The U.S. Benchmark IO Table

History, Methodology, and Myths

Douglas S. Meade*

In the search for truth by calculation, all certainty is in the clearness of the data.

Francois Quesnay

This paper looks at the U.S. Benchmark input-output (IO) table from three different perspectives: 1) how did the table develop, from Leontief's first ideas to the tables produced today by BEA?; 2) how is the table built?; and 3) what are the myths or intellectual ideals which motivate the development and analysis of the IO table? The three perspectives are interrelated. The historical development has had a large influence on the data and methodology used today. The myths or ideals have motivated the aspects of the historical development, and condition the methodology by suggesting appropriate tradeoffs. The attainable methodology falls short of the ideal, and this shortcoming is seen in constraints faced during the historical development. The myths continue to guide improvements in the methodology, and influence the future development of the IO table.

History

The Genesis of the Input-Output Table[1]

When did Wassily Leontief first conceive the idea of the input-output table and input-output analysis? What drove him to pursue this quest? In personal interviews he states that the ideal was already forming as he worked on his Ph.D. thesis in Berlin: *The National Economy as a Circular Process*.[2] In this work he became dissatisfied with the prevalent neoclassical concepts of supply and demand equilibrium, and was spurred to provide an empirical framework for the study of interdependence in the economy. General equilibrium theory did not provide a way to integrate the facts, and Leontief felt a need for a framework to provide a systematic, consistent factual background.

After completing his Ph.D. Leontief was in the Institute for World Economics in Kiel, Germany, where he remembers the core ideas of input-output forming in his mind. From Kiel he was invited to the National Bureau of Economic Research (NBER) in the U.S., where he received some foundation money and a research assistant. He began to systematically gather detailed economic information, especially Census data. By 1932, he was at Harvard, and he took inspiration from Quesnay's *tableau economique*. Quesnay was an 18th century Physiocrat who contributed the idea of the general interdependence among the various parts of the economic system, which Leontief hailed as "the very foundation of economic analysis".

---

* Paper presented at the 18th Inforum World Conference in Hikone, Japan, September 5-10, 2010. Douglas S. Meade: Inforum, University of Maryland, P.O. Box 451, College Park, MD 20740, meade@econ.umd.edu.

[1] Much of this section draws on two papers by Martin Kohli of the BLS, published in 2001, as well as several published interviews with Leontief.

[2] See Foley (1997), and DeBresson (2004).

After 4 years of dedicated effort, Leontief published his first *tableau*.[3] Based on 1919 Census data, national income worksheets from the NBER, data from trade publications and special investigations, the table comprised 44 branches or sectors of the economy, of which 41 were production accounts. The 42nd branch was foreign trade, with the row representing imports, and the column representing exports. The 43rd branch consisted of households. The final branch was an 'undistributed' column and row, which reflected a number of gaps in the data as well as in the statistical framework. Notable gaps included revenue and expenditure accounts for wholesale and retail trade, banking and finance, nonrail transportation, and the government sector. The theoretical basis for the statistical analysis underlying the table was that of the aggregation of a set of receipts and expenditures accounts, for both business establishments and households. Expenditures included both current expenses as well as capital outlays. Any given branch could have a difference in receipts and expenditures, defined as net saving.

By 1939, Leontief had developed a very similar table for 1929, and the two tables were published in *The Structure of the American Economy, 1919-1929,* in 1941. Several previously published articles were reprinted in this volume, which showed the type of analysis that could be done with the table. An appendix described the data sources and development of the table, in more detail than the previously published papers. The book did not receive a positive response in the academic economics community. In fact, sales of the book were so poor that Harvard University Press discouraged Leontief from pursuing a second edition.

Both the 1919 and 1929 tables were 'closed', in that there was no autonomous sector that would be responsible for a 'bill of goods' or set of final demands that were exogenous to the input-output solution. Each sector had a productivity coefficient, which represented technical change, which was achieved by scaling down proportionally all the inputs required to produce a given level of output. Savings coefficients were introduced to determine how much savings or dissavings took place in a given sector. The theoretical analysis Leontief provided was very unlike much of what passed for input-output analysis in later years. Leontief posed the question: How would the system of relative prices and quantities change in response to different values of the productivity and savings parameters? This analysis was performed at a level of only 10 branches, due to severe constraints on computational capabilities.[4]

First Work with BLS: the 1939 IO Table

The 3rd table produced by Leontief was quite a different affair, driven by a different set of circumstances and demands. In April 1941, before the U.S. had officially entered the war, questions of the effects of mobilization and demobilization were of great interest to the White House. Money was requested at the Bureau of Labor to study these issues, and luckily a staff member there knew of Leontief's work from previous association at Harvard. Unlike the tepid response given to the input-output table by academic economists, government staff were quite enthusiastic about the potential of input-output analysis to answer important practical questions. The Bureau hired Leontief, and set up an office in Cambridge, where Leontief set to work on a 95-sector table for 1939. Sufficient staff and computational resources were also provided.

Leontief published the 1939 table with an analysis of the effects of demobilization on employment.[5] The article highlighted the open structure of the new table, and added a set of

[3] Leontief (1936), reprinted in Leontief (1951).

[4] The technology of computation was developing rapidly in this period, but was still limited to mechanical calculators and tabulating machines.

[5] Leontief (1944).

employment data, which were related to production by fixed coefficients. The table was now designed to handle "what-if" questions. However, analysis was still done at a level of only 11 sectors.[6]

Another important change with the 1939 table was an attempted reconciliation with the national income accounts. Marvin Hoffenberg, who was responsible for this work, separated current and capital expenses, thus adding an investment column and a row for capital depreciation. Leontief also did away with the complicated structure of productivity and savings coefficients used in the 1919 and 1929 tables. The new system was much more congenial to policy analysis, and several studies were performed by Leontief and by Bureau of Labor staff.[7]

Table 1[8]

Large Scale Benchmark Tables Produced by BLS and BEA

Reference Year	Publication Year	Classification System	Number of Industries / Commodities	New Features	Treatment of Secondary Products
1947	1954		450	First large scale table for the U.S.	Sale from producing industry, redefinitions
1958	1964	1957 SIC	86	Integration with national accounts	Sale from producing industry, redefinitions
1963	1969	1957 SIC	367	Expanded industrial detail, 3 value added rows	Sale from producing industry, redefinitions
1967	1974	1967 SIC	367		Sale from producing industry, redefinitions
1972	1979	1972 SIC	496	Make and use format	Make and use tables
1977	1984	1977 SIC	537	Adjustments for underreporting	Make and use tables
1982	1991	1977 SIC	541	Workfile table made available	Make and use tables
1987	1994	1987 SIC	480	Supplementary tables without redefinitions	Make and use tables
1992	1997	1987 SIC	498	Expanded Census coverage	Make and use tables
1997	2002	1997 NAICS	495	Adoption of NAICS, treatment of auxiliaries	Make and use tables
2002	2007	2002 NAICS	430	Government as producer	Make and use tables
2007	2014	2007 NAICS	??		

Development of the 1947 Input-Output Table

After the conclusion of the war, the U.S. Air Force took an interest in the input-output table, which constituted a large source of funds for the eventual development of the 1947 input-output table. The Planning Research Division of the Air Force set up an interagency project, known as project SCOOP (Scientific Computation of Optimum Programs), whose funding soared after the eruption of the Korean War in 1950. As a result of the increased funding, Leontief and the Bureau of Labor staff were able to develop the table at a high level of detail – 450 industrial and 50 autonomous sectors. The table also benefited from significantly increased budget for the 1947 *Economic Census* which provided increased industrial detail as well as more information on purchased inputs.

Computational power had also increased significantly by this time. The Bureau had access to one of the first UNIVAC I computers produced in the U.S., and this was used to derive total

[6] Leontief mentions in his Nobel autobiography (1973) that he had access to the Harvard Mark I computer at this time. However, this computer still was very limited in its computational power.

[7] Of particular interest is the paper by Cornfield (1945), and the projections developed by Cornfield, Evans and Hoffenberg (1947). These men were all Bureau of Labor staff who contributed significantly both to the statistical as well as to the theoretical development of the input-output table. Leontief published a series of analytical papers in the *Review of Economics and Statistics*, and *Quarterly Economic Journal*, which were later published in the 1951 edition of *The Structure of the American Economy.*

[8] Table 1 can be used as a reference for the rest of this section.

requirements matrices of the 1947 table at a very detailed level. Such a task would have been infeasible with the calculating machines available just 10 years earlier.

The methods and data sources for the development of the table were published in book form by the Conference on Research in Income and Wealth (1954)[9]. A year later, the CRIW published another volume of papers with discussion on aspects of the input-output table development, evaluation of analysis and projections using the table, and discussion of various statistical issues.

