Using Input–Output Tables in Simulation

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Introduction

Input-Output (I-O) tables can be used to study the interdependence of industries in an economy and simulate the impact of various changes on the economy as they provide detailed information on the industrial structure. This article introduces the use of I-O tables for simulation and illustrates the application using two case studies.

Overview of I-O Tables

For the purpose of this article, the I-O tables are presented in terms of two industries: *Goods* industry and *Services* industry.[1,2] The Industry by Industry Flow matrix (Table 1) records the transactions between the two industries and final consumers, and other production requirements of the two industries in 2010.

Based on the relationships between producers and consumers, an I-O model can be constructed to estimate the change in output resulting from changes in final demand. The latter may come from changes in household spending, government spending, investment in new building, machinery and software, or exports to the rest of the world.

The intuition behind the I-O model is that a change in production activity of an industry will have impact on other industries. Hence, an increase in final demand for an industry's output will stimulate production of output in other industries. This is also known as the output multiplier effects (Chart 1).

TABLE 1 INDUSTRY BY INDUSTRY FLOW MATRIX, 2010

Billion Dollars

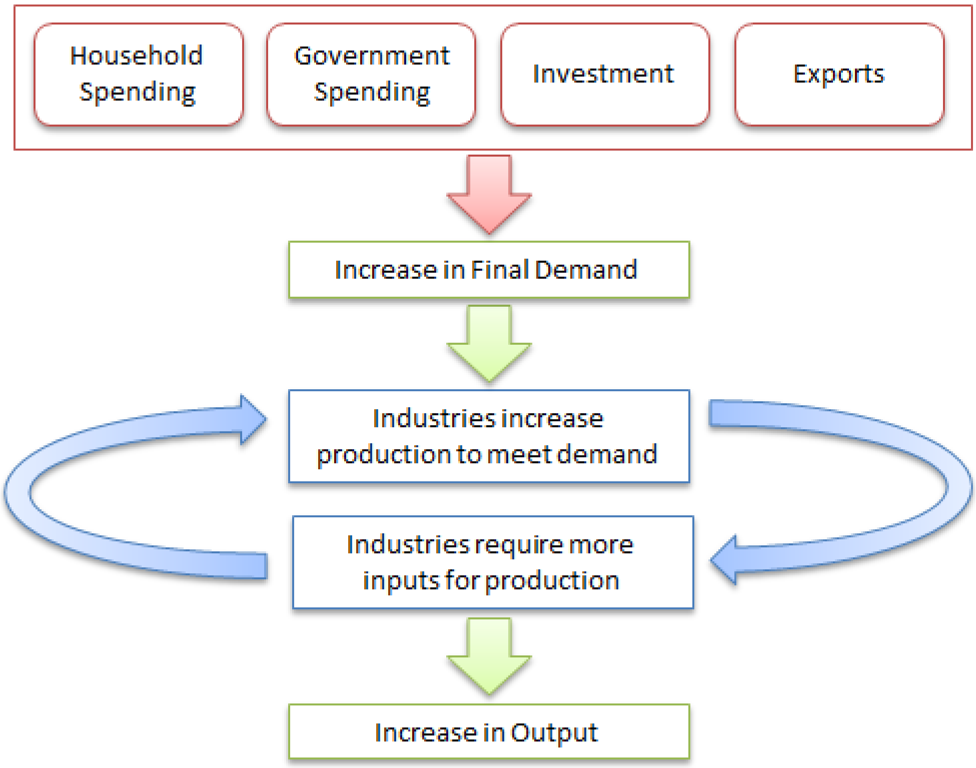
	Goods	Services	Final Demand	Total Output
Goods	88.8	25.7	245.4	359.8
Services	33.0	125.0	317.7	475.7
Imports	153.5	104.2	44.6	302.4
Taxes on Products	0.2	0.7	17.0	17.9
Value-added	84.3	220.1	-	304.4
Total Input	359.8	475.7	624.7	1,460.2

Note: Figures may not add up to the total due to rounding.

[1] The I-O tables are generated from the 2010 Singapore Supply and Use Tables, which are compiled at 127 I-O industries/ products codes.

[2] For this article, the "*Goods* industry" refers to the goods-producing industries comprising manufacturing, utilities, other goods and construction while the "*Services* industry" refers to the service-producing industries comprising the remaining industries, including wholesale and retail trade, accommodation and food services, transportation and storage, information and communications, finance and insurance, business services, and other services.

