The Anatomy of Value Creation: Input-Output Linkages, Policy Shifts, and Economic Impact in India's Mobile Phone GVC

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Abstract

Participation in the Global Value Chain (GVC) is increasingly viewed as a crucial pathway for industrialisation and employment generation in developing economies. This paper examines the economic impact of India's involvement in the mobile phone manufacturing Global Value Chain (GVC), a sector marked by rapid growth and significant policy attention. We specifically quantify the domestic value addition (DVA), employment generation (direct and indirect, disaggregated by skill and gender), and evidence of upgrading, considering the influence of recent policy shifts from import substitution (Phased Manufacturing Programme) to export-oriented incentives (National Policy on Electronics 2019, Production Linked Incentive scheme). Methodologically, this study pioneers the construction and application of highly disaggregated (7-digit National Product Classification for Manufacturing Sector - NPCMS) annual Supply-Use Tables (SUTs) and symmetric Input-Output Tables (IOTs) for the Indian economy. These tables are derived from plant-level microdata from the Annual Survey of Industries (ASI) for the period 2016-17 to 2022-23. Applying the Leontief Input-Output framework, we trace inter-sectoral linkages and decompose economic impacts. Our findings reveal a significant expansion in Domestic Value Added within the mobile phone sector, with indirect DVA growing exceptionally, indicating a substantial deepening of domestic backward linkages. The share of DVA in gross output rose markedly, reaching an average of more than 22% in the later period (2019-22). The sector has become a significant employment generator, supporting over a million direct and indirect jobs on average between 2019-20 and 2022-23, with a notable surge in export-linked employment and increased female participation, alongside a rise in contractual labour. Furthermore, we present evidence of product upgrading through rising export unit values and a doubling of a constructed Output Quality Index. Our refined analysis of trade data, which accounts for actual component utilisation and foreign exchange savings, indicates a positive and growing adjusted trade balance for the sector since early 2019. This paper contributes granular, firm-level, data-driven evidence to the debate on the benefits of GVC participation, particularly for economies engaged in assembly-led manufacturing. The results suggest that strategic policy interventions that foster scale and export competitiveness can significantly enhance domestic economic gains, even in the presence of initial import dependencies. The findings provide critical insights for policymakers seeking to maximise value capture and promote sustainable industrial development through deeper Global Value Chain (GVC) integration.

Keywords: Global Value Chains, Domestic Value Added, Input-Output Analysis, Mobile Phone Manufacturing, India, Supply-Use Tables, Employment Linkages, Backward Linkages, Industrial Policy, Upgrading.

JEL Classifications: F14, F63, L63, O14, O25, C67, J21, R15

1 Introduction

1.1 Motivation and Context

The quest for sustainable economic growth, structural transformation, and the creation of gainful employment for a burgeoning workforce is a paramount challenge for developing economies. India, with its demographic dividend and aspirations for a more prominent global manufacturing role, epitomises this challenge. The imperative to generate approximately 90 million new non-farm jobs by 2030, as highlighted by McKinsey Global Institute (2020), underscores the scale of this endeavour, particularly as a significant portion of these roles are anticipated to be blue-collar. Achieving such employment elasticity necessitates robust GDP growth, ideally from 8.0% to 8.5% annually. However, prevailing macroeconomic conditions, including heightened debt burdens across various sectors, suggest that domestic demand alone may be insufficient to propel such growth in the medium term (Chatterjee & Subramanian, 2023).

In this context, integration into Global Value Chains (GVCs) has emerged as a pivotal strategy for export diversification, industrial upgrading, and employment generation (World Bank, 2020). For India, with its large, relatively low-wage workforce, participation in GVCs, particularly through "backward linkages" – where imported inputs are utilised to produce goods for export – offers a promising avenue for leveraging its comparative advantages. Network product sectors such as electronics, alongside traditional labour-intensive industries, are prime candidates for such GVC-led growth (Athukorala, 2014; Veeramani and Dhir, 2016, 2017; Ministry of Finance, 2020). The ongoing realignment of GVCs, spurred by geopolitical shifts and the quest for supply chain resilience (Amiti et al., 2019; Baldwin & Tomiura, 2020; Javorcik, 2020), presents a critical, albeit potentially brief, window of opportunity for economies like India to position themselves as key manufacturing and assembly hubs.

India's mobile phone manufacturing sector offers a compelling case study of this dynamic. Propelled by strategic policy interventions such as the "Make in India" initiative, the Phased Manufacturing Programme (PMP), and more recently, the National Policy on Electronics (NPE) 2019 and the Production Linked Incentive (PLI) scheme, the sector has witnessed a meteoric rise. Domestic production has surged, and India has rapidly transformed from a net importer to a significant exporter of mobile phones, becoming the world's 5th largest by 2022-23. This trajectory, from focusing on import substitution to embracing export-oriented production, provides a rich empirical setting to examine the tangible economic benefits and potential limitations of GVC participation. While the headline figures are impressive, a scholarly debate has emerged regarding the depth of value creation, the nature of employment generated, and the actual net impact on the economy, particularly when accounting for the high import intensity of critical components (Rajan & Lamba, 2023; Chauhan et al., 2023).

1.2 Research Questions

This paper aims to contribute to the debate by conducting a rigorous and granular analysis of India's mobile phone manufacturing sector (NPCMS code: 4722200, "telephones for cellular networks or other wireless networks"). Our primary research question is:

> To what extent has India's engagement in the mobile phone manufacturing GVC, particularly through the development of domestic backward linkages, contributed to (a) domestic value addition (DVA), (b) employment generation (disaggregated by skill-type and gender), and (c) aggregate wage earnings?

Arising from this central query are several interconnected secondary questions:

- How has the composition of DVA (direct versus indirect) evolved over the period 2016-17 to 2022-23, particularly when comparing the import-substitution focused PMP regime (Phase 1: 2016-17 to

2018-19) with the export-oriented NPE/PLI regime (Phase 2: 2019-20 to 2022-23)?

- What is the veridical net trade impact of the mobile phone sector, once imports of crucial components are meticulously accounted for using actual input-use coefficients, and foreign exchange savings from import substitution are considered?
- Is there quantifiable evidence of product or process upgrading within India's mobile phone manufacturing ecosystem, suggesting a move beyond low-value assembly operations?
- What do these empirical findings imply for the broader theoretical understanding of how developing countries can maximise gains from GVC participation, particularly during the initial stages that might be assembly-led?

1.3 Contribution of the Paper

This study makes several distinct contributions to the literature. Methodologically, its core innovation lies in the construction and application of highly disaggregated 7-digit National Product Classification for Manufacturing Sector (NPCMS) product-level Supply-Use Tables (SUTs) and symmetric Input-Output Tables (IOTs) for the Indian economy. These tables, derived from comprehensive plant-level microdata from the Annual Survey of Industries (ASI) for the period 2016-17 to 2022-23, offer an unparalleled level of detail for analysing inter-sectoral linkages. The meticulous methodology, adhering to SNA (2025) principles and employing the Industry Technology Assumption for SUT-IOT transformation, allows for a more precise quantification of economic impacts than previously available studies.

Empirically, the paper provides robust and nuanced estimates of:

- Direct and, crucially, indirect Domestic Value Added (DVA), offering insights into the depth of backward linkages with the domestic economy, including connections to the unorganised sector (facilitated by integrating ASI with RBI KLEMS data).
- Detailed employment effects, disaggregated by production/non-production roles, skill levels, gender, and contractual status, thereby painting a comprehensive picture of the labour market impact.
- Evidence of product upgrading through analysing export unit values and a newly constructed Output Quality Index (OQI) derived from plant-level data.

Theoretically and policy-wise, this research directly addresses and provides empirical counterpoints to the critiques surrounding India's mobile manufacturing success (Rajan & Lamba, 2023; Chauhan et al., 2023). By demonstrating substantial indirect DVA and significant employment generation, even with a high import content in the initial phases, the paper contributes to the understanding of how GVC participation can foster industrial development. The findings also provide actionable insights for policymakers seeking to deepen domestic linkages, encourage upgrading, and maximise the socio-economic benefits of GVC integration across various sectors. The emphasis on the absolute expansion of DVA and employment, rather than solely focusing on DVA per unit of export, provides a critical lens for evaluating GVC participation strategies.

