

Input / Output analysis

Output Data Analysis

for Simulations

Input-Output Analysis

- 20th-century economic analysis developed by the Russian-born U.S. economist Wassily W. Leontief; observes interdependence of an economy's various productive sectors by viewing the product of each industry both as a commodity demanded for final consumption and as a factor in the production of itself and other goods; useful in planning production levels in various industries necessary to meet given consumption goals; also used to analyze the effects throughout the economy of changes in certain components; most widely used in planned economies and in developing countries.
- Economic analysis, in which the interdependence of an economy's various productive sectors is observed by viewing the product of each industry both as a commodity demanded for final consumption and as a factor in the production of itself and other goods. Certain simplifying assumptions are made, such as that productive resources will always be combined in the same proportions to produce any amount of a final product. Then it is possible to determine the total quantities of various goods that must be produced to obtain a given amount for final consumption.

... Input-Output Analysis

- The analysis usually involves constructing a table in which each horizontal row describes how one industry's total product is divided among various production processes and final consumption. Each vertical column denotes the combination of productive resources used within one industry. If, for example, the first row of a table for a very simple economy describes the distribution of the total production of trucks, it would show that a certain quantity of trucks is used in the production of more trucks, a certain quantity in the production of agricultural commodities, a certain quantity in the production of houses, a certain quantity by private households, and so on. If the numbers are added across the row, the total quantity of trucks produced is obtained. A table of this type illustrates the dependence of each industry on the products of other industries: for example, an increase in food output is also seen to require an increase in the production of trucks.
- Input-output tables can be constructed for whole economies or for segments within economies. They are useful in planning the production levels in various industries necessary to meet given consumption goals and in analyzing the effects throughout the economy of changes in certain components. They have been most widely used in planned economies and in developing countries.

Input-Output Model

- In economics, an input-output model uses a matrix representation of a nation's (or a region's) economy to predict the effect of changes in one industry on others and by consumers, government, and foreign suppliers on the economy. Wassily Leontief (1905-1999) is credited with the development of this analysis. Francois Quesnay developed a cruder version of this technique called *Tableau économique*. Leontief won the Nobel Memorial Prize in Economic Sciences for his development of this model. And, in essence, Léon Walras's work *Elements of Pure Economics* on general equilibrium theory is both a forerunner and generalization of Leontief's seminal concept. Leontief's contribution was that he was able to simplify Walras's piece so that it could be implemented empirically. The International Input-Output Association[1] is dedicated to advance knowledge in the field input-output study, which includes "improvements in basic data, theoretical insights and modelling, and applications, both traditional and novel, of input-output techniques."
- Input-output depicts inter-industry relations of an economy. It shows how the output of one industry is an input to each other industry. Leontief put forward the display of this information in the form of a matrix. A given input is typically enumerated in the column of an industry and its outputs are enumerated in its corresponding row. This format, therefore, shows how dependent each industry is on all others in the economy both as customer of their outputs and as supplier of their inputs. Each column of the input-output matrix reports the monetary value of an industry's inputs and each row represents the value of an industry's outputs. Suppose there are three industries. Column 1 reports the value of inputs to Industry 1 from Industries 1, 2, and 3. Columns 2 and 3 do the same for those industries. Row 1 reports the value of outputs from Industry 1 to Industries 1, 2, and 3. Rows 2 and 3 do the same for the other industries.

... Input-Output Model

- ▣ While most uses of the input-output analysis focuses on the matrix set of interindustry exchanges, the actual focus of the analysis from the perspective of most national statistical agencies, which produce the tables, is the benchmarking of gross domestic product. Input-output tables therefore are an instrumental part of national accounts. As suggested above, the core input-output table reports only intermediate goods and services that are exchanged among industries. But an array of row vectors, typically aligned below this matrix, record non-industrial inputs by industry like payments for labor; indirect business taxes; dividends, interest, and rents; capital consumption allowances (depreciation); other property-type income (like profits); and purchases from foreign suppliers (imports). At a national level, although excluding the imports, when summed this is called "gross product originating" or "gross domestic product by industry." Another array of column vectors is called "final demand" or "gross product product consumed." This displays columns of spending by households, governments, changes in industry stocks, and industries on investment, as well as net exports. (See also Gross domestic product.) In any case, by employing the results of an economic census which asks for the sales, payrolls, and material/equipment/service input of each establishment, statistical agencies back into estimates of industry-level profits and investments using the input-output matrix as a sort of double-accounting framework.

... Input-Output Model

- ▣ The mathematics of input-output economics is straightforward, but the data requirements are enormous because the expenditures and revenues of each branch of economic activity has to be represented.
- ▣ As a result, not all countries collect the required data and data quality varies, even though a set of standards for the data's collection has been set out by the United Nations through its System of National Accounts[2](SNA): the replacement for the current 1993 SNA standard is pending.
- ▣ Because the data collection and preparation process for the input-output accounts is necessarily labor and computer intensive, input-output tables are often published long after the year data was collected--typically as much as 5-7 years after.
- ▣ Moreover, the economic "snapshot" the benchmark version of the tables provide of the economy's cross-section are taken only once every few years, at best. Although many developed countries estimate input-output accounts annually and with much greater recency.

Econ. Base vs Input-Output Models

srdc.msstate.edu/03econimpact/doeksen_inputoutput.ppt

- ▣ Leontief developed an “input-output” method for estimating economic impacts and tracing the flows of dollars. Leontief later won the Nobel Prize in 1973, largely related to this work.
- ▣ Input-Output expands heavily upon the economic base model of the economy.

Economic Base Techniques

- 1) Basic and Non-basic sectors
- 2) Ripple (multiplier) effects analyzed at the B/NB level
- 3) Analyzes changes and impacts at a gross B/NB level
- 4) Very general, but...