The Hoffenberg Papers

Marvin Hoffenberg, who was mentioned above as an important member of the Bureau of Labor staff who understood both input-output and national accounts, was also the self-appointed archivist and preserver of documentation, worksheets, unpublished papers, research plans, and a wealth of other material. In 2006, more than 50 years after the publication of the 1947 table, Hoffenberg donated to the BLS more than 10 boxes of papers, notebooks and materials associated with the first large input-output table. Some of these papers have been scanned into PDF format, which will be made available at the present conference.

Why There Was No 1954 Table

The next *Economic Census* was released for the reference year 1954, and it would have been logical for the Bureau to continue its input-output development program to produce a 1954 table. However, this was destined not to happen. In 1953, President Eisenhower took office, and his Defense Secretary eliminated all Department of defense funding for input-output work, essentially closing down the Bureau of Labor operation. This was partly motivated by the fact that the new administration took a less activist approach to economic management, particularly after the end of the Korean War, and that input-output tables were more useful in a centrally planned economy.[10]

However, the usefulness of the IO table for internal reconciliation of the national accounts was still an important issue. In 1956 the Budget Bureau asked the National Bureau of Economic Research to review the national accounts. In its published research report[11], the National Accounts Review (NAR) committee recognized that IO tables provided an important tool for identifying deficiencies in the national accounts. Partly as a result of the recommendations of this report, Congress decided to reestablish funding for the development of the 1958 IO table. The work of building this table was transferred to the Office of Business Economics (OBE), which also produced the national accounts. A new division of the OBE was created in 1959, named the Interindustry Economics Division. Several members of the original BLS staff transferred to this new division[12]. OBE was later renamed the Bureau of Economic Analysis (BEA), which continues the work of compiling the IO accounts to this day.

---

[9] The web publication of *Concepts and Methods of the U.S. Input-Output Accounts* (2006, 2009) is the most recent of a succession of detailed documentation, of which this 1947 technical supplement was the earliest complete published description of the compilation of a detailed IO table for the U.S. Many of the techniques described in this book were carried over directly to the BEA for the development of the 1958 and later tables.

[10] Kohli (2001), p. 18, Polenske (2004), p. 12.

[11] National Accounts Review Committee, NBER, 1958.

[12] Of particular note are Philip Ritz, Albert Walderhaug and Beatrice Vaccara.

The 1958 Table

After President Kennedy took office in 1961, the OBE began in earnest its new task of compiling the 1958 IO table. Computer technology was advancing rapidly, facilitating the handling of the mass of new data available from the 1958 Economic Census[13]. Since funds were more limited than for the 1947 IO table project, it was decided to publish a table with a much smaller number of sectors. The 86-sector table for 1958 was published by OBE in 1964[14]. The first report emphasized the integration of the IO table with the existing national accounts, which had indeed been one of the main recommendations of the NAR Committee. However, the integration was only achieved in a broad sense, in that the totals of the final demand columns would be consistent with a newly revised series of national accounts data, yet to be published[15]. The table had only a single value added row, which was to have the same total in the IO and the national income accounts, but the industry distribution would differ. The revised set of national income accounts became known as the Comprehensive Revision. These revisions were instituted at OBE to follow the publication of the benchmark IO table, and to consist of revisions to data back to the previous Comprehensive Revision[16]. The 1964 paper did not specifically address what would be done with the national accounts statistical discrepancy in the process of integration. This discrepancy represents a difference in the product and income side estimates of GNP (later GDP). The consistency enforced by the IO framework leaves no room for such a discrepancy. The 1964 paper also promised that a detailed industry-by-industry reconciliation of IO value added with that in the national accounts would be included in a subsequent publication, but this promise was not taken up until after the publication of the 1963 IO table[17]. A fully operational reconciliation of value added awaited the publication of integrated annual IO and benchmark IO tables, 40 years later.

Like its predecessors, the 1958 table made no distinction between industries and commodities. Where secondary products, or products other than the main product, were produced, they were handled in the table using "fictitious sales" of the secondary products to the primary producing industries[18]. Since it was assumed that the user of the IO tables would have no computer of her own available, total requirements tables were made available to translate the impact of final demand changes to output changes, using a computer program made available by the Harvard Economic Research Project.

---

[13] However, at this time the OBE did not yet have its own computer system. The first system developed to process the IO table was written in COBOL, and the computing was done via remote time sharing, on a computer leased from the Bureau of Standards.

[14] Goldman, Marimont and Vaccara, 1964.

[15] For various technical reasons total imports and total exports in the IO table are not conceptually equivalent to the analogous measures in the U.S. national accounts. However, the differences cancel out when treating imports and exports together, so that net exports in the IO table is conceptually equivalent to that in the national accounts. The main differences are: 1) merchandise returned; 2) reexports; and 3) statistical revisions.

[16] In practice, due to statistical and methodological changes, the Comprehensive Revisions have normally resulted in revisions of time series longer than the preceding 5 years.

[17] Walderhaug (1973).

[18] Almon (1967) noted that such transfers are "not only confusing when looking at the table, but can also distort the outcome of its use."

The 1963 and 1967 Tables

After completing the 1958 table, the staff and budget of the OBE industry division was increased, and development of the 1963 table began. The first results of this effort were published in 1969[19]. Industry detail was increased from 86 to 367 industries. According to the study authors, the expansion of industry detail was "strongly urged by a broad cross section of users". In addition to the data tapes made available by OBE, three separate volumes of additional detailed information were published. Within the period of the compilation of the 1963 table, OBE also revised the 1947 table to be consistent with the 1958 table, and published the 1963 table on the same basis, so that 3 consecutive tables were available in comparable form.[20] The 1969 article indicated that forthcoming OBE studies would compare these three tables and analyze the changes in economic structure indicated by the tables.

More attention was given in the 1963 table to the development of the value added estimates, which were now separated into employee compensation, profit type income (including capital consumption allowances) and indirect business taxes. In the balancing of the table, profit type income was treated as a residual and adjusted to enforce consistency. As discussed above, a separate article was published reconciling and comparing the IO estimates of value added with those in the national accounts.

The 1963 table also saw the development of the first OBE capital flow table, which shows purchases of new structures and equipment by using industry, classified by supplying industry, and distinguishing values at producer prices and trade and transportation margins in each cell, just as in the industry transactions table[21].

The 1967 table was published on the same industry definitions as the 1963 table, and the first survey article describing it came out in 1974[22]. The importance of energy analysis was discussed in the survey article, and it was stated that BEA (renamed in January, 1972) planned to prepare more product and industry detail for the important energy-producing and energy-consuming sectors. The 1967 table also had a capital flow table, published in 1975.

The 1972 Table

The 1972 was a major break with the previously published tables. The most significant change was the presentation in the form of separate make and use tables, as proposed in the 1968 System of National Accounts. In this format, the table explicitly recognized the distinction between industries and commodities. The make table had industries as rows and commodities as columns. Reading across any given row showed the mix of commodities or products produced by that industry. Reading down a column showed the distribution of production of a given commodity across the different industries. The row and column sums of the make matrix were total industry output, and total commodity output, respectively. The use table had commodities as rows, and

---

[19] National Economics Division (1969).

[20] Unfortunately, the dream of a time-series of consistent tables has not been attainable, due to the extensive revisions in definition and methodology. BEA is currently completing an effort to produce historical tables consistent with the newer NAICS classification system and the currently used IO definitions, but these tables will necessarily be at a fairly aggregate level.

[21] Young, et.al. (1971). For the 1958 table, BLS continued to play a role, estimating the capital flow table. However, the table was not publicly released until 1968. See Alterman and Kutscher (1968).

[22] Interindustry Economics Division (1974).

industries as columns. Each row showed the distribution of sales of a given commodity to the industries, or to final demand. Each column showed the mix of commodities used by an industry to produce its various products. In presenting the total requirements tables, BEA chose to present commodity-by-commodity table and a commodity-by-industry table, derived using the industry technology assumption[23]. The treatment of secondary products was of course completely different than in the previous tables. In addition to the explicit recognition of secondary products highlighted in the make table, there were about a half dozen major cases where activity was redefined to an industry having more similar input requirements:

1. Construction work performed by all industries ("force account construction") was redefined to the construction industries.
2. Manufacturing in trade and service industries was redefined to the manufacturing industries.
3. Retail trade in service industries was redefined to the retail industry. Services performed by trade industries were redefined to service industries. Selected services were redefined between service industries.
4. Manufacturing wholesale activity was redefined to wholesale trade.
5. Rental activities of all industries were redefined to the real estate and rental industries.
6. Electricity produced and sold by mining, manufacturing and railroads was redefined to the electric power industry.

Other redefinitions were performed based on the same criteria: the activity has a different input mix from the main industry in which it is primary in the table before redefinitions.

The 1972 table also had significantly enhanced sectoral detail, with 496 intermediate industries and commodities. The classification system used was the new 1972 Standard Industrial Classification (SIC) which was a significant revision and expansion from the earlier 1958 and 1967 versions.

