Hoffenberg, the Bureau’s expert on national accounts, had the responsibility for this work, and he realized the desirability of modifying Leontief’s original accounting scheme. This scheme had been built on expenditure and receipt accounts that contained *all transactions* between accounting units. Hoffenberg assumed that firms kept separate accounts for current and capital spending and income. Purchases of capital goods were registered as expenses on the capital account, while depreciation charges counted as capital account revenue. 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 showed depreciation charges. The column sum was gross private investment, which Hoffenberg needed for his reconciliation, while the row sum was total private-sector depreciation. After removing investment spending from the interindustry transactions and taking into account changes in inventories, the Bureau sought to impose the constraint on the industrial sectors 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 first tables, had estimates of all four of the components of the product side of GNP. Because the Commerce Department’s product-side numbers were based on a commodity flow table, it

was difficult to complete a reconciliation of them with input-output table's industry-based numbers. Hoffenberg was able to reconcile the income side numbers, however. 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 Department of Commerce estimate was \$400 million less, or 0.6 percent, because of different treatments of contingency reserves, bad debt allowances, and inventory revaluations (Bureau of Labor Statistics n.d.)

When the Bureau began constructing the 1939 table, it had intended to use the table to forecast postwar employment. In 1944, using assumptions about decreases in war spending and increases in personal consumption, it calculated its first comprehensive, albeit unpublished, forecasts of employment for the War Production Board. For more detailed discussions of the Bureau's early applications, see Duncan and Shelton (1978) and Kohli (2001a).

Cornfield (1945), which examined the employment that was attributable, industry by industry, to U.S. exports in 1939, was the Bureau's first published application of input-output analysis. This was also the first article by a government agency that examined the amounts of labor embodied, directly and indirectly (in other words, in intermediate inputs) in internationally traded goods.

#### 4. MEASURING THE NATIONAL PRODUCT AND INDUSTRIAL OUTPUT

In 1947 W. Duane Evans, who had taken over the responsibility for the Bureau's input-output work, confronted two problems. First, he had decided that the 1939 table needed to be updated, a process that would require more resources. Second, the Truman Administration had decided to trim the Bureau's budget by 20 percent. The shortage of funds prompted him to search for money at better-funded agencies. In the same year Marshall Wood, who had an interest in techniques for coordinating training and materials-

procurement activities, became chief of the Planning Research Division of the Air Force. In 1948, with the Cold War growing chillier, Wood had the Bureau's input-output work included in an interagency project, funded by the Air Force, known as Project SCOOP (Scientific Computation of Optimum Programs). After the Korean War erupted in 1950, funding for Project SCOOP soared. While the 1939 table was motivated by concern with the effects of peacetime demobilization, the 1947 table was in large part motivated by Evans's desire to refresh his aging data and Wood's concern with possible obstructions to a wartime mobilization. Klein (2001) discussed other innovations in measurement associated with Project SCOOP, including Dantzig's development of the simplex algorithm.

The result of the Pentagon's largesse was an unprecedented level of detailed information—450 industrial and 50 autonomous sectors, which were reduced to 37 and 5 respectively in Leontief (1951a), the first published version of this table. As Table 2 shows, the undistributed account declined to a mere 3 percent of gross output, a significant improvement over the 1939 table.

[Insert Table 2 about here.]

The Bureau changed how international trade was represented. This change had nothing to do with identifying bottlenecks, but it was consistent with the theoretical development of open-economy macroeconomics. As macroeconomists recognized net exports 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. (This was how international trade was treated in the detailed tables. In the table published in Evans and Hoffenberg (1952) international trade was still represented by one row for imports and one column for exports.)

The classification of the competitive imports by industry allowed Leontief (1953) to investigate the factor-content of U.S. trade. His principal finding, that U.S. exports were

labor intensive compared with the import-competing goods, raised questions about the factor-abundance theory of competitive advantage and continues to generate an voluminous literature, some of which has criticized Leontief's methodology. Since the focus of this study is the development of a framework for measurement, there are two important points about this literature. First, until imports were classified in this theoretically relevant manner, it was not possible to measure how trade influenced the employment of factors. Second, as Leamer, a critic of Leontief's methodology, has noted: this "finding preceded and apparently stimulated a search of great breadth and intensity for a new theory of trade that could account for his results. In fact it is difficult to find another empirical result that has had as great an impact on the intellectual development of the discipline" (1987).