Input-Output Analysis

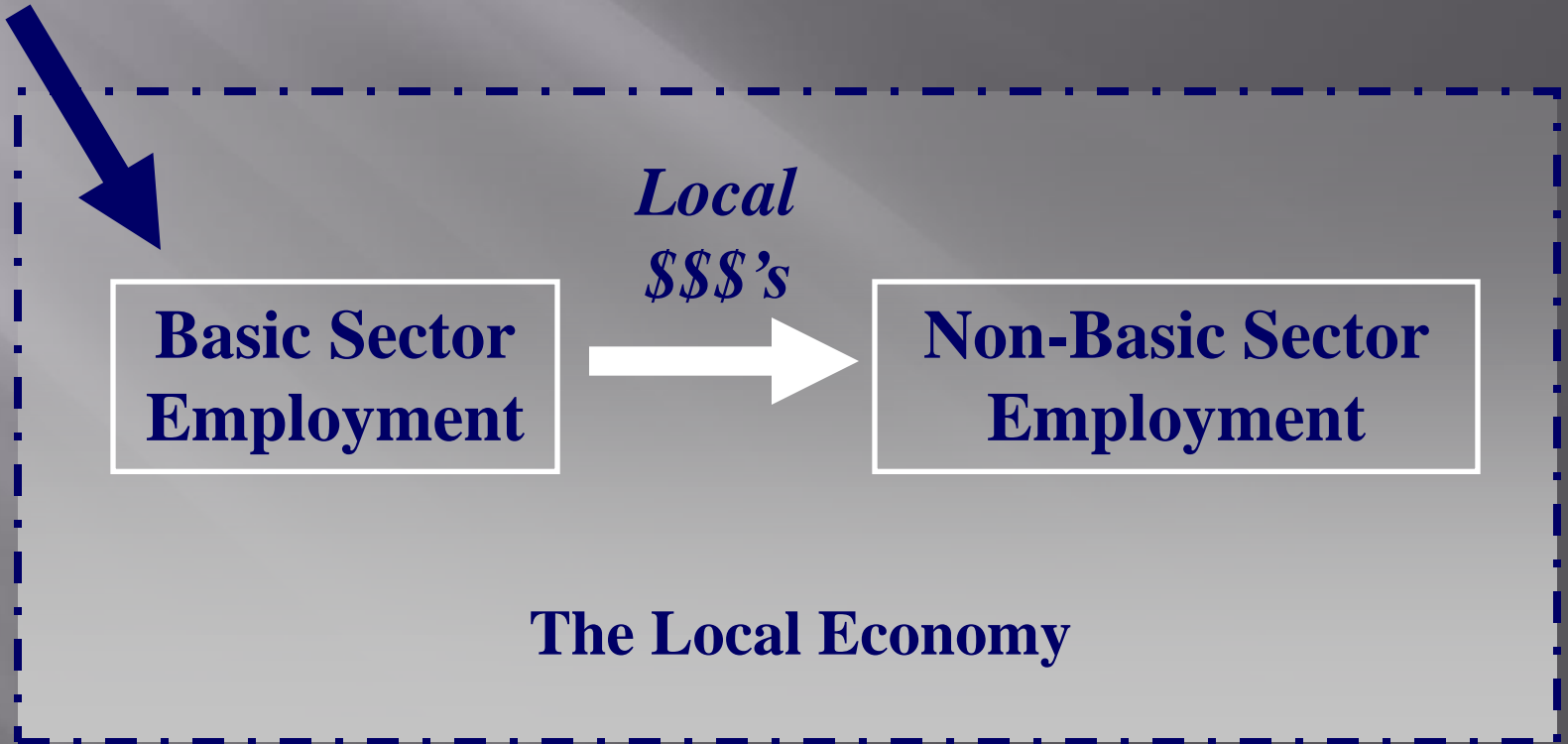
- 1) Many different industries/sectors
- 2) Ripple (multiplier) effects contained in the interindustry transactions
- 3) Analyzes changes and impacts at a sector by sector level, tracing flows of dollars between industries
- 4) Much more precise, but...

The Economic Base Theoretical Model

- The EB model assumes that the *basic sector is the primary cause of local economic growth; that is, it is the economic base of the local economy.*