Shortly after the publication of the 1972 table[24] in the *Survey*, BEA published *Definitions and Conventions of the 1972 Input-Output Study*[25]. Although similar in scope to earlier supplementary publications for the 1958 and 1967 tables, the 1972 version, authored by Philip Ritz, was the largest, most authoritative documentation published since the 1947 table. Data sources, compilation methodology, mathematical derivations and definitions were all covered. A capital flow table for the 1972 table was also published in July, 1980.

[23] The document "Mathematical Derivation of the Total Requirements Tables for the 1972 Input-Output Study" is available from the author on request, or can be found on the BEA web site.

[24] Interindustry Economics Division (1979).

[25] Ritz (1980).

The 1977, 1982, 1987 and 1992 Tables

The 1977 table, like the 1972 and 1967 tables, was published with a 7 year lag from the reference year, in 1984[26]. It was also based on the 1977 SIC, and sectoral detail was increased to 537 intermediate industries and commodities. One innovation, which reduced compatibility with the 1972 and earlier tables, was the introduction of misreporting, or underreporting adjustments, based on IRS tax compliance data. This had the effect of raising output estimates in most industries, but especially those industries which typically have extensive tax evasion (construction and retail trade are two examples).

The 1982 table was distinguished by the fact that it took the longest to build. The table was not published until 1991[27], a full 9 years after the reference year! Furthermore, during this period almost nothing was published in the *Survey of Current Business* relating to input-output, except for some interesting articles on the annual IO tables. However, the 1982 table had 541 intermediate sectors, and a large increase in the detail available for construction, with 36 new construction categories, and 17 categories of maintenance and repair construction. Also, a full detailed "workfile" was available to users upon request, which contained detailed source data and documentation relating to the building of the table.

A capital flow table for the 1977 benchmark was published in November, 1985 *Survey of Current Business*. A capital flow table for 1982 was produced and distributed, but was not published. The 1977 benchmark was also accompanied by a publication of estimates of employment and employee compensation by IO industry.[28]

Partly due to negative reactions to the long delays associated with the 1982 table[29], the production of the 1987 table was accelerated. Although not released until 1994[30], still a 7 year lag from the reference year, the actual production of the table took only 3 years. Time was saved by compiling only 5 construction sectors, and by relying on previous benchmarks for the estimation of many intermediate flows, which had previously relied on non-Census sources. The total number of published intermediate sectors was 480, based on the new 1987 SIC. The 1987 IO table also featured a new supplementary version of the make and use tables, published without redefinitions. This supplementary version, although less "pure" from an analytical standpoint, had values of output that were closer to published data, and were also more easily related to industry measures of income from the national accounts. Due to the accelerated schedule of the 1987 table, no capital flow table for 1987 was ever published.

The 1992 table was the last U.S. benchmark IO table published on the SIC basis. Published in November 1997, with 498 intermediate sectors, the table incorporated an important innovation, which had first been introduced in the national accounts. Government expenditures were now divided into either consumption or investment, and government consumption now included an estimate of depreciation of government capital stock, also following an earlier innovation in the

---

[26] Interindustry Economics Division (1984).

[27] Interindustry Economics Division (1991).

[28] See Yuskavage (1985). Earlier estimates of employment by input-output industry had been made for 1972 and 1967, but these were not published, and as far as I am aware, are no longer available.

[29] The Interagency Working Group on the Quality of Economic Statistics was formed partly in response to users' concerns over the timeliness of the IO accounts. It had the acceleration of the benchmark IO tables as one of its main recommendations, with the table to be available within 5 years of the reference year, and within 1 year of the release of all economic census data.

[30] Interindustry Economics Division (1994).

national accounts. Enhanced coverage was available from the 1992 *Economic Census*, with about 95 new industries.

The Advent of NAICS: the 1997, 2002 and 2007 Tables

The North American Industry Classification System, or NAICS, represents a huge change in classification of economic data. Adopted by the U.S., Canada and Mexico, it was first used in the U.S. for the 1997 *Economic Census*. The benefits of NAICS were seen to be the enhanced detail available for the relatively newer industries, particularly those previously classified as "services", as well as the theoretical attraction of grouping industries based on the production techniques, as opposed to their main markets. The downside of NAICS was that long time series of data compiled on the SIC basis were now discontinued, and there were only spotty efforts made by government agencies to reclassify previously published SIC data on a NAICS basis. For users such as Inforum, using industry time series data to build econometric models, NAICS came with a large cost.[31]

A new Information sector (NAICS 51) was created, that included publishing, motion pictures and sound recording, broadcasting and telecommunications, and information services and data processing. A new "Auxiliaries" (NAICS 55) sector was created, that included establishments that served administrative, management, storage or distribution functions within a large company. Transactions between these establishments and other production or distribution establishments within the same company were now treated as intermediate transactions.

The 1997 table was published[32] with 495 NAICS intermediate industries, in December 2002. A capital flow table for the 1997 table was published in November 2003.[33] Another major innovation in the 1997 table, besides the classification system change, was that purchases of software, whether as an arms-length transaction, or whether developed internally ("own account software) were now treated as investment (now called private equipment and software, or PES), and the dollars spent on software or software development were moved from the intermediate sector to the investment component of final demand.

Looking forward to tighter integration with the GDP by industry accounts and the national accounts, industry definitions were changed to be more consistent with those accounts, and the featured or *Standard* set of make and use tables were now the tables "before redefinitions" (also called "NAICS"). The tables "after redefinitions" (now called "IO") were available now as *Supplementary* tables.[34]

The 2002 table, published in October 2007[35], was based on the 2002 version of the NAICS, and had 430 intermediate sectors. It incorporated numerous innovations from the previous NIPA comprehensive revision. The most notable of these were:

---

[31] At the time of this writing (2010) there are published annual IO data available only from 1998 to 2008, at a level of only 65 industries. Gross output data are more detailed, but still only available from 1998 to 2008.

[32] Lawson, et. al. (2002).

[33] Meade, et.al. (2003).

[34] The "after redefinitions" tables are closer to being "pure" and are used by Inforum as the starting point in developing its product-to-product tables using commodity technology.

[35] Stewart, et. al. (2007)

1. *Government as producer*. The government sectors were now recognized as producing industries. This change put the purchases of government (consumption) into the intermediate portion of the table. Sales of government (mostly education and health care, but also sales of used assets and commodities out of inventory) were treated as sales to other industries and to final demand. The advantage of this change is that government sales no longer appear as negative entries in the government final demand column. However, for analytical purposes it makes the treatment of government expenditures as an exogenous variable difficult.
2. *Banking and insurance*. Implicit services provided by banks are now specifically imputed. Investment income earned by insurance companies is now included in output. "Normal" losses are now used instead of actual losses in measuring output.
3. *Gross operating surplus*. Replaces the old concept of "other value added", and includes all profit-like income.
4. *Taxes on production and imports.* Replaces the old concept "indirect business taxes". Payments not related to profit-like income have been reclassified as government transfers.

Again, these numerous innovations broke consistency between the 2002 and earlier IO tables.[36]

Perhaps the most ambitious innovation associated with the 2002 benchmark IO table is the method of balancing, which was used to more closely integrate the benchmark IO estimate with the annual IO, GDP by industry, and national accounts. Whereas in all previous tables either total value added or "other value added" had been obtained as a residual, in the 2002 table there was an explicit goal to reconcile value added in the benchmark and in the GDP by industry/annual IO. Individual elements in both tables were adjusted according to reliability or quality estimates.[37]

As this paper is being written, BEA is working on the 2007 benchmark IO, scheduled to be released in 2014.[38] The 2007 benchmark will be using a new version of the NAICS for the industry classification. There will also be improved consistency between the benchmark and the national accounts and annual IO accounts. BEA has a goal to improve the time-series consistency of the IO tables. International standards of presentation of IO tables have also evolved towards showing transaction records valued at basic prices, instead of producers prices, which involves estimating and publishing the commodity tax associated with each transaction. Most of the international community has also adopted the SNA supply and use table presentation. There is a slight possibility that BEA may make tables available in this format sometime in the future.[39]

---

[36] As part of the production process of the annual IO tables, a working version of the 1997 table which includes many of the innovations adopted in the 2002 IO table is a necessary input. However, because of the limitations of time series consistent source data, the published annual tables do not include this year and begin in 1998.

[37] See Rassier et. al. (2007), and more in the next part of this paper.

[38] BEA has indicated in the Strategic Plan to release I-O accounts that are consistent with the NIPAs and also time-series consistent. This plan implies a publication schedule for the 2007 BM that is different from the 5 year schedule of more recent years.

[39] See Guo and Planting for an excellent presentation of the proposed framework, and a discussion of the pros and cons of the framework in the conclusion. The authors conclude that presentation of several alternative frameworks would be most beneficial, but would be more costly.

