Input-output analysis

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6 March 2017

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Word Count: 2,690

Abstract

Input-output analysis describes the interdependence among industries in an economy. General equilibrium theory provides the theoretical foundation for input-output analysis, while the input-output table is a prerequisite for empirical input-output work. Advances in science and technology especially the development of high-speed computers, have made input–output analysis more comprehensive and practical. Among the most important developments in input-output analysis are the implementation of computable general equilibrium (CGE) models and the ability to continually update and expand the tables. Input-output analysis is very helpful for investigating the growth and involvement of producer services in an economy.

Main Text

Input-output analysis is one of the most widely applied analytical frameworks in economics. Its fundamental purpose is to analyze the interdependence of various industries or sectors in an economy, such as agriculture, manufacturing and services. The original idea for input-output analysis can be traced as far back as the early work of a British physician and Oxford professor, William Petty, in the mid seventeenth century. The first historic breakthrough was made by a Russian-born U.S. economist, Wassily W. Leontief (1905–1999), in the late 1930s for which he received the Nobel Prize in Economic Science in 1973 (Miller and Blair, 2009).

1. Two Pillars of Input-Output Analysis

Over the past eight decades, the evolution of input-output analysis has been based upon two major pillars: theoretical foundation and data construction. Therefore, some studies may be purely theoretical, exploring the formal relationships that can be derived under various assumptions from sets of equations; other studies may be purely descriptive and dependent upon the construction of input-output tables; or others will incorporate a mixture of both empirical data and theoretical relationships in an attempt to explain or predict actual interdependence between industries or sectors (Christ, 1955).

The theoretical foundation of input-output analysis, or the input-output model, is viewed by Leontief as a general equilibrium theory. In its most basic form, an input–output model consists of a system of n linear equations with n unknowns which form a matrix that can be readily used to represent the mathematical structure of the model. An essential condition for empirical input-output analysis is the input-output table, which was first used by the French economist Francois Quesnay in *Tableau Économique* (1759). Input–output analysis became a widely used tool of economic analysis after a standardized system of economic accounts built around input–

output concepts was developed initially by Wassily W. Leontief (1941, 1951) and then by Richard Stone (1961) who was awarded the Nobel Prize in Economic Science in 1984 (Miller and Blair, 2009).

The basic structure of an input-output table records the flows of goods or services from each sector (as a producer or seller), to each of the other sectors or itself (as consumers or purchasers) (Table 1). The distinction commonly made in input-output analysis is between the production of goods and services and their utilization as reflected in the four quadrants of the input-output table. Quadrant I shows the intermediate transactions i.e. the flows of goods and services which are both produced and consumed in the process of current production. Quadrant II shows the sales by the producing industries to final uses such as private consumption, government consumption, fixed capital formation, and net exports. Quadrants I and II together allocate the total output of each industry in the economy. Quadrant III shows the primary (factor) inputs that are required by each producing industry; these constitute the gross value added (including employee compensation, depreciation of capital, and indirect business taxes) in each industry. Quadrants I and III combined show the total inputs used for production by each industry in the economy. Quadrant IV records two equivalent measures of gross domestic product (GDP): one derived from expenditure components, and the other from value added components.

Table 1 Basic Structure of a National Input-Output Table

Output / Input		Intermediate use (producers as consumers)				Final use (final demand)			
		sector 1	sector 2	…	sector *n*	Final consumption expenditure by households	Final consumption expenditure by government	Gross fixed capital formation	Net export
Producers (intermediate inputs)	sector 1	Quadrant I				Quadrant II			
	sector 2								
	…								
	sector *n*								
Primary inputs (value added)	Employees	Quadrant III				Quadrant IV: GDP			
	Business owners and capital								
	Government								

Source: Based on Miller and Blair (2009, p.3).

2. Recent Major Developments in Input-Output Analysis

The widespread availability of high-speed modern computers has made input–output analysis more comprehensive and practical. Among the most important advances are the improved implementation of computable general equilibrium (CGE) models and the ability to continually update and expand input-output tables.

CGE models use the input-output model as a benchmark for working with actual economic data to estimate how an economy might react to changes in policy, advances in technology or other external factors. So far, there are two versions of mathematical programming and optimization software suitable for CGE modeling and analysis: the general algebraic modeling system (GAMS) (see http://www.gams.com/) and the general equilibrium modeling package (GEMPACK) (see http://www.monash.edu.au/policy/gempack.htm).