The work on the 1947 table had other measurement-related consequences. Duncan and Shelton asserted that "the most important and lasting impression which came out of this work was how incomplete, unsystematic, and seemingly contradictory were the basic detailed economic statistics for the United States" (1978, p. 111). They cited several particular problems, including measurement problems in services and trade. They could have cited, although they did not, the measurement of prices by the Bureau of Labor Statistics. For example, the Wholesale Price Index, which later became the Producer's Price Index, covered less than half the value of the products produced by the mining and manufacturing sectors (Glaser 1955). It used a so-called judgement sample rather than a probability sample, and it relied on its own classification of commodities, which was not consistent with the taxonomies used in the Bureau's survey of consumer prices (Bureau of Labor Statistics 1997) and in the Commerce Department's records of international trade.

Given the unsystematic character of government statistics, it was not surprising that serious doubts arose about the measurement of the economic aggregates. During the development of industry accounts for construction, the Bureau became aware of a discrepancy between its estimates of the quantities of materials consumed and the Commerce Department data on output, which were also used to measure investment in the national

income accounts. The Bureau raised its estimate of construction output from \$24.8 billion to \$28.7 billion, thus making a judgement that the figures based on a consistent set of accounts were more likely to be correct (Evans and Hoffenberg 1952). Kohli (2001b) documented that the Budget Bureau and outside observers who examined the issue came to the same conclusion.

In 1953 President Eisenhower took office. The Defense Department stopped funding the Bureau's work on input-output, 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. This was one of the reasons the committee gave for recommending that the federal government resume the work of developing the tables.

The national accounts review committee revisited a second issue that the Bureau of Labor Statistic's input-output work had raised: the construction of price indexes for the output of industries. Early critics of Leontief's work had attacked the assumption that past year's coefficients could be used to make forecasts of future output and employment. Attempting to examine the relative stability of the coefficients, Leontief and others had taken one year's vector of final demand and used an earlier year's matrix to compute predicted levels of industrial output for the later year (Leontief 1944). 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. The bills of goods were measured as the products of industries, and the comprehensive scope of the bill of goods, which coincided with the national product, meant that a set of price indices that covered all industries was required. To facilitate this adjustment, in 1953 the Bureau recoded quotations from its wholesale price program to create its first indexes of producer's prices by detailed industry. (Evans and Hoffenberg (1955) described the construction of these indexes, while Goldberg and Moye

(1985) identified the year as 1953). The Bureau did not publish these, perhaps because of problems with their scope.

These indexes, even in their early and imperfect forms, would turn out to have important uses for the Bureau. To measure productivity one needs to measure industry output in real terms. Using its first measures of industrial prices, in 1955 the Bureau presented the first series on the real output and the productivity of production workers in manufacturing (Bureau of Labor Statistics 1955). As Bureau redesigned its survey of producers' prices, indexes for other sectors became available, and the Bureau was able to publish additional measures of sectoral productivity.

## 5. THE CONTINUING RELEVANCE OF INDUSTRY ACCOUNTS

In 1957 the NBER's national accounts review committee recognized the need for industry accounts and for a comprehensive set of industry price indexes. Work on input-output tables began again in the early 1960s, and in 1964 the Commerce Department published a table for 1958. Since then tables have published regularly. Presently, the Bureau of Economic Analysis maintains industry accounts for 62 private-sector industries and four categories of government production, and these accounts are used to develop the input-output tables and measures of gross product by industry in both nominal and real terms.

