Input-Output Economics

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Input-Output Economics

Concerning a new method which can portray both an entire economy and its fine structure by plotting the production of each industry against its consumption from every other

by Wassily W. Leontief

IF THE GREAT 19th-century physicist James Clerk Maxwell were to attend a current meeting of the American Physical Society, he might have serious difficulty in keeping track of what was going on. In the field of economics, on the other hand, his contemporary John Stuart Mill would easily pick up the thread of the most advanced arguments among his 20th-century successors. Physics, applying the method of inductive reasoning from quantitatively observed events, has moved on to entirely new premises. The science of economics, in contrast, remains largely a deductive system resting upon a static set of premises, most of which were familiar to Mill and some of which date back to Adam Smith's *The Wealth of Nations*.

Present-day economists are not universally content with this state of affairs. Some of the greatest recent names in economics—Léon Walras, Vilfredo Pareto, Irving Fisher—are associated with the effort to develop quantitative methods for grappling with the enormous volume of empirical data that is involved in every real economic situation. Yet such methods have so far failed to find favor with the majority of professional economists. It is not only the forbidding rigor of mathematics; the truth is that such methods have seldom produced results significantly superior to those achieved by the traditional procedure. In an empirical science, after all, nothing ultimately counts but results. Most economists therefore continue to rely upon their "professional intuition" and "sound judgment" to establish the connection between the facts and the theory of economics.

In recent years, however, the output of economic facts and figures by various public and private agencies has increased by leaps and bounds. Most of this information is published for reference purposes, and is unrelated to any particular method of analysis. As a result we have in economics today a high concentration of theory without fact on the one hand, and a mounting accumulation of fact without theory on the other. The task of filling the "empty boxes of economic theory" with relevant empirical content becomes every day more urgent and challenging.

This article is concerned with a new effort to combine economic facts and theory known as "interindustry" or "input-output" analysis. Essentially it is a method of analysis that takes advantage of the relatively stable pattern of the flow of goods and services among the elements of our economy to bring a much more detailed statistical picture of the system into the range of manipulation by economic theory. As such, the method has had to await the modern high-speed computing machine as well as the present propensity of government and private agencies to accumulate mountains of data. It is now advancing from the phase of academic investigation and experimental trial to a broadening sphere of application in grand-scale problems of national economic policy. The practical possibilities of the method are being carried forward as a cooperative venture of the Bureau of Labor Statistics, the Bureau of Mines, the Department of Commerce, the Bureau of the Budget, the Council of Economic Advisers and, with particular reference to procurement and logistics, the Air Force. Meanwhile the development of the technique of input-output analysis continues to interest academic investigators here and abroad. They are hopeful that this method of bringing the facts of economics into closer association with theory may induce some fruitful advances in both.

ECONOMIC theory seeks to explain the material aspects and operations of our society in terms of interactions among such variables as supply and demand or wages and prices. Economists have generally based their analyses on relatively simple data—such quantities as the gross national product, the interest rate, price and wage levels. But in the real world things are not so simple. Between a shift in wages and the ultimate working out of its impact upon prices there is a complex series of transactions in which actual goods and services are exchanged among real people. These intervening steps are scarcely suggested by the classical formulation of the relationship between the two variables. It is true, of course, that the individual transactions, like individual atoms and molecules, are far too numerous for observation and description in detail. But it is possible, as with physical particles, to reduce them to some kind of order by classifying and aggregating them into groups. This is the procedure employed by input-output analysis in improving the grasp of economic theory upon the