There have been two important developments in the use of input-output tables in recent decades. First, since 1936, when Leontief first presented US interindustry transactions tables for

1919 and 1929, an increasing number of countries and regions around the world have been routinely constructing input-output tables. Two crucial advances can be identified in the evolution of these national-level input-output tables. One is the compilation of regional and multiregional input-output (or MRIO) tables, which provide the basis for impact analysis and examining the interconnections among different regions within a country. The other is the construction of non-competitive import type input-output (or non-competitive IO) tables. In these tables domestically produced intermediate inputs and imported intermediate inputs are treated separately as they are presumed to be poor substitutes for each other. If the inputs imported by a country are differentiated further by countries of origin, it is possible to trace its external economic and trade relationship with other~~s~~ countries (of which more below).

Second, as more and more countries have become engaged with the process of globalization, industrial linkages now reach well beyond national borders and it has become more difficult for the conventional national-level input-output tables to capture the details of global industrial and value chains. Therefore, various attempts to harmonize the input-output tables for different countries and to construct international input-output tables are ongoing. Examples include, the Asian IDE-JETRO tables compiled by the Institute of Developing Economies and Japan External Trade Organization (see http://www.ide.go.jp/English/Research/Topics/Eco/Io/), the GTAP tables constructed by Purdue University (see https://www.gtap.agecon.purdue.edu/default.asp#4), and the recently released World Input-Output Database (WIOD) which coves 27 EU countries and 13 other major countries in the world for the period from 1995 to 2011. The latter attempts to analyze the effects of globalization on trade patterns, environmental pressures and socio-economic development (see http://www.wiod.org/database/) (Timmer, 2012). In contrast to a national input-output table, a world input-output table traces flows of products or services both for intermediate and final use that are divided into those that are produced domestically and those that are imported (see Table 2).

Table 2 Basic Structure of World Input-Output Table with Three Economies

Input \ Output			Intermediate use			Final use/consumption		
			Country A	Country B	Rest of World(RoW)	Country A	Country B	RoW
			Sectors: 1…n	Sectors: 1…n	Sectors: 1…n			
Intermediate inputs	Country A	Sectors: 1…n	Intermediate use of domestic output	Intermediate use by B of exports from A	Intermediate use by RoW of exports from A	Final use of domestic output	Final use by B of exports from A	Final use by RoW of exports from A
	Country B	Sectors: 1…n	Intermediate use by A of exports from B	Intermediate use of domestic output	Intermediate use by RoW of exports from B	Final use by A of exports from B	Final use of domestic output	Final use by RoW of exports from B
	RoW	Sectors: 1…n	Intermediate use by A of exports from RoW	Intermediate use by B of exports from RoW	Intermediate use of domestic output	Final use by A of exports from RoW	Final use by B of exports from RoW	Final use of domestic output
Primary inputs (value-added)			value-added in A	value-added in B	value-added in RoW			

Source: Based on Timmer (2012).

3. An Application of Input-Output Analysis to Producer Services

In contrast to consumer services, producer services enter the production process of other manufacturing and services firms as an input (Grubel and Walker, 1989; Stibora and de Vaal, 1995). Firms can obtain producer services via two channels: in-house provision and/or market transactions. The former reflects the specialized division of labor inside the producers or firms, and thus the internal resource allocation and industrial linkages directed by firms' decisions. Unfortunately, these types of producer services cannot be captured by input-output tables in the System of National Account (SNA) and will frequently be grouped according to firms' main business (e.g., manufacturing). The latter, market driven group reflects the specialization and division of labor among different firms in the market, and hence the resource allocation and industrial linkages based on market competition. These types of producer services are captured in the SNA input-output tables with the number of such records increasing as the outsourcing and marketization of producer services, a natural evolution of specialized division of labor and resource allocation from inside the firm to the market, continues.

However, from a statistical perspective it is difficult to distinguish between producer services and consumer services; activities such as banking or transport not only fulfill intermediate demand but also meet the needs of final consumers, even though individual firms may emphasize the provision of services to one group or the other. As a result, research that uses an arbitrary classification of producer services cannot accurately detail their status, their role and their contribution to a national economy. In order to circumvent such problems, some researchers have turned to input-output analysis (Khayum, 1995; Windrum and Tomlinson, 1999; Cheng and Daniels, 2014).

