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The Anatomy of India's Industrial Interdependencies: 7-Digit Product-Level Supply-Use and Input-Output Tables from ASI Data (2016-2022) with a Case Study of the Mobile Phone Sector

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Abstract: This paper outlines the construction of high-resolution, 7-digit product-level Supply-Use Tables (SUTs) and symmetric Input-Output Tables (IOTs) for the Indian economy, leveraging microdata from the Annual Survey of Industries (ASI) for the period 2016-2022. We delineate a robust methodology encompassing the generation of detailed input and output flows, with a particular focus on the reconciliation of data from registered and unregistered manufacturing sectors through a meticulously developed NPCMS-NIC concordance. The critical transformation from the often-rectangular SUTs to square, symmetric product-by-product IOTs is explicated using the Industry Technology Assumption, a choice justified by its suitability for handling by-products prevalent in a diverse manufacturing landscape. The analytical prowess of this newly constructed high-resolution IOT framework is then demonstrated through its application to assess key economic impacts, specifically the Domestic Value Added (DVA) generated and the employment supported by production and export activities. A detailed case study of India's rapidly evolving mobile phone manufacturing sector (NPCMS 4722200) for the 2016-2022 period reveals profound structural shifts: significant output growth coupled with notable import substitution, a remarkable surge in exports, and a dynamic evolution in the DVA versus Foreign Value Added (FVA) shares, particularly in export-oriented production. The analysis further uncovers substantial employment growth, albeit with an increasing reliance on contractual labour and a heartening rise in female participation in the workforce. These meticulously constructed tables represent a significant methodological advancement and provide an invaluable empirical resource for nuanced analysis of sectoral interdependencies, the efficacy of industrial policy, and the complex dynamics of India's engagement with global value chains.

Keywords: Supply-Use Tables (SUTs); input-output analysis; annual survey of industries (ASI); manufacturing sector; domestic value added (DVA); Employment linkages; backward linkages; mobile phone industry; national product classification for manufacturing sector (NPCMS); India KLEMS; industry technology assumption

JEL Classification: F14, F63, L63, O14, O25, C67, J21

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1. Introduction

The architecture of modern economies is characterized by intricate networks of inter-industry linkages, where the output of one sector serves as an input for another, culminating in the production of goods and services for final demand. Understanding this complex web is paramount for effective economic analysis and evidence-based policymaking. The System of National Accounts (SNA), particularly the forthcoming SNA 2025, underscores the centrality of Supply-Use Tables (SUTs) and Input-Output Tables (IOTs) (Chapters 15 & 36, respectively) in this endeavor. In an era defined by the pervasive influence of global value chains (GVCs), rapid digitalization, and the pressing challenges of climate change, these tables have become indispensable tools. They offer a coherent and comprehensive

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framework for tracking inter-sectoral flows, measuring value addition at various production stages, and analyzing the ripple effects of economic policies or external shocks throughout the economy.

The practical compilation of input-output statistics necessitates careful consideration of the desired properties and compilation methods of symmetric IOTs even while working on the SUTs. As Eurostat (2008) emphasizes, appropriate choices in the grouping and structure of SUTs can facilitate the construction of a robust database that seamlessly transforms into symmetric IOTs with minimal data manipulation. Thage and Ten Raa (2007) recommend a structured three-step approach: first, the meticulous compilation of SUTs, defining industries and activities; second, the preparation of this data for analytical use, which involves making informed assumptions to derive symmetric tables; and third, the calculation of standard analytical results like multipliers and impact analyses. Indeed, the direct application of SUTs in economic analysis has witnessed a significant surge, propelled by computational advancements and the increasing availability of microdata.

This paper makes a significant contribution to the Indian context by constructing highly granular, 7-digit product-level SUTs and symmetric product-by-product IOTs for the period 2016-2022. This level of disaggregation, derived from the rich microdata of the Annual Survey of Industries (ASI), offers an unprecedented depth of detail compared to previously available tables for India. Such granularity is crucial for understanding the nuances of a diverse and evolving economy like India's, particularly its dynamic manufacturing sector.

Our primary focus is threefold:

1. To present a transparent and replicable methodology for the construction of these high-resolution SUTs and IOTs, detailing the process of generating input and output flows, and the critical step of reconciling data from various sources and classification systems (NPCMS and NIC).
2. To elucidate the mathematical transformation from SUTs to symmetric IOTs, employing the Industry Technology Assumption, a choice we argue is particularly pertinent for economies with significant by-production.
3. To demonstrate the analytical utility of this framework by applying it to estimate Domestic Value Added (DVA), Foreign Value Added (FVA), and employment linkages (both direct and indirect) supported by production and exports. This is vividly illustrated through an in-depth case study of India's mobile phone manufacturing sector, a sector of immense strategic importance under current industrial policy initiatives.

