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A Study on Application of Input–Output Analysis in the Indian Food Processing Industry

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Abstract

This paper determines the links from Agriculture, forestry and fishing industry to Food and Beverages industry by the help of structural relationships associated in input-output tables. The paper develops a methodology to modify the magnitude of economic fluctuations and trace their downstream effects throughout the entire value chain. This section categories the fundamental principles of input-output analysis and gives its practical application through a simplified inter-industry transaction model, using data sourced from the Library with ADB Data, India: Input-Output economic indicators (Tables)-2020. The analysis infers that input-output frameworks streamline cost management; by requiring a precise definition of each sector's value-added function, they allow for more rigorous oversight of production inputs.

Keywords: *Input-Output Analysis, Agriculture, Food & Beverages Industry, Economic Fluctuations, Value Chain.*

MSC: *91B02, 91B74, 15A15, 90B30.*

1. Introduction

Input-output analysis demonstrates as a quantitative framework for mapping inter-industry transactions inside a financial system. Beyond its traditional utility in calculating sectoral value-adding capabilities, the model is increasingly applicable to environmental which refers to evaluate the ecological consequences of industrial development. In 1936, Wassily Leontief applied earlier Physiocratic and Soviet fundamentals to create input-output analysis, a tool for mapping how demand in one sector fulfils production in others. The model depends on 'Leontief technologies,' where input ratios remain constant in spite of price changes. This fixed-ratio approach allows for easy approximation but can be less realistic than more complex frameworks like the von Neumann model, which makes for various production techniques but requires far more data to implement.

1.1 Agriculture, forestry, and fishing Industry

1.1.1 Agriculture

Agriculture is the prime source upon which Half of Indians still depends on. Throughout the twentieth century, which has a new scenario. The agricultural area, has been improved and is significant that more than half of the country's total area, a part controlled by few other countries in the world. In the regions where it is fertile, like the eastern coast's deltas or the Indo Gangetic Plain, the proportion of cultivated to total land usually it is more than nine-tenths.

1.1.2 Forestry

Commercial forestry is not significantly developed in India. It is the tragic fact that the annual cut down of hard woods is among the highest number of countries in the world. Teak, deodar, sal, sissoo, and chir pine are included in the Species which are the different sources of timber, matchwood, veneers, plywoods and pulp. For firewood, large part of it go into making charcoal. Bamboo, cane, dyes, tanning agents, gum, resins, lac, and medicinal plants are included under minor forest products.

1.1.3 Fishing

Production from freshwater fisheries and marine are equal. Total catches are very few, and annual per capita fish consumption is less as very less fishing crafts are mechanized. It has been inexorable for the shift to modern processing and mechanization. A very little craft of fishing families, in coastal region, are very difficult to reach as a progressively massive part of the catch now comes from fishing grounds.

1.2 Indian Food and Beverage Industry

The Industry regarding Food and as well as Beverage from India, is also now in the process of developing as a high-profit sector, which shows of India's Gross Domestic Product for about 3 % and it constitutes around $2/3^{rd}$ of the total retail market also in India. Really for the session 2020-2024, the revenue within the beverage and food business sector is also calculated to perform a CAGR growth rate of around 14.2 %. The projected volume of market is USD 1,264 million by 2024. There are various aspects that are driving this growth as if very fast growth of urbanization, food habits of the surging generation, which changes the lifestyle and also increases family consumption rate, etc.

1.2.1 Tea Sector

In India the tea market is around Rs. 26,000 Crores. There is huge customer demand for the milk tea which is boiled and also very tasty, but in sub-category black tea is included. It is hopefully to be 3% of the branded category for Green tea, that grows at the rate of 12.5%. It is a strong trend for health & wellness to continue. Now-a-days consumers get benefits from the cup of chai (such as Tulsi and Ayurveda Tea).

1.2.2 Coffee Sector

In 2019 the retail coffee market which is branded in India, and is calculated at Rs. 2,750 Crores. Industry proving the emergence of artisanal and gourmet premium coffees – calculated to be 5% of the traditional organized market. The sector sees various behaviours of consumer in the South India and segments in terms of at-home consumption in rest part of India. During winter it is essential to take coffee and there is high demand for coffee, especially in the rest of India. Otherwise, we consume on regular basis of both roasted, instant and Ground (filter coffee) in the South.