THIS TABLE SHOWS THE EXCHANGE OF GOODS

INDUSTRY

	1 AGRICULTURE AND FISHERIES	2 FOOD AND KINDRED PRODUCTS	3 TEXTILE MILL PRODUCTS	4 APPAREL	5 LUMBER AND WOOD PRODUCTS	6 FURNITURE AND FIXTURES	7 PAPER AND ALLIED PRODUCTS	8 PRINTING AND PUBLISHING	9 CHEMICALS	10 PRODUCTS OF PETROLEUM AND COAL	11 RUBBER PRODUCTS	12 LEATHER AND LEATHER PRODUCTS	13 STONE, CLAY AND GLASS PRODUCTS	14 PRIMARY METALS	15 FABRICATED METAL PRODUCTS	16 MACHINERY (EXCEPT ELECTRIC)	17 ELECTRICAL MACHINERY	18 MOTOR VEHICLES	19 OTHER TRANSPORTATION EQUIPMENT	20 PROFESSIONAL AND SCIENTIFIC	21 MISCELLANEOUS	22 COAL
INDUSTRY PRODUCING																						
1 AGRICULTURE AND FISHERIES	10.86	15.70	2.16	0.02	0.19	—	0.01	—	1.21	—	—	0.05	*	0.01	—	—	—	—				
2 FOOD AND KINDRED PRODUCTS	2.38	5.75	0.06	0.01	*	*	0.03	*	0.79	*	—	0.44	*	*	*	*	*	—				
3 TEXTILE MILL PRODUCTS	0.06	*	1.30	3.88	*	0.29	0.04	0.03	0.01	*	0.44	0.09	0.03	—	0.01	0.02	0.05	0.15				
4 APPAREL	0.04	0.20	—	1.96	—	0.01	0.02	—	0.03	—	—	*	*	—	*	*	*	0.10				
5 LUMBER AND WOOD PRODUCTS	0.15	0.10	0.02	*	1.09	0.39	0.27	*	0.04	0.01	—	0.02	0.02	0.06	0.06	0.09	0.05	0.05				
6 FURNITURE AND FIXTURES	—	—	0.01	—	—	0.01	0.01	—	—	—	—	—	—	—	*	0.01	0.10	0.03				
7 PAPER AND ALLIED PRODUCTS	*	0.52	0.08	0.02	*	0.02	2.60	1.08	0.33	0.11	0.02	0.05	0.18	*	0.09	0.04	0.07	0.03				
8 PRINTING AND PUBLISHING	—	0.04	*	—	—	—	—	0.77	0.02	—	—	—	—	—	0.01	0.01	0.01	—				
9 CHEMICALS	0.83	1.48	0.80	0.14	0.03	0.06	0.18	0.10	2.58	0.21	0.60	0.13	0.12	0.18	0.13	0.08	0.20	0.11				
10 PRODUCTS OF PETROLEUM AND COAL	0.46	0.06	0.03	*	0.07	*	0.06	*	0.32	4.83	0.01	*	0.05	0.90	0.02	0.04	0.02	0.03				
11 RUBBER PRODUCTS	0.12	0.01	0.01	0.02	0.01	0.01	0.01	*	*	*	0.04	0.05	0.01	*	0.01	0.13	0.03	0.50				
12 LEATHER AND LEATHER PRODUCTS	—	—	*	0.05	*	0.01	—	*	—	—	—	1.04	—	—	*	0.02	*	0.01				
13 STONE, CLAY AND GLASS PRODUCTS	0.06	0.25	*	*	0.01	0.03	0.03	—	0.26	0.05	0.01	0.01	0.43	0.21	0.07	0.07	0.12	0.19				
14 PRIMARY METALS	0.01	*	—	*	0.01	0.11	—	0.01	0.19	0.01	0.01	*	0.04	6.90	2.53	2.02	1.05	1.28				
15 FABRICATED METAL PRODUCTS	0.08	0.61	*	0.01	0.04	0.14	0.02	*	0.13	0.08	0.01	0.02	*	0.05	0.43	0.62	0.34	0.97				
16 MACHINERY (EXCEPT ELECTRIC)	0.06	0.01	0.04	0.02	0.01	0.01	0.01	0.04	*	0.01	—	—	0.01	0.07	0.28	1.15	0.17	0.63				
17 ELECTRICAL MACHINERY	—	—	—	—	—	—	—	—	*	—	—	—	0.01	0.05	0.24	0.58	0.86	0.62				
18 MOTOR VEHICLES	0.11	*	—	—	*	—	—	—	—	*	—	—	*	*	0.03	0.03	0.01	4.40				
19 OTHER TRANSPORTATION EQUIPMENT	0.01	—	—	—	—	—	*	—	*	*	*	—	*	*	—	—	*	0.01				
20 PROFESSIONAL AND SCIENTIFIC EQUIPMENT	—	—	—	—	—	*	0.01	0.03	0.01	—	—	—	*	*	0.04	0.04	0.01	0.07				
21 MISCELLANEOUS MANUFACTURING INDUSTRIES	*	0.01	*	0.26	*	0.02	0.01	—	0.03	—	*	0.02	0.01	*	0.02	0.05	0.11	0.02				
22 COAL, GAS AND ELECTRIC POWER	0.06	0.20	0.11	0.04	0.02	0.02	0.12	0.03	0.19	0.56	0.04	0.02	0.20	0.35	0.08	0.10	0.05	0.06				
23 RAILROAD TRANSPORTATION	0.44	0.57	0.09	0.06	0.14	0.05	0.22	0.07	0.29	0.27	0.04	0.04	0.15	0.52	0.13	0.16	0.07	0.23				
24 OCEAN TRANSPORTATION	0.07	0.13	0.01	0.01	0.01	*	0.02	*	0.04	0.09	*	*	0.01	0.08	*	*	*	*				
25 OTHER TRANSPORTATION	0.55	0.38	0.08	0.03	0.14	0.04	0.12	0.03	0.10	0.47	0.01	0.02	0.07	0.16	0.03	0.04	0.03	0.07				
26 TRADE	1.36	0.46	0.23	0.37	0.06	0.06	0.18	0.03	0.17	0.02	0.05	0.06	0.05	0.36	0.20	0.26	0.14	0.06				
27 COMMUNICATIONS	*	0.04	0.01	0.02	0.01	0.01	0.01	0.04	0.02	0.01	0.01	*	0.01	0.02	0.02	0.03	0.02	0.02				
28 FINANCE AND INSURANCE	0.24	0.15	0.02	0.02	0.08	0.02	0.02	0.02	0.02	0.13	0.01	0.01	0.05	0.06	0.04	0.05	0.04	0.02				
29 REAL ESTATE AND RENTALS	2.39	0.09	0.03	0.10	0.02	0.02	0.03	0.06	0.03	—	0.01	0.02	0.02	0.06	0.03	0.04	0.03	0.02				
30 BUSINESS SERVICES	0.01	0.63	0.07	0.10	0.02	0.06	0.02	0.06	0.42	0.04	0.02	0.05	0.01	0.03	0.05	0.09	0.06	0.08				
31 PERSONAL AND REPAIR SERVICES	0.37	0.12	*	*	0.04	*	*	0.02	0.01	0.01	*	*	0.03	0.01	0.01	0.01	*	*				
32 NON-PROFIT ORGANIZATIONS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
33 AMUSEMENTS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
34 SCRAP AND MISCELLANEOUS INDUSTRIES	—	—	0.02	—	—	—	0.25	—	0.01	—	0.01	—	0.01	1.11	0.02	0.05	*	—				
35 EATING AND DRINKING PLACES	—	—	—	—	—	—	—	*	—	—	—	—	—	—	—	—	—	—				
36 NEW CONSTRUCTION AND MAINTENANCE	0.20	0.12	0.04	0.02	0.01	0.01	0.04	0.01	0.04	0.03	0.01	0.02	0.03	0.10	0.03	0.05	0.02	0.04				
37 UNDISTRIBUTED	—	1.87	0.30	1.08	0.73	0.27	0.17	0.50	1.49	0.65	0.27	0.27	0.47	0.32	1.14	1.71	0.89	0.41				
38 INVENTORY CHANGE (DEPLETIONS)	2.66	0.40	0.12	0.19	*	0.01	0.09	0.03	0.14	0.01	*	0.03	*	0.11	*	*	*	0.01				
39 FOREIGN COUNTRIES (IMPORTS FROM)	0.69	2.11	0.21	0.28	0.18	0.01	0.62	0.01	0.59	0.26	*	0.04	0.14	0.62	0.01	0.05	*	0.02				
40 GOVERNMENT	0.81	1.24	0.64	0.38	0.34	0.11	0.50	0.34	0.76	0.78	0.11	0.14	0.32	0.82	0.48	0.77	0.40	0.66				
41 PRIVATE CAPITAL FORMATION (GROSS)	DEPRECIATION AND OTHER CAPITAL CONSUMPTION ALLOWANCES ARE INCLUDED IN HOUSEHOLD ROW																					
42 HOUSEHOLDS	19.17	7.05	3.34	4.24	2.72	1.12	2.20	3.14	3.75	5.04	1.08	1.20	2.35	5.53	4.14	6.80	3.41	3.39				
TOTAL GROSS OUTLAYS	44.26	40.30	9.84	13.32	6.00	2.89	7.90	6.45	14.05	13.67	2.82	3.81	4.84	18.69	10.40	15.22	8.38	14.27				