The remainder of this paper is structured as follows: Section 2 briefly touches upon the foundational literature. Section 3 delves into the intricate methodology of compiling the SUTs, including the generation of input and output flow matrices. Section 4 explains the transformation process from SUTs to symmetric IOTs using the Industry Technology Assumption and the derivation of the Leontief inverse. Section 5 details the framework for estimating DVA, FVA, and employment linkages. Section 6 presents the empirical findings from our case study of India's mobile phone manufacturing sector, analyzing trends in output, trade, value addition, and employment. Section 7 concludes with a summary of findings, policy implications, limitations, and avenues for future research.

2. Foundational Concepts in Input-Output Analysis

The input-output framework, pioneered by Wassily Leontief (1936), provides a powerful quantitative lens to examine the structural interdependencies within an economy. Leontief's seminal work laid the groundwork for understanding how industries are linked through their purchases and sales of goods and services. This framework has since been expanded and refined by numerous scholars, particularly in the context of analyzing international trade and global value chains (GVCs).

Key contributions include the work of Hummels, Ishii, and Yi (2001), who explored the nature and growth of vertical specialization in world trade. Koopman, Wang, and Wei (2014) developed methodologies for tracing value-added in gross exports and addressing the issue of double counting, which is critical for understanding a country's true contribution in GVCs. Timmer et al. (2014) provided insights into the "slicing up" of global value chains, highlighting how production processes

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are increasingly fragmented across countries. Los, Timmer, and de Vries (2015) applied demand-side analysis using IOTs to assess the importance of exports for job growth in China. More recently, Borin and Mancini (2019) have focused on measuring what truly matters in GVCs and value-added trade.

In the Indian context, studies by Veeramani and Dhir (2022) and Veeramani et al. (2023) have been instrumental in developing and applying methodologies based on IOTs to estimate domestic value addition and employment supported by exports. Their work provides a valuable precedent for the analytical applications undertaken in this paper. This paper builds upon these foundational concepts and methodologies, aiming to provide an even more disaggregated and up-to-date understanding of India's economic structure through the construction of 7-digit product-level IOTs.

3. Methodology Part 1: Compilation of Supply and Use Tables

The compilation of SUTs forms the empirical backbone of the IOTs. SUTs provide a detailed matrix recording how supplies of various goods and services, originating from domestic production and imports, are allocated to different uses, including intermediate consumption by industries and final uses.

3.1. Definitions and Structure

3.1.1. The Supply Table

The Supply Table offers a comprehensive view of the total supply of goods and services available in an economy within a specific accounting period. It delineates this supply by type of product and by the industry producing it, crucially distinguishing between goods and services supplied by domestic industries and those imported from abroad. In essence, it captures the output (by product) generated by various domestic economic activities and the imports (by product) sourced internationally.

A simplified structure of the Supply Table, as often presented in national accounting manuals (e.g., Eurostat, 2008; UN Handbook, 2018), is illustrated below. Conceptually, it is a matrix where rows typically represent products and columns represent industries for domestic output, with an additional column for imports.

Table 1. Conceptual Structure of the Supply Table

Products	Industry 1 (e.g., Agri.)	Industry 2 (e.g., Mining)	...	Industry n (e.g., Services)	Imports by Product	Total Supply by Product
Product A (e.g., Agri. good)	Output of A by Industry 1	Output of A by Industry 2	...	Output of A by Industry n	Imports of A	Total Supply of A
Product B (e.g., Mineral)	Output of B by Industry 1	Output of B by Industry 2	...	Output of B by Industry n	Imports of B	Total Supply of B
...	...	...	...	...	...	...
Product Z (e.g., Service)	Output of Z by Industry 1	Output of Z by Industry 2	...	Output of Z by Industry n	Imports of Z	Total Supply of Z
Total Output by Industry	**Total Output of Industry 1**	**Total Output of Industry 2**	**...**	**Total Output of Industry n**	**Total Imports**	**Grand Total Supply**

Source: Adapted from national accounting manual concepts.

The totals in the last column represent the total supply available for each product, while the totals in the bottom row show the total output generated by each domestic economic activity and the aggregate value of imports.

3.1.2. The Use Table

Complementing the Supply Table, the Use Table provides a detailed account of how these available goods and services are utilized within the economy. It shows the use of products broken down by:

- **Intermediate consumption by industry:** This details how much of each product is consumed by various industries in their production processes.
- **Final uses:** This captures the demand for products for:

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- Final consumption (by households, government, and non-profit institutions serving households).
- Gross Capital Formation (investment in fixed assets and changes in inventories).
- Exports (products sold to the rest of the world).

Furthermore, the Use Table delineates the components of Gross Value Added (GVA) by industry. These components typically include compensation of employees, other taxes less subsidies on production, consumption of fixed capital, and net operating surplus.

The conceptual structure is a matrix where rows represent products and columns represent industries (for intermediate consumption) and final demand categories.