Non-Local

\$\$\$'s



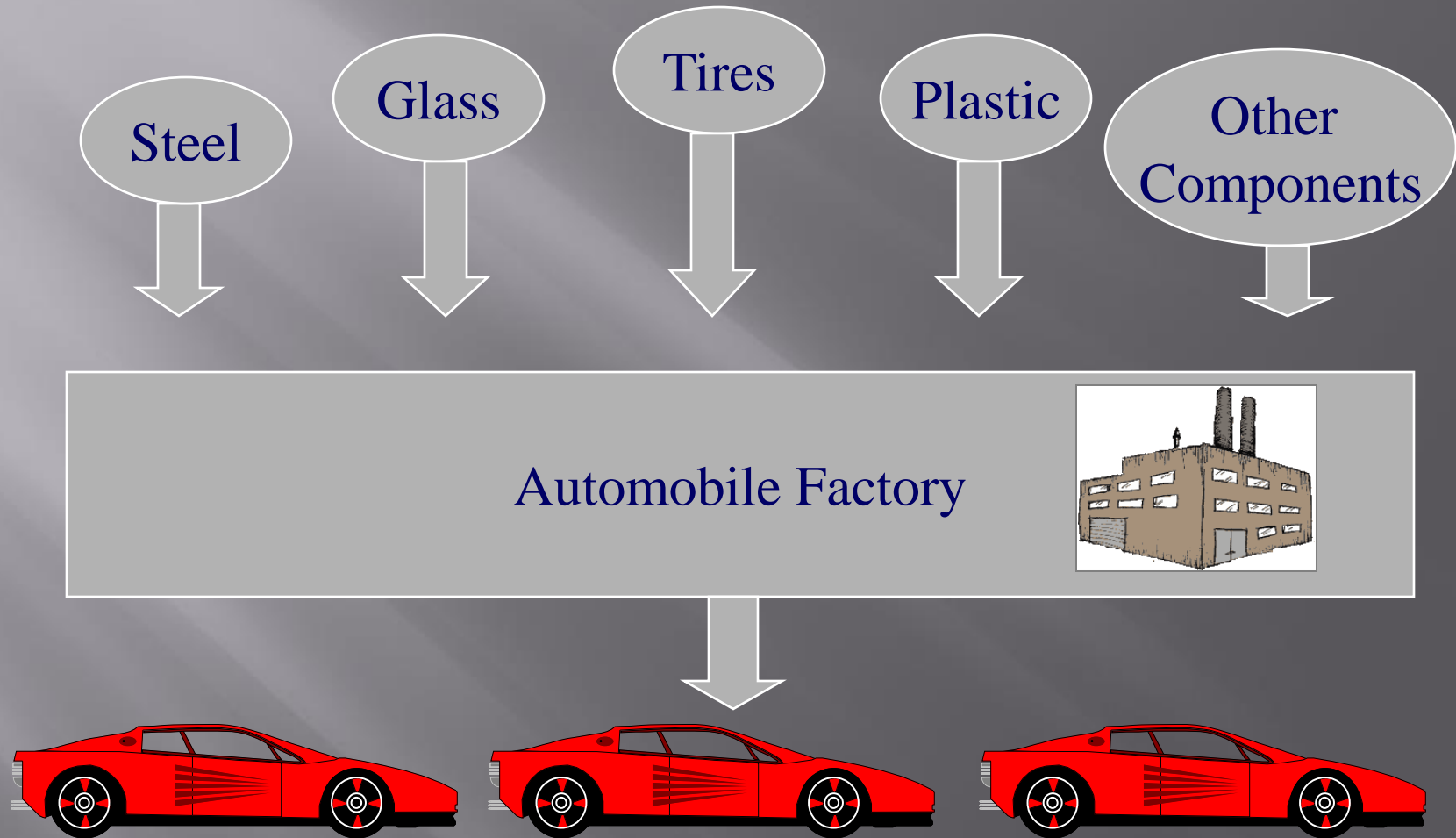
The Local Economy

Input-Output Model

- ▣ The IO model is centered on the idea of inter-industry transactions:
 - Industries use the products of other industries to produce their own products.
 - For example - automobile producers use steel, glass, rubber, and plastic products to produce automobiles.
 - Outputs from one industry become inputs to another.
 - When you buy a car, you affect the demand for glass, plastic, steel, etc.

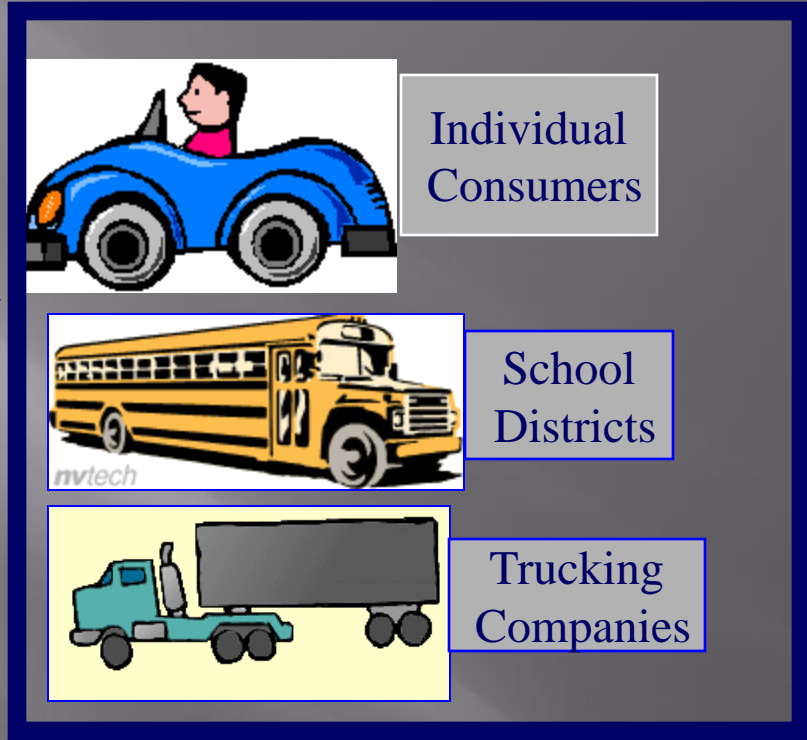
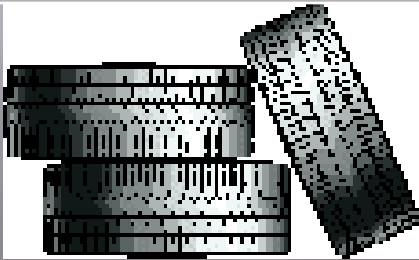
*Taken from a Power Point presentation prepared by
Pam Perlich at the University of Utah.
<http://www.business.utah.edu/~bebrpsp/IO/IO.ppt>*

Basic Input-Output Logic

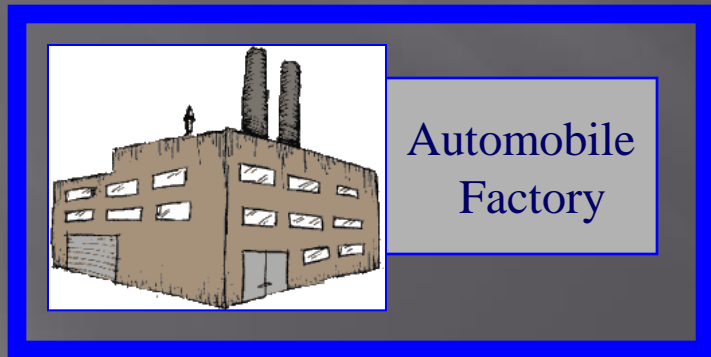
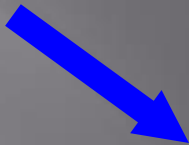