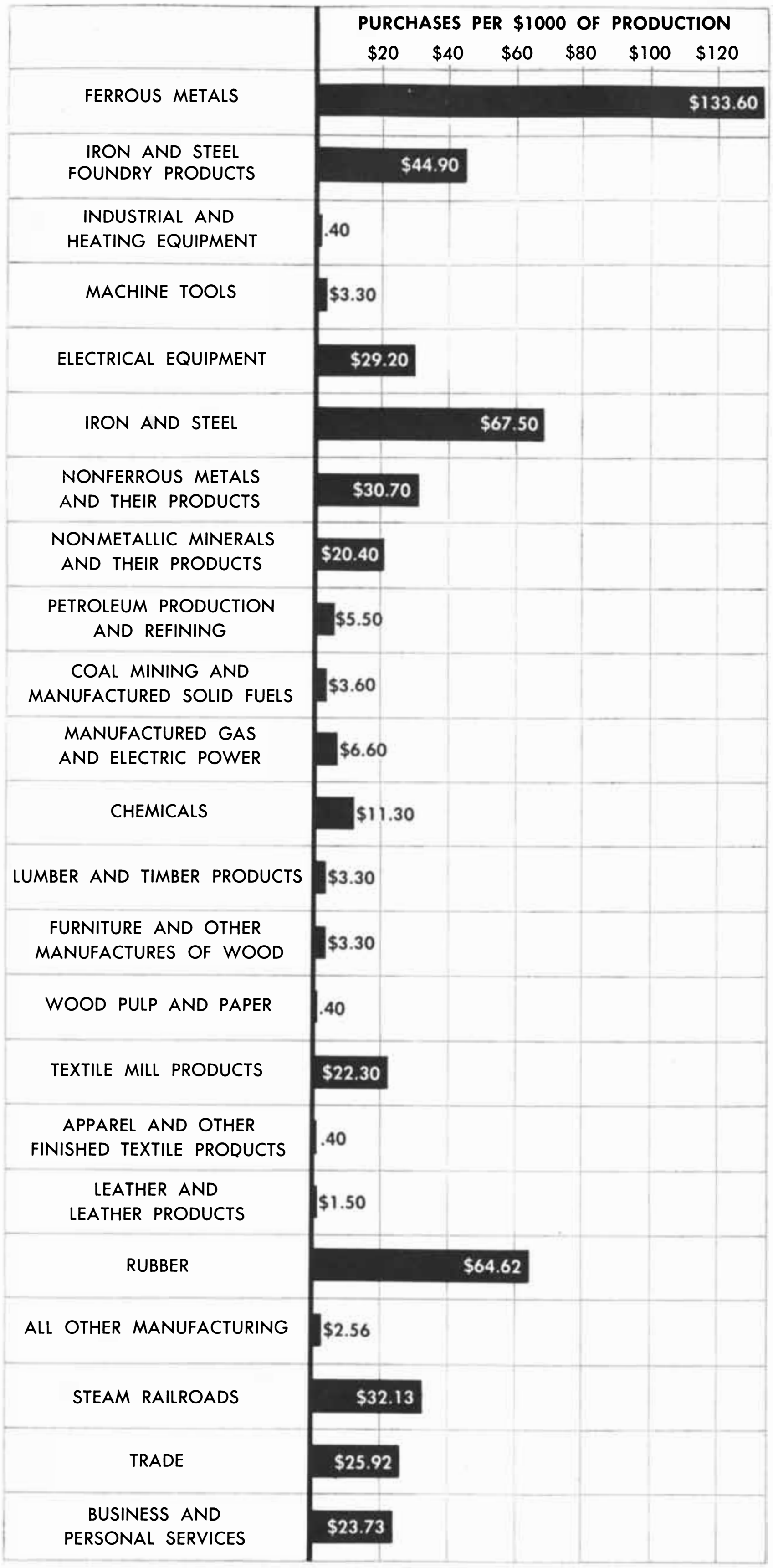
INTERINDUSTRY TABLE summarizes the transactions of the U. S. economy in 1947, for which preliminary data have just been compiled by the Bureau of Labor Statistics. Each number in the body of the table represents billions of 1947 dollars. In the vertical column at left the entire economy is broken down into sectors; in the