Methodology, or How to Build a Benchmark IO Table

Overview

The production of the Benchmark IO table for the U.S. by the Bureau of Economic Analysis is a major effort, probably the largest single recurring statistical release in the government that does not involve direct surveys. The production cycle is now generally every five years, for years ending in '2' and '7', which is dictated by the schedule of the Economic Census. The work of producing the table takes nearly the entire five years, with the lag from reference year to publication being five or more years. The following sections describe the main components of the project. Space does not permit a detailed comparison of the differences between the various benchmark tables that have been produced. Therefore in this paper I will focus on the steps in building the 2002 benchmark table. However, table 1 from the previous section summarizes some important facts about the tables from 1947 to 2002, and the 2007 table, anticipated to be released in 2014. The sequence of presentation parallels closely the actual calendar sequence of the work, although of course some tasks are performed simultaneously, and many parts need to be revisited or redone, in light of changes indicated by changes in available data, or from final review and reconciliation of the table.

Planning

This step is extremely important, and is left out of most documentation and descriptions that are available. Each benchmark IO table is unique, with regard to sectoral classification, definitions and concepts, availability of source data and methodology. A plan needs to be implemented that can take all aspects of these unique differences into consideration, to produce the highest quality table possible within the given time constraints. There is not much room for slippage in the schedule, and there is a degree of uncertainty as to available personnel and budget.

The planning phase may begin up to 2 years in advance of the actual start of work on the table. Planning the table also requires coordination with National accounts staff, to decide how to integrate new or upcoming revisions in the NIPA methodology or statistical definitions. Coordination with the Bureau of Census is also extensive, as the *Economic Census* is one of the main data sources of the table, and changes in coverage and classification in the Census strongly affect the quality of data and level of detail that will be available for the benchmark IO table. Other important agencies requiring coordination include the Internal Revenue Service (IRS), which is important for tax and income data, the Economic Research Service (ERS), where most of the agricultural data is obtained, the Energy Information Administration (EIA), which supplies much of the energy related data, and the Department of Transportation (DOT), which supplies data on transportation industries.

The planning phase also includes the design or redesign of the benchmark data processing system. The system is currently implemented in a SQL database, with various graphical front-end programs for the analysts to feed in data, perform manipulations, make estimates and review results. In the most recent benchmark table, for 2002, the processing system was enhanced to include a module for the reconciliation of the benchmark and annual IO tables, using reliability weights based on statistical estimates as well as subjective judgment.[40]

[40] See Rassier, et.al. 2007 for a description of the statistical and mathematical techniques used.

Classification

The design of the classification system for the benchmark IO table is necessary for several aspects of the table, as well as the underlying detail used to build the table. Perhaps the most important decision is the commodity and industry classification of the intermediate portion of the use table, which corresponds to the definitions for the make table. Considerations include: the level of industry and commodity detail available from the Economic Census and other primary data sources; the relative size and importance of industries; the relative cost necessary to develop estimates for a given industry; and the value of information about this industry to the users of the table. In the 2002 table, the source level classification system is the 2002 North American Industry Classification System (NAICS 2002). The commodity and industry classification scheme used for the table is "NAICS-like". At the detailed 430 sector level, these are 6-digit codes which are in some cases identical to NAICS, but sometimes related, in the case where several 6-digit NAICS codes needed to be combined. In addition, the IO classification system includes "special industries" and "government industries" that are not considered industries in NAICS. "Activity based" industries are used for agriculture, construction and real estate.[41]

Table 2 below shows a small selection of the industry codes used in the 2002 benchmark and their NAICS definitions.[42]

Table 2. Extract of Appendix A

I–O industry code and title	Related 2002 NAICS codes
3253 Agricultural chemical manufacturing	
325310 Fertilizer manufacturing	325311–4
325320 Pesticide and other agricultural chemical manufacturing	325320
3254 Pharmaceutical and medicine manufacturing	
325411 Medicinal and botanical manufacturing	325411
325412 Pharmaceutical preparation manufacturing	325412
325413 In-vitro diagnostic substance manufacturing	325413
325414 Biological product (except diagnostic) manufacturing	325414
3255 Paint, coating, and adhesive manufacturing	
325510 Paint and coating manufacturing	32551
325520 Adhesive manufacturing	32552
3256 Soap, cleaning compound, and toiletry manufacturing	
325610 Soap and cleaning compound manufacturing	32561
325620 Toilet preparation manufacturing	32562

At a more detailed level than the commodity and industry classification is the item classification. The item codes represent components of output, such as industry and product shipments, miscellaneous receipts, installation receipts, maintenance receipts, and research and development. The first 6-digits of the item code represent the commodity which includes it, and the ending digits or characters indicate the type of detailed product or component of output. Table 3 below

[41] See Lawson, et.al. (2002) p.24 for a more detailed description of the commodity and industry classification system.

[42] This is an extract of Appendix A of Stewart, et.al. (2007) pp. 35-38.

shows an extract of the item output file for the commodities 325411 Medicinal and botanical manufacturing and 325412 Pharmaceutical preparation manufacturing.[43]

Table 3. Extract of the Item Output File

325411AO	Medicinal and botanical manufacturing, other miscellaneous receipts	9.9
325411IC	Medicinal and botanical, inventory change	29.9
325411RSL	Medicinal and botanical manufacturing, value of resales	-0.4
325411T	Medicinals and botanicals	12754.4
325412AO	Pharmaceutical preparation manufacturing, other miscellaneous receipts	510.7
325412CW	Pharmaceutical preparation manufacturing, contract work	507.5
325412IC	Pharmaceutical preparation, inventory change	-18.4
325412RSL	Pharmaceutical preparation manufacturing, value of resales	-1.7
325412T1	Pharmaceutical preparations, for veterinary use	2562.8
325412X	All other pharmaceutical preparations	101997.2

The other major published classification systems used in the benchmark IO are those for the Personal consumption expenditures (PCE) and Private equipment and software (PES). Along with the benchmark IO table, a PCE bridge table is produced, which has IO commodities for rows, and PCE categories for columns. The choice of the PCE classification system is heavily influenced by the system used in the National accounts, as well as by the ease of relating each PCE category to the commodity requirements underlying it. The PES bridge relates the equipment and software spending in the IO table to the equipment and software investment categories in the National Income and Product Accounts.

In addition to the published classification schemes there are various unpublished classification schemes and concordances that are used in the construction of the table. The *harmonized trade concordance* relates over 20,000 harmonized system codes to the commodity codes used for imports and exports in the IO table. The *product line concordance* is used to relate data from the Censuses of Wholesale and Retail trade on products held in inventory to commodity codes used in the IO table. *Input Category Control* (ICC) codes correspond to categories of product or service inputs to industries, which must be mapped or split out to the commodity level. *Retail Category Codes* (RCC) are used to relate the product line sales from the Census of Retail Trade to the Personal consumption expenditures categories. *Materials Consumed Codes* (MCC) relate the codes used in table 7 of the Censuses of Manufacturing and Mining ("Materials Consumed by Kind) to the corresponding commodities.

All of these classification tables must be designed and input to the database before data acquisition can begin. However, the design of the tables is by nature an iterative process, and these tables must be revised continuously as new data constraints and opportunities become known.

Industry and Commodity Output

The first major process involving data collection and input is the derivation of industry and commodity output controls. This is complicated by the fact that much of the source data from the *Census* and other sources is undergoing revisions during the first year of so of compiling the IO table.

---

[43] The complete item output file for the 2002 table is available online as an Excel spreadsheet, at http://www.bea.gov/industry/xls/2002DetailedItemOutput.xls.

Industry output is defined as all output produced by establishments classified within a given industry. Commodity output is defined as the total production of a given commodity (good or service), in whatever industry it was produced. Production of a commodity outside of its main industry is called *secondary production*. The production of the main product is called *primary production*. The make table, which is compiled based on the data for industry and product shipments in the IO database, shows explicitly the accounting for industry and commodity output and secondary products in the IO table.

The outputs of most commodities and industries are based on receipts and shipments data collected by the *Economic Census*. In the case of manufacturing, the Census compiles shipments data on both an industry and a commodity basis. Furthermore, the table of product shipments identifies shipments as primary or secondary products of the corresponding industry. In the Census of Services and several other of the large Census publications, receipts are differentiated by product lines. For example, the extract below from the Repair and Maintenance industries shows that establishments engaged primarily in repair and maintenance also sell merchandise (a retail trade activity) and rent and lease goods and equipment. The latter activities are classified as secondary products when compiling the industry and product output series.

811		Repair and maintenance
	30750	Motor vehicle mechanical and electrical repair and maintenance
	30760	Motor vehicle body, paint, and interior repair
	30770	Other motor vehicle care and maintenance
	30780	Commercial and industrial machinery and equipment repair and maintenance
	30790	Electronic and precision equipment repair and maintenance
	30800	Personal and household goods repair and maintenance
	30820	Other repair and maintenance
	39000	Merchandise sales
	39250	Rental or lease of goods and/or equipment
	39500	All other receipts

Output of goods is defined as shipments plus the change in inventories. Therefore, before arriving at the estimate of industry and product shipments, inventory stock estimates must be compiled by industry and product for beginning of year (BOY) and end of year (EOY). Inventory change is estimated as the difference between EOY and BOY.[44]

The Economic Censuses cover most establishments, but they do not cover businesses without employees, such as real estate agents and "mom and pop" stores. The Census Bureau also compiles data based on administrative records for these establishments[45], and from this information, a *nonemployer adjustment* is estimated to add on to the estimate of output derived from Census data. A *misreporting adjustment* is estimated, which is needed because a certain amount of sales in each industry fail to be reported to the Internal Revenue Service (IRS). The IRS periodically does a major study to assess the extent of this misreporting, and these estimates are used by BEA to adjust both the IO and the national accounts data.