1.2.3 Salt Sector

It is now estimated to be Rs. 7,000 Crores for Indian salt market. It has players who are unorganized, forms 12% of the category. For providing better quality of product, for branded play the growth drivers remain the increasing awareness, which is visible purity and iodine content.

1.2.4 Pulses Sector

In India pulses are produced in huge quantity, also consumed and imported. In FY 2018-19, the overall Derivatives industry and pulses are estimated to be Rs. 1,50,000 Crores, which has branded item only 1% of the segment. It is primarily dominated by a host of factors. It includes value addition which are low perceived by players who are packaged in nature (leading to consumers unwilling to pay price premium). It is considered in case of low penetration and regarding adulteration in unbranded. It took place for the concern of low consumer.

1.2.5 Spices Sector

In India spices are produced in large extent in the world, consumed and also exported, which is approximately about half of spice trade in case global. The worth of total Spices industry is Rs. 60,000 Crores. In FY 2018-19 branded Spices industry is approximated to be Rs. 18,000 Crores. It is also fragmented with the presence of many regional players. However, branded products are demanded in large quantities. So, better quality products are required for consumers in pure/ straight spices (with best quality of raw materials which is being used). It increases the adoptability of blended spices in the kitchen (here taste is consistent with higher convenience).

2. Practical application of Input-Output model

It is essential to maintain a gold standard in input-output (I-O) model for regional analysis due to its unique flexibility in measuring economic multipliers and environmental impacts. According to Rose, the lasting relevance stems of model from its empirical foundation and its ability to bridge the gap between technical engineering and economic policy. Key advantages are its structural layout, neutrality across different political systems, and its "total accounting" approach. Other advantages are intermediate, good and service in production.

3. Literature Review

Miernyk (1965, 2020) analysed the Elements of Input-Output Analysis. Gordon (2022) explained the Input-Output Analysis. Kenton (2021) experimented Input-Output Analysis. Stilwell et al. (2000) analysed input-output analysis and its potential application to the mining industry. Similarly, Zuhdi (2015) studied an application of input-output analysis in analyzing the impacts of final demands changes on the total outputs of Japanese energy sectors.

Wu et al. (2011) analyzed inflationary effect of oil-price shocks in an imperfect market. Manasse et al. (2020) demonstrated various methods to tackle lockdown through an economy, which is an input output analysis of the Italian case. Duchin (1992) was arguing that industrial input-output analysis: implications for industrial ecology. Boylan (2020), applied by using input-output analysis to measure healthy sustainable food systems. Different authors like Lefèvre (2023), Malik et al (2023), Tennakoon(2024), Mardones et al. (2025), Tsirimokos(2025), Zhao et al. (2025), Miller et al.(2025), and Dutta(2025) have analysed different input–output models.

It is a well-known strategy that Input-output tables show some optimistic approach. It shows how outputs and outputs are managed among the different sector of the economy. The fundamental Leontief input-output model establishes a square matrix system which shows industrial sectors in identical order through its leftmost column and top row. The design allows for complete economic accounting through its goods and services mapping system which shows economic activity across all sectors. The framework operates through its rows which serve as linear equations to explain how different sectors distribute their production according to the coefficients and variables that Rose and Miernyk established for each participating industrial sector. The rows function as separate linear equations which connect specific coefficients with variables that correspond to each industrial sector analysed in the study (Rose and Miernyk). i.e.,

$$X_i = X_{i1} + X_{i2} + \cdots + X_{in} + Y_i \; (i = 1,2,\ldots,n) \ldots\ldots \quad [1]$$

Where the variable X_i serves to denote the total gross output generated by sector i which represents the complete value of all output produced by that specific sector. The variable Y_i represents the autonomous final demand for the products of sector i , accounting for the portion of output consumed by end-users rather than being repurposed for further industrial production. The definition of the variable Xij would be an indication of the amount of sales from the sector i to every capitalist-paid sector j.

Input-Output models use different transaction tables to show how much labour needs to be applied for every rupee spent on industrial production or capital investment.

4. Mathematical Model

Assume a basic economic framework comprising two primary industries, A_1 and A_2, each characterized by a single-product output. In this model, we account for internal consumption, where each sector utilizes a portion of its own or the other's production as an intermediate input of its own output. It is also necessary for rest of the product from the other industry for its smoothest way of operation.