AND SERVICES IN THE U. S. FOR THE YEAR 1947

PURCHASING — **FINAL DEMAND**

	EQUIPMENT	MANUFACTURING INDUSTRIES	GAS AND ELECTRIC POWER	RAILROAD TRANSPORTATION	24 OCEAN TRANSPORTATION	25 OTHER TRANSPORTATION	26 TRADE	27 COMMUNICATIONS	28 FINANCE AND INSURANCE	29 REAL ESTATE AND RENTALS	30 BUSINESS SERVICES	31 PERSONAL AND REPAIR SERVICES	32 NON-PROFIT ORGANIZATIONS	33 AMUSEMENTS	34 SCRAP AND MISCELLANEOUS INDUSTRIES	35 EATING AND DRINKING PLACES	36 NEW CONSTRUCTION AND MAINTENANCE	37 UNDISTRIBUTED	38 INVENTORY CHANGE (ADDITIONS)	39 FOREIGN COUNTRIES (EXPORTS TO)	40 GOVERNMENT	41 PRIVATE CAPITAL FORMATION (GROSS)	42 HOUSEHOLDS	TOTAL GROSS OUTPUT
—	*	*	—	*	*	0.01	—	*	—	—	—	—	0.12	—	—	0.87	0.09	0.17	1.01	1.28	0.57	0.02	9.92	44.26
—	0.01	0.02	*	0.08	0.01	0.03	0.07	0.01	—	—	—	*	0.25	*	0.02	3.47	*	0.42	0.88	1.80	0.73	—	23.03	40.30
0.01	0.05	0.08	0.07	—	0.01	0.01	0.03	*	—	—	*	0.03	*	—	0.01	—	0.05	0.52	0.06	0.92	0.10	0.02	1.47	9.84
0.01	*	*	*	*	*	*	0.02	*	—	—	—	0.02	0.02	*	0.01	0.02	*	0.15	0.21	0.30	0.28	*	9.90	13.32
0.03	*	0.06	0.06	—	0.01	*	0.03	*	—	0.14	*	*	*	—	0.11	0.01	2.33	0.35	0.17	0.17	0.01	0.04	0.07	6.00
0.02	*	—	*	—	—	*	—	*	0.04	0.08	—	—	*	—	—	—	0.20	0.20	0.08	0.03	0.05	0.57	1.46	2.89
0.02	0.08	0.07	*	*	—	*	0.57	*	*	—	*	0.06	0.03	—	0.68	0.06	0.17	0.31	0.04	0.15	0.06	—	0.34	7.90
—	*	—	*	0.04	*	0.02	0.10	0.03	0.21	—	2.45	0.03	0.17	0.01	0.01	0.03	—	0.68	*	0.07	0.16	0.09	1.49	6.45
0.02	0.05	0.17	0.06	0.03	0.01	0.02	0.07	*	*	—	0.01	0.20	0.22	*	0.03	0.04	0.64	1.25	0.30	0.81	0.19	—	1.96	14.05
0.01	*	0.01	0.47	0.27	0.09	0.45	0.20	*	0.01	0.78	*	0.06	0.06	*	0.01	0.01	0.62	0.36	0.06	0.68	0.18	*	2.44	13.67
0.01	*	0.04	*	*	—	0.13	0.06	*	0.01	*	—	0.07	*	—	*	*	0.06	0.47	0.09	0.17	0.02	0.01	0.71	2.82
*	0.01	0.01	*	—	—	*	*	—	—	—	—	0.03	0.01	—	0.01	—	*	0.29	0.11	0.08	0.03	0.02	2.03	3.81
0.01	0.03	0.06	0.02	0.01	*	*	0.04	*	—	—	—	0.02	0.01	—	*	0.06	1.74	0.36	0.10	0.21	0.02	0.01	0.34	4.84
0.43	0.07	0.20	0.05	0.20	—	0.01	—	*	—	—	—	—	*	—	0.15	*	1.19	1.24	0.16	0.77	0.02	—	0.02	18.69
0.10	0.07	0.04	*	0.03	*	0.01	0.06	*	—	—	*	0.03	0.01	—	0.06	0.02	3.09	1.44	0.21	0.39	0.05	0.28	0.95	10.40
0.22	0.03	*	0.03	0.06	—	0.01	0.01	—	0.02	—	—	0.15	*	—	0.07	—	0.51	2.24	0.37	1.76	0.18	5.82	1.22	15.22
0.12	0.03	0.02	0.02	0.04	—	0.01	0.01	0.05	—	—	0.01	0.09	*	—	0.04	—	0.77	1.27	0.25	0.44	0.17	1.75	0.93	8.38
*	—	—	0.01	*	—	0.13	0.02	*	—	*	—	1.05	*	—	0.07	*	0.04	0.67	0.40	1.02	0.15	2.98	3.13	14.27
0.30	—	—	*	0.04	0.08	0.13	—	—	—	—	—	*	—	—	0.01	—	*	0.46	0.02	0.32	1.25	1.20	0.17	4.00
0.02	0.18	0.02	*	—	—	*	—	*	—	—	0.01	0.05	0.18	—	0.01	—	0.02	0.24	0.03	0.18	0.08	0.26	0.62	2.12
*	0.03	0.16	*	*	*	*	0.01	*	—	—	0.15	0.16	0.05	0.05	0.11	0.02	0.03	0.68	0.04	0.19	0.08	0.51	1.89	4.76
0.03	0.01	0.03	1.27	0.44	*	0.09	0.49	0.01	0.06	3.15	*	0.31	0.16	0.05	—	0.22	0.03	0.02	0.03	0.35	0.20	—	—	9.21
0.04	0.01	0.03	0.15	0.41	*	0.06	0.08	*	0.01	0.42	0.03	0.03	0.05	*	0.03	0.25	0.71	0.30	0.08	0.59	0.33	0.27	2.53	9.95
*	*	0.01	*	—	0.22	—	—	—	—	—	—	—	—	—	*	—	—	*	—	1.16	0.31	—	0.10	2.29
0.01	0.01	0.01	0.03	0.19	0.04	0.25	0.31	*	*	0.13	0.03	0.01	0.02	*	0.02	0.10	0.57	0.17	0.04	0.32	0.35	0.10	4.77	9.86
0.07	0.04	0.05	0.05	0.03	0.01	0.42	0.20	0.01	0.04	0.75	0.14	0.37	0.29	0.01	0.09	1.06	2.52	1.01	0.20	1.00	0.05	2.34	26.82	41.66
0.01	0.01	0.01	0.02	0.02	*	0.04	0.33	0.06	0.09	0.06	0.43	0.12	0.07	0.01	—	0.01	0.04	0.08	—	0.04	0.15	—	1.27	3.17
0.02	0.01	0.02	0.05	0.02	0.12	0.30	1.00	*	1.85	0.56	0.02	0.12	0.09	0.03	—	0.07	0.40	—	—	0.14	0.03	—	6.99	12.81
0.02	0.01	0.03	0.05	0.02	0.01	0.15	1.96	0.05	0.21	0.21	0.06	0.71	0.40	0.18	—	0.39	0.08	—	—	—	0.22	0.80	20.29	28.86
0.01	0.05	0.06	0.01	0.02	*	0.03	1.71	0.09	0.14	0.04	0.06	0.12	0.02	0.10	—	0.06	0.13	0.42	—	*	0.04	—	0.18	5.10
*	*	*	0.02	0.11	0.01	0.26	1.42	0.02	0.11	0.03	0.07	0.56	0.08	0.02	0.03	0.23	0.82	1.17	—	—	0.08	0.27	8.35	14.30
—	—	—	—	—	*	*	—	—	0.02	—	—	—	0.09	—	—	—	—	0.16	—	—	5.08	—	8.04	13.39
—	—	—	—	—	—	—	—	—	—	—	—	—	0.01	0.39	—	—	—	0.01	—	0.13	—	—	2.40	2.94
—	*	—	—	—	—	0.04	0.39	0.01	0.11	0.03	0.02	*	*	0.01	—	—	*	0.01	—	0.03	*	—	—	2.13
—	—	—	—	—	—	0.01	—	—	—	—	—	—	0.15	—	—	—	—	—	—	—	—	—	13.11	13.27
0.02	0.01	0.02	0.27	1.12	*	0.13	0.18	0.18	0.03	4.08	*	0.06	0.34	0.02	—	0.07	0.01	—	—	—	5.26	15.70	0.15	28.49
0.34	0.19	0.87	0.25	0.10	0.04	0.03	2.59	0.01	0.71	0.36	0.31	1.13	0.91	0.22	—	0.59	0.43	—	—	—	—	—	—	21.60
0.01	0.05	0.16	*	—	—	—	—	—	—	—	—	—	—	—	0.40	—	—	—	—	0.02	—	—	—	4.43
0.01	0.05	0.14	0.01	0.04	0.50	0.08	—	0.03	0.10	—	—	—	—	*	0.07	—	—	0.01	—	—	1.31	—	1.32	9.52
0.12	0.13	0.19	1.14	0.91	0.26	0.77	3.30	0.44	1.11	4.00	0.21	0.50	0.17	0.32	0.07	1.41	0.47	2.19	0.34	0.83	3.46	0.22	31.55	63.69
1.95	0.90	2.17	5.11	5.70	0.90	6.20	26.42	2.15	7.93	14.06	1.08	8.20	9.41	1.50	—	4.20	10.73	2.27	—	0.85	30.06	—	2.12	223.58
4.00	2.12	4.76	9.21	9.95	2.29	9.86	41.66	3.17	12.81	28.86	5.10	14.30	13.39	2.94	2.13	13.27	28.49	21.60	5.28	17.21	51.29	33.29	194.12	