Table 2. Conceptual Structure of the Use Table

Products/GVA Components	Industry 1 (e.g., Agri.)	Industry 2 (e.g., Mining)	...	Industry n (e.g., Services)	Final Consumption	Gross Capital Formation	Exports	Total Use by Product
Intermediate Consumption								
Product A (e.g., Agri. good)	Use of A by Industry 1	Use of A by Industry 2	...	Use of A by Industry n	Final Cons. of A	GCF of A	Exp. of A	Total Use of A
Product B (e.g., Mineral)	Use of B by Industry 1	Use of B by Industry 2	...	Use of B by Industry n	Final Cons. of B	GCF of B	Exp. of B	Total Use of B
...	...	...	...	...	...	...	...	...
Product Z (e.g., Service)	Use of Z by Industry 1	Use of Z by Industry 2	...	Use of Z by Industry n	Final Cons. of Z	GCF of Z	Exp. of Z	Total Use of Z
Value Added								
Comp. of Employees	GVA Comp. in Industry 1	GVA Comp. in Industry 2	...	GVA Comp. in Industry n				Total GVA Comp.
Other Taxes less Subsidies	GVA Comp. in Industry 1	GVA Comp. in Industry 2	...	GVA Comp. in Industry n				Total GVA Comp.
Cons. of Fixed Capital	GVA Comp. in Industry 1	GVA Comp. in Industry 2	...	GVA Comp. in Industry n				Total GVA Comp.
Net Operating Surplus	GVA Comp. in Industry 1	GVA Comp. in Industry 2	...	GVA Comp. in Industry n				Total GVA Comp.
Total Input by Industry	**Total Input of Ind. 1**	**Total Input of Ind. 2**	...	**Total Input of Ind. n**	**Total Final Cons.**	**Total GCF**	**Total Exp.**	**Grand Total Use**

Source: Adapted from national accounting manual concepts.

The row totals in this table represent the total uses for each product, while column totals for industries show their total inputs (intermediate consumption plus value added), and column totals for final use categories show their respective aggregates.

3.2. Product and Industry Classifications

A crucial aspect of SUT and IOT construction is the classification system used for products and industries (economic activities). In practice, product classifications are often more detailed than industry classifications, resulting in SUTs that are rectangular (more product rows than industry columns). For example, the output of the "dairy industry" might be shown separately for products like "processed milk," "butter," "yoghurt," and "cheese," rather than a single aggregate "dairy products". This granularity at the product level is a strength of SUTs.

This study employs:

- **National Industrial Classification (NIC)**: The 5-digit NIC codes are used for classifying economic activities or industries, adhering to the International Standard Industrial Classification of All Economic Activities (ISIC) framework (ISIC Rev. 4, UN, 2008). ISIC's purpose is to provide a standardized set of activity categories for internationally comparable statistics, classifying units like establishments or enterprises based on their principal economic activity.
- **National Product Classification for Manufacturing Sector (NPCMS)**: The 7-digit NPCMS codes are used for classifying manufactured products. For services and primary sector products, NIC codes are adapted. The NPCMS aligns with the Central Product Classification (CPC) (Version 2.1, UN, 2015), which aims to categorize all goods and services resulting from economic production, including transportable goods, non-transportable goods, and services.

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The relationship between product (CPC/NPCMS) and activity (ISIC/NIC) classifications is complex and not necessarily one-to-one. An economic unit (e.g., a firm) may engage in multiple production activities. These are typically categorized into:

- **Principal Activity:** The activity contributing most to the unit's value added, determined by a "top-down method" hierarchically through the classification levels. This method means the principal activity might not always account for over 50% of total value added, though it often does.
- **Secondary Activities:** Other production activities undertaken by the unit.
- **Ancillary Activities:** Activities supporting the main productive activities (e.g., accounting, transportation within the firm), not typically shown as separate outputs in SUTs.

3.3. Generation of Input and Output Flows

The generation of detailed input and output flows is the cornerstone of constructing the SUTs. This study has meticulously established these flows, relying on the aforementioned NPCMS (7-digit) codes for manufacturing sectors and NIC (5-digit) sector codes for other sectors. A critical step involves the conversion of NPCMS codes (used for many input products in manufacturing) to NIC sector codes using a specially developed NPCMS-NIC concordance to ensure consistency and reliability across the entire economic system.

The input and output flows for registered and unregistered manufacturing industries are analyzed separately before consolidation.