Hence, it is considered that industries are interdependent. Further suppose that it is necessary to consume whatever is produced for optimization resources. There must not be any extra resource which remains unused.

Our objective is to calculate the output levels of both industries in order to find a difference in final objective, which is based on knowledge of the given outputs of the both industries, of course under the assumption that the structure of the economy remains unchanged.

Table I

A transaction table (simplified form)

	Intermediate demand	**Final demand**	**Total output**
Intermediate inputs Value adding Primary inputs, Imports and **GDP components** Total input	Quadrant I: Intermediate production and Consumption Quadrant III: Primary inputs to Production	Quadrant II: Final output of Production sectors Quadrant IV: Primary inputs to Final demand	Sum of; Intermediate input and Final demand

Let's consider that a_{ij} be the rupee value of the output of A_i consumed by A_j, $i, j = 1,2$.

Suppose that x_1 and x_2 be the rupee value of the current outputs of A_1 and A_2 respectively.

For the outputs of A_1 and A_2, suppose d_1 and d_2 be the rupee value of the final demands respectively.

Let's formulate the following two equations by using above assumptions:

$$a_{11} + a_{12} + d_1 = x_1; \qquad a_{21} + a_{22} + d_2 = x_2 \qquad \cdots (1)$$

Let $b_{ij} = \frac{a_{ij}}{x_j}, i, j = 1,2$

$$b_{11} = \frac{a_{11}}{x_1}; b_{12} = \frac{a_{12}}{x_2}; b_{21} = \frac{a_{21}}{x_1}; b_{22} = \frac{a_{22}}{x_2}$$

The following form of equations (1) can be written in:

$$b_{11}x_1 + b_{12}x_2 + d_1 = x_1; b_{21}x_1 + b_{22}x_2 + d_2 = x_2$$

The following form of above equations can be rearranged as:

$$(1 - b_{11})x_1 - b_{12}x_2 = d_1 \text{and} - b_{21}x_1 + (1 - b_{22})x_2 = d_2$$

The matrix form of the above equation will be:

$$\begin{pmatrix} 1 - b_{11} & -b_{12} \\ -b_{21} & 1 - b_{22} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}$$

$$\left[\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} - \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}\right] \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}$$

$$(I-B)X=D$$

Where,

$$B=\begin{pmatrix}b_{11} & b_{12}\\ b_{21} & b_{22}\end{pmatrix};I=\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix};X=\begin{pmatrix}x_1\\ x_2\end{pmatrix};D=\begin{pmatrix}d_1\\ d_2\end{pmatrix}.$$

We get on solving: $X=(I-B)^{-1}D$

It is called the **technology matrix** for matrix B.

4.1 The Hawkins-Simon conditions

The viability of the system is ensured by Hawkins – Simon conditions. Following two conditions are mentioned by Hawkins – Simon where B is the technology matrix:

i. The elements in main diagonal in $I - B$ must be positive and

ii. The determinant value, $|I - B|$ must be a positive value.

For example- The Hawkins-Simon conditions together with the internal technology matrix provide us with the necessary tools to evaluate this economy's economic performance. The system is considered viable if the industries do not consume more than they produce which we verify through positive results from Leontief matrix determinant calculations that use input requirements. The matrix determined that its determinant value of 0.17. Since this value is positive and the diagonal elements (0.6 and 0.4) are also positive, the system is fully capable of meeting external demand while sustaining its own internal production needs. The economy needs to produce gross output which exceeds 50 tons of steel and 100 tons of coal because the two sectors "trade" materials between each other. The matrix equation $X=(I-A)^{-1}D$ shows that the gross output which needs to be produced amounts to 176.47 tons of steel and 558.82 tons of coal. The labor intensities calculation shows that steel requires 5 days per ton while coal needs 2 days per ton which results in a workforce requirement of 2,000 labor days. The industries function efficiently because their "circular" operation allows them to produce the required market surplus through two thousand days of human work after they supply each other all essential raw materials.