horizontal row at the top the same breakdown is repeated. When a sector is read horizontally, the numbers indicate what it ships to other sectors. When a sector is read vertically, the numbers show what it consumes from other sectors. The asterisks stand for sums less than $5 million. Totals may not check due to rounding.



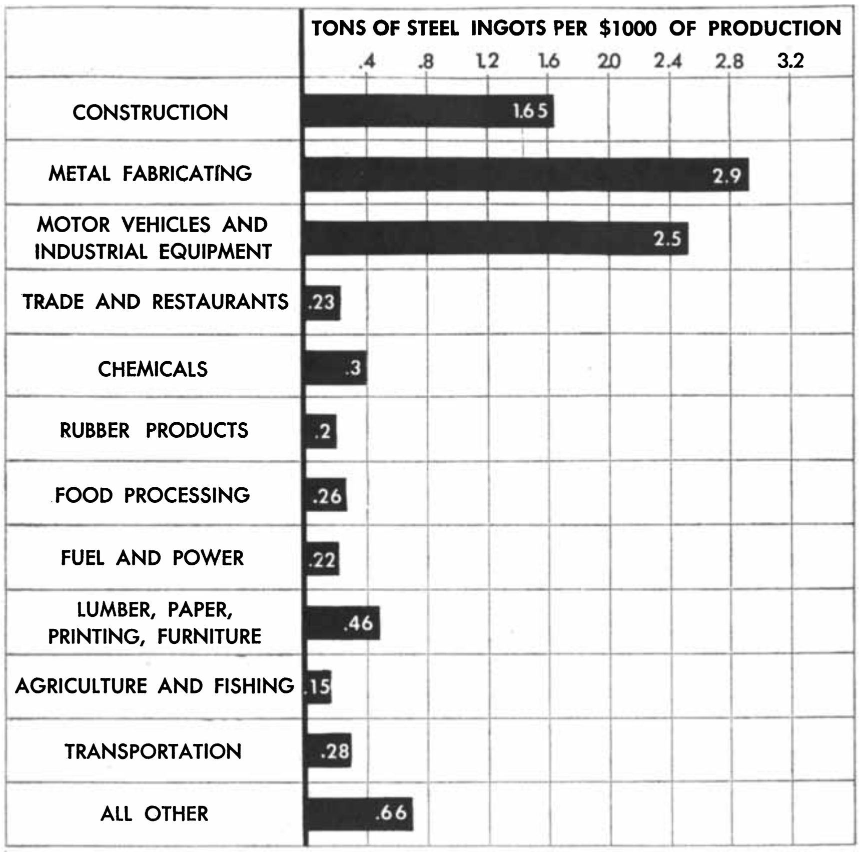
INPUT TO AUTO INDUSTRY from other industries per $1,000 of auto production was derived from the 1939 interindustry table. Comparing these figures with those for the auto industry in the 1947 table would show changes in input structure of the industry due to changes in prices and technology.

facts with which it is concerned in every real situation.