- **Registered Manufacturing:** Detailed results from the Annual Survey of Industries (ASI) for 2016-2022 form the primary data source. Input flows are compiled by aggregating data for each industry sub-group from ASI Blocks I (Indigenous input items, raw materials excluding energy), H (Imported input items, raw materials excluding energy), and F (Other input items including energy). Output flows are derived from Blocks J (Products and by-products manufactured by the unit) and G (Other outputs/receipts). Within these industry sub-groups, products are categorized to align with NIC sectors, and industry sub-groups are also consolidated to NIC sectors. A significant challenge is the presence of unidentified input items such as 'other basic materials', 'other chemicals', 'other packing materials', and 'others'. These are meticulously handled: for example, 'other chemicals' are redistributed among specific chemical sectors proportionate to existing entries; materials for building maintenance are treated as purchases from construction, and machinery maintenance materials are linked to relevant producing sectors. Remaining unidentified items are allocated through careful manual balancing.
- **Unregistered Manufacturing:** Data for this segment is based on specifically tabulated data for inputs and outputs by product, often linked to results from surveys of the unorganized sector and the KLEMS database for time consistency and comprehensive coverage. Sector codes (NIC) are assigned using concordance tables. Uncoded products at the time of survey are converted to NIC sector codes. Adjustments are made to align data from 2016-17 to 2022-23, linking with KLEMS.

3.3.1. The Input Flow Matrix (Conceptual Use Table Construction)

Once data for registered and unregistered manufacturing are prepared, they are combined to obtain total flows for manufacturing sectors. This comprehensive manufacturing input flow matrix is then integrated with input flow matrices for the primary (agriculture, mining, etc.) and service sectors of the economy, resulting in an aggregated classification of around 5,000 products. The vectors representing final demand (consumption, capital formation, exports) are positioned outside these inter-industry transaction columns.

The input flow at purchasers' prices is constructed by depicting the inter-industry flows and final uses of products in rows. Sectoral estimates of Gross Value Added (GVA) are introduced as a row at the bottom, adjacent to the row showing total inputs by industries. This results in an initial, typically unbalanced, input-output transactions table at purchasers' prices (a product-by-industry matrix). In

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this matrix, the sum of entries in a column indicates the respective industry's output at ex-factory prices (basic prices plus taxes on products, less subsidies on products, excluding deductible VAT). The sum of entries along any row shows the total inter-industry use and final use of that product. It is important to note that in this product-by-industry format, row totals (total use of a product) and column totals (total input of an industry) are not expected to match even after final balancing, as the table reflects product utilization and industry input structures, not a symmetric product-by-product or industry-by-industry account yet.

3.3.2. The Output (Make) Matrix

To ensure the overall balance of the SUT system and to facilitate the transformation to symmetric IOTs, it is essential to classify outputs by both industry and product. This is represented in the **Make Matrix** (often denoted as V, where rows are industries and columns are products, or V^T as used in some notations in the provided documents where rows are products and columns are industries).

Similar to the input flow compilation, output flows for registered and unregistered manufacturing are derived separately from detailed coded output data and then consolidated into a single matrix for the entire manufacturing sector. The data sources for industry-specific output details on products and by-products are the same as those used for input flows (ASI Blocks J and G for registered manufacturing, and corresponding data for unregistered). These output details are meticulously organized into an industry-by-product matrix by merging the output flows from both manufacturing segments and integrating production flows from primary and service industries. This Make Matrix is fundamental, as it details not only the principal product of each industry but also any secondary products produced.

3.4. Balancing Supply and Use Tables

The SUT framework is built upon fundamental accounting identities that must hold true for the system to be coherent. The process of balancing ensures these identities are met, confronting data from various sources and making adjustments to achieve consistency. The three basic identities are:

1. **Identity (1): Output = Intermediate Consumption + Gross Value Added.** For each economic activity (industry), its total output must equal the sum of its intermediate consumption and the gross value added it generates. This is represented as $g = Ui + Wi$ in matrix notation for the Use Table in the NSO MoSPI slides.
2. **Identity (2): Total Supply by Product = Total Use by Product.** For each product, the total supply (from domestic production and imports) must equal its total use (as intermediate consumption, final consumption, gross capital formation, or exports). This is $q = Ui + Y_d + Y_m$ (where Y includes all final uses) from the Use table perspective, and $q = V^T i + m$ from the Supply table perspective.
3. **Identity (3): GVA (Production Approach) = GVA (Income Approach).** For each industry, the Gross Value Added calculated using the production approach (Output - Intermediate Consumption) must equal the GVA estimated using the income approach (Compensation of Employees + Gross Operating Surplus/Mixed Income + Other Taxes less Subsidies on Production).

The SUTs framework ingeniously brings together the components of all three approaches to measuring Gross Domestic Product (GDP): the production, income, and expenditure approaches. The UN Handbook's figure provides an excellent graphical overview of this integrated framework, explicitly highlighting these balancing identities. For instance, total supply by product (from the Supply table, V^T plus imports m to get q) equals total use by product (from the Use table, $U_d + U_m$ plus final uses $Y_d + Y_m$ to get $X + m$ which is q). Also, total output by industry (g^T) is consistent across both tables.