Solution

Here the technology matrix is given under:

	Steel	**Coal**	**Final demand**
Steel	0.4	0.1	50
Coal	0.7	0.6	100
Labour days	5	2	–

The technology matrix is

$$B=\begin{bmatrix}0.4 & 0.1\\ 0.7 & 0.6\end{bmatrix}$$

$$I - B = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} 0.4 & 0.1 \\ 0.7 & 0.6 \end{bmatrix} = \begin{bmatrix} 0.6 & -0.1 \\ -0.7 & 0.4 \end{bmatrix}$$

$$|\ I - B\ | = \begin{vmatrix} 0.6 & -0.1 \\ -0.7 & 0.4 \end{vmatrix}$$

$$= (0.6)(0.4) - (-0.7)(-0.1)$$

$$= 0.24 - 0.07 = 0.17$$

Since the diagonal elements of $I - B$ are positive and the value of $|\ I - B\ |$ is positive, the system is viable.

$$\text{adj}(I - B) = \begin{bmatrix} 0.4 & 0.1 \\ 0.7 & 0.6 \end{bmatrix}$$

$$(I - B)^{-1} = \frac{1}{|\ I - B\ |}\text{adj}(I - B)$$

$$= \frac{1}{0.17}\begin{bmatrix} 0.4 & 0.1 \\ 0.7 & 0.6 \end{bmatrix}$$

$$X = (I - B)^{-1}D, \quad \text{where } D = \begin{bmatrix} 50 \\ 100 \end{bmatrix}$$

$$= \frac{1}{0.17}\begin{bmatrix} 0.4 & 0.1 \\ 0.7 & 0.6 \end{bmatrix}\begin{bmatrix} 50 \\ 100 \end{bmatrix}$$

$$= \frac{1}{0.17}\begin{bmatrix} 30 \\ 95 \end{bmatrix}$$

$$= \begin{bmatrix} 176.5 \\ 558.8 \end{bmatrix}$$

Output of Coal =558.8 tonnes

Output of Steel =176.5 tonnes

Days required for total labour = 2(Output of Coal) + 5(Output of Steel)

=2(558.8) + 5(176.5)

=1117.6 + 882.5 =2000.1

≅ 2000 labour days.

5. Application of IO-analysis to Indian food processing industry

Industry	**Agriculture, Forestry and Fishing**	**Food and Beverages**	**Total Output**
Agriculture, Forestry and Fishing	78,768	93,409	602,024
Food and Beverages	3,660	29,778	235,093

Table 2: India Input-Output Table, 2020

(At current prices, $ million)

A simple transaction table for Indian Food Processing Industry, using illustrative values is shown in Table2. This states that the Agriculture, Forestry and Fishing industry requires an input of its own goods and services with a value of 78,768$.The other section i.e. Food and Beverages industry requires inputs of the Agriculture, Forestry and

Fishing industry with value of 93,409$.The total intermediate output of Agriculture, Forestry and Fishing industry was therefore 602,024$. Likewise, Food and Beverages industry supplied goods and services of value 3,660$ to Agriculture, Forestry and Fishing industry and requires 29,778$ of its own goods and services. Its total intermediate output was therefore 235,093$.

$$a_{11} = 78768,\ \ a_{12} = 93409,\ \ x_1 = 602024$$
$$a_{21} = 3360,\ \ \ a_{22} = 29778,\ \ x_2 = 235093$$
$$b_{11} = \frac{a_{11}}{x_1} = \frac{78768}{602024} = 0.138$$
$$b_{12} = \frac{a_{12}}{x_2} = \frac{93409}{235093} = 0.397$$
$$b_{21} = \frac{a_{21}}{x_1} = \frac{3660}{602024} = 0.006$$
$$b_{22} = \frac{a_{22}}{x_2} = \frac{29778}{235093} = 0.126$$

Therefore, the technology matrix is

$$B = \begin{bmatrix} 0.138 & 0.397 \\ 0.006 & 0.126 \end{bmatrix}$$
$$I - B = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} 0.138 & 0.397 \\ 0.006 & 0.126 \end{bmatrix} = \begin{bmatrix} 0.862 & -0.397 \\ -0.006 & 0.874 \end{bmatrix},$$

Elements of main diagonal are positive.

$$|\ I - B\ | = \begin{vmatrix} 0.862 & -0.397 \\ -0.006 & 0.874 \end{vmatrix}$$
$$= (0.862 \times 0.874) - (-0.006 \times -0.397)$$
$$= 0.753 - 0.002382$$
$$= 0.751 > 0$$

Confirmation of compliance of the Hawkins-Simon conditions can be based on the two main factors. The first one is the fact that, if $|I - B|$ is block negative definite, both diagonal elements of $|I - B|$ are positive.