1.4 Roadmap

The remainder of this paper is structured as follows. Section 2 reviews the relevant theoretical and empirical literature on GVCs, industrial development, the mobile phone industry, and input-output analysis. Section 3 outlines the theoretical framework underpinning our analysis, focusing on gains from GVCs, upgrading dynamics, and the Flying Geese Model. Section 4 provides a detailed exposition of our

data sources and the methodologies employed for constructing the SUTs/IOTs and for estimating DVA, employment, trade impacts, and product upgrading. Section 5 presents the core empirical results and their analysis, focusing on India's mobile phone manufacturing sector. Section 6 discusses these findings in the context of the existing literature and policy debates. Finally, Section 7 concludes with a summary of key insights, policy implications, and avenues for future research.

2 Literature Review

The empirical investigation undertaken in this paper is situated at the confluence of several important strands of economic literature: the role of Global Value Chains (GVCs) in economic development and industrialisation; India's specific experience with GVC integration; the evolving architecture of the global mobile phone industry's value chain; the application of Input-Output (IO) methodologies to quantify GVC impacts; and the contemporary debate surrounding the true extent of India's recent achievements in mobile phone manufacturing.

2.1 Global Value Chains, Industrialisation, and Economic Development

The proliferation of GVCs, in which different stages of the production process are geographically dispersed across multiple countries, has fundamentally reshaped international trade and industrial organisation over the past few decades. A significant body of literature explores the multifaceted implications of GVC participation for developing economies. Standard trade theory, extended by Grossman & Rossi-Hansberg (2008) in their "trade in tasks" framework, suggests that offshoring and GVC participation can lead to specialisation, efficiency gains, and productivity improvements for all participating countries. The World Bank's *World Development Report 2020: Trading for Development in the Age of Global Value Chains* comprehensively argues that GVCs can be powerful drivers of income growth, job creation, and poverty reduction, provided countries implement complementary domestic policies.

However, the benefits are not automatic. Constantinescu et al. (2019) find that vertical specialisation can indeed increase productivity; however, the extent of the gains often depends on the nature of participation and the depth of domestic linkages. Dollar, Khan, and Pei (2019) caution against pursuing high domestic value added (DVA) in exports as a sole policy objective, arguing that the overall scale of production and export activity, facilitated by Global Value Chains (GVCs), might be more critical for employment and income.

The literature also extensively discusses the concept of "upgrading" within Global Value Chains (GVCs)—the process by which firms, industries, or economies transition to higher-value-added activities. This can take various forms, including product upgrading (making more sophisticated products), process upgrading (improving efficiency), functional upgrading (acquiring new functions like design or branding), and chain upgrading (moving to new, more profitable value chains) (Gereffi, Humphrey, & Sturgeon, 2005; Giuliani, Pietrobelli, & Rabellotti, 2005). A key visual metaphor in this context is the "smile curve," which posits that value addition is highest at the upstream (R&D, design, key inputs) and downstream (branding, marketing, services) ends of the value chain, with manufacturing and assembly commanding lower shares (Hess & Coe, 2006). A critical question for developing countries is how to navigate this curve and capture greater value.

2.2 India's Engagement with GVCs

India's integration into Global Value Chains (GVCs) has been a subject of growing scholarly and policy interest. Athukorala (2014) provided an early comprehensive analysis of how India fits into global

production sharing, highlighting both opportunities and policy challenges. Veeramani and Dhir (2016, 2017) have examined India's export performance in labour-intensive products and questioned the specific manufacturing activities India should prioritise under its "Make in India" initiative. The Government of India's *Economic Survey 2019-20* (Ministry of Finance, 2020) explicitly advocated for specialising in the exports of network products to create jobs and foster growth, signalling a policy orientation towards deeper GVC integration. Despite these policy thrusts, concerns have been raised about India's relatively shallow GVC participation compared to other East Asian economies and the need for further reforms to enhance its attractiveness as a GVC hub.

2.3 The Mobile Phone Industry Global Value Chain

The mobile phone industry is a paradigmatic example of a sector driven by a Global Value Chain. Its value chain has evolved dramatically from the vertically integrated structures of the 1980s to the highly fragmented and globally dispersed networks of today. Lee & Gereffi (2013) provide a detailed analysis of the co-evolution of concentration in mobile phone Global Value Chains (GVCs) and its impact on social upgrading in developing countries. They highlight the strategic clustering of key suppliers by leading firms, such as Apple and Samsung, in regions where manufacturing occurs, a practice that enhances efficiency and shortens the design-to-market cycle. The roles of Original Equipment Manufacturers (OEMs), Electronics Manufacturing Services (EMS) firms (such as Foxconn), and Original Design Manufacturers (ODMs) are crucial to understanding the industry's governance. China's experience, where firms transitioned from assembly to supplying critical components and even developing their global brands, such as Huawei and Xiaomi (Xing, 2019), offers valuable lessons on potential upgrading paths. The "Flying Geese Model" (Akamatsu, 1962) provides a valuable framework for understanding the sequential relocation of electronics manufacturing, including mobile phones, across Asian economies as countries move up the technological ladder and wage structures evolve.

2.4 Input-Output Analysis for Measuring GVC Impacts

Quantifying the domestic economic impact of GVC participation, particularly the DVA embodied in exports and the associated employment, necessitates robust analytical tools. The Input-Output (IO) framework, pioneered by Leontief (1936), provides the foundational methodology for this purpose. Hummels, Ishii, and Yi (2001) were seminal in developing measures of vertical specialisation using input-output (IO) tables. Subsequent research has refined these techniques to decompose gross exports into their DVA and foreign value-added (FVA) components, accounting for complex inter-sectoral linkages and double counting issues (e.g., Koopman, Wang, and Wei, 2014; Timmer et al., 2014; Los, Timmer, and de Vries, 2015; Borin & Mancini, 2019). These methodologies are crucial for accurately evaluating the genuine contribution of export-oriented activities to a national economy. The construction of detailed SUTs and their transformation into symmetric IOTs, as detailed in the UN Handbook (2018) and the Eurostat Manual (2008), is a prerequisite for such analysis, enabling the tracing of value addition through direct and indirect linkages. Veeramani et al. (2023) and Veeramani and Dhir (2022) have applied input-output (IO) techniques to estimate export-supported direct value added (DVA) and employment in India, highlighting the importance of backward linkages.

2.5 The Debate on India's Mobile Manufacturing Success and the Present Study

Despite the impressive growth statistics in India's mobile phone manufacturing sector, critical questions have been raised. Rajan and Lamba (2023) and Chauhan et al. (2023) argue that India's success is

primarily assembly-based, heavily reliant on imported components, and that the true DVA is limited. They contend that when the import bill for components is factored in, the perceived trade surplus in mobile phones might be a deficit, questioning the efficacy of government incentives like the PLI scheme. These critiques underscore the need for a more nuanced and methodologically rigorous evaluation of the sector's economic contributions.

This paper directly engages with this debate. By constructing and utilising highly disaggregated (7-digit NPCMS) SUTs and IOTs from ASI plant-level data, we aim to provide a more precise quantification of DVA (both direct and indirect), trace the actual utilisation of imported components in mobile phone production, and estimate the overall employment and wage impacts. This granular approach enables us to move beyond aggregate estimates and provide a more nuanced understanding of the economic transformations underway in India's mobile phone Global Value Chain (GVC), thereby contributing fresh evidence to ongoing scholarly and policy discussions.

3 Theoretical Framework

The empirical analysis in this paper is grounded in several key theoretical constructs that explain how participation in Global Value Chains (GVCs) drives economic development, the mechanisms through which value is created and captured, and the patterns of industrial evolution in a globalised economy. We specifically draw upon theories concerning gains from Global Value Chains (GVCs), strategies for upgrading within these chains, and the 'Flying Geese' model of regional industrial transformation.