By way of illustration, two examples are presented here. First, the output of any one specific service sector must be classified into two parts; output consumed by final users and output which will be used by firms as an input. The ratio of the former part in the output is the consumer services ratio, while the latter part (*SI/SO= Services input / Services output*) is the producer services ratio. This identifies the extent to which a specific service sector category is a producer service. A large producer services ratio means that more of the output of a specific service sector is being used as input to other parts of the economy; this suggests that the sector is more like a producer service. If the ratio is low for a specific service sector it is considered to be functioning more like a consumer service. As a general rule, a ratio of 50 percent or above is considered the threshold for judging whether a service activity can be characterized as a producer service. Data for the USA (Table 3) shows that the sectors with a producer services ratio averaging 50 percent or more are research and development (R&D) (about 90 percent), other business activities (about 80 percent, which are of the KIBS natures and include consulting, design, legal services, etc.), transport and storage (70 percent), post and telecommunications (over 60 percent), and finance and insurance (above 55 percent). The remaining sectors with values below 50 percent are more closely aligned with consumer services. For China in the mid-2000s (see Table 3) six activities have more than 60 percent of their output used as producer services: wholesale and retail trade and repairs, hotels and restaurants, transport and storage, post and telecommunications, finance and insurance, and other business activities. The comparison suggests that although R&D behaves more as a producer service in the United States, in China it is more akin to a consumer service, along with real estate activities, education, and health and social work. On the other hand, wholesale and retail trade and repairs and hotels and restaurants in China act more as producer rather than as consumer services.

Table 3 Application of Input-Output Analysis: China and the USA

Service sector	Producer Services Ratios (SI/SO)				Backward Linkage Coefficients (BL_j)				Forward Linkage Coefficients (FL_j)			
	Early-2000s		Mid-2000s		Early-2000s		Mid-2000s		Early-2000s		Mid-2000s	
	China	USA	China	USA	China	USA	China	USA	China	USA	China	USA
Wholesale and retail trade and repairs	66.42	30.21	61.96	30.14	0.97	0.85	0.8	0.8	1.65	1.9	1.29	1.93
Hotels and restaurants	62.17	22.11	67.82	21.16	1.01	1.04	1.01	0.97	0.77	0.73	0.9	0.68
Transport and storage	80.46	70.17	77.96	70.81	0.94	1.02	0.97	0.95	1.17	1.54	1.72	1.47
Post and telecommunications	81.14	61.88	75.29	65.88	0.97	1.04	0.97	1.02	0.79	1.19	0.84	1.19
Finance and insurance	76.1	56.63	74.59	56.05	0.66	0.97	0.74	0.85	1.02	1.79	0.9	1.73
Real estate activities	31.14	29.87	20.13	32.05	0.8	0.79	0.57	0.77	0.54	1.25	0.49	1.3
Research and development (R&D)	-	89.22	37.29	89.65	-	0.91	1.09	0.88	-	1.71	0.4	1.83
Other business activities	54.77	79.9	76.22	78.78	1.06	0.85	1.14	0.78	1.12	1.38	1.07	1.38
Education	12.55	16.52	9.46	17.38	0.89	0.95	0.78	0.86	0.47	0.57	0.42	0.53
Health and social work	4.49	2.25	13.18	2.09	1.18	0.91	1.16	0.84	0.42	0.55	0.45	0.51

Source: Calculation based on input–output tables of China and the USA. "-" denotes data vacancy. Both coefficients have in their denominator the average value of a coefficient in the inverse matrix.

Input-output analysis is also used to compute two linkage coefficients: the backward linkage coefficient (BL_j) $BL_j=(\sum^n_{j=1}b_{ij})/[1/n(\sum^n_{i=1}\sum^n_{j=1}b_{ij})]$ and the forward linkage coefficient (FL_i) $FL_j=(\sum^n_{i=1}b_{ij})/[1/n(\sum^n_{i=1}\sum^n_{j=1}b_{ij})]$ (from the Leontief inversion matrix $B=(b_{ij})_{n\times n}=(I–A)^{-1}$, the Leontief complete consumption coefficients b_{ij} can be obtained, where A is an input coefficient matrix based on Quadrant I in Table 1 and I is an identity matrix). The first coefficient measures the backward economic linkage of one specific sector j to the rest of the economy, i.e. when the output of sector j (e.g. transport services) increases by one unit, how much of the increased demand from sector j (as a purchaser) will rely on (upstream) sectors (e.g. transport vehicles) whose outputs are used as inputs to production in sector j. The greater the value of this coefficient, the stronger the pulling power of sector j on the rest of the economy. The second coefficient measures the forward economic linkage of one specific sector i to other sectors, i.e. when the output in every sector of the economy increases by one unit, how much of the increased demands from these (downstream) sectors will depend on sector i (as a seller) (e.g. transport services). The greater this coefficient, the higher the pressure of demand experienced by sector i.