From the Tire Producer's Perspective

Tire Factory



FINAL DEMAND FOR TIRES



INTER-MEDIATE DEMAND FOR TIRES

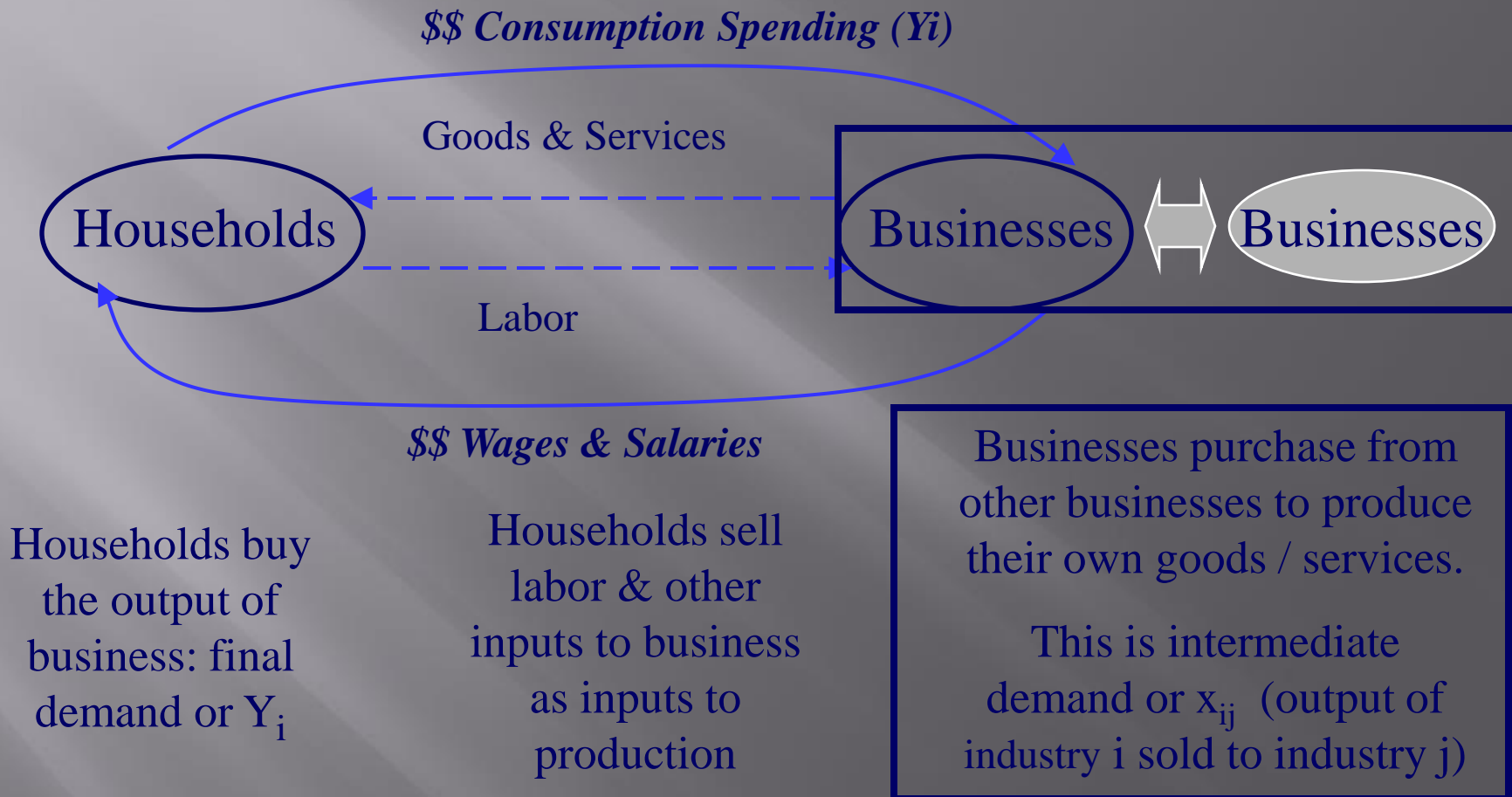
Input-Output Analysis: The BIG Point

- The implicit assumption in economic base techniques is that each basic sector job has a multiplier (or ripple) effect on the wider economy because of purchases of non-basic goods and services to support the basic production activity. (*the Basic Sector drives the Non-basic Sector*)
- However, we know that Non-basic sector businesses purchase Non-basic goods and services and Basic sector businesses purchase Basic sector goods and services. There are *inter-industry linkages* not contained within the Economic Base model. The economy is much more complex than the economic base techniques allow or attempt to model.
- The central advantage of Input-Output analysis is that *it tries to estimate these inter-industry transactions and use those figures to estimate the economic impacts of any changes to the economy.*
- Instead of assuming a change in a basic sector industry having a generalized multiplier effect, the IO approach estimates how many goods and services from other sectors are needed (*inputs*) to produce each dollar of *output* for the sector in question. Therefore it is possible to do a much more precise calculation of the economic impacts of a given change to the economy.

IO Conceptualization of the Economy

- The major conceptual step is to divide the economy into “purchasers” and “suppliers”.
 - Primary Suppliers*: They sell primary inputs (labor, raw materials) to other industries. Payments to these suppliers are “primary inputs” because they generate no further sales. (example: Households)
 - Intermediate Suppliers*: They purchase inputs for processing into outputs they supply to other firms or to final purchasers. (example: Automaker)
 - Intermediate Purchasers*: They purchase outputs of suppliers for use as inputs for further processing. (example: Automaker)
 - Final Purchasers*: Purchase the outputs of suppliers in their final form and for final use. (example: Households)
- *Intermediate Suppliers* and *Intermediate Purchasers* are the same thing!
- *Primary Suppliers* and *Final Purchasers* may or may not be the same entities. When they are the same (households), these activities are understood as separate activities.