3.1 Measuring Gains from GVC Participation: Beyond Per-Unit Metrics

A central theme in the literature on GVCs is the assessment of developmental gains for participating countries. While a standard metric is the domestic value added (DVA) per unit of gross exports, an exclusive focus on this ratio can be misleading, especially for developing economies in the early stages of global value chain (GVC) integration. As argued by Dollar, Khan and Pei (2019) and the World Bank (2020), the **absolute value of DVA** and the **total employment generated** are often more crucial indicators of the overall economic impact. Even if the DVA per unit of exported goods is initially low due to reliance on imported intermediates (a characteristic of "backward GVC participation"), the sheer scale effects and productivity enhancements associated with producing for the global market can lead to a significant expansion in the total DVA and, consequently, higher job creation.

The mechanism for this expansion is significantly tied to the development of backward linkages. When export-oriented industries increase their sourcing from domestic upstream suppliers (e.g., components, materials, and services), the value created is not confined to the final exporting sector but ripples through the domestic economy. Deepening domestic inter-sectoral linkages is vital for amplifying the gains from GVCs, fostering indigenous industrial capabilities, and promoting a more inclusive growth pattern. Therefore, this paper posits that a key channel through which India can benefit from its mobile phone manufacturing GVC is the strengthening of these backward linkages, leading to increased indirect DVA and employment.

3.2 Upgrading Trajectories in Global Value Chains and the 'Smile Curve'

A critical concern for developing countries participating in GVCs, particularly in assembly-oriented activities, is the risk of being "locked into" low-value segments. The GVC literature, however, emphasises that participation can be dynamic, offering pathways for "upgrading"—the process by which firms and

economies transition to higher-value-added activities (Gereffi, Humphrey, & Sturgeon, 2005; Giuliani, Pietrobelli, & Rabellotti, 2005). This upgrading can manifest in several forms:

Product Upgrading: Shifting to more sophisticated product lines (e.g., from feature phones to smartphones, or from standard to high-precision components).

Process Upgrading: Enhancing the efficiency and quality of production through better technology, organisation, and skills.

Functional Upgrading: Taking on new, higher-value functions within the value chain, such as design, research and development (R&D), branding, or marketing. This can involve moving from being an EMS provider to an Original Design Manufacturer (ODM) or even an Original Brand Manufacturer (OBM).

Chain Upgrading: Applying the competencies gained in one value chain to move into new, often more technologically advanced or profitable, value chains.

The concept of the "smile curve," initially applied to the IT industry (Hess and Coe, 2006, referencing Shih, 1996), is relevant here. It illustrates that the highest value-added activities in many GVCs are concentrated at the "ends" of the chain—R&D, design, and the creation of core intellectual property (IP) and key components (upstream), as well as branding, marketing, sales, and after-sales services (downstream). The manufacturing and assembly stages, typically located in the "middle" of the curve, often capture a smaller share of the total value. For developing countries, the challenge and opportunity lie in strategically moving from the trough of the smile towards its higher-value ends. This paper will empirically assess whether India's mobile manufacturing sector is showing signs of such upgrading, particularly product upgrading, as an initial step on this trajectory. The argument we make is that even initial participation in lower-value assembly can serve as a stepping stone if coupled with policies that strengthen domestic capabilities and foster linkages.

3.3 The Flying Geese Paradigm and Sectoral Transformation

The "Flying Geese" model, initially proposed by Akamatsu (1962) to describe Japan's industrial development and its subsequent spread to other East Asian economies, offers a dynamic framework for understanding regional industrial transformation and the international relocation of production. The model posits a hierarchical but evolving pattern where a "lead goose" (a more advanced economy) pioneers an industry and then, as its labour costs rise and technology matures, progressively offshores standardised or labour-intensive parts of the production process to "follower geese" (less developed economies). These follower economies, in turn, absorb the technology, develop their capabilities, and may eventually become lead geese in that industry or move into new sectors, creating space for another tier of followers.

This paradigm has been widely applied to the electronics industry in Asia, explaining the successive waves of manufacturing relocation from Japan to the Newly Industrialising Economies (NIEs), then to ASEAN countries, and subsequently to China, and more recently, to countries such as Vietnam. The model suggests that as a country like China moves up the value chain in electronics (e.g., focusing more on components and R&D rather than just final assembly, as indicated by the RCA analysis), it creates an opportunity for other labor-abundant countries like India to enter or expand their presence in the assembly space. This paper will implicitly test this hypothesis by examining India's recent surge in mobile phone manufacturing and exports within the broader regional context. India's success in this sector can be seen as an attempt to join the "flying geese" formation, leveraging its labour resources and evolving policy environment. The extent to which it can then progress from assembly to more sophisticated stages will determine its long-term success within this dynamic regional hierarchy.

4 Data and Methodology

This study employs a combination of official microdata, aggregate industry statistics, and established macroeconomic methodologies to analyse the economic impact of India's mobile phone manufacturing sector. A key element of our approach is the construction of highly disaggregated Supply-Use Tables (SUTs) and symmetric Input-Output Tables (IOTs), which serve as the basis for estimating domestic value added (DVA), employment, and other economic indicators.

4.1 Data Sources

The empirical analysis draws upon several key datasets:

Annual Survey of Industries (ASI): The primary source for constructing the SUTs and IOTs is the plant-level microdata from the Annual Survey of Industries, conducted by the National Statistical Office (NSO), Ministry of Statistics and Programme Implementation (MOSPI), Government of India. We utilise ASI data from 2016-17 to 2022-23. Specific ASI schedule blocks are crucial: Block H (details on domestically sourced inputs), Block I (details on imported inputs), Block F (expenditure on services used as inputs), Block J (details of products and by-products manufactured), and Block G (details of by-products). This firm-level data allows for unprecedented granularity.

Product Classification: Products are classified at the 7-digit level of the National Product Classification for Manufacturing Sector (NPCMS), which is harmonised with the Central Product Classification (CPC) Ver. 2.1. Our specific focus is on the mobile phone manufacturing sector, identified by NPCMS code 4722200 ("Telephones for cellular networks or other wireless networks"). The NPCMS classification encompasses approximately 5,000 distinct products, serving as the basis for our detailed input-output (IO) tables.

RBI KLEMS Database: To capture linkages with the unorganised (informal) sector and to derive economy-wide coefficients for value-added, employment, and output where ASI coverage is limited to the organised manufacturing sector, we utilise data from the Reserve Bank of India's KLEMS (Capital, Labour, Energy, Materials, Services) database. This is particularly important for estimating indirect effects that ripple through the entire economy. We use the latest available release, as referenced in the source documents (e.g., 2024 release).

Industry and Trade Aggregates:

- **India Cellular & Electronics Association (ICEA):** Data from ICEA's reports using MeitY, DoC and Industry estimates provide aggregate figures on mobile phone production, domestic sales, and export value, which serve as control totals and for contextual analysis.
- **Directorate General of Commercial Intelligence and Statistics (DGCI&S), Ministry of Commerce, Government of India:** Official data on imports and exports of final mobile phones and components, typically at the 8-digit level of the Harmonised System (HS), are crucial for trade analysis and for adjusting component import data.
- **UN Comtrade Database:** Although our primary focus is domestic, international trade data from the UN Comtrade database is utilised by us for comparative analysis of export trends and market shares, providing context for India's performance.

4.2 Construction of Supply-Use Tables (SUTs) and Input-Output Tables (IOTs)

The construction of detailed SUTs and symmetric IOTs is a cornerstone of this paper's methodology, enabling a robust analysis of inter-sectoral linkages. This process involves several steps:

4.2.1 SUT Framework

Our SUTs are compiled following the System of National Accounts (SNA) framework (explicitly referencing SNA 2025 guidance) and the Eurostat Manual of Supply, Use, and Input-Output Tables (Eurostat, 2008). The Supply Table shows the supply of products by domestic industries and from imports. It maps outputs of industries (Make Matrix, V) to products. The Use Table details the use of these products as intermediate consumption by industries and for final demand (household consumption, government consumption, gross capital formation, exports). Also, it incorporates components of value added by industry. Key identities ensure consistency: Output = Intermediate Consumption + GVA; Total Supply = Total Use; GVA (production) = GVA (income).

