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Input-Output

Overview

Wassily Leontief (1905–1999) was the founder of input-output economics, for which he received the Nobel Prize in 1973. Input-output analysis is a macro-economic method that provides a snap-shot of the economy. It shows how the output of one industry becomes the input of another, revealing supplier and demander interdependencies.

Input-Output Tables

An input-output table is a matrix, which means that it has rows and columns. The row and column headers are the names of the economic sectors of an economy. All economic sectors are represented across the header row – the x axis – and the same set of economic sectors is listed down the lead column – the y axis. This means that there is an intersection between every industry sector with every other industry sector.

	black coal	natural gas	iron ore	Etc…	gravel	clays	steel making	alumina	nickel	etc
black coal										
natural gas										
iron ore							XXXXXXXX			
Etc…										
gravel										
clays										
steel making										
alumina										
nickel etc										

The number at the intersection of row **iron ore** with column **steel making** is a dollar figure (or yen, or pounds sterling etc). The dollar figure at the intersection of row **iron ore** and column **steel making** tells you the amount spent on iron ore by the steel industry that year to make steel. It is the *output* of iron ore that goes *into* steel making.

There is a dollar figure for every pair of industries. For example: the amount spent on **wool** by **knitting mills**; the amount spent on **trucks** by the **wheat industry**; the amount spent on **paper** by the **insurance industry.**

A modern economy is so complex that the input-output table is full. Looking at it you can begin to appreciate the interactions between all actors in the economy. From the input-output table you can see what everyone needs from everyone else, the whole mix of interactions is laid out in front of you. In short – you know everyone’s production recipe.

The cells of each column contain the value of an industry's inputs and each row represents the value of an industry's outputs. The input-output matrix can illuminate how changes in one economic sector may have a flow-on effect in other sectors.

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What can you do with this information?

Let's say you know from the table the cost of **paper** bought by the **insurance industry**. You work out that the insurance industry buys 1m$'s worth of paper to produce 100m$'s worth of insurance policy[1]. That is the same as saying that they need 1 cent's worth of paper for every 1$'s worth of output.

Now you go to the paper industry. Let's say that you find that the **paper industry** needs 25c's worth of **wood** to produce 1$'s worth of paper.

Now to the **wood industry**. Let's say they need 10c's worth of **machinery** to produce 1$'s worth of timber.

Now the **machinery industry**. Say they need 20c's worth of **steel** to make 1$'s worth of forestry machines.

Next the **steel industry**. Say they need 40c's worth of **iron ore** to make 1$'s worth of steel.

Now for the million dollar question.

How much iron ore does it take to make a $2000 insurance policy[2] from this one supply chain: **iron ore** for **steel** for **machine** for **wood** for **pape**r for **insurance policy?**

And the answer is…

$$2000\$\text{insurance} \times \frac{\text{1c paper}}{\textbf{\$ insurance}} \times \frac{\text{25c wood}}{\textbf{\$ paper}} \times \frac{\text{10c machine}}{\textbf{\$ wood}} \times \frac{\text{20c steel}}{\textbf{1\$ machine}} \times \frac{\text{40c iron ore}}{\textbf{\$1 steel}} =$$

$$\mathbf{2000 \times 0.01 \times 0.25 \times 0.1 \times 0.2 \times 0.4 =} \ \textbf{4c iron ore}$$

But think twice before you ask your child's teacher to sneak a question onto the school's trivia night quiz list. This is just one supply chain amongst millions.

The calculation above is a **structural path**, it is one small part of a production recipe. It works in the same way as a cooking recipe. For example your recipe might require one cup of fruit per person, or one tablespoon of butter per serve[3]. In each case your reference point is a standard denominator (*per* person, *per* serve). In the case of the industrial production recipe it is cents of input *per* dollar's worth of output.

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[1] i.e. the total cost to insurance policy buyers is $100m

[2] i.e. one that costs you $2000 to buy

[3] For desert you might decide to serve sago pudding. The recipe you are following needs half a litre of milk per pudding and you calculate that you will need half a pudding per person. There are ten people for dinner…

$$10\ \text{guests} \times \frac{\text{0.5 pudding}}{\textbf{person}} \times \frac{\text{0.5 milk}}{\textbf{pudding}} =$$

$$\mathbf{10 \times 0.5 \times 0.5 =} \ \textbf{2.5 litres of milk}$$

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Why is this important?