CHART 1 OUTPUT MULTIPLIER EFFECTS



In the I-O framework, the relationships between the producers and consumers are represented by the following equations:

Output of *Goods* industry: $X_1 = X_{11} + X_{12} + F_1$
$= a_{11}X_1 + a_{12}X_2 + F_1$

Output of *Services* industry: $X_2 = X_{21} + X_{22} + F_2$
$= a_{21}X_1 + a_{22}X_2 + F_2$ (1.1)

where

X_i = the value of output produced by industry i

X_{ij} = the value of output produced by industry i and sold to industry j

F_i = the value of output produced by industry i and sold to final consumers (Final Demand)

a_{ij} = $\frac{X_{ij}}{X_j}$, the value of intermediate inputs[3] from industry i required by industry j to produce $1 of output

The a_{ij} from equations (1.1), also known as the direct requirement coefficients of industries, are computed from Table 1 and presented in Table 2.

[3] Intermediate inputs are goods and services used by industries for production of other goods and services.

TABLE 2 DIRECT REQUIREMENT COEFFICIENTS, 2010

	Goods	Services
Goods	0.247	0.054
Services	0.092	0.263
Imports	0.427	0.219
Taxes on Products	0.001	0.002
Value-Added	0.234	0.463
Total	1.000	1.000

Note: Figures may not add up to the total due to rounding.

By substituting the direct requirement coefficients into equations (1.1), we obtain:

Output of *Goods* industry: $X_1 = 0.247\,X_1 + 0.054\,X_2 + F_1$

Output of *Services* industry: $X_2 = 0.092\,X_1 + 0.263\,X_2 + F_2$ (1.2)

Using linear algebra, equations (1.2) can be expressed in the following form:

Output of *Goods* industry: $X_1 = \theta_{11}F_1 + \theta_{12}F_2$

$= 1.340\,F_1 + 0.098\,F_2$

Output of *Services* industry: $X_2 = \theta_{21}F_1 + \theta_{22}F_2$

$= 0.167\,F_1 + 1.369\,F_2$ (1.3)

where

θ_{ij} = the value of output produced by industry i due to $1 increase in final demand for the output of industry *j*

In equations (1.3), output can be expressed as a function of final demand which allows us to estimate the output for both industries X_1 and X_2 corresponding to final demand F_1 and F_2.

Further, equations (1.3) can be multiplied by the direct requirement coefficients to estimate other variables of interest such as value-added corresponding to the final demand F_1 and F_2. Equations (1.4) show the computation for value-added. Other variables can be computed in a similar fashion.

Value-added generated in *Goods* industry: $VA_1 = a_1^{VA} \times (\theta_{11}F_1 + \theta_{12}F_2)$

$= 0.234 \times (1.340\,F_1 + 0.098\,F_2)$

Value-added generated in *Services* industry: $VA_2 = a_2^{VA} \times (\theta_{21}F_1 + \theta_{22}F_2)$

$= 0.463 \times (0.167\,F_1 + 1.369\,F_2)$ (1.4)

where

VA_i = the value-added generated in industry i

a_i^{VA} = the value-added generated to produce $1 of output in industry i

Simulation of Economic Impact using I-O Tables

Assumptions of the I-O Tables

While I-O tables are useful tools for simulation in economic impact studies, users need to bear in mind the following three basic assumptions underlying the use of the I-O model, and the extent to which they can be met.

1. **Homogeneity** - All companies classified in the same industry have the same production process and inputs requirements.

If a new company uses new production technologies which require significantly fewer inputs from other companies, then the actual impact of the new company will be lower than the simulated impact. This is because the I-O model assumes the new company will stimulate the same level of production in other companies, which is not the case.

2. **Fixed proportion** - Industries have fixed input requirements proportion relative to output. If an industry doubles its output, its input requirements such as intermediate inputs, imports and employment for production must also double.

If an industry is operating at below capacity with under-utilised inputs and can increase its output without increasing its inputs proportionately, the direct requirement coefficients used for the I-O model may not be applicable. In such a case, the actual impact will be lower than the simulated impact.

3. **No supply constraint** - There are limitless supplies of intermediate inputs and labour for production, at a fixed price.

If there are limited supplies of resources, industries may have to consider alternatives such as raising imports. In such a case, the actual impact of an increase in final demand will be lower since local production is unable to fully satisfy the demand and hence the multiplier effects will be correspondingly lower.

Case Studies

The following two case studies illustrate how I-O tables can be used for simulation.