The development of comprehensive industry price indexes is taking—the use of the present tense is intentional—much longer. In 1977 the Bureau expanded the industry coverage of the wholesale price index to include virtually all mining and manufacturing industries. Service sector industries have been added, but as of 1996 the Bureau had not yet been able to include, in part because of funding constraints, health services, real estate, and business services (Bureau of Labor Statistics 1997). The Bureau has also made efforts to coordinate the sample design for the CPI and PPI, but there remain a number of industries and industry segments with problematic measures of the price of output. In these industries,

listed in Table 3, the costs of inputs are used to deflate the nominal figures on output, which is clearly not optimal.

[Insert Table 3 about here.]

One area of special concern, because of its size, is health services (this includes hospital services, for which Bureau does have price index for output, as well other health services, for which the Bureau does not). Part of the problem here is conceptual. As Federal Reserve Chairman Alan Greenspan has noted, “What do we mean by the standardized unit of output? Is it the procedure, the treatment or the outcome?” (Greenspan 2001). The Bureau currently focuses on the treatment, but, as Greenspan argued, this approach is not entirely unproblematic. For a detailed discussion of how the Bureau currently measures the prices of hospital services, see Cardenas (1998) and several of the contributions in Cutler and Berndt (2001).

## 6. AN UNFINISHED CHAPTER

According to several accounts, the Bureau of Labor Statistics work with Leontief was important because it secured the resources to flesh out Leontief’s ideas. In fact, the Bureau also made several conceptual developments to Leontief’s framework. The most important of these was Hoffenberg’s decision to redefine capital-account transactions out of the industry accounts. This made it possible to compile figures on the composition by industry of investment spending, figures which were necessary to reconcile the input-output table with the national income accounts. As Duncan and Shelton (1978) documented, the need to plan and finance World War II created an urgent demand for accurate estimates of the national income and product and of their components. After the war ended, the interest of policy makers, government agencies, and professional economists in these measures did not disappear. What was once a wartime imperative became a peacetime routine, as the Budget

Bureau recognized in 1955 when it made the national income and product accounts the central framework for federal statistics.

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 made possible Leontief's path-breaking studies of the factor content of U.S. trade.

The importance of these measurements brings us back to the methodological debate between Leontief and Koopmans. Earlier we saw that Koopmans regarded economic theory as a deductive system, the premises of which were "well-chosen approximations to a complicated reality" (1957, p. 142). Leontief objected to references to the degrees of the "realism" of premises, which assumed a uniquely describable reality. Instead, he contended that economic variables can only be measured "through an intricate system of basic definitions, classifications, and rules of measurement." Leontief held out a rosy scenario in which "an apt set of basic definitions" lead to an "effective theoretical formulation," which in turn permitted "sharper observations" (1958, p. 105). One can argue that the development of input-output analysis illustrates this dynamic: the theoretically based refinement of definitions and classifications by Leontief and his collaborators, along with the work of others, made possible more detailed models, which spurred new measurements. Polenske (2000) presented an argument, similar to the one presented here, concerning the theoretical development of models of interregional trade by Leontief and Walter Isard and important measurements of differences between regional economies.

Duncan and Shelton identified the development of the national accounts and the use of probability sampling as two of the four crucial developments in federal statistics during the 1926-76 period (1978, p. 1). Much of the history chronicled above relates to the development of the accounts, but this was not entirely unrelated to the spread of probability samples. The accounting framework provided a basis for assessing the sample design of the Producer Price Index, and efforts to improve that survey's scope, concepts and classifications continue to this

day. The chapter in the history of economic measurement begun by Leontief remains unfinished.

Solidelle Wasser sparked this project, researched much of it, and commented on numerous drafts. Marvin Hoffenberg provided insights from the invaluable perspective of a participant. I owe an important reference to Karen Polenske. Sam Ehrenhalt reminded me that the issues raised 50 years ago were still very much with us. However, the author alone is responsible for the form and content.