You may be surprised that something material like iron is necessary to make something immaterial such as an insurance policy because you probably did not associate insurance with needing a lot of material resources.

The Washington Post

Support of the Service Industry Has Large Role in U.S. Emissions

The service industry's supply chain accounts for more than one-third of U.S. commercial greenhouse gas emissions, according to a study published in the journal Environmental Science & Technology.

University of Minnesota industrial ecology professor Sangwon Suh analyzed the supply-chain network for 480 goods and services, excluding only electric utilities and transportation, and concluded that it accounts for 37.6 percent of the nation's industrial emissions.

The Environmental Protection Agency, by contrast, calculates that service industries directly account for less than 5 percent of total emissions.

A bank, for example, needs a building made of concrete and steel to operate, and producing those materials releases greenhouse gases into the atmosphere. Likewise, hospitals use surgical equipment and medical appliances to operate, and these generate carbon dioxide and other emissions as well.

"What I'm looking at is the entire supply chain that allows services to be offered," Suh said Friday. "If we take that into account, the percentage is totally different than what we have normally perceived."

People see power plants as the primary villains in the climate change story, Suh said, but other industries play a significant role in producing pollution that helps warm the earth.

— **Juliet Eilperin**

Monday November 6, 2006

This is not an unusual example. In 2006 the Washington Post reported the work of Sangwon Suh[1] who has shown that services are responsible for a significant percentage of US emissions just because of their supply chain network.

Hybrid input-output table

Hybrid accounts combine physical flow accounts and national, monetary accounts. In these accounts *the environment* plays an active role in providing input, such as minerals, water, or CO_2. Hybrid flow accounts record physical flows in the same way as economic transactions are presented in the National Accounts. Thus, hybrid flow accounting has the ability to connect environmental burdens to economic benefits and environmental benefits to economic costs (United Nations Statistics Division 2003). Just as monetary accounts must balance, an important feature of hybrid accounts is that inputs and outputs balance both in monetary and in physical terms.

How can this help?

If input-output analysis can tell you how many cent's worth of iron ore is needed to make the steel that made the machine that processed the wood to make the paper to get that insurance policy to you…

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…then a hybrid analysis can tell your organisation, *BigInsuranceCo,* where all that CO_2-e is hidden in your supply chain…

For example:

Structural Path	Amount	Percentage
Softwoods > Pulp, paper and paperboard > Recorded media and publishing > BigInsuranceCo	489 t CO2-e	0.41 %

0.41% of *BigInsuranceCo*'s CO_2-e – that's 489tonnes – comes from softwoods used by the pulp, paper and paperboard industry to supply the recorded media and publishing industry who supply the insurance company with a publishing service.

Structural Path	Amount	Percentage
Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Market research and other business management services > Services to finance and investment > BigInsuranceCo	12.2 ha	0.61 %

…or how much land you disturb…

For example 12.2 ha of land is disturbed by beef cattle sent to the fresh meat industry to supply hotels, clubs, restaurants and cafes which are frequented by market research and other business management services which in turn are used by services to finance and investment that are used by the *BigInsuranceCo*. This constitutes 0.61% of the insurance company's total land disturbance.

Structural Path	Amount	Percentage
Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > BigInsuranceCo	13.7 ML	1.54 %

…or how much water you use…

For example 13.7 ML is used in growing grapes for the wine industry to supply hotels, clubs, restaurants and cafes used by *BigInsuranceCo* to entertain its clients!

The structural paths that you can see in the example are of a finite length. The input-output insurance path has 5 nodes. In an input-output table that say, distinguishes 100 sectors there would be 100 1-node paths to the final product because the company making this product would have 100 suppliers. Each of those suppliers has 100 suppliers in turn so there would be 100x100 2-node paths (suppliers of suppliers of the product). There would be one million 3-node paths, 100 million 4-node paths, 10 billion 5-node paths and so on.

Input-output analysis covers supply chains of infinite length and it covers all of them. How can it possibly do that? The short answer is because Wassily Leontief was a genius. The longer answer is because input-output analysis uses mathematical techniques that turn and infinite series (a series is a sequence of additions) into a single matrix inverse. Since Leontief developed his input-output theory it has been used by thousands of researchers over more than five decades.