(A) When Final Demand is known

A company announces the decision to set up a new manufacturing plant in Singapore. The new plant is expected to manufacture $100 million worth of goods that will be exported to an overseas manufacturing plant for further processing.

In this case, the value of the final demand is $100 million and the relevant industry is the *Goods* industry. Hence, F_1 = 100 and F_2 = 0.

Using the equations (1.3) with F_1 = 100 and F_2 = 0, $150.7 million of additional output is expected to be produced in the economy, comprising $134.0 million from the *Goods* industry (which includes the initial $100 million or F_1) and $16.7 million from the *Services* industry.

The additional output produced by the two industries can be found in the last column of Table 3 which shows the total economic impact of the new manufacturing plant. The table also shows the value of inputs required to produce these additional output, which are computed based on the direct requirement coefficients.

For example, the *Goods* industry requires $33.1 million of intermediate inputs from its own industry, $12.3 million of intermediate inputs from the *Services* industry, and $88.7 million of factor inputs (comprising $57.2 million of imports, $0.1 million of taxes on products and $31.4 million of value added).

Output of *Goods* industry: $X_1 = 1.340 \times 100 + 0.098 \times 0$

$= 134.0$

Output of Services industry: $X_2 = 0.167 \times 100 + 1.369 \times 0$ (1.5)

$= 16.7$

Total output produced in the economy $= X_1 + X_2 = 150.7$

TABLE 3 TOTAL ECONOMIC IMPACT OF THE NEW MANUFACTURING PLANT

Million Dollars

	Goods	Services	Final Demand	Total Output
Goods	33.1	0.9	100.0	134.0
Services	12.3	4.4	0.0	16.7
Imports	57.2	3.7	-	60.8
Taxes on Products	0.1	0.0	-	0.1
Value-added	31.4	7.7	-	39.1
Total Input	134.0	16.7	100.0	

Note: Figures may not add up to the total due to rounding.

(B) When Final Demand is unknown

When final demand is unknown, I-O tables may be utilised to simulate the economic impact using other information such as employment or income.

Suppose a services company decides to hire an additional 200 workers for production and the output of the services company will be sold to households. Assuming that the homogeneity and fixed proportion assumptions are applicable, the increase in output of the services company can be estimated since any increase in the inputs will result in a proportionate increase in output.

In 2010, the *Services* industry hired approximately 2,182,700 workers[4] to produce $475.7 billion of output. Hence, with the additional 200 workers, the services company is expected to produce an additional $43.6 million of output to meet final demand from households.

With the estimated final demand, F_1 = 0 and F_2 = 43.6, the economic impact of hiring an additional 200 workers can be similarly computed as in case study (A).

The $43.6 million increase in final demand will generate $64.0 million of additional output, comprising $4.3 million from the *Goods* industry and $59.7 million from the *Services* industry (which includes the initial $43.6 million or F_2). The total economic impact of the increased employment in the *Services* industry is presented in Table 4.

[4] Source: Ministry of Manpower, "Table C.1, Employment by Industry", *Singapore Yearbook of Manpower Statistics 2014*

$$\text{Output of services company} = \text{Increase in workers} \times \frac{\text{Output of } \mathit{Services} \text{ industry}}{\text{Number of workers in } \mathit{Services} \text{ industry}}$$

$$= 200 \times \frac{\$475.7 \text{ billion}}{2{,}182{,}700} \qquad (1.6)$$

$$= \$43.6 \text{ million}$$

TABLE 4 TOTAL ECONOMIC IMPACT OF THE INCREASED EMPLOYMENT IN THE SERVICES COMPANY

Million Dollars

	Goods	Services	Final Demand	Total Output
Goods	1.1	3.2	0.0	4.3
Services	0.4	15.7	43.6	59.7
Imports	1.8	13.1	-	14.9
Taxes on Products	0.0	0.1	-	0.1
Value-added	1.0	27.6	-	28.6
Total Input	4.3	59.7	43.6	

Note: Figures may not add up to the total due to rounding.

Conclusion

I-O tables are useful tools for economic impact studies as they provide detailed information on the structure of the economy. This article introduces how I-O tables can be used for simulation. Although policy changes may not be as straight-forward as illustrated in the case studies, simulation using I-O tables can be extended to more industries to analyse the economic impact in greater detail.

Technical details on the applications of I-O tables can be found in the publication on "Singapore Supply and Use, and Input-Output Tables 2010", available for free downloading from the SingStat website.

Contents

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