The balancing of the Input-Output Table (IOT), which is derived from these SUTs, is carried out to ensure that discrepancies between the generated row and column totals (which represent total input and total output for each product/industry in the symmetric table) do not exceed a pre-defined tolerance, for instance, 5%. For SUTs, the estimated row totals (total supply of products) in the balancing process often involve adding distributive margins (trade margins, transport margins, and net indirect taxes on products) to the product outputs obtained from the Make Matrix (valued at basic prices) to arrive at purchaser prices.

3.5. Distinguishing Domestic and Imported Product Use

A crucial step, particularly for advanced economic analysis like calculating domestic value-added in exports or understanding import penetration, is the disaggregation of product uses into those of domestically produced goods/services and imported ones. While the basic Use Table records total intermediate consumption and final uses by product type, it often does not initially distinguish the origin (domestic vs. imported) of these products.

Although such a split is not an absolute prerequisite for creating balanced SUTs at current prices, it is a critical transformation for linking SUTs to the construction of domestic IOTs and for many analytical applications. The methodology involves constructing an **Imports Use Table**, which details the use of imported products by industries (as intermediate consumption) and by final demand categories. Once this Imports Use Table is meticulously constructed, the **Domestic Use Table** can be derived by subtracting the Imports Use Table, element by element, from the total Use Table. These two tables – the Imports Use Table and the Domestic Use Table – then form the basis for constructing separate input-import tables and domestic IOTs, respectively. This distinction is vital for deriving the domestic coefficient matrix (A_d) used in subsequent DVA and employment linkage analyses. The ASI-derived SUTs used in this study possess the advantage of distinguishing between imported and domestic inputs, which is leveraged for this purpose. When this direct distinction is not available for all components, a proportionality assumption (assuming that industries and final users consume domestic and imported products in the same proportion as their availability in the total supply of that product) is often used to separate imported inputs, thereby creating a time series of Domestic Use Tables (DUTs).

4. Methodology Part 2: From Supply-Use Tables to Symmetric Input-Output Tables

While SUTs provide a rich database, for many analytical purposes, transforming this pair of tables (Supply and Use) into a single, square, symmetric Input-Output Table (IOT) offers considerable advantages. Symmetric IOTs, either product-by-product or industry-by-industry, possess algebraic properties that make them particularly well-suited for analyses such as estimating the effects of changes in final demand on sectoral outputs and employment, assessing the impact of relative price changes, quantifying labor and capital requirements under different output scenarios, and tracing the consequences of shifting demand patterns. They can also serve as the foundation for expanded environmental-economic accounts, estimating the demands made on the environment by economic activities.

The IOTs derived from SUTs further elucidate the intricate interrelationships between industries and products, mapping the sale and purchase connections between producers and consumers within the economy. In these symmetric tables, the dual identities of the SUT system (output = intermediate consumption + GVA for industries, and total supply = total use for products) are typically reduced to a single type of identity: for each product (in a product-by-product table) or for each industry (in an industry-by-industry table), total input equals total output.

The simplified product-by-product IOT transforms the columns of the original Use Table, which are industry-based, into product-based structures. Consequently, the relationships between output and input now depict relations between products (as outputs) and the products and primary inputs necessary to produce them in homogeneous production units. Primary inputs are those inputs that are not the outputs of other domestic industries within the production boundary, such as imports of goods and services, and the components of GVA (compensation of employees, gross operating surplus, etc.).

4.1. Technology Assumptions for Transformation

The transformation from rectangular SUTs to square IOTs is not merely an arithmetic rearrangement; it necessitates making explicit assumptions about the nature of production technology,

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particularly concerning secondary products (products produced by an industry that are not its principal products). The choice of assumption significantly influences the resulting IOT and its analytical properties. The main assumptions are:

- **For Product-by-Product IOTs:**
  - **Product Technology Assumption (Model A in Eurostat):** This assumes that each product is produced using its own specific and unique input structure (technology), irrespective of the industry in which it is produced.
  - **Industry Technology Assumption (Model B in Eurostat):** This assumes that each industry has its own specific and unique input structure (technology), irrespective of its product mix. All products produced by a particular industry (both principal and secondary) are therefore assumed to be produced using that same industry's average input structure. This assumption is often considered more suitable for by-products or joint products.
- **For Industry-by-Industry IOTs:**
  - **Fixed Industry Sales Structure Assumption (Model C in Eurostat):** This assumes that each industry has its own specific sales structure for its outputs, irrespective of its product mix.
  - **Fixed Product Sales Structure Assumption (Model D in Eurostat):** This assumes that each product has its own specific sales structure, regardless of the industry producing it.

Additionally, **Hybrid Technology Assumptions** can be applied. This paper adopts the **Industry Technology Assumption for constructing product-by-product IOTs**.