## REFERENCES

- Battelle Memorial Institute (1973), *Interactions of Science and Technology in the Innovative Process: Some Case Studies*, Columbus, OH: Author.
- Bureau of Labor Statistics (n.d.), *Full Employment Patterns, 1950: The Structure of the American Economy under Full Employment Conditions*, Washington, DC. Duplicated.
- (1955), *Trends in Output per Manhour and Manhours per unit of Output—Manufacturing 1939-53*, Report 100, Washington, DC: Author.
- (1997), *BLS Handbook of Methods*, Bulletin 2490, Washington, DC: Author.
- Cardenas, E. M. (1996), "Revision of the CPI Hospital Services Component," *Monthly Labor Review*, 119:12, 40-48.
- Christ, C. F. and Hurwicz, L. (1987), "Koopmans, Tjalling Charles," in *The New Palgrave: A Dictionary of Economics* (Vol. 3), eds. J. Eatwell, M. Milgate, and P. Newman, New York: The Stockton Press.
- Cornfield, J. (1945), "Employment Resulting From United States Exports, 1939," *Monthly Labor Review*, 68:7, 37-38.
- (1964), Interview by Jonathan Grossman, edited by Marvin Hoffenberg, 1981, Duplicated.
- Cutler, D. M. and Berndt, E. R. (2001), *Medical Care Output and Productivity: Studies in Income and Wealth* (Vol. 62), Chicago, IL: University of Chicago Press.
- Dantzig, G. B. (1963), *Linear Programming and Extensions*, Princeton, NJ: Princeton University Press.
- Dorfman, R. (1973), "Wassily Leontief's Contribution to Economics," *Swedish Journal of Economics*, 75, 430-449.
- Duncan, J. W. and Shelton, W. C. (1978), *Revolution in United States Government Statistics, 1926-1976*, Washington, DC: U.S. Department of Commerce.
- Greenspan, A. (2001), "The Challenge of Measuring and Modeling a Dynamic Economy," Remarks delivered at the Washington Economic Policy Conference of the National Association of Business Economists, Washington DC.
- Evans, W. and Hoffenberg, M. (1952), "The Interindustry Relations Study for 1947," *Review of Economics and Statistics*, 34:2, 97-148.
- (1955), "The Nature and Uses of Interindustry-Relations Data and Methods," in *Input-Output Analysis: An Appraisal: Studies in Income and Wealth* (Vol. 18), ed. R. Goldsmith, Princeton, NJ: Princeton University Press, pp. 53-125.

- Glaser, E. (1955), "Comment," in *Input-Output Analysis: An Appraisal: Studies in Income and Wealth*, vol. 18, ed. R. Goldsmith, Princeton, NJ: Princeton University Press, pp. 49-51.
- Goldberg, J. P. and Moye, W. T., (1985), *The First Hundred Years of the Bureau of Labor Statistics*, Washington, DC: U.S. Department of Labor.
- Kohli, M. (2001a), "The Leontief-BLS Partnership: A New Framework for Measurement," *Monthly Labor Review*, 124: 6, 29-37.
- (2001b), "Leontief and the U.S. Bureau of Labor Statistics, 1941-54: Developing a Framework for Measurement," , in *The Age of Economic Measurement*, eds. J. L. Klein and M.S. Morgan, Durham, NC: Duke University Press, pp. 190-212.
- Koopmans, T. C. (ed.) (1951), *Activity Analysis of Production and Allocation: Proceedings of a Conference*, New York: John Wiley & Sons.
- (1957), *Three Essays on the State of Economic Science*, New York: McGraw-Hill.
- Kuhn, T. S. (1977), *The Essential Tension*, Chicago, IL: University of Chicago Press.
- Klein, J. L. (2001), "Reflections from the Age of Measurement," in *The Age of Economic Measurement*, eds. J. L. Klein and M. S. Morgan, Durham, NC: Duke University Press, pp. 111-136.
- and Morgan, M. S. (eds.) (2001), *The Age of Economic Measurement*, Durham, NC: Duke University Press
- Leamer, E. (1987), "The Leontief Paradox," in *The New Palgrave: A Dictionary of Economics* (Vol. 3), eds. J. Eatwell, M. Milgate, and P. Newman, New York: The Stockton Press.
- Leontief, Wassily W. (1936), "Quantitative Input and Output Relations in the Economic System of the United States," in *The Structure of American Economy, 1919-1939* (1951), White Plains, NY: International Arts and Sciences Press.
- (1937), "Interrelation of Prices, Output, Savings, and Investment," in *The Structure of American Economy, 1919-1939* (1951), White Plains, NY: International Arts and Sciences Press.
- (1944), "Output, Employment, Consumption, and Investment," in *The Structure of American Economy, 1919-1939* (1951), White Plains, NY: International Arts and Sciences Press.
- (1946), "Export, Imports, Domestic Output, and Employment," in *The Structure of American Economy, 1919-1939* (1951), White Plains, NY: International Arts and Sciences Press.
- (1951), "Input-Output Economics," in *Input-Output Economics* (2nd ed.), New York: Oxford University Press.
- (1953), "Domestic Production and Foreign Trade: The American Capital Position Reconsidered," *Proceedings of the American Philosophical Society*, 97, 332-349.