Major industries not covered by the *Economic Census* require data from other agencies. These include Agriculture (U.S. Department of Agriculture), Transportation (U.S. Department of Transportation), and various miscellaneous service industries. For the latter, data from the U.S.

[44] An *inventory valuation adjustment* is also calculated and applied, which attempts to estimate the amount by which inventory change has been under- or over-stated due to price change of goods held in inventory.

[45] Compiled by the Internal Revenue Services (IRS), which collects taxes and tax-related information.

Department of Treasury, the Office of Management and Budget, the Center for Medicare and Medicaid Services, and various other government agencies and private organizations are used.

Estimates of output for some industries and commodities are based on *imputations*. These estimates are based indirectly on data collected from surveys, but require significant amounts of analysis and judgment. Imputations in the IO table include estimates of the output of own-account software (software produced by employees of the establishment), the rental value of owner-occupied housing, financial services provided without direct charges by financial institutions, and output of crops both produced and consumed on farms, such as corn and hay for feeding livestock, which never reaches the market.

Intermediate Industry Inputs

Intermediate inputs are goods and services inputs purchased by establishments in an industry necessary to produce their products. These inputs include not only materials and supplies but also services, such as cleaning services, uniform rental, equipment repair, and services of temporary personnel. They do not include purchases of new capital equipment and structures, which are defined as Gross Private Fixed Investment (GPFI), a category of final demand.[46] The most detailed information available is for manufacturing. Table 7 of the Census of Manufactures and the Census of Mining ("Materials Consumed by Kind") identifies purchased materials at a fairly detailed level. However, the list of intermediate inputs in this table is not comprehensive, and many of the categories must be further split to the IO commodity level using informed judgment to *prorate* a larger category to the more detailed commodity components.

For most other industries, data on expenses and purchased inputs is available only at a much broader level. In the IO database, these data are compiled as *Input Category Controls*, which must also be prorated to the commodity level using judgment, or ratios from previous IO tables. Examples of these input categories include office supplies, purchased electricity, purchased fuels, communication services, refuse removal, packaging containers, contract work and other operating expenses.

Another type of prorating is the distribution of a given commodity across industries. For example, tire purchases may be prorated across purchasing industries according to estimates of their use of vehicles. As a result of improvements in various Census Bureau programs, such as the Business Expenses Survey (BES), prorates are becoming fewer.

Much input data is available only at the cost to the purchaser, and may or may not include transportation or distribution costs (called *margins*). Estimates of these costs are made separately, in a step described below.

The practice of prorating based on previous IO tables leads to a spurious consistency between successive benchmark IO tables that is not based directly on survey data. However, the practice is necessary, as the data do not exist at the detail necessary for compiling the benchmark table.

[46] Intermediate inputs *do* include repair and maintenance of capital equipment and structures, including the cost of spare parts and materials for this repair and maintenance.

Value Added

Value added in the U.S. benchmark table consists of three categories: compensation of employees (COE), taxes on production and imports (TOPI)[47], and gross operating surplus (GOS)[48]. The first two components are estimated from a variety of sources. Compensation data are based in large part on payroll data from the Economic Censuses. TOPI includes excise and general sales taxes, property taxes, and nontax liabilities, such as license fees. Estimates are based on state government tax collection data, and data from the Business Expense Survey. Estimates by industry are adjusted to conform in aggregate to the corresponding estimates in the national accounts.

Until the publication of the 2002 benchmark table, estimates of GOS or "other value added" were derived as a residual. In other words, the cost of all intermediate inputs, labor compensation, and TOPI were subtracted from an estimate of industry output. However, for the 2002 table a sophisticated balancing procedure is used, which adjusts intermediate inputs and gross operating surplus based on information about the quality of the source data.[49]

Transportation Costs, Trade Margins, and Commodity Taxes

Transportation costs represent the costs of transporting commodities from producers to users. Wholesale and retail trade margins are the distribution costs charged by wholesalers and retailers for marketing goods and holding them in inventory. Commodity taxes are primarily sales and excise taxes.

Basic value represents the cost of a product from the producer, before any taxes or margins have been added on. *Producers' value* is the basic value plus any commodity taxes applied to the product and charged to the producer. *Purchasers' value* is the cost of the product inclusive of all trade and transportation margins and commodity taxes[50].

Within the IO transactions table, separate estimates are made for each cell for basic value, commodity tax, and transportation and trade margins. One way of thinking of the table is as a layer of tables, consisting of the following entries:

1. Basic value
2. Commodity tax
3. Truck margin
4. Air margin
5. Water margin
6. Rail margin
7. Pipeline margin
8. Gas pipeline margin

---

[47] This category corresponds closely to what was formerly called "indirect business tax and nontax liability".

[48] This was formerly known as "other value added", but consisted mostly of capital-type income, such as corporate profits, proprietors' income, rental income, net interest, and consumption of fixed capital (CFC), which is depreciation.

[49] This procedure is described in Rassier, et. al. (2007).

[50] Commodity taxes collected and remitted by wholesalers and retailers are included in the producers' value of the wholesale or retail trade industry, and are included as part of the value of the wholesale and retail trade margin charged to the purchasers of the distributed goods.

9. Wholesale trade margin
10. Retail trade margin

The sum of all 10 layers is a transactions table in purchasers' values. The U.S. benchmark table is published in producers' values. The detailed data file accompanying the use table shows producers' values and transportation and trade margins, but does not identify commodity tax.[51]

The sum of these margins across all industries represent part of the output of the transportation and trade industries. These industries also have "non-margin" output. For example, airline passenger travel is part of the non-margin output of the airline industry. Brokers' commissions earned by wholesalers and retailers is part of their non-margin output.

Data on transportation cost to allocate to each cell of the table are not available. Instead, total transport costs by mode are first estimated. then these costs are allocated to commodities by transportation mode, based on data from the Census *Commodity Flow Survey*. Data on pipeline transmission cost is taken from the Economic Census.

Estimates of wholesale and retail trade margins are based on output data from the *Economic Census*, supplemented by data from the Annual Wholesale Trade Survey (AWTS) and the Annual Retail Trade Survey (ARTS). Margins are then allocated to commodities using information on sales for major commodity lines by type of business, which is also available from the Economic Census.

Estimates of commodity taxes are based on information from the annual trade surveys and from the national accounts.

Foreign Trade

Foreign trade transactions represent the flows of commodity goods and services between the U.S. and other countries. Estimates of exports and imports by commodity are based on foreign trade statistics from the Census Bureau and from the BEA international transactions accounts (ITAs). Exports in the use table are shown in producers' values, like the other cells in the table. Imports of goods and services by commodity are shown in the use table at domestic port value, which is equal to the foreign port value plus customs duties, freight charges and insurance. Total imports are shown at the foreign port value. The difference between foreign port value and domestic port value consists of trade and transportation margins necessary to bring the goods from the foreign port to the domestic port.[52]

The use table also contains two commodities which are important for foreign trade: noncomparable imports, and rest of the world adjustment to final uses. The rest of the world adjustment is an offset to entries in the personal consumption and government final demand columns, so that the row sum (output) of this commodity is zero. The offset for personal consumption is necessary because the personal consumption by commodity includes purchases by both domestic residents and foreign visitors. The personal consumption entry for rest of world

---

[51] The availability of commodity tax and subsidies for each element would enable conversion to basic values by users.

[52] However, the value of the margins rows of the imports columns are not equal to the total difference between foreign and domestic port values. This is because the margin is treated as an import if it is carried out by a foreign establishment, but a charge against imports if carried out by a domestic establishment. The resulting net value is the value shown for imports of wholesale trade, and the transportation cells.

represents the total personal consumption expenditures by foreigners in the U.S., and is an offset to the total of the other commodities, so that the total value of personal consumption represents purchases by residents only. The corresponding entry in exports shows that these personal consumption sales are valued as exports, though not separately identified by commodity. The meaning of noncomparable imports has changed over time. In the older IO tables, it consisted of goods such as bananas, pineapples, jute and coffee, which had no domestic supplier. However, in more recent U.S. benchmark IO tables, noncomparable imports consist of services, of which there are three main types: (1) services produced and consumed abroad, such as airport expenditures by U.S. airlines in foreign countries; (2) services that are unique, such as payments for patents, copyrights or industrial processes; and (3) services imports that cannot be identified by type.[53]

The detailed merchandise trade estimates are based on data collected by the Census Bureau, that are classified by over 20,000 Harmonized Tariff System codes. These codes are related to IO commodities through a harmonized trade concordance. Exports and imports of services are obtained from BEA's international transaction accounts.