4.2. Mathematical Transformation under Industry Technology Assumption

The mathematical procedure to transform SUTs into a product-by-product IOT using the Industry Technology Assumption involves deriving a set of input coefficients that represent the amount of each product required to produce one unit of another product. Let us define the key matrices and vectors involved:

- U: Matrix of intermediate use of products by industries (rows = products, columns = industries). For deriving A_d, U_d is used.
- V^T: Supply or Make Matrix where rows are products and columns are industries, representing the output of products by industry.
- g: Column vector of gross industry output totals.
- x: Column vector of gross product output totals.
- W: Matrix or row vector(s) of value added components by industry.
- $\hat{g}$: Diagonalized vector g.
- $\hat{x}$: Diagonalized vector x.
- T: Transformation matrix.
- A: Input coefficient matrix (product-by-product).
- R: Value added coefficient matrix (value added components by product).

The transformation steps are as follows:

1. **Product Mix Matrix (C):** This matrix represents the share of each product in an industry's total output. Each element C_{ij} is the share of product i in the output of industry j.

$$C = V^T(\hat{g})^{-1}$$

2. **Transformation Matrix (T):** Under the Industry Technology Assumption, this matrix is used to convert industry-based inputs into product-based inputs.

$$T = C^T$$

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This transformation matrix T (dimensions: industries $\times$ products) effectively assumes that an industry's specific input structure applies proportionally to all the products it manufactures.

3. **Input Coefficient Matrix (A) (Product-by-Product):** Each element A_{ij} represents the amount of input product i required directly to produce one unit of output product j.

$$A = UT(\hat{x})^{-1}$$

If we are deriving the domestic coefficients matrix A_d, then U should be U_d.

4. **Value Added Coefficient Matrix (R):** This matrix represents the primary inputs required per unit of product output.

$$R = WT(\hat{x})^{-1}$$

The resulting matrix A (or A_d) forms the inter-quadrant of the symmetric product-by-product IOT. The dimensions of this IOT, as constructed in this study, are 5725×5725.

5. Methodology Part 3: Analytical Applications - The Leontief Inverse and Economic Impact Analysis

The construction of a symmetric IOT, represented by the coefficient matrix A (or A_d for domestic inputs), opens the door to a wide array of powerful economic analyses. Central to these is the **Leontief Inverse**.

5.1. The Leontief Inverse

The Leontief Inverse matrix, denoted as $(I - A_d)^{-1}$, is the cornerstone of input-output analysis. Here:

- I is the Identity Matrix.
- A_d is the domestic input coefficient matrix.

The Leontief Inverse matrix, $(I - A_d)^{-1}$, encapsulates the total (both direct and indirect) input requirements that must be produced across the entire domestic economy to satisfy one unit of final demand for any specific product. For the Leontief inverse to be economically meaningful, the Hawkins-Simon conditions must be met.

This matrix is invaluable for calculating multipliers, conducting impact analyses, and tracing Global Value Chains (GVCs).

5.2. Estimating Domestic Value Added (DVA) and Foreign Value Added (FVA)

A significant application of the IOT framework is the quantification of value added domestically. The core equation for DVA is:

$$dva = v(I - A_d)^{-1}\hat{X}$$

Where:

- dva is a $(1 \times n)$ row vector representing the DVA embodied in the production or exports of each of the n sectors/products.
- v is a $(1 \times n)$ row vector of direct value-added-to-output ratios for each sector/product.
- $(I - A_d)^{-1}$ is the Leontief inverse.
- $\hat{X}$ is an $(n \times n)$ diagonal matrix where the diagonal elements represent the gross value of production or exports.

Foreign Value Added (FVA) embodied in exports can then be calculated by subtracting the DVA in exports from the gross value of exports:

$$fva = \hat{X}_{exp}i - dva_{exp}$$

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Where $\hat{X}_{exp}$ is the diagonal matrix of gross exports, i is a summation column vector, and dva_{exp} is the DVA embodied in those exports. Total DVA ($\sum dva_j$) can be further decomposed into:

- **Direct DVA (dva_d):** Value added generated directly within the producing or exporting sector itself.
- **Indirect DVA (dva_{bw}):** Value added generated in upstream domestic sectors supplying inputs.

5.3. Estimating Employment Linkages

Parallel to the DVA estimation, the IOT framework can be used to estimate the number of direct and indirect jobs. The core equation for estimating employment (e) is:

$$e = l(I - A_d)^{-1}\hat{X}$$

Where:

- e is a $(1 \times n)$ row vector of jobs supported by production/exports in each sector/product.
- l is a $(1 \times n)$ row vector of employment coefficients (labor per unit of output).
- $(I - A_d)^{-1}$ and $\hat{X}$ are as defined previously.

Total employment ($e = \sum e_j$) associated with production or exports can be decomposed:

- **Direct Employment (e_d):** Jobs created directly within the producing/exporting sector itself.
- **Indirect Employment (e_{bw}):** Jobs created in upstream domestic sectors ($e_{bw} = e - e_d$).