4.2.2 From ASI Data to SUTs

- **Input Flow Matrices:** Plant-level input data from ASI Blocks H (domestic materials), I (imported materials), and F (services) are aggregated by NPCMS 7-digit product codes for each industry (defined by NIC codes). Output data from Blocks J and G are similarly processed.
- **NPCMS-NIC Concordance:** A crucial step is the mapping between NPCMS product codes and National Industrial Classification (NIC) codes for industries to ensure consistency across input and output data.
- **Handling Unidentified Inputs & Proportionality:** Since ASI input data at the plant level is not directly linked to specific products manufactured by multi-product plants, a proportionality assumption is employed: inputs are allocated to specific products based on the proportional share of each product in the plant's total output. Unidentified inputs (e.g., 'other basic materials') are redistributed based on established procedures.
- **Registered and Unregistered Sectors:** While ASI covers the registered (organised) manufacturing sector, linkages with the unregistered (unorganised) sector are incorporated using data from the RBI KLEMS database and NSSO surveys, ensuring a comprehensive view.
- **Domestic and Imported Use Tables:** By distinguishing between domestic inputs (Block H) and imported inputs (Block I), separate Domestic Use Tables (U_d) and Imported Use Tables (U_m) are constructed. This is vital for calculating domestic leakages and true DVA.

4.2.3 Derivation of Symmetric IOTs from SUTs

The SUTs, which are often rectangular (products x industries), are transformed into symmetric square product-by-product IOTs for analytical purposes.

- **Technology Assumption:** This transformation requires assumptions about production technology. While Product Technology Assumption (PTA) and hybrid models exist, this paper primarily employs the Industry Technology Assumption (ITA). ITA assumes that each industry has a specific input structure, which is applied proportionally to all products it manufactures (suitable for by-products).

- **Mathematical Transformation under ITA** (Mahajan et al., 2018; National Accounts Statistics, 2012b):
  - Let V be the Make Matrix (Supply Matrix, dimensions: industries $\times$ products). V^T (products $\times$ industries) shows the output of products by industry.
  - Let U be the total intermediate Use Matrix (products $\times$ industries). U_d refers to the use of domestic products.
  - Let g be the column vector of gross industry output. $\hat{g}$ is its diagonalised form.
  - Let x be the column vector of gross product output. $\hat{x}$ is its diagonalised form.
  - Product Mix Matrix (Market Share Matrix) C: Represents the share of each product in an industry's total output.

$$C = V^T(\hat{g})^{-1} \quad \text{(Dimensions: products} \times \text{industries)}$$

  - Transformation Matrix T: Under ITA, $T = C^T$. (Dimensions: industries $\times$ products). This matrix reallocates industry inputs to product outputs.
  - Domestic Technical Coefficient Matrix (Product-by-Product) A_d: Represents the amount of domestic input product i required per unit of output product j.

$$A_d = U_d T(\hat{x})^{-1}$$

    This matrix is the core of the domestic IOT.
  - Value Added Coefficient Matrix R_v: Represents primary inputs (value added components W by industry) per unit of product output.

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

4.3 Estimating Economic Impacts (DVA, Employment, Wages)

The derived IOTs, specifically the domestic technical coefficient matrix (A_d), are used within the standard Leontief IO framework to estimate various economic impacts.

4.3.1 Leontief Input-Output Model

The fundamental relationship is $x = (I - A_d)^{-1} f_d$, where x is the vector of gross domestic output, f_d is the vector of final demand for domestically produced goods and services, and $(I - A_d)^{-1}$ is the domestic Leontief Inverse matrix, capturing the total (direct and indirect) domestic output required to satisfy one unit of final demand.

4.3.2 Domestic Value Added (DVA) Calculation

The DVA generated by a vector of final demand f_d (e.g., total output $\hat{y}$, or exports $\hat{X}$) is given by: $dva = v(I - A_d)^{-1} f_d$ where v is a row vector of direct DVA to gross output ratios for each product/sector ($v_j = DVA_j / X_j$).

Decomposition of DVA:

- Direct DVA (DDVA): $dva_d = v(I - A_d)^{-1} f_d$, where $(I - A_d)^{-1}$ is a matrix containing only the diagonal elements of the Leontief inverse.

- Indirect DVA (IDVA) / Backward Linkage DVA (dva_{bw}): $dva_{id} = dva - dva_d$. This captures the DVA generated in all upstream domestic supplying industries.

4.3.3 Foreign Value Added (FVA) Calculation

FVA is the portion of gross output or gross exports that comprises imported inputs and value added abroad. It is calculated as: FVA = Gross Output (or Exports) - DVA.

4.3.4 Employment and Wage Impact Calculation

- Employment (e): $e = l(I - A_d)^{-1} f_d$ where l is a row vector of employment coefficients (e.g., number of employees per unit of gross output, $l_j = L_j / X_j$).
- Wages and Salaries (ws): $ws = q(I - A_d)^{-1} f_d$ where q is a row vector of wage and salary coefficients (wages and salaries paid per unit of gross output, $q_j = WS_j / X_j$).

Like DVA, employment and wages are decomposed into direct and indirect effects. Coefficients v, l, q are derived from ASI data for the organised sector. To estimate total economic impacts, these are supplemented or scaled using information from the RBI KLEMS database, applying appropriate concordances between NPCMS and NIC classifications.

4.4 Addressing Trade Data Discrepancies and Measuring Net Foreign Exchange Impact

To counter critiques (e.g., Chauhan et al., 2023) that India's mobile phone trade surplus is illusory due to high component imports, this study employs a more nuanced methodology:

Refined Estimation of Imported Component Use: HS codes of key mobile phone components are mapped to 7-digit NPCMS codes via UN concordance tables (HS to CPC Rev.2, then CPC to NPCMS). Using ASI data, two ratios are estimated for each component k:

- $Ratio1_k$: Proportion of total domestic output of component k (by NPCMS code) that is used as an intermediate input by *all* industries (excluding final consumption by households).
- $Ratio2_k$: Proportion of component k's total use as an intermediate input (across all industries) that is directly consumed by the mobile phone manufacturing sector (NPCMS 4722200).

Adjusted Imports of Component k for Mobile Sector = (Actual Import Value of component k at HS 8-digit) $\times$ $Ratio2_k$.

Estimating Foreign Exchange Saved from Import Substitution: A counterfactual import scenario is constructed: what would have been the import bill for final mobile phones if domestic production had not substituted these imports post-2017-18 (i.e., if the pre-tariff import-to-domestic demand ratio persisted)? Historical import-to-domestic demand ratio for final mobile phones (average of 2014-15 to 2017-18, e.g., 0.325) is applied to actual domestic demand in subsequent years. Foreign Exchange Saved = (Counterfactual Imports of final phones) – (Actual Imports of final phones).

Adjusted Trade Balance: Adjusted Trade Balance = (Exports of mobile phones + Exports of components used in phones + Foreign Exchange Saved) – (Imports of final mobile phones + Adjusted Imports of components used in phone production).

4.5 Measuring Product Upgrading

Two approaches are used to assess product upgrading:

Export Unit Values (UVs): Calculated as (Export Value of mobile phones) / (Export Quantity of mobile phones). India's UVs are compared to those of competitor nations (e.g., China, Korea, Vietnam) in major export markets to proxy for changes in product quality and sophistication.

Output Quality Index (OQI): This index is constructed using detailed plant-level data from ASI for mobile phones (NPCMS 4722200). It is calculated as a weighted average of unit prices (derived from value and quantity of output) for mobile phones sold in the domestic market and in export markets. The base year is set at 2016 (OQI_{2016}=100). An increasing OQI suggests a shift towards higher-value products.

4.6 Period of Analysis and Policy Phases for Comparison

The primary quantitative analysis covers the period from 2016-17 to 2022-23, aligning with the availability of consistent ASI data and the focus of the source reports. To assess the impact of policy shifts, results are often compared across two distinct phases:

- **Phase 1 (e.g., 2016-17 to 2018-19):** Characterised by the import substitution-oriented Phased Manufacturing Programme (PMP).
- **Phase 2 (e.g., 2019-20 to 2022-23):** Characterised by the export-oriented National Policy on Electronics (NPE) 2019 and the Production Linked Incentive (PLI) scheme.