The essential principles of the method may be most easily comprehended by consulting the input-output table on the past two pages. This table summarizes the transactions which characterized the U. S. economy during the year 1947. The transactions are grouped into 42 major departments of production, distribution, transportation and consumption, set up on a matrix of horizontal rows and vertical columns. The horizontal rows of figures show how the output of each sector of the economy is distributed among the others. Conversely, the vertical columns show how each sector obtains from the others its needed inputs of goods and services. Since each figure in any horizontal row is also a figure in a vertical column, the output of each sector is shown to be an input in some other. The double-entry bookkeeping of the input-output table thus reveals the fabric of our economy, woven together by the flow of trade which ultimately links each branch and industry to all others. Such a table may of course be developed in as fine or as coarse detail as the available data permit and the purpose requires. The present table summarizes a much more detailed 500-sector master table which has just been completed after two years of intensive work by the Interindustry Economics Division of the Bureau of Labor Statistics.

FOR purposes of illustration let us look at the input-output structure of a single sector—the one labeled "primary metals" (sector 14). The vertical column states the inputs of each of the various goods and services that are required for the production of metals, and the sum of the figures in this column represents the total outlay of the economy for the year's production. Most of the entries in this column are self-explanatory. Thus it is no surprise to find a substantial figure entered against the item "products of petroleum and coal" (sector 10). The design of the table, however, gives a special meaning to some of the sectors. The outlay for "railroad transportation" (sector 23), for example, covers only the cost of hauling raw materials to the mills; the cost of delivering primary metal products to their markets is borne by the industries purchasing them. Another outlay requiring explanation is entered in the trade sector (sector 26). The figures in this sector represent the cost of distribution, stated in terms of the trade margin. The entries against trade in the primary metals column, therefore, cover the middleman's markup on the industry's purchases; trade margins on the sale of primary metal products are charged against the consuming industries. Taxes paid by the industry are entered in the row labeled "government" (sector 40), and all payments to individuals, including wages, salaries and dividends, are summed up in the row labeled "households" (sector 42). How the output of the metals industry is distributed among the other sectors is shown in row 14. The figures indicate that the industry's principal customers are other industries. "Households" and "government" turn up as direct customers for only a minor portion of the total output, although these two sectors are of course the principal consumers of metals after they have been converted into end products by other industries.

Coming out of the interior of the table to the outer row and columns, the reader may soon recognize many of the familiar total figures by which we are accustomed to visualize the condition of the economy. The total outputs at the end of each industry row, for example, are the figures we use to measure the size or the health of an industry. The gross national product, which is designed to state the total of productive activity and is the most commonly cited index for the economy as a whole, may be derived as the grand total of the five columns grouped under the heading of final demand, but with some adjustments necessary to eliminate the duplication of transactions between the sectors represented by these columns. For example, the total payment to households, at the far right end of row 42, includes salaries paid by government, a figure which duplicates in part the payment of taxes by households included in the total payment to government.



OUTPUT OF STEEL INDUSTRY depends heavily on what kinds of goods are demanded in the ultimate market. This table shows the amount of steel required to meet each $1,000 of the demand for other goods in 1939. The current demand for the top three items is responsible for the steel shortage.

WITH this brief introduction the lay economist is now qualified to turn around and trace his way back into the table via whatever chain of interindustry relationships engages his interest. He will not go far before he finds himself working intuitively with the central concept of input-output analysis. This is the idea that there is a fundamental relationship between the volume of the output of an industry and the size of the inputs going into it. It is obvious, for example, that the purchases of the auto industry (column 18) from the glass industry (row 13) in 1947 were strongly determined by the number of motor vehicles produced that year. Closer inspection will lead to the further realization that every single figure in the chart is dependent upon every other. To take an extreme example, the appropriate series of inputs and outputs will show that the auto industry's purchases of glass are dependent in part upon the demand for motor vehicles arising out of the glass industry's purchases from the fuel industries.

These relationships reflect the structure of our technology. They are expressed in input-output analysis as the ratios or coefficients of each input to the total output of which it becomes a part. A table of such ratios on the opposite page, computed from a table for the economy as of 1939, shows how much had to be purchased from the steel, glass, paint, rubber and other industries to produce $1,000 worth of automobile that year. Since such expenditures are determined by relatively inflexible engineering considerations or by equally inflexible customs and institutional arrangements, these ratios might be used to estimate the demand for materials induced by auto production in other years. With a table of ratios for the economy as a whole, it is possible in turn to calculate the secondary demand on the output of the industries which supply the auto industry's suppliers and so on through successive outputs and inputs until the effect of the final demand for automobiles has been traced to its last reverberation in the farthest corner of the economy. In this fashion input-output analysis should prove useful to the auto industry as a means for dealing with cost and supply problems.

The table of steel consumption ratios on this page suggests, incidentally, how the input-output matrix might be used for the contrasting purpose of market analysis. Since the ultimate markets for steel are ordinarily buried in the cycle of secondary transactions among the metal-fabricating industries, it is useful to learn from this table how many tons of steel at the mill were needed in 1939 to satisfy each thousand dollars worth of demand for the products of industries which ultimately place steel products at the disposal of the consumer. This table shows the impressively high ratio of the demand for steel in the construction and consumer durable-goods industries which led the Bureau of Labor Statistics to declare in 1945 that a flourishing postwar economy would require even more steel than the peak of the war effort. Though some industry spokesmen took a contrary position at that time, steel production recently has been exceeding World War II peaks, and the major steel companies are now engaged in a 16-million-ton expansion program which was started even before the outbreak of the war in Korea and the current rearmament.