5.4. Data Sources for Impact Analysis

The empirical analysis relies on:

- **Annual Survey of Industries (ASI):** For the organized manufacturing sector, forming the basis for SUTs and IOTs (2016-17 to 2022-23). ASI is used for direct estimates.
- **India KLEMS Database (RBI):** For comprehensive indirect estimates covering organized and unorganized segments.
- **National Sample Survey Office (NSSO):** Data for unorganized enterprises.

A proportionality assumption is often used to create Domestic Use Tables (DUTs).

5.5. Assumptions and Limitations of IO-based Impact Estimation

Key assumptions include fixed input coefficients (homogeneity and proportionality). Limitations include the static nature of the model (not capturing dynamic effects like technological change or full general equilibrium impacts) and potential biases if national average coefficients are used without adjustment for specific firm characteristics (e.g., exporters' higher productivity). Standard IO analysis typically captures direct and indirect effects, potentially underestimating broader induced effects unless specifically modeled.

6. Case Study: India's Mobile Phone Manufacturing Sector (NPCMS 4722200), 2016-2022

To illustrate the analytical capabilities of the newly constructed 7-digit product-level SUTs and IOTs, we undertake a detailed case study of India's mobile phone manufacturing sector (NPCMS code 4722200). This analysis focuses on the period 2016-2022, comparing average performance metrics for the triennia 2016-2018 and 2019-2022.

6.1. Output and Trade Dynamics

- **Total Output:** The average triennial output increased by a significant 81%, from $20 billion (2016-2018) to $36 billion (2019-2022).
- **Total Imports:** The annual average import value decreased by 49%, from $2,967 million to $1,525 million. Imports as a percentage of total domestic output fell from 29% in 2016 to approximately 4% on average during 2019-2022.

- **Total Exports:** The average annual export value skyrocketed by 800%, from $661 million to $5,950 million. The share of exports in total output rose from 1% in 2016 to 25% in 2022.

6.2. Value Addition: Domestic (DVA) vs. Foreign (FVA)

- **Direct Domestic Value Added (DDVA - ASI based):** Grew by 283%, from an average of $1,193 million to $4,571 million.
- **Indirect Domestic Value Added (IDVA - KLEMS based):** Showed growth of 604%, from $470 million to $3,308 million. ASI-based IDVA grew 537% ($511m to $3,258m).
- **Total Domestic Value Added (TDVA - KLEMS based):** Grew by 374%, from $1,663 million to $7,879 million. ASI-based TDVA increased by 359% ($1,704m to $7,829m).
- **Direct Foreign Value Added (DFVA):** Average DFVA increased by 28%, from $17,263 million to $22,128 million. Its share in gross output significantly decreased.
- **Indirect Foreign Value Added (IFVA):** Surged by 528%, from $626 million to $3,934 million.
- **Total Foreign Value Added (TFVA):** Average TFVA rose by 46%, from $17,890 million to $26,062 million. Its share in total output fell from approximately 91% to around 72%.
- **DVA in Exports:** Experienced average growth of 2063%, from $62 million to $1,335 million. Its share in exports rose from 9% to 22%.
- **FVA in Exports:** Increased by an average of 670% ($599m to $4,615m). Its share in exports declined from 91% to 78%.

6.3. Employment Dynamics

- **Total Employment (KLEMS Production):** Average rose by 106%, from 582,878 to 1,198,498. Export-related jobs (KLEMS Export) surged by 681% (26,890 to 2,10,135).
- **Direct Employees (ASI Production):** Grew by 497% (27,052 to 1,61,623). Export-related grew 3327% (856 to 29,328).
- **Indirect Employees (KLEMS Production):** Grew by 87% (555,826 to 1,036,876). Export-related grew 594% (26,034 to 180,807).
- **Shift towards Contractualization (KLEMS Production):** Total Contractual Workers average 207% (233,380 to 715,796), vs. Total Regular Workers average 17% (281,699 to 328,671).
- **Female Participation (KLEMS Production):** Total Female Workers average 37% (96,394 to 132,232), vs. Total Male Workers average 6% (185,305 to 196,439).

6.4. Wages and Salaries

- **Total Wages/Salaries (KLEMS Production):** Average increased by 69% ($1,710m to $2,886m). Export-related grew by 476% ($91m to $524m).
- **Wages for Contractual Workers (KLEMS Production, Total):** Average surged 449% ($224m to $1,226m).
- **Wages for Regular Workers (KLEMS Production, Total):** Average grew 63% ($458m to $746m).
- **Direct Wages (ASI Production):** Grew 395% (avg. $123m to $609m). Export direct wages grew 2515% (avg. $4.2m to $110m).