This detailed methodological framework, particularly the construction of granular IOTs and the refined trade analysis, forms a robust foundation for the following empirical results.

5 Empirical Results and Analysis (Focus on India's Mobile Phone Sector - NPCMS 4722200)

This section presents the empirical findings from our analysis of India's mobile phone manufacturing sector (NPCMS code: 4722200) for the period 2016-17 to 2022-23. We analyse the evolution of production and trade, the extent and nature of domestic value addition (DVA) and its linkages, employment generation patterns, wage dynamics, and evidence of product upgrading. Where relevant, we compare outcomes across two policy phases: Phase 1 (2016-17 to 2018-19), dominated by the Phased Manufacturing Programme (PMP), and Phase 2 (2019-20 to 2022-23), characterised by the National Policy on Electronics (NPE) 2019 and the Production Linked Incentive (PLI) scheme.

5.1 Evolution of Production, Trade, and Market Structure

India's mobile phone manufacturing sector has undergone a dramatic transformation in recent years, marked by explosive output growth and a significant shift in its trade orientation.

- **Surge in Domestic Production:** The sector's gross value of output experienced a remarkable expansion. The analysis shows that the total output in US dollars grew from approximately \$13 billion in 2016-17 to \$44 billion in 2022-23. The average output increased by 81% from \$19.67 billion during 2016-18 to \$35.50 billion during 2019-22. This indicates a more than fivefold increase in domestic production value, from \$8.2 billion in 2015-16 to \$44 billion in 2022-23. This growth

significantly outpaced the rise in domestic demand, which increased from $14 billion to $34 billion (a 2.4 times increase) over the same 2015-16 to 2022-23 period.

- **Shift from Import Dependence to Export Orientation:** Historically reliant on imports, the sector has pivoted towards becoming a significant exporter.
  - *Declining Imports:* Imports of final mobile phones substantially declined. According to our analysis, imports fell from roughly $3.8 billion in 2016-17 to $1.4 billion in 2022-23. It indicates that the share of total imports in output fell from 29% in 2016 to approximately 3% in 2022, with the average import value declining by 49% between the 2016-18 period ($2.97 billion) and the 2019-22 period ($1.5 billion).
  - *Skyrocketing Exports:* Conversely, exports of mobile phones surged. We report an increase from a mere $166 million in 2016-17 to $11.1 billion in 2022-23—a more than 50-fold increase, with the average annual export value increasing by an astounding 554% from $661 million (2016-18) to $5.95 billion (2019-22). The share of exports in total output rose from 1% in 2016 to 25% in 2022.

  This dynamic shift led India to achieve a balanced trade in mobile phones by 2018-19 and subsequently transition to a growing trade surplus in final mobile phones.

- **Addressing the Trade Balance Nuance (Phones and Components):** Critics have highlighted the high dependency on component imports. Our analysis, incorporating the refined methodology for "adjusted component imports" (not in this paper), provides a more accurate picture: We demonstrate that net exports for final mobile phones *plus* adjusted components, while negative until January 2019, showed a predominantly positive trend thereafter, reflecting a proportionally larger increase in exports relative to the relevant component imports. This contrasts with analyses that sum all potentially related component imports without accounting for their specific use in mobile phone manufacturing. It further shows that net exports for *final* mobile phones turned positive from September 2018 (excluding the COVID-19 impact period), while the components sector, as expected, generally exhibited negative net exports. Crucially, when accounting for foreign exchange saved due to domestic production substituting imports of final mobile phones, the "Adjusted Trade Balance" reveals significantly larger net positive foreign exchange earnings for the country from February 2019 onwards compared to the unadjusted net export figures.

5.2 Domestic Value Addition (DVA) and Linkages

The growth in output and exports has been accompanied by a significant and evolving pattern of domestic value addition, indicating deepening linkages within the Indian economy.

- **Direct Domestic Value Added (DDVA):** This represents the value added directly within the mobile phone manufacturing plants (NPCMS 4722200). Our estimates, based on ASI data, indicate that DDVA has grown substantially. Our analysis reports an increase in average DDVA from $1,193 million during Phase 1 (2016-17 to 2018-19) to $4,571 million in Phase 2 (2019-20 to 2022-23), representing a 283% growth. This DDVA growth (283%) notably outpaced the average output growth (81%) during the comparable periods.

- **Indirect Domestic Value Added (IDVA) – Capturing Backward Linkages:** IDVA measures the value added in domestic upstream supplier industries. The growth in IDVA has been remarkable, signifying a substantial expansion of the domestic supplier ecosystem. Our computation, using KLEMS data to capture economy-wide linkages (both organised and unorganised

sectors), estimates that average IDVA surged by 604%, from $470 million in Phase 1 to $3,308 million in Phase 2. Even when considering only the organised sector (ASI-based IDVA), we show a 537% increase in IDVA. This rapid growth in IDVA underscores a significant positive "ripple effect" on the broader Indian economy.

- **Total Domestic Value Added (TDVA):** Combining direct and indirect contributions: TDVA (KLEMS-based for the whole economy) grew by an impressive 374%, from an average of $1,663 million in Phase 1 to $7,879 million in Phase 2. This growth rate is considerably higher than the 81% increase in overall mobile phone manufacturing output during the same period.

- **Share of DVA in Gross Output:** A critical indicator of deepening domestic capabilities. We show that the share of (total) DVA in the gross output of the mobile phone sector rose from an average of 9% in Phase 1 to more than 22% in Phase 2. This implies that, despite an increased production scale, the reliance on foreign value added (FVA) per unit of output declined, while domestic content increased. The Supply-Use and Input-Output Tables Using ASI Data report that, using KLEMS data, the DVA share of output reached 25% in 2019 (from 12% in 2016), while ASI-based figures show a peak of 26% in 2019 (from 13% in 2016, with a dip in between). The differences highlight the accounting for unorganised sector linkages, which KLEMS captures more broadly.

- **Deepening Domestic Linkages - Evidence from Input Coefficients:** Granular data from ASI, as we analysed, confirms a growing interconnectedness. There was a significant increase in both the *number* of domestically sourced components (NPCMS/NPCSS codes with technical coefficients ≥ 0.01) and the *average values of their technical coefficients* during Phase 2 compared to Phase 1. For instance, the average sum of technical coefficients for major domestic components rose from 0.37 in Phase 1 to 0.51 in Phase 2. This indicates that mobile phone manufacturers are incorporating more inputs from a broader range of domestic suppliers.

- **DVA in Exports:** The export boom has been a major driver of DVA. We estimate that the average DVA embodied in mobile phone exports surged by a phenomenal 2063%, from $62 million in Phase 1 to $1,335 million in Phase 2. Consequently, the share of DVA in gross exports also increased substantially, rising from around 9% in the early years (2016-17) to between 23% (2022) and a peak of 25% (2019) according to analysis. This suggests that exports are becoming increasingly embedded with domestic content. The FVA share in exports correspondingly declined from over 90% to around 77%.

5.3 Employment Generation

The expansion of the mobile phone manufacturing sector has had a profound impact on employment, both directly within the sector and indirectly in linked industries.

- **Direct Employment (ASI-based, organised sector):** Analysis reports a 497% growth in average direct employment, from 27,052 employees in Phase 1 to 1,61,623 in Phase 2. Direct employees reached 2,54,270 in the 2022-23 fiscal year.

- **Indirect Employment (KLEMS-based, total economy):** Average indirect employment supported by the sector grew by 87%, rising from 5,55,826 in Phase 1 to 10,36,876 in Phase 2. This reflects the positive spillover to upstream industries. Indirect employment within the organised sector alone (ASI-based) also showed significant growth.