- (1954), "Mathematics in Economics," in *Essays in Economics: Theories, Theorizing, Facts, and Policies* (1985), New Brunswick, NJ: Transaction Books
- (1958), "The State of Economic Science," *Review of Economics and Statistics*, 40, 103-106.
- Leontief, W. et al. (1953), *Studies in the Structure of the American Economy*, White Plains, NY: International Arts and Sciences Press.
- Lum, S. K., Moyer, B. C., and Yuskavage, R. E. (2000), "Improved Estimates of Gross Product by Industry for 1947-98," *Survey of Current Business*, 80:6, 24-54.
- Morgan, M.S. (1990), *The History of Econometric Ideas*, Cambridge, UK: Cambridge University Press.
- Polenske, K. R. (2000), "Leontief's Magnificent Machine and Other Contributions to Applied Economics," Paper presented at the Thirteenth Annual International Input-Output Association Conference, 21-25 August, Macerata, Italy.
- Porter, T. M. (2001), "Economics and the History of Measurement," in *The Age of Economic Measurement*, eds. J. L. Klein and M. S. Morgan, Durham, NC: Duke University Press, pp. 4-22.
- Stigler, S. (1999), *Statistics on the Table: The History of Statistical Concepts and Methods*, Cambridge: Harvard University Press.

Table 1. Selected cells from “Quantitative Input and Output Relations in the Economic System of the United States, 1919.”

(in millions of dollars)

Distribution

of outlays

Distribution of output

		Iron and steel	Automobiles	Exports	Consumption	Total output
		14	15	42	43	
14	Iron and steel	503	381	896	634	11,610
15	Automobiles		997	152	1,773	3,305
	...	...	...	...	...	...
42	Imports	36			572	4,205
43a	Wages and salaries	4,096	677		3,464	33,356
43b	Capital and entrep. services	866	207		5,382	30,937
43c	Total services	4,962	884		8,846	64,293

Total outlays	12,482	3,488	7,890	52,362	205,576
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Source: Leontief (1937).

Table 2. Features of the Early Input-Output Tables

Feature	Table year		
	1919 and 1929	1939	1947
Fundamental accounting concept	Revenue and expenditure accounts for establishments	Separate current and capital accounts for establishments	Separate current and capital accounts for establishments
Government	In undistributed sector	Separate sector	Separate sector
Unit of measurement for labor	Current dollars	Employee years	Employee years
Number of sectors	44	95	500
Imports	Classified by using sector	Classified by using sector	Classified by industry producing rival products

Table 3. Industries in which real gross domestic output is measured at least in part by using the value of inputs

Industry	Output (billions of dollars)
Agricultural services	n.a.
Construction:	
For the Department of Defense	n.a.
For state and local highways	n.a.
For private electric and gas utilities	n.a.
For farms, excluding residential	n.a.
For other nonresidential maintenance and repair	n.a.
For other residential maintenance and repair	n.a.
School buses	n.a.
Marine cargo handling	n.a.
Other air transportation	n.a.
Freight transportation arrangement	n.a.
Other transportation services	n.a.
Nondepository institutions	78.5
Holding and other investment offices	24.2
Other computing services	n.a.
Other health services	n.a.
Social services	57.8
Membership organizations	53.7
General government	972.3

Note: n.a. means not available.

Source: Lum, Moyer, and Yuskavage (2000).