The ratios shown in these two tables are largely fixed by technology. Others in the complete matrix of the economy, especially in the trade and services and households sectors, are established by custom and other institutional factors. All, of course, are subject to modification by such forces as progress in technology and changes in public taste. But whether they vary more or less rapidly over the years, these relationships are subject to dependable measurement at any given time.

Here we have our bridge between theory and facts in economics. It is a bridge in a very literal sense. Action at a distance does not happen in economics any more than it does in physics. The effect of an event at any one point is transmitted to the rest of the economy step by step via the chain of transactions that ties the whole system together. A table of ratios for the entire economy gives us, in as much detail as we require, a quantitatively determined picture of the internal structure of the system. This makes it possible to calculate in detail the consequences that result from the introduction into the system of changes suggested by the theoretical or practical problem at hand.

In the case of a particular industry we can easily compute the complete table of its input requirements at any given level of output, provided we know its input ratios. By the same token, with somewhat more involved computation, we can construct synthetically a complete input-output table for the entire economy. We need only a known "bill of final demand" to convert the table of ratios into a table of magnitudes. The 1945 estimate of postwar steel requirements, for example, was incidental to a study of the complete economy based upon a bill of demand which assumed full employment in 1950. This bill of demand was inserted into the total columns of a table of ratios based on the year 1939. By arithmetical procedures the ratios were then translated into dollar figures, among which was the figure for steel, which showed a need for an absolute minimum of 98 million ingot tons. Actual production in 1950, at the limit of capacity, was 96.8 million tons.

THOUGH its application is simple, the construction of an input-output table is a highly complex and laborious operation. The first step, and one that has little appeal to the theoretical imagination, is the gathering and ordering of an immense volume of quantitative information. Given the inevitable lag between the accumulation and collation of data for any given year, the input-output table will always be an historical document. The first input-output tables, prepared by the author and his associates at Harvard University in the early 1930s, were based upon 1919 and 1929 figures. The 1939 table was not completed until 1944. Looking to the future, a table for 1953 which is now under consideration could not be made available until 1957. For practical purposes the original figures in the table must be regarded as a base, subject to refinement and correction in accord with subsequent trends. For example, the 1945 projection of the 1950 economy on the basis of the 1939 table made suitable adjustments in the coal and oil input ratios of the transportation industries on the assumption that the trend from steam to diesel locomotives would continue throughout the period.

The basic information for the table and its continuing revision comes from the Bureau of the Census and other specialized statistical agencies. As the industrial breakdown becomes more detailed, however, engineering and technical information plays a more important part in determining the data. A perfectly good way to determine how much coke is needed to produce a ton of pig iron, in addition to dividing the output of the blast furnace industry into its input of coke, is to ask an ironmaster. In principle there is no reason why the input-output coefficients should not be entirely derived from "below," from engineering data on process design and operating practice. Thus in certain studies of the German economy made by the Bureau of Labor Statistics following World War II the input structures of key industries were set up on the basis of U. S. experience. The model of a disarmed but self-supporting Germany developed in these studies showed a steel requirement of 11 million ingot tons, toward which actual output is now moving. Completely hypothetical input structures, representing industries not now operating, have been introduced into tables of the existing U. S. economy in studies conducted by Air Force economists.

THIS brings us to the problem of computation. Since the production level required of each industry is ultimately dependent upon levels in all others, it is clear that we have a problem involving simultaneous equations. Though the solution of such equations may involve no very high order of mathematics, the sheer labor of computation can be immense. The number of equations to be solved is always equal to the number of sectors into which the system is divided. Depending upon whether a specific or a general solution of the system is desired, the volume of computation will vary as the square or the cube of the number of sectors involved. A typical general solution of a 42-sector table for 1939 required 56 hours on the Harvard Mark II computer. Thanks to this investment in computation, the conversion of any stipulated bill of demand into the various industrial production levels involves nothing more than simple arithmetic. The method cannot be used, however, in the solution of problems which call for changes in the input-output ratios, since each change requires a whole new solution of the matrix. For the larger number of more interesting problems which require such changes, special solutions are the rule. However, even a special solution on a reasonably detailed 200-sector table might require some 200,000 multiplications and a greater number of additions. For this reason it is likely that the typical non-governmental user will be limited to condensed general solutions periodically computed and published by special-purpose groups working in the field. With these the average industrial analyst will be able to enjoy many of the advantages of the large and flexible machinery required for government analyses relating to the entire economy.

A demonstration of input-output analysis applied to a typical economic problem is presented in the table on the opposite page, which shows the price increases that would result from a general 10 per cent increase in the wage scale of industry. Here the value of the matrix distinguishing between direct and indirect effects is of the utmost importance. If wages constituted the only ultimate cost in the economy, a general 10 per cent rise in all money wages would obviously lead to an equal increase in all prices. Since wages are only one cost and since labor costs vary from industry to industry, it can be seen in the chart that a 10 per cent increase in wages would have decidedly different effects upon various parts of the economy. The construction industry shows the greatest upward price change, as it actually did in recent decades. For each industry group the chart separates the direct effect of increases in its own wage bill from the indirect effects of the wage increases in other industries from which it purchases its inputs. Giving effect to both direct and indirect increases, the average increase in the cost of living is shown in the chart to be only 3.7 per cent. The 10 per cent money-wage increase thus yields a 6.3 per cent increase in real wage rates. It should be noted, however, that the economic forces which bring increases in wages tend to bring increases in other costs as well. The advantage of the input-output analysis is that it permits the disentanglement and accurate measurement of the indirect effects. Analyses similar to this one for wages can be carried through for profits, taxes and other ultimate components of prices.

In such examples changes in the economy over periods of time are measured by comparing before and after pictures. Each is a static model, a cross section in time. The next step in input-output analysis is the development of dynamic models of the economy to bring the approximations of the method that much closer to the actual processes of economics. This requires accounting for stocks as well as flows of goods, for inventories of goods in process and in finished form, for capital equipment, buildings and, last but not least, for dwellings and household stocks of durable consumer goods. The dynamic input-output analysis requires more advanced mathematical methods; instead of ordinary linear equations it leads to systems of linear differential equations.