- **Total Employment (Direct + Indirect, KLEMS-based):** The average total number of employees supported by the sector rose from 5,82,878 in Phase 1 to 11,98,498 in Phase 2.
- **Export-Related Employment:** The surge in exports has been a key driver of job creation. Direct employment attributed to mobile phone exports skyrocketed by 3327%, from an average of 856 employees in Phase 1 to 29,328 in Phase 2. Indirect employment linked to exports grew by 594%, from an average of 26,034 in Phase 1 to 1,80,807 in Phase 2. The total (direct + indirect) employment linked to exports increased by an average of 681% between the two periods.
- **Employment Composition:**
  - *Skill Categories:* Both production (blue-collar) and non-production (white-collar, supervisory, and managerial) workers experienced significant job growth. Direct production workers increased from an average of 23,683 (Phase 1) to 1,39,723 (Phase 2), while direct non-production workers grew from 3,368 to 21,898.
  - *Gender Dynamics:* A notable trend is the substantial increase in female employment. Direct employment for female production workers rose from an average of 4,605 in Phase 1 to 12,871 in Phase 2. For male production workers, the increase was from 10,200 to 22,993. The paper shows that direct female employment in production grew by 180% on average, and total female employment (direct + indirect) related to production grew by 37%.
  - *Contractualization:* A clear trend toward increased contractual employment is evident. The number of Total Contractual Workers (direct + indirect, related to production) increased by 207% on average between 2016-18 and 2019-22, compared to a 17% rise for Regular Workers.

5.4 Wages and Salaries

The employment growth has translated into significant increases in aggregate wages and salaries earned.

- **Direct Wages and Salaries (ASI-based):** These increased by 395%, from an average of $123 million in Phase 1 to $609 million in Phase 2. Income from wages and salaries directly tied to exports increased much faster, from an average of $4.19 million in Phase 1 to $109.61 million in Phase 2.
- **Total Wages and Salaries (KLEMS-based, Direct + Indirect for production):** These experienced a 33% growth, increasing from an average of $1,710 million in Phase 1 to $2,886 million in Phase 2.
- **Wage Dynamics by Employment Type:** Notably, average wages for Contractual Workers (linked to production) surged by 449% (from $224 million to $1,226 million between 2016-18 and 2019-22 averages), far exceeding the 63% growth for Regular Workers (from $458 million to $746 million). This, combined with the increasing share of contractual workers, suggests complex dynamics in the wage structure.

5.5 Evidence of Product Upgrading

The sector shows tangible signs of moving towards higher-value production, a crucial indicator of successful GVC participation.

- **Rising Export Unit Values (UVs):** Analysis by us reveals a positive trend, with India's export unit values for mobile phones steadily increasing across major export markets and approaching

those of its competitors (China, Korea, Vietnam) by 2022. This suggests an improvement in the quality and sophistication of exported mobile phones.

- **Output Quality Index (OQI):** The OQI, constructed from ASI plant-level data (base year 2016 = 100), provides further evidence. We show the average OQI doubling from 145 during 2016-18 to 318 during 2019-22, representing a growth of 119%. The paper presents findings, with the OQI (base 2016) peaking at 438 in 2019 and maintaining a significantly higher average in the 2019-22 compared to 2016-18. This significant rise is partly attributed to the entry of premium mobile phone manufacturers, such as Apple, into the Indian production ecosystem.

In summary, the empirical results paint a picture of a highly dynamic mobile phone manufacturing sector in India that has not only scaled up production and exports dramatically but has also significantly deepened its domestic linkages, generated substantial employment and wage income, and begun a process of product upgrading. The shift in policy orientation towards export promotion and scale appears to have coincided with amplified gains in DVA and export-related employment.

6 Discussion

The empirical findings presented in Section 5 provide a rich and nuanced perspective on India's involvement in the global mobile phone manufacturing value chain. This section discusses these results in the context of our theoretical framework, addresses the ongoing debate regarding the nature of India's manufacturing growth, and considers the policy implications and limitations of our analysis.

6.1 Interpreting the Findings: Beyond Assembly and Towards Deeper Linkages

A key debate surrounding India's recent manufacturing surge, particularly in electronics, revolves around whether it represents genuine industrial deepening or merely low-value final assembly heavily reliant on imported components (Rajan & Lamba, 2023; Chauhan et al., 2023). Our findings provide substantial evidence to suggest a more optimistic and complex reality.

- **The Significance of Indirect Domestic Value Added (IDVA):** The extraordinary growth in IDVA (a 501% increase in the economy-wide average between Phase 1 and Phase 2, as shown is perhaps the most compelling evidence against a simplistic "assembly-only" narrative. This surge in value added within domestic upstream supplier industries indicates a significant strengthening of backward linkages. Mobile phone manufacturers are increasingly sourcing components and services from within India, stimulating a wider network of domestic economic activity. This finding aligns with the theoretical expectation that GVC participation, even if initially focused on assembly, can spur broader industrial development if domestic linkages are fostered. The increase in the average technical coefficients for domestically sourced inputs provides micro-level corroboration of this deepening integration.

- **Evolving DVA/FVA Composition:** The rise in the overall share of DVA in gross output from an average of 9% in Phase 1 to +22% in Phase 2 further supports this. While FVA in absolute terms also grew due to the industry's sheer expansion, the increasing proportion of value captured domestically per unit of output points towards the maturation of the domestic ecosystem. It suggests that India is not merely a passive recipient of foreign components but is increasingly contributing its value to the final product. The DVA share in exports also showed a marked increase, reinforcing that Indian exports are becoming more domestically embedded.

- **Policy Effectiveness (PMP vs. NPE/PLI):** The comparative analysis across the two policy phases suggests that the shift from an import-substitution focus (PMP, Phase 1) to an export-oriented, scale-focused approach (NPE/PLI, Phase 2) has been instrumental in achieving policy effectiveness. While PMP likely laid some foundational groundwork for assembly, the policies in Phase 2 appear to have catalysed a more significant expansion in overall DVA (mainly indirect DVA), exports, and export-linked DVA and employment. This aligns with the theoretical understanding that producing for the global market can unlock scale and efficiency gains, which, in turn, create more substantial opportunities for value addition and job creation than a purely domestic market focus.

- **Addressing Trade Balance Critiques:** Our refined methodology for calculating the net trade impact of the mobile phone sector, which meticulously accounts for the actual use of imported components in mobile phone production and the foreign exchange saved through import substitution, presents a more encouraging picture than some critiques suggest. While component import dependency is undeniable, particularly for high-tech items, the overall foreign exchange impact, when correctly measured, turned positive and has been growing. This methodological refinement is a key contribution to accurately assessing the sector's external balance implications.

- **Job Creation – Quantity, Quality, and Composition:** The sector's average support of over a million direct and indirect jobs in Phase 2 is a significant developmental outcome, addressing India's pressing need for job creation. The exponential growth in export-related employment underscores the job-creating potential of GVC integration. However, the discussion must also acknowledge nuances in job quality. The faster growth in contractual employment compared to regular employment warrants policy attention to ensure fair labour practices and social security. Simultaneously, the marked increase in female employment, particularly in direct manufacturing roles, is a highly positive development for gender inclusivity and women's economic empowerment; however, further research into the quality and stability of these roles is warranted. The surge in wages for contractual workers, while numerically impressive, also needs to be contextualised against their baseline and job security.

- **Upgrading Dynamics – An Incipient Journey:** The evidence of product upgrading, indicated by rising export unit values and the doubling of the Output Quality Index (OQI), is a crucial finding. It suggests that India is not static in the "trough" of the smile curve but is beginning to move towards producing higher-value goods. The entry of premium manufacturers, such as Apple, has likely accelerated this trend. This aligns with the theoretical expectation that GVC participation can provide learning opportunities and pathways for upgrading, even from an initial assembly base. However, this is likely the beginning of a longer journey towards significant functional upgrading (e.g., R&D, design, branding).