Now, these parameters serve to guarantee that the mathematical model achieves a valid and sustaining solution.

$$\operatorname{adj}(I - B) = \begin{bmatrix} 0.874 & 0.397 \\ 0.006 & 0.862 \end{bmatrix}$$
$$(I - B)^{-1} = \frac{1}{|I - B|} \operatorname{adj}(I - B)$$
$$= \frac{1}{0.751} \begin{bmatrix} 0.874 & 0.397 \\ 0.006 & 0.862 \end{bmatrix} = \begin{bmatrix} 1.164 & 0.529 \\ 0.008 & 1.148 \end{bmatrix}$$
$$X = (I - B)^{-1} D, \qquad \text{where } D = \begin{bmatrix} 425612.767 \\ 2018959.138 \end{bmatrix}$$
$$= \begin{bmatrix} 1.164 & 0.529 \\ 0.008 & 1.148 \end{bmatrix} \begin{bmatrix} 425612.767 \\ 2018959.138 \end{bmatrix}$$
$$= \begin{bmatrix} (1.164)(425612.767) + (0.529)(2018959.138) \\ (0.008)(425612.767) + (1.148)(2018959.138) \end{bmatrix}$$
$$= \begin{bmatrix} 1563122.365 \\ 2319140.345 \end{bmatrix}$$

Therefore, the output of Agriculture, forestry and fishing industry should be 1,563,122$ and output of Food and Beverages industry should be 2,319,140$.

6. Analysis and finding

6.1 Three types of economic impact

Input-Output models enable complete economic dependency analysis through their ability to classify stimulus results into three distinct impact categories which include direct effects and indirect effects and induced effects. The framework demonstrates how the multiplier effect operates by tracing its path from initial direct sector spending through supply chain indirect demand creation to the resulting household consumption increase which causes tertiary induced economic effects. Economists use ripple effect mapping to predict how a single industry input change will spread across multiple industrial sectors and result in widespread economic output changes throughout the entire economy.

- The first stage of an economic shock starts with its immediate effects which show up as decreased spending in particular industries. The initial stage of the project requires direct project expenses which include all essential costs needed to start the work. The first "drop" in the pond creates economic ripple effects which will continue to spread throughout the economy.
- These external impacts are further enhanced by stakeholders' interferences over the project.
- The tertiary impact which is also called the induced impact happens when supply chain workers spend their earnings within the economy by purchasing different products and services. The consumption cycle functions as the final step of the ripple effect while researchers can use the complete analytical framework to discover which input changes caused an observed total economic output variation.

6.2 LIMITATIONS AND SCOPE

6.2.1 LIMITATIONS

- ➢ The framework rests on Leontief's belief that technical coefficients remain static throughout his model. The assumption of constant returns to scale operates correctly in stationary economic environments but fails to capture actual economic fluctuations.
- ➢ Research methods face these scientific assumptions which limit their ability to deliver accurate real-world results. The model cannot handle non-linear phenomena including supply chain bottlenecks and rising marginal costs because dynamic inter-industry variables remain absent from its design.
- ➢ The IOA model operates through its narrow scope which restricts its analysis to macroeconomic production processes. The model explains particular input-output patterns through its explanation of macroeconomic driving forces.

- Researchers consider transaction value studies that combine multiple years of data to be their most significant research assessment.
- Real-time commodity flow data integrates with digital tracking systems to reduce temporal delays which now achieve better accuracy.
- The model's primary vulnerability changed from its theoretical foundation to its operational infrastructure; the system depends on accurate data to create the transaction matrix which determines its operational performance.

6.2.2 SCOPE

- The research improves current methods while solving some fundamental problems. However, researchers still have multiple possibilities to keep studying this subject.
- Through their resource-intensive sector analysis organizations achieve better cost efficiency while directing their financial resources towards the most beneficial industries.
- Input-Output analysis provides stable framework which enables economic modeling to achieve high reliability while maintaining low risk of system failure.
- The methodology has achieved worldwide recognition as a standardized tool which enables complete economic evaluation. The massive volume of worldwide commodity shipments exceeds human capacity to manage them. Input-Output analysis creates an organized system which enables monitoring and control of complicated industrial relationships.

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