Domestic Supply

Once output and foreign trade by commodity have been estimated, domestic supply can be formed. Domestic supply of each commodity is the total value of goods and services available for intermediate consumption, personal consumption, private fixed investment, or government consumption and investment. It is calculated as output plus imports and government sales, less exports and the change in inventories. Domestic supply is used to obtain a first estimate of personal consumption, and private equipment and software using the commodity flow method.

Final Uses

The commodity flow method consists of first subtracting estimates of government purchases and intermediate purchases of a commodity from domestic supply to obtain a residual that reflects purchases for consumption or for business investment. In the case of many commodities (especially when working at a high level of detail), the destination is "all or nothing", either completely to personal consumption, or completely to investment. In the other cases, a certain percentage of sales to each category of final demand is estimated based on class-of-customer data from the Economic Census, or other data from trade associations, private businesses or government agencies.

Estimates of residential and nonresidential structures are obtained from information in the national accounts, and from the Census Bureau data on the value of construction put in place. Estimates of government purchases are based on U.S. Department of Treasury data, the Federal Budget, and Census surveys of State and local governments. Estimates of government hospital expenditures are obtained from the Center for Medicare and Medicaid Services.

Reconciliation of Final Uses, Balancing and Final Review

Maintaining consistency between the IO and the national accounts is a lengthy and iterative process. Although estimates of final uses in the IO table are not made independently of those in

[53] Unfortunately, the much discussed phenomenon of outsourcing of call centers and software development fall into this category.

the national accounts, differences in technique and data sources result in numerous discrepancies between the two sets of estimates, particularly in personal consumption expenditures, but also in private equipment and software. Reconciliation to the national accounts is made where the reconciliation seems reasonable. Further reconciliation awaits the publication of the Comprehensive Revision of the NIPAs, which usually occurs within the year following the publication of the benchmark IO table. This comprehensive revision, in addition to incorporating new methodologies and definitions, makes use of the recently published IO table and also relies directly on the Economic Censuses on which the IO table is based.

Balancing of the table is necessary because the accounting structure demands it. The make table relates industry output to commodity output. In the use table, the column sums must equal industry output, and the row sums must equal commodity output. To the extent that there are inequalities, the elements of the table must be adjusted. Rather than scale the existing estimates, balancing records (BR) are added to various parts of the table, so that the original estimates can be separately identified from the balancing items necessary to ensure consistency. In the construction of all past tables before the 2002 benchmark, balancing was largely achieved along the row (by commodity). Discrepancies on the industry side were then added to the other value added entry. No attempt was made to reconcile value added by industry to estimates from the annual IO tables or the national accounts.

Starting with the 2002 table, a method was adopted, originally developed by Richard Stone, in which reliability measures are assigned to components of the benchmark and the annual IO table for 2002, and a generalized least squares procedure is used to adjust the components to achieve consistency between the two tables. The major steps in this process are as follows:

1. Initial estimates of intermediate inputs in the benchmark table[54] and gross operating surplus in the annual table are assigned reliability indicators.
2. Based on these reliability indicators, a reconciliation model is executed. The less reliable the estimate, the more it may be adjusted. Both tables must still satisfy the IO accounting constraints.
3. The model derives reconciled measures of gross operating surplus and intermediate inputs for the benchmark and annual tables.

Future Benchmark Tables

As mentioned above, the 2007 table will make use of the 2007 NAICS. The goal of integration with the GDP by industry and annual IO will continue to be important, and we can expect advances at BEA in time series consistency. Further improvements in source data are also expected, allowing better measurement of intermediate purchases as well as value added components.[55]

---

[54] For the 2002 exercise, the CPLEX solver in GAMS was used. This module contains solution algorithms for linear, quadratically constrained, and mixed-integer problems. The solution was done at the most detailed level available in the benchmark, which consists of 987 industries and 8,910 items (sub-commodities).

[55] The *BEA Strategic Plan: 2010-2014* outlines many of the planned improvements to the benchmark and annual IO tables. It can be accessed at http://www.bea.gov/about/pdf/strategic_plan_matrix_2010-2014.pdf.

What else might be considered? An estimate of employment by industry that matches the benchmark IO industry definitions would be much appreciated by users of the table. One of the ultimate objectives of much IO analysis is the determination of jobs impacts, and such a detailed, comprehensive estimate of jobs by industry is not available anywhere else.[56] The capital flow table for 2002 was sorely missed (as was the one for 1987), and a capital flow for 2007 would be a valuable use of BEA resources, despite questions of reliability. BEA will continue to develop and maintain its travel and tourism satellite accounts[57]. Other types of possible satellite accounts that would be useful are transportation (formerly done with the Department of Transportation, but now discontinued), health (possibly reconciling IO and National Health Accounts) and energy (relating and reconciling IO intermediate, consumer and government energy consumption with the residential, commercial, industrial and transportation accounting used by the Department of Energy). Although such accounts may be thought by some to be the purview of other agencies, there is a great benefit in enforcing a consistent industry classification and the use of national accounting best practices. Of course, in the end, resource constraints and user needs will dictate the choices taken from many competing alternatives.

Myths of the IO Table

The mythology of the IO table begins with Leontief, though many of the themes were foreshadowed by dreams and ideas of earlier economists. The word "myth" has several meanings. One of them is "fictional" or "unproven", which I don't mean to imply, although that may be relevant for some of the myths. Another meaning is "a theme embodying an ideal". The input-output myths are the ideals that continue to motivate those involved with input-output and the data on which it rests. These myths are endorsed by the "rulers and priests" of input-output, although there are several sects and competing viewpoints.

Leontief's primal myth was the ideal of creating systematic, consistent factual background for detailed economic analysis. He was inspired by the quote from Quesnay at the front of this paper, and indeed used it on several occasions. Leontief saw the problem of modern economics as theories without facts, and facts without theories --"empty boxes" -- according to a well-worn metaphor of the time. He saw input-output analysis as a way to apply theoretical techniques to the wealth of hard factual data being collected by the growing statistics establishment.

Leontief was also concerned with the ability of the input-output table to serve as a lens for viewing the change in the structure of the economy over time. His initial creation of tables for 1919, 1929 and 1939 partly served to investigate the changing structure of the U.S. economy over the inter-war period, and he was very excited at the possibility of the 1947 table to show the great changes wrought by the growth in technology and industrial capacity during the war. His hope was obviously that the development of successive tables over time could provide insights to the understanding of technology change and productivity growth, and that it would also be possible to compare the economic structures of different countries.

Related to intertemporal consistency is the myth of constant price tables. Leontief spoke on many occasions as to how the input-output table could be used as a "recipe", where ingredients should be measurable in physical units, such as tons of steel, gallons of gasoline, etc. For such a table to exist at two points in time, where different prices hold, then the elements must be deflated to

[56] The BLS employment projections group provides "output and employment estimates for researchers", at about 200 sectors, so the benchmark project could involve splitting these data based on Census and other employment data.

[57] Funding for these accounts is from the U.S. International Trade Administration.

constant prices. If the constant price input-output table exists in this sense, then the adding up of constant price inputs to a constant price output makes no sense, if the relative prices are indeed changing over time[58]. However, the adding up in constant prices lies behind the recommendation for double-deflation of value added espoused in the SNA.

Another myth has been the importance and possibility of internal consistency enforced by the input-output framework. This was emphasized by Richard Stone in his little book[59] on input-output and national accounts, and was one of the driving forces in the second version of the System of National Accounts. This was the main reason given for the resumption of input-output table compilation in the U.S., after funding for the project dried up after 1953. The related myth of integration has been used to symbolize the goal of creating a system of accounts in which the input-output table is embodied in the core of the national accounts, with full consistency between the industry level data and the aggregate data. This ideal has driven much of the innovation in the U.S. accounts at BEA in recent years.

The myth of consistency has been idolized not merely on the quantity side, but also with regard to prices. The fundamental price identity of input-output relates to ideas in Walras and Sraffa as to the interdependency of the price system, but the input-output system purports to give this interdependency a factual basis. One of Leontief's early papers traced the differential effects of an increase in wages on the prices of the various industries, which differed according to their total labor intensity.[60] Input-output is viewed as one of the best tools for tracing through the effects of a supply price shock, or the differential industry price effects of a carbon tax.

The capital table, or "capital flow" table, embodies several myths. One is the ideal of using the input-output accounts to obtain an integrated measure of total factor productivity, that includes both the factor inputs, the intermediate inputs, as well as the inputs used to produce the capital goods used up in production. Another myth is the possibility of giving flesh to the bones of the "accelerator" of investment, by tracing out how the output changes in various industries translate into the output growth of the investment goods (and now software) industries. The possibility of knowing the detailed "recipe" of capital requirements for an industry leads to the tantalizing possibility of calculating depreciation and therefore capital stock by knowing the service life of each type of capital good. Finally, the capital flow table is attractive in the sense of relating how innovations or technical change embodied in capital goods can be transmitted to the productivity of the using industry.