Simplified Circular Flow View of The Economy



Taken from a Power Point presentation prepared by Pam Perlich at the University of Utah.
<http://www.business.utah.edu/~bebrpsp/IO/IO.ppt>

The Structure of IO Analysis

- The ultimate goal of the Input-Output Analysis technique is to generate a *Total Requirements Table* that shows the flows of dollars between industries in the production of output for a given sector.
- To arrive at this final result, IO Analysis requires two earlier steps:
 - 1) *Transactions table*: Contains basic data on the flows of goods and services among suppliers and purchasers during a study year.
 - 2) *Direct requirements table*: Derived from the transactions table, this shows the inputs required directly from different suppliers by each intermediate purchaser for each unit of output that purchaser produces.
- “Input output analysis can be thought of as documenting and exploring the precise systems of interindustry exchange through which different components of regional product become different components of regional income.” (Bendavid-Val, p. 87-88)
- Let’s review Bendavid-Val’s “Islandia example”.

The Transaction Table and Direct Reqs Tables

The Transactions Table (in thousands of units)				
	Intermediate Purchasers		Final Purchasers	Total
	--Agriculture	--Manufacturing	--Households	Sales (outputs)
Intermediate Suppliers				
--Agriculture	10	30	60	100
--Manufacturing	5	10	35	50
Primary Suppliers				
--Households	85	10	15	110
Total Purchases (inputs)	100	50	110	260

Direct Requirements Table (in thousands of units)			
	Purchasers		
	--Agriculture	--Manufacturing	
Intermediate Suppliers			Every unit of output requires inputs of a certain amount from other areas of the economy.
--Agriculture	0.10	0.60	
--Manufacturing	0.05	0.20	
Primary Suppliers			
--Households	0.85	0.20	
Total Purchases (inputs)	1.00	1.00	

The First Round of Economic Impacts

Direct Requirements Table (in thousands of units)		
	Intermediate Purchasers	
	--Agriculture	--Manu
<i>Intermediate Suppliers</i>		
--Agriculture	0.10	0.60
--Manufacturing	0.05	0.20
<i>Primary Suppliers</i>		
--Households	0.85	0.20
Total Purchases (1.00	1.00

Total Requirements Calculation (First Round) (in thousands of units)

	Sales to Final Purch.	Sales as Direct Inputs		Total
		To Agr	To Manu	
By Agriculture	200	20	60	80
By Manufacturing	100	10	20	30
By Households	0	170	20	190
Total indirect rounds				
By All Suppliers	300			300

To
Rd. 2

The Second-Fourth Rounds of Econ. Impacts

Total Requirements Calculation (Second Round)
(in thousands of units)

	<i>Sales to</i>		<i>Sales as Direct Inputs</i>		<i>Total</i>
	<i>Final Purch.</i>	<i>To Agr</i>	<i>To Manu</i>		
By Agriculture	80	8.0	18.0	26.0	
By Manufacturing	30	4.0	6.0	10.0	
By Households	0	68.0	6.0	74.0	
Total indirect rounds				110.0	

Total Requirements Calculation (Third Round)
(in thousands of units)

	<i>Sales to</i>		<i>Sales as Direct inputs</i>		<i>Total</i>
	<i>Final Purch.</i>	<i>To Agr</i>	<i>To Manu</i>		
By Agriculture	26	2.6	6.0	8.6	
By Manufacturing	10	1.3	2.0	3.3	
By Households	0	22.1	2.0	24.1	
Total indirect rounds				36.0	

Total Requirements Calculation (Fourth Round)
(in thousands of units)

	<i>Sales to</i>		<i>Sales as Direct inputs</i>		<i>Total</i>
	<i>Final Purch.</i>	<i>To Agr</i>	<i>To Manu</i>		
By Agriculture	8.6	0.9	2.0	2.8	
By Manufacturing	3.3	0.4	0.7	1.1	
By Households	0	7.3	0.7	8.0	
Total indirect rounds				11.9	

and so on
until the mult.
effect ends

The Total Requirements Results

Total Direct and Indirect Requirements Calculation					
(in thousands of units)					
		<i>Sales to Final</i>	<i>Total</i>	<i>Total</i>	<i>Total</i>
		<i>Purchasers</i>	<i>Direct Sales</i>	<i>Indirect Sales</i>	<i>Sales</i>
	Agriculture	200.0	80.0	38.7	318.7
	Manufacturing	100.0	30.0	14.9	144.9
	Households	--	190.0	109.6	299.6
	Total	300.0	300.0	163.1	763.1

When:

- 1) there are “Final Sales” of Agriculture = 200 and “Final Sales” of Manufacturing = 100
- 2) we see a Total Economic Impact = 763.1, with that impact broken down as:
 - 1) 300.0 in *Initial Sales to Final Purchasers*
 - 2) 300.0 in *Total Direct Sales*
 - 3) 163.1 in *Total Indirect Sales*

The 300 units in Final Sales generate an additional 463.1 units of economic activity. This illustrates the multiplier effect captured by IO models.

The Total Requirements Table

Total Requirements Table			
		<i>Every Unit in Final Demand of...</i>	
<i>Requires Total Sales by</i>		<i>Agriculture</i>	<i>Manufacturing</i>
	Agriculture	1.15	0.86
	Manufacturing	0.07	1.29
	Households	1.00	1.00
	Total	2.22	3.15
	<i>For Agriculture</i>	1.00	Sales to Final Purchasers
		1.00	Sales by Primary Suppliers
		0.22	Interindustry transactions
	<u>Similar to our Base Multiplier in Econ Base Theory</u>		
	A 1.0 unit increase in demand for agriculture leads to a total of 2.22 of sales.		
	<i>For Manufacturing</i>	1.00	Sales to Final Purchasers
		1.00	Sales by Primary Suppliers
		1.15	Interindustry transactions
	<u>Similar to our Base Multiplier in Econ Base Theory</u>		
	A 1.0 unit increase in demand for manufacturing leads to a total of 3.15 of sales.		