Indeed, there has been considerable literature arguing about the linkage measures and offering numerous suggestions for differing definitions and refinements of them (Beyers, 1976; Miller and Blair, 2009). Our aim here is just to introduce the simplest forms of these measures and in particular to show how they are derived from information in the IO table.

It is common for the same kind of services (e.g. transport services) to be used as both upstream and downstream services. Referring again to Table 3, in the mid-2000s R&D, other business activities, education, and health and social work have larger backward linkage coefficients in China than in the USA. However, the backward linkage coefficients of real estate activities and finance and insurance are obviously much smaller (only 0.57 and 0.74, respectively) in China. The values of the forward linkage coefficients for wholesale and retail trade and repairs, transport and storage, and other business activities in China are greater than one in China, while the values for the other sectors are much lower; five scored less than 0.5 in the mid-2000s. In the USA, the forward linkage coefficient for R&D was well above 1.7 from the early 2000s, approximately four times the equivalent value for China. Indeed, almost all the service sectors in China, except hotels and restaurants and transport and storage, have much smaller forward linkage coefficients.

The fact that every sector of the economy in China depends to a significant degree on hotels and restaurants and on transport and storage again confirms that these services are utilized more as producer services and have therefore performed a key role in industrialization. Once again, the forward linkage coefficient for real estate activities in China is less than 0.5 and is just one third of the equivalent USA values. It is clear that Chinese real estate activities cannot exert strong pulling or pushing powers on the rest of economy i.e. this sector functions independently from (or is not strongly connected to) the rest of economy since both linkage coefficients are well below one.

To sum up, subject to the availability of suitable and reliable data, an input-output analysis can greatly improve our understanding of the development and contribution of producer services to economic change and restructuring, especially at the national scale but also at the global scale as the appropriate models for analysis begin to be introduced.

SEE ALSO:

De-industrialization; Demand and supply; Externalization; Factors of Production; Global Production Network; Globalization; Industrial Linkage; Producer services; Value-added.

References and Further Readings:

1. Beyers, William Bill. 1976. "Empirical Identification of Key Sectors: Some Further Evidence." *Environment and Planning A*, 8(2): 231-236.
2. Christ, Carl. 1955. "A Review of Input-Output Analysis." In *Input-Output Analysis: An Appraisal*, edited by Conference on Research in Income and Wealth, 137-182. Princeton: Princeton University Press.
3. Cheng, Dazhong and Peter Daniels. 2014, "What's So Special about China's Producer Services?" *China and World Economy*. 22 (1): 103–120.
4. Grubel, Herbert and Michael Walker. 1989. *Service Industry Growth: Causes and Effects*. Vancouver, BC: Fraser Institute.
5. Khayum, Mohammed. 1995. "The Impact of Service Sector Growth on Intersectoral Linkages in the United States," *The Service Industries Journal*, 15(1): 35–49.
6. Leontief, Wassily. 1951. *The Structure of American Economy 1919–1939*. New York: International Arts and Science Press.
7. Miller, Ronald and Peter Blair. 2009. *Input–Output Analysis: Foundations and Extensions* (Second Edition). Cambridge: Cambridge University Press.
8. Stibora, Joachim and Albert de Vaal. 1995. *Services and Services Trade: A Theoretical Inquiry*. Amsterdam: Thesis Publishers.
9. Stone, Richard. 1961. *Input-Output and National Accounts*. Paris: Organization for Economic Cooperation and Development.
10. Timmer, Marcel (ed.). 2012. "The World Input-Output Database (WIOD): Contents, Sources and Methods." *WIOD Working Paper Number 10*. Accessed December 10, 2013. http://www.wiod.org/publications/papers/wiod10.pdf.
11. Windrum, Paul and Mark Tomlinson. 1999. "Knowledge-intensive Services and International Competitiveness: A Four Country Comparison." *Technology Analysis and Strategic*

Management, 11(3): 391–408.

Key Words:

Backward linkage coefficient; Computable general equilibrium (CGE) model; Forward linkage coefficient; General equilibrium theory; Producer services; System of National Account (SNA)