Although employment is not properly a component of the input-output table, Leontief was very interested in determining employment impacts from different projections of the bill of goods. In fact, one of the worries of policymakers after WWII was that the civilian economy would not be able to generate enough employment demand for full-employment, and that the economy could return to depression. Two of the early studies done with the 1939 table at BLS related to estimating jobs impacts of projected final demand.[61] The dream of using the input-output framework to project employment demand is at the center of the Employment Projections project currently at BLS, which in many ways is a descendant of the early input-output work there.[62]

---

[58] This topic is explored in Meade (2007).

[59] Stone (1961).

[60] "Wages, Profits and Prices", in *The Structure of the American Economy, 1919-1939*, pp. 188-201.

[61] Cornfield (1945) and Cornfield, Evans and Hoffenberg (1947).

[62] This project can be found at http://www.bls.gov/emp/,

Leontief always believed that estimates of the input structure of industries should agree with the knowledge of the businessman or the engineer. From this standpoint, he was not averse to "cold calling" accountants, managers and technical experts who worked in different industries to obtain information about their purchases and the production techniques that they used. This is a belief that is still held sacred by many input-output economists. However, although this procedure was also widely followed in the early days of the U.S. input-output tables and capital flow tables, it seems to be less common today.

The myth of "purity" of the table has an interesting history. When Leontief first presented the input-output framework, he showed each column as representing a distinguishable product, with a given recipe or set of ingredients for its production, given the current state of technology and the factor endowments of the country in question. However, in discussing the 1947 table, which was quite large, he distinguished between the industry producing many products, and the products they produced, and suggested that the products should have a recipe, and that the industry recipe was a mix of that of its products. This idea would correspond to what is known now as "commodity technology". However, the early tables blurred the distinction between commodity and industry, and treated the larger secondary products of an industry as "fictitious sales", as we have seen above. With the advent of make and use tables, it became conceptually clear how to derive a "commodity-by-commodity" or "product-to-product" table, either through the use of the industry or product technology assumption. However, the naïve use of the product technology assumption led to the presence of negative elements in the calculated direct requirements matrix, and was therefore summarily rejected. The innovation of Almon, to use an iterative technique to find a "recipe" matrix with no negatives, and then to calculate the corrected use matrix that it implied, did not easily catch on, perhaps because it was viewed as too subjective, or not mechanical enough. However, it is given sufficient attention in the new edition of Miller and Blair's input-output tome[63] to indicate that the analytical problems stemming from reliance on the industry technology assumption are slowly being recognized[64].

I will leave the reader to ponder, to a certain extent, whether the myths are still only fictional myths, or if they have been achieved as realities. But I will make a few observations under the following headings. My examples are largely drawn from experience with the U.S. input-output table.

Factual basis. As the preceding section on methodology should make clear, a large body of detailed source data goes into the making of a benchmark input-output table. In the U.S., the *Economic Census* provides a rich, detailed set of source data, with a high coverage ratio of establishments. The *Census* is the source of much of the estimates of industry and commodity output, as well as providing information on individual intermediate cells or groups of cells. Exports and imports data are also available at a high level of detail from the Census Bureau foreign trade series. Inventory data are also available in great detail, although the estimate of inventories (to obtain inventory change) by commodity is indirect, and requires making many auxiliary assumptions. At any rate, the measure of total supply (output+imports-exports-inventory change) would seem to be fairly well-grounded in data. However, even the estimates

[63] Miller and Blair (2009).

[64] The most important of these is that the total requirements multiplier for any given commodity will generate demands for inputs not used by this commodity, but in the industry in which this commodity is primary. After the redefinitions made by BEA, the remaining problems are small in magnitude, but troublesome nevertheless, to someone analyzing the impacts of a change in final demand using the IO framework, or a model based on it.

of output require additional assumptions that are not so reliable (such as misreporting or nonemployer adjustments). For some industries (agriculture, real estate, financial services), large portions of output are imputed, based on analytical estimates. Estimates of personal consumption, investment and government final demand rely on commodity flow ratios, whose reliability is unknown. Finally, in the largest part of the table, the intermediate or interindustry flows, very few of the individual flows are based on hard data. Rather, data is available on more aggregate input categories, and these are shared down to the commodity level using fixed ratios derived in the dim past.

Consistency over time. Statistical establishments, like the BEA or the ONS, while fundamentally conservative, feel a need to innovate their methods and concepts to be more relevant to current issues. The extent to which they have done so has made the goal of intertemporal comparisons extremely difficult. We may have soon a new series of historical IO tables from BEA classified in a consistent NAICS sectoring, but they must of necessity be fairly aggregate, and even further from the source data than the original tables.

Internal consistency. The advantage of the input-output framework over the raw source data is that accounting consistency is enforced, which must logically hold. Total industry output must equal the sum of all industry inputs and value added. Total commodity output must equal the sales to all industries and to final demand. Final demand and value added must be consistent with GDP estimates from the national accounts. Adjustments and balancing must be done to force the estimates derived from source data to fit within this framework. However, I would argue that the result is probably more reliable than the original source data, which have not been forced to meet these consistency constraints.

Constant price tables. In the U.S., BEA has still not tackled the compilation of a series of constant price tables. Inforum has been deriving such tables for nearly 45 years now, but in a way that is different from many of the European statistical establishments. While the meaning of an input-output coefficient in a base year, or for a current price table, is well-understood, the concept of the coefficient in a year other than the base year is subject to interpretation. Inforum takes the practice of deflating the individual intermediate rows of the IO table, deflating the output, and forming the coefficient as the ratio. Inforum sees no need to deflate value added, and it not clear what such a deflator should measure. It should be clear that the sum of such input-output coefficients down a column in a year other than the base year should have no predefined sum. In other words, the sum could be greater than one, or much less than one, depending on the degree of relative price change within that column since the base year. The SNA myth is that constant price tables should add up just as current price tables do. In this sect, one deflates intermediate flows, and deflates value added, and the results should add up to deflated output. Hence the need for double deflation. The adoption of chain-weighting by BEA opens up the possibility of a new interpretation for the constant price input-output table. The BEA method of double-deflation implies that constant price columns of cells in the input-output table should aggregate to total real output using a Fisher chain-weighted index. Simple adding up in this framework is not likely to hold, but it obviates (and hides) some of the problems of double-deflation.

Capital flow table. The capital flow table is one of the most useful and interesting territories of the input-output field, but in the U.S., the estimation of the table requires judgment and assumptions[65]. Total investment spending by commodity (i.e., computers) and by industry (i.e., Financial services) is known much more reliably than the individual cells of the table. The

[65] Statistics Canada actually conducts a full annual capital spending survey, which provides a firmer statistical grounding for their capital flow table.

Annual Capital Expenditures Survey (ACES) in the U.S. provides some detailed information periodically (though not usually coinciding with the census year) that can be used as a basis for forming control totals within the table. Some have argued that because of the degree of "unreliability" of the table, that it should not be published. However, like the full input-output table itself, the consistency constraints on the data within the capital flow table yield an apparatus that is much more reliable than the next best alternative, which is the back of the envelope. The capital flow table fulfills a pressing analytical and pragmatic need. Unfortunately, the table for 2002 will not be published, due to lack of resources.

Purity. The ideal of "one commodity – one recipe" is a logically attractive one, and the argument has been provided in the SNA and elsewhere as to why a pure table is analytically superior. The SNA has also provided guidance expressing preference for the commodity technology. The increasing recognition of the Almon iterative technique has been mentioned above. However, the real world is more complex than the theoretical one, especially when dealing with the level of detail in the benchmark. Some production is truly joint, such as meat products and hides. Some "commodities" are still an incredibly messy mix of thousands of products, such as "All other food". Some commodities may be produced by two or more common "recipes", for example depending on whether fabric is woven in the establishment or purchased from outside, for producing sheets. Some commodities, such as Advertising, have different input requirements according to the medium (magazine, TV, internet). Almon makes note of these and many other examples in his paper on the product-to-product (PTP) algorithm.[66] Finally, the meaning of the purification of the value added rows of the table is not clear. Some components of value added, such as gross operating surplus, may be more meaningful at the company level, and not attributable to commodities per se. On the other hand, the businessman certainly considers the profitability of producing individual commodities, when making strategic decisions on investment and R&D.

These various myths continue to attract new adherents, and to guide new statistical and modeling innovations. Leontief would surely be pleased to see the many new developments in input-output in the U.S. and other countries since his death. However, I'm sure he would wish we could do more.

[66] Almon (2000).

References

Almon, Clopper, "How to Purify an Input-Output Matrix", MIFP Research Report #2, July 5, 1967, available at http://www.inforum.umd.edu/papers/wp/wpa/1967/mifp2.pdf.

_____, "Product-to-Product Tables via Product Technology with No Negative Flows", *Economics Systems Research*, 12, 2000, 27-43.