RIMS Multipliers

- The Bureau of Economic Analysis (BEA) produces State Level Regional Input-Output Multipliers by industrial sector which are often used as the basis for constructing an IO model.
- Originally developed in the 1970s, RIMS (Regional Industrial Multiplier System) multipliers are used for “impact analysis” for a given economy.
- RIMS II data were developed in the 1980’s (latest version is 1998)
- Users can purchase data from BEA for \$275 per region. BEA provides handbooks for the use of this data.
- County or multi-county regional RIMS data come in two series
 - Series I: for 490 detailed industries
 - Series II: for 38 industry aggregations
- Empirical analysis shows that RIMS II data is accurate within 5% of locally developed industry multipliers.
- Advantages of the RIMS Multipliers:
 - 1) Cheap
 - 2) Can be compared across regions
 - 3) Detailed industries
 - 4) Updated regularly to reflect new data

Example RIMS Multipliers

**Table 2.4.—Total Multipliers for Output, Earnings, and Employment by Industry Age
Jackson County, MO**

	Final-demand multiplier		
	Output ¹ (Dollars)	Earnings ² (Dollars)	Employment ³ (Jobs)
	(1)	(2)	(3)
Farm and agricultural services, forestry, and fishing:			
Farm products and agricultural, forestry, and fishing services	1.7944	0.5693	57.6
Forestry and fishing products	1.4646	.2058	10.5
Mining:			
Coal mining	1.0000	0	0
Oil and gas extraction	1.4591	.1584	6.7
Metal mining and nonmetallic minerals, except fuels	1.5680	.3337	12.6
Construction:			
Construction	1.8723	.4528	21.4
Manufacturing:			
Food and kindred products and tobacco products	1.5222	.2060	8.5
Textile mill products	1.4834	.2795	16.6
Apparel and other textile products	1.4528	.2776	16.5
Paper and allied products	1.4647	.2763	10.7
Printing and publishing	1.6296	.3174	12.6
Chemicals and allied products and petroleum and coal products	1.6214	.2812	9.5
Rubber and miscellaneous plastics products and leather and leather products	1.5946	.3112	14.5
Lumber and wood products and furniture and fixtures	1.6863	.3702	17.6
Stone, clay, and glass products	1.7749	.3348	14.0
Primary metal industries	1.7600	.3125	11.7
Fabricated metal products	1.7173	.3722	14.1
Industrial machinery and equipment	1.7207	.3916	15.3
Electronic and other electric equipment	1.6214	.3334	13.9
Motor vehicles and equipment	1.6967	.3160	10.7
Other transportation equipment	1.5913	.3769	12.0
Instruments and related products	1.6120	.3556	12.8
Miscellaneous manufacturing industries	1.7072	.3744	20.2

¹Total dollar impact due to \$1 in output in the industry. ²Change in earnings due to \$1 change in industry. ³Change in employment resulting from \$1 million increase in output delivered to final demand.

For More Info on RIMS Multipliers

- The Bureau of Economic Analysis (BEA) has several web resources on RIMS Multipliers and how they are prepared:

RIMSII Home Page

<http://www.bea.doc.gov/bea/regional/rims/>

Brief Description of RIMS II

<http://www.bea.doc.gov/bea/regional/rims/brfdesc.cfm>

RIMSII User's Handbook

<http://www.bea.doc.gov/bea/ARTICLES/REGIONAL/PERSI/NC/Meth/rims2.pdf>

The Problems with IO Analysis

Practical Issues

- *Data needs and complexity*: IO models are *tremendously complex* and *very data hungry*. This typically places these models in the hands of experts.

Theoretical Issues

- *Time/Data issues*: Usually a single year's data are used to develop the Total Requirements Table. But 1) purchases may actually reflect a longer term investment and 2) short term trends may impact the data.
- *Stability of the technical coefficients over time*: Technology changes, prices change, and demand changes, all affecting the coefficients in the Tot Reqs Table. This can impact the results if the coefficients are "out of date".
- *IO assumes a linear relationship between increasing demand for inputs and outputs*: This assumes away 1) externalities and 2) increasing/decreasing returns to scale.
- *Industrial categorization*: IO models still assume that each industry 1) has a single, homogeneous production function and 2) each produces one product. These assumptions do not reflect the real economy very well.

The Power of IO Models

- Despite these problems IO analysis is a tremendously popular and powerful analytical tool.
- “The chief value of regional input-output analysis is in its descriptive analytical power.” (Bendavid-Val, p.113)
- “As a descriptive tool, input-output tables:
 - *present an enormous quantity of information in a concise, orderly, and easily understood fashion;*
 - *provide a comprehensive picture of the interindustry structure of the regional economy;*
 - *point up the strategic importance of various industries and sectors;*
 - *highlight possible opportunities for strengthening regional income and employment multiplication.”* (Bendavid-Val, p.113)
- Urban Planners should be capable of understanding the structure, assumptions, and data requirements of Input-Output Analysis. While you may not be performing this analysis in your jobs, you almost certainly will come across this type of work sometime in your career.

Bibliography

- ▣ Dietzenbacher, Erik and Michael L. Lahr, eds. *Wassily Leontief and Input-Output Economics*. Cambridge University Press, 2004.
- ▣ Isard, Walter et al. *Methods of Regional Analysis: An Introduction to Regional Science*. MIT Press 1960.
- ▣ Lahr, Michael L. and Erik Dietzenbacher, eds. *Input-Output Analysis: Frontiers and Extensions*. Palgrave, 2001.
- ▣ Leontief, Wassily W. *Input-Output Economics*. 2nd ed., New York: Oxford University Press, 1986.
- ▣ Miller, Ronald E. and Peter D. Blair. *Input-Output Analysis: Foundations and Extensions*. Prentice Hall, 1985.
- ▣ Miller, Ronald E., Karen R. Polenske, and Adam Z. Rose, eds. *Frontiers of Input-Output Analysis*. N.Y.: Oxford UP, 1989.[HB142 F76 1989/ Suzz]
- ▣ Miernyk, William H. *The Elements of Input-Output Analysis*, 1965.[\[5\]](#).
- ▣ Polenske, Karen. *Advances in Input-Output Analysis*. 1976.
- ▣ ten Raa, Thijs. *The Economics of Input-Output Analysis*. Cambridge University Press, 2005.
- ▣ US Department of Commerce, Bureau of Economic Analysis . *Regional multipliers: A user handbook for regional input-output modeling system (RIMS II)*. Third edition. Washington, D.C.: U.S. Government Printing Office. 1997.