6.5. Output Quality Index (OQI)

- Average OQI (Base: 2016) increased by 119%, from 145 (2016-2018) to 318 (2019-2022).
- Average Domestic Quality Index (DQI) fell by 30% (739 to 519).
- Average Import Quality Index (IQI) surged by 774% (126 to 1,104).

6.6. Backward Linkages (Key Inputs)

- **Key Domestic Components:** Services (Trade - F11, Business - F1/F3, Financial - F10, Construction - F4, Rental - F6), copper/aluminium wires (4294299), plastic parts (3694005), some PCBs (4713002) and ICs (4715002).

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- **Key Foreign Components:** Parts of cellular sets (4740100), transmission apparatus parts (4740300), consumables (9922100), electronic components (PCBs, ICs, digital cameras, LCDs, batteries).

6.7. Discussion of Findings (Mobile Phone Sector)

The case study of India's mobile phone manufacturing sector from 2016 to 2022 reveals a narrative of remarkable transformation, significant achievements, and evolving challenges.

The substantial growth in output, the dramatic surge in exports, and the clear trend of import substitution for finished goods are strong indicators of the positive impact of government initiatives like "Make in India" and the PLI schemes. The sector has evidently responded to policy incentives aimed at boosting domestic production.

The value addition story is complex. While Direct DVA (ASI) has grown, its share in output remains modest. The explosive growth in Indirect DVA (both KLEMS and ASI) is encouraging, suggesting a deepening of domestic backward linkages. However, the simultaneous surge in Indirect FVA indicates that these domestic suppliers are, in turn, relying heavily on imported components. The most positive sign is the dramatic increase in the share of DVA in exports (from 9% to 22%), implying that India is capturing more value from its burgeoning export activities. Nevertheless, the overall FVA (direct + indirect) share in total output, though declining, remains high (around 72% in 2019-22), underscoring continued dependence on global supply chains for critical inputs and technology.

The sector has been a significant job creator. However, the much faster growth of contractual employment compared to regular employment raises questions about job quality, security, and worker benefits. The substantial increase in female participation is a highly positive development.

The significant rise in the overall wage bill reflects the sector's expansion. The sharp increase in wages for contractual workers is notable.

The improvement in the Output Quality Index is a testament to the sector's maturing capabilities. However, the concurrent surge in the Import Quality Index suggests that final product quality improvement may be heavily driven by the use of high-quality imported components.

The analysis of input components reveals that while domestic service inputs are growing, critical electronic components often continue to be sourced internationally.

In essence, the mobile phone manufacturing sector in India has successfully scaled production and become a major exporter. It is progressively adding more domestic value, especially in its exports. However, the journey towards greater self-reliance in high-value components and ensuring high-quality employment for its workforce is ongoing.

7. Conclusion and Way Forward

This paper has detailed the methodology for constructing high-resolution 7-digit product-level Supply-Use Tables (SUTs) and symmetric Input-Output Tables (IOTs) for the Indian economy for the period 2016-2022, utilizing microdata from the Annual Survey of Industries (ASI). By adhering to the System of National Accounts (SNA) guidelines and employing the Industry Technology Assumption for the transformation from SUTs to IOTs, this research offers a significant empirical contribution to understanding the intricate structure of the Indian economy.

The application of this framework to India's mobile phone manufacturing sector yielded several key findings:

1. **Dynamic Growth and Trade Reorientation:** The sector demonstrated robust output growth (81% average increase), a significant reduction in import dependency for finished goods (from 29% to 4% of output), and an explosive surge in exports (800% average increase).
2. **Evolving Value Addition:** There was a marked increase in Domestic Value Added (DVA), particularly its share in the rapidly expanding exports (rising from approximately 9% to 22%).
3. **Substantial Employment Creation with Structural Shifts:** The sector has been a major job generator (average total employment 106%), driven heavily by export-related job growth (681%).

Concurrently, there have been significant shifts in the labor structure: a substantial rise in contractual work (207% in production) and an increase in female participation (37% in production).

4. **Wage Dynamics:** Wages, particularly for contractual workers, saw significant increases.

The detailed SUTs and IOTs developed in this study provide a critical empirical foundation for evidence-based policy analysis. They enable policymakers to design targeted interventions to further deepen domestic value addition, assess the employment impact of various policies, and analyze India's integration into Global Value Chains more effectively.

Limitations and Future Research: While the Industry Technology Assumption was employed, future research could explore the implications of using alternative assumptions. Applying this granular SUT-IOT framework to other key manufacturing sectors would yield invaluable insights. Further research is also crucial to fully understand the long-term implications of the observed shifts in labor composition and wage structures.

In conclusion, the development of these 7-digit product-level SUTs and IOTs represents a methodological advancement that enhances the analytical toolkit for Indian economic research. They offer a pathway to more nuanced, disaggregated, and evidence-backed policymaking aimed at fostering sustainable industrial growth, improving domestic value capture, and ensuring the creation of quality employment opportunities for India's workforce.

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