6.2 India's Trajectory in the "Flying Geese" Paradigm

The rapid expansion of India's mobile phone assembly and export operations, particularly in Phase 2, can be interpreted within the "Flying Geese" model. As China gradually shifts its focus within the electronics Global Value Chain (GVC) towards more sophisticated components and R&D, a window of opportunity has indeed opened for countries like India and Vietnam to capture a larger share of labour-intensive assembly. Our findings suggest that India is successfully capitalising on this shift. The critical question, however, is India's future trajectory within this paradigm. Will it remain primarily an assembly hub, or can it leverage this phase to build capabilities for moving into higher-value segments of the GVC, similar to the path taken by earlier "follower geese" such as South Korea or even China

itself? The observed deepening of domestic linkages and initial signs of product upgrading are positive indicators. However, sustained progress will require concerted policy efforts to build a robust domestic component ecosystem, foster innovation, and develop a high-skilled workforce. Without these, the risk of remaining in a relatively lower-value segment of the "smile curve" persists.

6.3 Robustness, Limitations, and Methodological Considerations

The findings of this paper are strengthened by the use of highly disaggregated firm-level data and a rigorous IO methodology. The construction of detailed SUTs and IOTs specifically for the Indian manufacturing landscape at the 7-digit NPCMS level represents a significant advancement for policy analysis. However, certain limitations inherent in the IO framework and data availability should be acknowledged:

- **Proportionality Assumption:** The allocation of inputs in multi-product firms based on output shares is a standard practice, but remains an assumption.
- **Static Framework:** The IO analysis is static and does not capture dynamic general equilibrium effects, such as how increased incomes from GVC employment might further stimulate demand in other sectors (multiplier effects), or the long-term productivity spillovers from participating in GVCs. Thus, the estimated employment and DVA impacts, while substantial, might still be conservative in capturing the full dynamic benefits.
- **Data Considerations:** While ASI data is comprehensive for the organised sector, incorporating the unorganised sector through KLEMS involves some level of aggregation and concordance, which may have limitations. The timeliness of official data releases can also be a constraint for analysing the most current trends. The distinction between "workers" and "non-workers" or skill categorisations in ASI may not perfectly map to economically defined skill levels.

Despite these limitations, the detailed and internally consistent framework developed here provides one of the most robust assessments to date of the economic impact of a key GVC-integrated sector in India.

7 Policy Implications

The empirical findings of this study, which demonstrate significant domestic value addition, robust employment generation, and nascent upgrading within India's mobile phone manufacturing Global Value Chain (GVC), offer valuable lessons for economic policy. A multi-pronged and strategically coherent policy approach is imperative to sustain and deepen these gains and replicate this success in other potential GVC-intensive sectors. The following recommendations, primarily informed by the analysis and supported by the detailed IO framework developed, are designed to foster deeper GVC integration and enhance domestic capabilities.

7.1 Fine-tuning Trade Policy for Seamless GVC Integration

Efficient integration into Global Value Chains (GVCs) necessitates a trade policy regime that minimises transaction costs and facilitates the smooth flow of intermediate goods.

- **Calibrated Import Tariffs:** Our findings show that while domestic linkages deepen, imported components remain crucial, especially in the initial phases of GVC participation and for technologically advanced inputs. Therefore, maintaining a relatively low and stable tariff regime, particularly for intermediate inputs and capital goods that are not yet produced competitively in

India, is crucial. This reduces production costs for firms operating in India, enhances their export competitiveness, and avoids disincentivising investment in domestic assembly and manufacturing operations that rely on global sourcing. Sudden or high tariffs on essential inputs can disrupt nascent value chains and undermine competitiveness.

- **Strategic Use of Rules of Origin (RoO) in Free Trade Agreements (FTAs):** As India engages in new FTAs, RoO should be designed to encourage Global Value Chain (GVC) trade. Overly restrictive RoO can hinder firms' ability to source inputs optimally from global markets, thereby limiting their participation in complex GVCs. A practical approach would involve negotiating for RoO that are facilitative of GVCs, perhaps allowing for regional or global cumulation, especially for products where India is aiming to become an assembly or manufacturing hub but does not yet possess deep backward integration for all components.

7.2 Strengthening the Domestic Ecosystem for Value Capture and Creation

While participating in GVCs is crucial, maximising the benefits requires a robust domestic ecosystem that can support and complement global linkages.

- **Reducing Service Link Costs:** The efficiency of "service links"—logistics, customs procedures, finance, and telecommunications—is paramount for GVC operations. India has made commendable strides in improving the ease of doing business. However, continuous efforts are needed to streamline administrative processes further, enhance digital infrastructure for trade facilitation, and reduce both the time and monetary costs associated with cross-border trade. The SUTs developed highlight the significant share of services, such as trade and transport, as inputs, underscoring their importance.

- **Aggressively Fostering a Domestic Component Ecosystem:** The substantial growth in IDVA observed indicates progress, but a more concerted effort is needed to build a deep and diversified domestic component base, particularly for high-value components.

  - *Targeted Incentives:* Special incentives, potentially extending beyond the PLI framework, should be considered to attract investment, both domestic and foreign, in the manufacturing of critical components such as semiconductors, display panels, advanced battery technologies, camera modules, and precision mechanics.

  - *Promoting Joint Ventures and Technology Transfer:* Encourage strategic joint ventures between Indian firms and leading global component manufacturers to facilitate the absorption of technology and enhance R&D capabilities within India.

  - *Dedicated Infrastructure:* Establishing well-equipped Special Economic Zones (SEZs) or manufacturing clusters with "plug-and-play" infrastructure designed explicitly for component suppliers can lower entry barriers and attract anchor investors in the component segment. This was a key success factor in other East Asian economies.

- **Empowering Small and Medium Enterprises (SMEs):** SMEs often form the backbone of the deeper supplier tiers in GVCs. Policies should focus on:

  - *Facilitating SME Linkages:* Creating platforms (e.g., digital B2B portals) to connect domestic SMEs with lead firms and first-tier suppliers in GVCs.

  - *Simplifying Regulatory Compliance:* Streamlining regulatory processes and reducing compliance burdens for SMEs aiming to enter GVCs will be crucial.

– *Access to Finance and Technology:* Enhancing SMEs' access to affordable finance and technology upgrading schemes.

7.3 Strategically Moving Up the Value Chain

The long-term objective should be to move beyond assembly towards higher DVA activities. Our initial findings on product upgrading are encouraging but require active nurturing.

- **Focus on Deeper Integration, Not Just Import Substitution:** While the PMP phase focused on progressive localisation through import substitution, the NPE/PLI phase has rightly emphasised scale and export competitiveness. The policy focus should remain on deeper *integration* within Global Value Chains (GVCs), which involves becoming a reliable and efficient node in global production networks, rather than on forced or inefficient import substitution that could harm competitiveness. True DVA enhancement stems from improving capabilities and efficiency, enabling Indian firms to undertake more complex tasks.
- **Incentivising R&D and Design Capabilities:** Transitioning from assembly to activities like product design, engineering, and R&D is key to capturing more value. Policies could include fiscal incentives for R&D expenditures, support for establishing design houses, and strengthening industry-academia linkages to foster innovation.
- **Skill Development for Higher-Value Activities:** The workforce needs to be equipped with the skills required for more sophisticated manufacturing processes, R&D, and global value chain (GVC) management. This requires a proactive approach to vocational training and higher education that is aligned with industry needs.

7.4 Ensuring Enabling Factor Conditions

Broader structural reforms are essential complements to sector-specific policies.

- **Labour Market Reforms:** While the mobile sector has created many jobs, the rise in contractual employment needs to be balanced with measures that ensure worker welfare and encourage skill formation. Flexible labour laws that enable firms to adapt to global demand fluctuations, combined with robust social safety nets and mechanisms for skill certification and mobility, are crucial.
- **Streamlined Land Acquisition and Infrastructure Development:** Efficient and transparent land acquisition processes are crucial for establishing large-scale manufacturing facilities and supplier parks. Continued investment in quality infrastructure (power, logistics) remains vital.

7.5 Leveraging the SUT-IOT Framework for Evidence-Based Policy

The detailed SUTs and IOTs, constructed at the 7-digit NPCMS level using ASI data as demonstrated in this research, provide a powerful analytical tool for policymakers. This framework can be used for:

- **Ex-ante Policy Impact Assessment:** Evaluating the potential economy-wide effects (DVA, employment, inter-sectoral flows) of proposed policy changes or new incentive schemes.
- **Identifying Key Sectors and Products:** Pinpointing specific products or upstream sectors that have high backward linkage potential and could be targeted for strategic promotion to maximise domestic economic impact.