The Leontief Open Production Model or Input-Output Analysis

Iris Jensen,
December 15, 2001

Abstract

Wassily Leontief won a Nobel Prize in Economics in 1973 for his explanation of the economy using his input-output model. There are two applications of the Leontief model: a closed model and an open model. A closed model deals only with the income of each industry whereas the open model finds the amount of production needed to satisfy an increase in demand. Example one will familiarize you with the terminology and what different vectors represent. Using the same vector names as in the example we run through the linear algebra. Then the technology matrix from 1992 will be used to analyze the interdependencies among the sectors. The most useful application of input-output analysis for the economist or a common broker is the ability to be able to see how the change in demand for one industry affects the entire economy. I will focus on showing that the same total increase of demand will have different effects on the Gross Domestic Product, when the demand is added to different industries.

Introduction

Ever wonder how the government can predict a deeper recession when the airline industry shrinks or why certain antiquated industries are subsidized by the government? Input-output analysis can be applied to any size economy from a business district to the entire world. It is most often used for city planning and analysis of our national economy. The Leontief Open Production Model provides us with a powerful economic analysis tool in the form of input-output analysis. Input-Output analysis the modern name for the process of manipulating a Leontief open production model. Before you can use this tool you must understand the linear algebra behind it. Gaining this basic understanding is the purpose of the simple example.

A Simple Example

The technology matrix A will describe the relations a sector has with all the other sectors. The technology matrix A will be a matrix such that each column vector represents a different industry and each corresponding row vector represents what that industry inputs as a commodity into the column industry.

The demand vector will be represented by D . The demand vector D is the amount of product the consumers will need. The total production vector X represents the total production that will be needed to satisfy the demand vector D . The total production vector X will be defined in this section.

Example 1. The technology matrix A below represents the relationships between the industries of Farming, Construction, and Clothing.

		Farming	Construction	Clothing
	Farming	.25	.24	.08
$A=$	Construction	.15	.05	.08
	Clothing	.10	.18	.04

... The Leontief Open Production Model or I-O Analysis

... A Simple Example

The relationships between the three industries in example one are as follows.

1. The entry a_{11} holds the number of units the farmer uses of his own product in producing one more unit of farming. The entry a_{21} holds the number of units the farmer needs of construction to produce one more unit of farming. The entry a_{31} holds the number of units the farmer needs of clothing to produce one more unit of farming.

2. The entry a_{12} holds the number of units that the builder needs from the farmer to produce one more unit of building. The entry a_{22} holds the number of units the builder needs of construction to produce one more unit of construction. The entry a_{32} holds the number of units the builder needs of clothing to produce one more unit of construction.

3. The entry a_{13} holds the number of units of farming that the tailor needs to produce one more unit of clothing. The entry a_{23} holds the number of units of construction that the tailor needs to produce one more unit of clothing. The entry a_{33} holds the number of units of clothing that the tailor needs to produce one more unit of his own product.

... The Leontief Open Production Model or I-O Analysis

... A Simple Example

		Farming	Construction	Clothing	
		Farming	25/100	15/110	10/120
A=	Construction	15/100	5/120	10/120	
		Clothing	10/100	20/110	5/120

In general each entry in the technology matrix is represented as

$$a_{ij} = x_{ij} / x_j ,$$

where x_j represents the physical output of sector j in our example the total production of an industry.

Finally x_{ij} represents the amount of the product of sector i the row industry needed as input to sector j the column industry.

... The Leontief Open Production Model or I-O Analysis

... A Simple Example

Example 1, let's suppose a technology matrix:

		Farming	Construction	Clothing
A=	Farming	.25(100)	.24(110)	.08(120)
	Construction	.15(100)	.05(110)	.08(120)
	Clothing	.10(100)	.18(110)	.04(120)

Suppose an external demand vector $A=$ $\begin{vmatrix} 50 \\ 79.9 \\ 85.4 \end{vmatrix}$

and a total production vector $X=$ $\begin{vmatrix} 100 \\ 110 \\ 120 \end{vmatrix}$

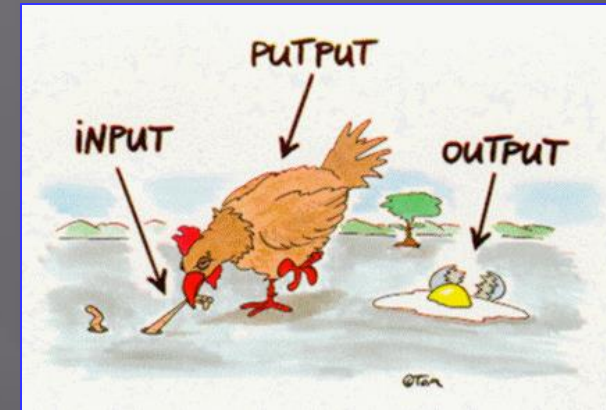
we will show that $D = X - AX$.

References

- [1] Leontief, Wassily. Input-Output Economics, Second Edition. Oxford University Press, 1986.
- [2] Arnold, David. His matlab and LATEX expertise.
- [3] U.S. Bureau of Economic Analysis. Benchmark Input-Output Accounts for the U.S.Economy. Ann M. Lawson
- [4] Strang, Gilbert. Introduction to Linear Algebra. Wellesley-Cambridge Press, 1998.
- [5] Smith, Karl J. Finite Mathematics Brooks-Cole, 1985.