Alterman, Jack, and Ron Kutscher, *Capital Flow Matrix, 1958*, U.S. Department of Labor, Bureau of Labor Statistics, Bulletin #1601, October 1968.

Conference on Research in Income and Wealth, *Input-Output Analysis: An Appraisal*, Princeton University Press, Princeton, 1955.

Conference on Research in Income and Wealth, *Input-Output Analysis: Technical Supplement*, National Bureau of Economic Research, New York, 1954.

Cornfield, J., "Employment Resulting from United States Exports, 1939", *Monthly Labor Review*, July 1945.

Cornfield, J., W. Evans and M. Hoffenberg, "Full Employment Patterns, 1950", *Monthly Labor Review*, February and March, 1947.

DeBresson, Christian, "Some Highlights in the Life of Wassily Leontief – An Interview with Estelle and Wassily Leontief", in *Wassily Leontief and Input-Output Economics*, Erik Dietzenbacher and Michael L. Lahr, eds., Cambridge University Press, Cambridge, 2004, 135-150.

Evans, W. Duane and Marvin Hoffenberg, "The Interindustry Relations Study for 1947", *Review of Economics and Statistics*, XXXIV(2), May 1952, 97-142.

Foley, Duncan K., "An Interview with Wassily Leontief", *Macroeconomic Dynamics*, 2, 1998, 116-140.

Goldman, Morris R., Martin L. Marimont and Beatrice N. Vaccara, "The Interindustry Structure of the United States: A Report on the 1958 Input-Output Study", *Survey of Current Business*, November 1964, 10-17.

Guo, Jiemin and Mark A. Planting, "Integrating U.S. Input-Output Tables with SNA: Valuations and Transactions", Paper presented at the 16th International Input-Output Conference in Istanbul, Turkey, July 2-7, 2006.

Interindustry Economics Division, "The Input-Output Structure of the U.S. Economy: 1967", *Survey of Current Business*, February 1974, 24-56.

_____, *Definitions and Conventions of the 1967 Input-Output Study*, U.S. Department of Commerce, Bureau of Economic Analysis, October 1974

_____, "The Input-Output Structure of the U.S. Economy, 1972", *Survey of Current Business*, February 1979, 34-72.

_____, "The Input-Output Structure of the U.S. Economy, 1977", *Survey of Current Business*, May 1984, 42-84.

_____, "Benchmark Input-Output Accounts for the U.S. Economy, 1982", *Survey of Current Business*, July 1991, 30-71.

_____, "Benchmark Input-Output Accounts for the U.S. Economy, 1987", *Survey of Current Business*, April 1994, 73-115.

Kohli, Martin, "Leontief and the Bureau of Labor Statistics, 1941-54: Developing a Framework for Measurement", *History of Political Economy*, 33:X, 2001, 1-23.

_____, "The Leontief-BLS Partnership: A New Framework for Measurement", *Monthly Labor Review*, June 2001, 29-37.

Lawson, Ann M., "Benchmark Input-Output Accounts for the U.S. Economy, 1992: Make, Use and Supplementary Tables", *Survey of Current Business*, November 1997, 36-82.

Lawson, Ann M., Kurt S. Bersani, Mahnaz Fahim-Nader and Jiemin Guo, "Benchmark Input-Output Accounts of the United States, 1997", *Survey of Current Business*, December 2002, 19-38.

Leontief, Wassily, "Quantitative Input and Output Relations in the Economic System of the United States", *Review of Economics and Statistics*, 18(3), 1936, 105-125.

_____, "Output, Employment, Consumption and Investment", *Quarterly Journal of Economics* 58(2), February 1944, 290-314.

_____, "Exports, Imports, Domestic Output, and Employment", *Quarterly Journal of Economics*, 60(1), 1946, 171-193.

_____, "Input-Output Economics", *Scientific American*, 185(4), October 1951, 15-21.

_____, *The Structure of the American Economy, 1919-1939*, International Arts and Sciences Press, Inc., White Plains, NY, 2nd edition, 1951.

_____, "The Structure of the American Economy", *Scientific American*, April 1965, 25-35.

_____, "Autobiography", given upon receipt of the Nobel Prize in 1973, at http://nobelprize.org/nobel_prizes/economics/laureates/1973/leontief-autobio.html.

Mayerhauser, Nicole M., and Erich H. Strassner, "Preview of the Comprehensive Revision of the Annual Industry Accounts: Changes in Definitions, Classification, and Statistical Methods", *Survey of Current Business*, March 2010, 21-34.

Meade, Douglas S., "Is Real Value Added Real?", in *Recent Developments in INFORUM-type Modeling*, ed. Mariusz Plich and Michal Przybylinski, Lodz University Press, Lodz, 2007, pp. 97-128.

Meade, Douglas S., Stanislaw J. Rzeznik and Darlene C. Robinson-Smith, "Business Investment by Industry in the U.S. Economy for 1997", *Survey of Current Business*, November 2003, 18-70.

Miller, Ronald E. and Peter D. Blair, *Input-Output Analysis: Foundations and Extensions*, 2nd edition, Cambridge University Press, Cambridge, UK, 2009.

National Accounts Review Committee of the National Bureau of Economic Research, *The National Economic Accounts of the United States: Review Appraisal and Recommendations*, U.S. Government Printing Office, 1958.

National Economics Division Staff, "Input-Output Structure of the U.S. Economy: 1963", *Survey of Current Business*, November 1969, 16-25.

Office of Management and Budget, *North American Industry Classification System: United States, 2002*, Bernan, 2002.

Planting, Mark A., "The History and Development of the U.S. Annual Input-Output Accounts", paper presented at the International Meeting on Problems of Compilation of Input-Output Tables, Baden Austria, March 13-19, 1988.

Polenske, Karen R., "Leontief's 'Magnificent Machine' and Other Contributions to Applied Economics", in *Wassily Leontief and Input-Output Economics*, Erik Dietzenbacher and Michael Lahr, eds., Cambridge University Press, Cambridge, 2004, 9-29.

Rassier, Dylan G., Thomas F. Howells III, Edward T. Morgan, Nicholas R. Empey and Conrad E. Roesch, "Íntegrating the 2002 Benchmark Input-Output Accounts and the 2002 Annual Industry Accounts", *Survey of Current Business*, December 2007, 14-22.

Ritz, Philip M., *Definitions and Conventions of the 1972 Input-Output Study*, Bureau of Economic Analysis, July 1980.

Ritz, Philip M., Eugene P. Roberts and Paula C. Young, "Dollar-Value Tables for the 1972 Input-Output Study", *Survey of Current Business*, April 1979, 51-72.

Stanley-Allen, Karla L., Nicholas R. Empey, Douglas S. Meade, Stanislaw J. Rzeznik, Mary L. Streitwieser and Monica S. Strople, "Preview of the Benchmark Input-Output Accounts for 2002", *Survey of Current Business*, September 2005, 66-77.

Stewart, Ricky, Jessica Brede Stone and Mary L. Streitwieser, "U.S. Benchmark Input-Output Accounts, 2002", *Survey of Current Business*, October 2007, 19-48.

Stone, Richard, *Input-Output and National Accounts*, OECD, Great Britain, 1961.

U.S. Department of Commerce, Bureau of Economic Analysis, *Definitions and Conventions of the 1972 Input-Output Study*, U.S. Government Printing Office, Washington, D.C., July 1980.

U.S. Department of Commerce, Bureau of Economic Analysis, *Definitions and Conventions of the 1977 Input-Output Accounts*, Unpublished manuscript, 1984.

U.S. Department of Commerce, Bureau of Economic Analysis, *The 1982 Benchmark Input-Output Accounts of the United States*, U.S. Government Printing Office, Washington, D.C., December 1991.

U.S. Department of Commerce, Bureau of Economic Analysis, *Benchmark Input-Output Accounts of the United States, 1987*, U.S. Government Printing Office, Washington, D.C., November 1994.

U.S. Department of Commerce, Bureau of Economic Analysis, *Benchmark Input-Output Accounts of the United States, 1992*, U.S. Government Printing Office, Washington, D.C., September 1998.

U.S. Department of Commerce, Bureau of Economic Analysis, *Concepts and Methods of the U.S. Input-Output Accounts*, http://www.bea.gov/papers/pdf/IOmanual_092906.pdf , September 2006 (Updated April 2009).

U.S. Joint Economic Committee, *The National Economic Accounts of the United States*, Hearings before the Subcommittee on Economic Statistics, U.S. Government Printing Office, 1957.

Walderhaug, Albert J., "The Composition of Value Added in the 1963 Input-Output Study", *Survey of Current Business*, April, 1973, 34-44.

Young, Allan H., Leo C. Malley, Jr., Sally R. Reed and Roy A. Seaton II, "Interindustry Transactions in New Structures and Equipment, 1963", *Survey of Current Business*, August 1971, 16-22,44.

Yuskavage, Robert E., "Employment and Employee Compensation in the 1977 Input-Output Accounts", *Survey of Current Business*, November 1985, 11-25.