- **Monitoring GVC Integration:** Regularly updating and analysing these tables can help track the progress of GVC integration, the deepening of domestic linkages, and shifts in value capture over time.

By adopting these policy measures, India can build upon the success observed in the mobile phone manufacturing sector, transforming itself into a more competitive and resilient global manufacturing hub, thereby creating high-quality jobs and fostering sustainable economic growth. The journey involves not only participating in GVCs but also strategically navigating them to maximise domestic value creation and technological advancement.

8 Conclusion

This paper has undertaken a rigorous and highly granular examination of India's participation in the global value chain for mobile phone manufacturing. This sector has witnessed transformative growth in recent years. By constructing and deploying detailed Supply-Use Tables (SUTs) and Input-Output Tables (IOTs) at the 7-digit NPCMS product level from firm-level ASI data for the period 2016-17 to 2021-22, this study offers novel insights into the true extent of domestic value addition (DVA), employment generation, trade impacts, and upgrading dynamics.

8.1 Summary of Key Findings

Our empirical analysis reveals a compelling narrative of success and structural evolution.

- **Dramatic Output and Export Expansion:** India's mobile phone manufacturing output surged, accompanied by a pivotal shift from import dependence to significant export orientation, particularly under the NPE 2019 and PLI policy regime (Phase 2).
- **Substantial Domestic Value Addition and Deepening Linkages:** Contrary to narratives suggesting mere low-value assembly, we find significant growth in overall DVA. Critically, indirect DVA (capturing backward linkages) grew at an exceptional rate (501% average economy-wide growth between Phase 1 and Phase 2), indicating a substantial deepening of the domestic supplier ecosystem. The share of DVA in gross output rose to an average of +22% in Phase 2, and DVA embodied in exports increased over fourteenfold.
- **Significant Employment Generation:** The sector has become a primary source of employment, supporting over a million direct and indirect jobs on average during Phase 2. Export-oriented activities have been particularly job-intensive. The analysis also highlights a significant increase in female employment, though accompanied by a notable rise in contractual labour.
- **Nuanced Trade Impact:** Our refined methodology, which accounts for the specific use of imported components in mobile manufacturing and the foreign exchange saved through import substitution, shows a positive and growing adjusted trade balance for the sector since early 2019, offering a more optimistic perspective than some critics suggest.
- **Incipient Product Upgrading:** Evidence from rising export unit values and a doubling of the Output Quality Index (OQI) between 2016-18 and 2019-22 suggests tangible product upgrading within the sector, indicating a shift towards higher-value segments.

8.2 Contribution Revisited

This paper's primary contribution lies in its robust methodological approach and the granular empirical evidence it brings to bear on the debate surrounding India's GVC participation. By moving beyond aggregate statistics and employing a detailed input-output (IO) framework, we provide a more accurate and nuanced assessment of the economic impacts of the mobile phone manufacturing global value chain (GVC). The findings challenge simplistic views of assembly-led growth and highlight the potential for significant domestic economic benefits when GVC participation is coupled with policies that foster scale, export competitiveness, and domestic linkages. The construction of such detailed SUTs/IOTs for the Indian economy is, in itself, a valuable contribution to the toolkit for evidence-based policymaking.

8.3 Overall Assessment and Future Trajectory

India's journey in the mobile phone manufacturing Global Value Chain (GVC) demonstrates that a developing country can successfully leverage global production networks to achieve significant economic gains, including substantial Domestic Value Added (DVA), large-scale job creation, and initial steps towards industrial upgrading. The transition from an import-substitution policy (PMP) to an export-oriented, scale-focused strategy (NPE/PLI) appears to have been pivotal in unlocking these benefits more fully.

The path forward, however, requires continuous strategic effort. While India has successfully entered the Global Value Chain (GVC) and deepened its domestic linkages in assembly and related activities, the next challenge lies in further advancing the value chain. This involves fostering a more comprehensive domestic component ecosystem, particularly for high-value inputs, enhancing R&D and design capabilities, and further improving the overall business and infrastructure environment. The "Flying Geese" paradigm suggests that such an upward trajectory is possible, but it is not automatic and depends critically on sustained and well-directed policy support.

8.4 Avenues for Future Research

This study opens several avenues for future research:

- **Extension to Other Sectors:** The methodological framework developed here can be applied to other GVC-intensive sectors in India (e.g., other electronics sub-sectors, automotive, textiles) to provide a comparative perspective on DVA and employment impacts.
- **Firm Heterogeneity:** Investigating how DVA capture and GVC participation vary across firms of different sizes, ownership structures (domestic vs. foreign), and technological capabilities would offer more profound insights.
- **Dynamic General Equilibrium Modelling:** Although this study employs a static IO framework, future research could utilise dynamic general equilibrium models to capture the broader, long-term impacts of GVC integration, including productivity spillovers and induced consumption effects.
- **Quality of Employment:** More in-depth qualitative and quantitative research is needed on the quality, stability, and skill content of the jobs being created, particularly concerning contractual and female employment.
- **Impact of Specific Policy Levers:** Econometric analysis could be used to more formally identify the causal impact of specific policy interventions (e.g., PLI disbursements) on firm-level DVA, investment, and upgrading decisions.

- **Forward Linkages and Services GVCs:** While this paper focused on backward linkages in manufacturing, analysing India's growing role in services GVCs and the forward linkages from manufacturing into services (e.g., apps, content for mobile devices) would provide a more complete picture.

In conclusion, India's engagement with the global mobile phone value chain (GVC) provides a powerful illustration of development through trade and integration. By continuing to refine its policy framework and invest in domestic capabilities, India is well-positioned to not only consolidate its gains in this sector but also to emerge as a more significant and sophisticated player in the global manufacturing landscape, truly "Making in India for the World."

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A Appendices

The Appendices provide detailed supplementary material that is too extensive for the main body of the paper but is essential for transparency, replicability, and a deeper understanding of our methodology and findings. Based on our framework and the documents, potential appendices (which we can show upon request) include:

A.1 Detailed Methodology for SUT and IOT Construction

This would elaborate on the steps outlined in Section 4.2. It should include:

- More detailed explanation of data cleaning and aggregation from ASI.
- The NPCMS-NIC concordance approach.
- Mathematical derivations for the Industry Technology Assumption (ITA) based transformations, including matrix algebra for V, U, C, T, A_d, R_v.
- Explanation of the balancing process for SUTs.
- Details on integrating organised (ASI) and unorganised (KLEMS/NSSO) sector data.

A.2 List of Major Domestic and Foreign Components Sourced by the Mobile Phone Industry (NPCMS 4722200)

This would present tables showing the key NPCMS/NPCSS codes for domestic and foreign inputs, along with their technical coefficients or shares for different years and phases.

A.3 Calculation of Adjusted Component Imports and Foreign Exchange Savings

- Detailed tables showing the mapping of HS codes to NPCMS codes for key components.
- The estimated Ratio 1 and Ratio 2 values for these components.
- Step-by-step calculation of "Adjusted Imports of Components."
- Data and calculations for the "Foreign Exchange Saved" counterfactual analysis.
- Annual data, and potentially the separate graphs for final mobile phones and components from Appendix D.

A.4 Supplementary Tables on DVA, Employment, and Wages

More disaggregated results are not fully presented in the main text. For example:

- Detailed year-wise DVA (direct, indirect, total) for both the organised and the total economy.
- Comprehensive tables on employment categories (production/non-production, male/female, regular/contractual, direct/indirect) for production and exports.
- Similar detailed tables for wages and salaries across various disaggregations.

A.5 Output Quality Index (OQI) – Construction Details and Data

- A more detailed explanation of the weighting scheme and data sources (plant-level unit prices from ASI) used to construct the OQI.
- Annual values for the OQI and potentially its sub-components (domestic vs. export quality if calculated separately).

A.6 Key NPCMS/HS Code Concordance Table (Optional)

A table showing the concordance for the most important product codes used in the analysis, if it aids clarity beyond what is in Appendix C.