Analysis of Interdependence Structures: Input-Output

<http://faculty.washington.edu/krumme/207/inputoutput.html>



Input-Output Literature:

- ▣ Baumol, William J. and E.N.Wolff, "A Key Role for Input-Output Analysis in Policy Design," *Regional Science and Urban Economics* 24, 1994, pp.93-113.
- ▣ Bourque, Philip. "The Washington Input-Output Study for 1982: A Summary of Findings," *Pacific Northwest Executive*, April 1987, pp.10-16.
- ▣ Carter, Anne P. and Peter A. Petri, "Leontief's Contributions to Economics," *Journal of Policy Modeling* 11 (Spring 1989), pp.7-30.
- ▣ Chase, Robert A., Philip J. Bourque and Richard S. Conway. [The 1987 Washington State Input-Output Study](#), 1993 ([pdf file](#)).
- ▣ Conway, Richard S., "The Stability of Regional Input-Output Multipliers," *Environment & Planning A*, vol.9, 1977, pp.197-214. [Use of Washington State coefficients for 1963, 1967 and 1972]

... Input-Output Literature:

- ▣ Foley, Duncan, "An Interview with Wassily Leontief," *Macroeconomic Dynamics* 2(1998), pp.116-40. (incl. Leontief Bibliography)
- ▣ Geoffrey J. D. Hewings and Rodney C. Jensen Regional, Interregional and Multiregional Input-Output Analysis, Handbook of Regional and Urban Economics Volume 1, Chapter 8 (Introduction, online) [<http://www.elsevier.nl/hes/books/07/01/contents/cnt0701.htm>]
- ▣ Hewings, Geoffrey. *Regional Input-Output Analysis*. Sage 1985 *Regional Input-Output Analysis*. [Geoffrey J D Hewings University of Illinois, Urbana-Champaign]. *Scientific Geography Series; Volume:7* Published 1986; 96 pages... [not listed anymore by Sage]
- ▣ Hoover, E.M., Introduction to Regional Economics, 3rd. ed., 1985 (OnLine) (Ch.11.3.2. "Regional Input-Output Analysis")
- ▣ P.R. Israilevich, R. Mahidhara, G.J.D. Hewings, The Choice of Input-Output Table Embedded in Regional Econometric Input-Output Models [CES 94-1 January 1994]
- ▣ Jackson, Randy. Regional Input-Output Modeling and Extensions. (a 5-credit course, Ohio State University)
- ▣ Landefeld, Steven J. and Staphanie H. McCulla, "Wassily Leontief and His Contributions to Aconomic Accounting," Survey of Current Business, March 1999, pp.9-11. [PDF: www.bea.doc.gov/bea/ARTICLES/NATIONAL/Inputout/1999/0399leon.pdf]

Simulation

Prof. Dave Goldsman

<http://www2.isye.gatech.edu/~sman/courses/Mexico2010/>

[Module 1 - Tentative Schedule](#)

[Module 1 - Whirlwind Tour](#)

[Module 1 - Mini-Demo Software](#)

[Module 1 - Mini-Demo Software Add-on](#)

[Module 2 - Prob/Stats Review](#)

[Module 2 - Link to Prob/Stats ISyE 6739](#)

[Module 3 - Hand Simulations](#)

[Module 4 - General Principles](#)

[Module 4 - General Principles, II](#)

[Module 5 - Intro to Arena](#)

[Module 5 - Arena Chapter 3 slides](#)

[Module 5 - Arena Baby Q'ing Example 3-1](#)

[Module 5 - Arena Chapter 4 slides](#)

[Module 5 - Arena Shopping Example](#)

[Module 5 - Arena Part Arrivals Example 4-1](#)

[Module 5 - Arena Call Center slides \(KSS'01\)](#)

[Module 5 - Arena Call Center Example 5-2](#)

[Module 5 - Arena Inventory Example 5-4 \(Christos Alexopoulos\)](#)

[Module 5 - Arena Manufacturing Center slides \(KSS'03\)](#)

[Module 5 - Arena Manufacturing Example 7-1 \(with Routes\)](#)

[Module 5 - Arena Manufacturing Example 8-1 \(with Resource-Constrained Transfers\)](#)

[Module 5 - Arena Manufacturing Example 8-2 \(with Transporters\)](#)

[Module 5 - Arena Manufacturing Example 8-4 \(with Conveyors\)](#)

[Module 5 - Arena Batch/Separate Example](#)

[Module 6 - Unif\(0,1\) Generation](#)

[Module 7 - Random Variate Generation](#)

[Module 8 - Input Analysis](#)

[Module 9 - Output Analysis](#)

[Module 10 - Advanced Output Analysis](#)

[Module 11 - Ranking and Selection](#)

III Spanish Conference on

INput **OUT**put
Analysis

**STRUCTURAL CHANGE AND
SUSTAINABLE DEVELOPMENT**

Albacete, 30th Sept. – 2nd Oct. 2009

**Input Data Analysis:
Specifying Model
Parameters &
Distributions**

Christos Alexopoulos
David Goldsman
School of Industrial &
Systems Engineering
Georgia Tech

**Simulation
Output
Analysis**

Dave Goldsman
School of ISyE, Georgia Tech,
Atlanta, Georgia, USA
May 26, 2010

TNMM01, **Introduction to Simulation** (6 hp)

- <http://webstaff.itn.liu.se/~krist/TNMM01/>

- **Welcome**
- *Welcome to course "Introduction to Simulation" TNMM01 (previously TDMM42).
First lecture in the course takes place on Wednesday, January 16th, 10-12 in room R35.
On these pages you will find the information about the course and it will be updated as course proceeds. Contact me if you have any questions regarding the course.*

- *Krisjanis Steins (krist@itn.liu.se)*