Among the questions the dynamic system should make it possible to answer one could mention the determination of the changing pattern of outputs and inventories or investments and capacities which would attend a given pattern of growth in final demand projected over a five- or ten-year period. Within such broad projections, for example, we would be able to estimate approximately not only how much aluminum should be produced, but how much additional aluminum-producing capacity would be required, and the rate at which such capacity should be installed. The computational task becomes more formidable, but it does not seem to exceed the capacity of the latest electronic computers. Here, as in the case of the static system, the most laborious problem is the assembly of the necessary factual information. However, a complete set of stock or capital ratios, paralleling the flow ratios of all of the productive sectors of the U. S. economy for the year 1939, has now been completed.

This table of capital ratios shows that in addition to the flow of raw pig-iron, scrap, coal, labor and so on, the steel works and rolling mills industry—when operating to full capacity—required $1,800 of fixed investment for each $1,000 worth of output. This would include $336 worth of tools, $331 worth of iron and steel foundry production and so on down to $26 worth of electrical equipment. This means that in order to expand its capacity so as to be able to increase its output by one million dollars worth of finished products annually, the steel works and rolling mills industry would have to install $336,000 worth of tools and spend corresponding amounts on all other types of new fixed installations. This investment demand constitutes of course additional input requirements for the product of the corresponding capital goods industries, input requirements which are automatically taken into account in the solution of an appropriate system of dynamic input-output equations.

ACTIVE experimental work with the dynamic system is under way. Meanwhile the demonstrated power of input-output analysis has thoroughly convinced many workers in the field of its practical possibilities. Of wider consequence is the expectation of theoretical investigators that this new grasp on the facts of the subject will further liberate economics from the confines of its traditionally simplified postulates.

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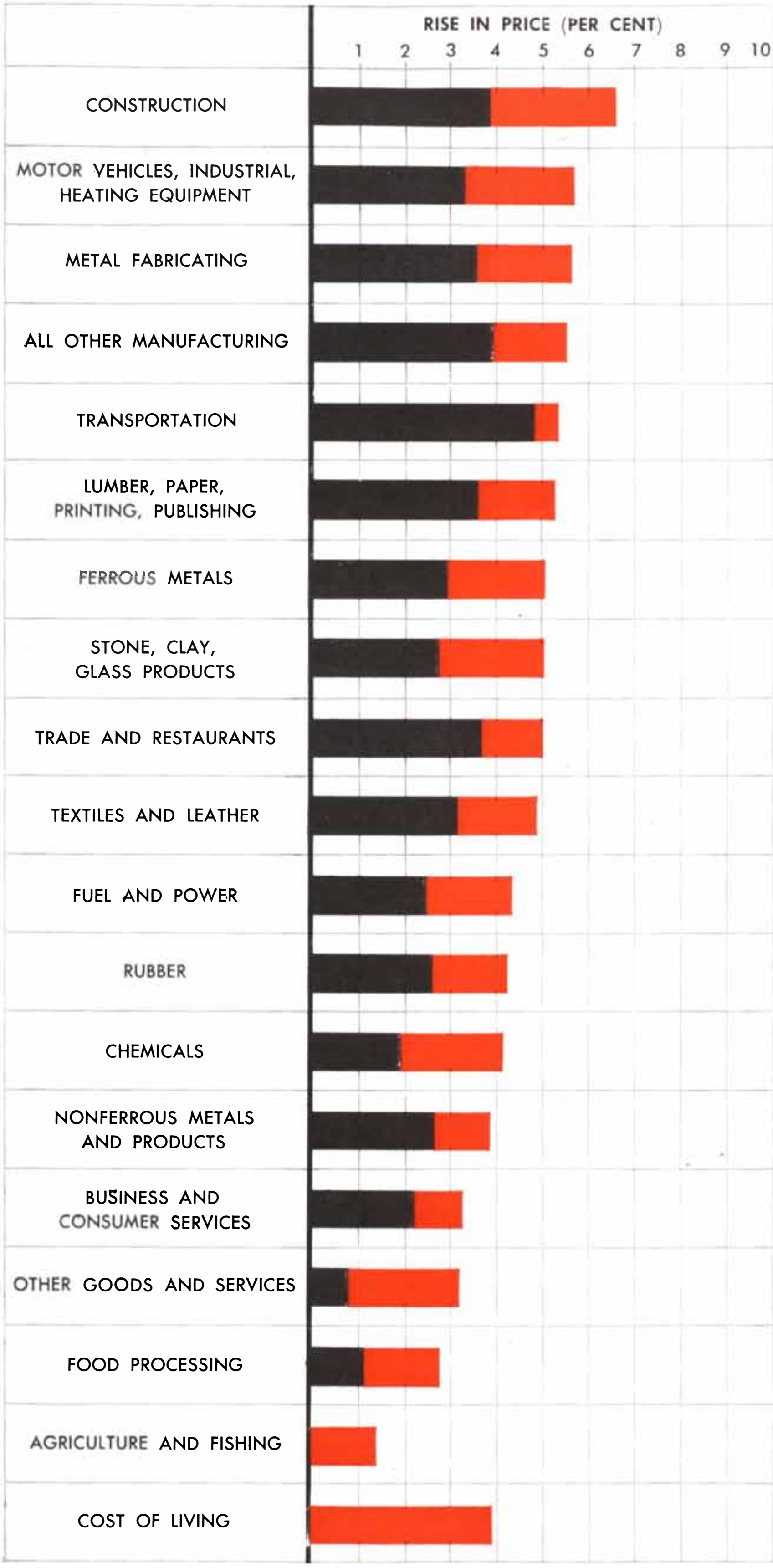

PRICE INCREASES that would be caused by a 10 per cent increase in wages were computed from the 1939 interindustry table. The increases include the direct effect of the rise in each industry's own wage bill (*black bars*) and the indirect effect of price increases on purchases from others (*red*).