

Evolution of Global Value Chain Participation of Indian Automotive Component Suppliers: A Clustering Analysis Based on OECD TiVA Data

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1. Introduction

This study examines the enhancement of international competitiveness in India's automotive manufacturing industry from 1995 to 2014, with a focus on the evolution of its participation structure within global value chains (GVCs). Using the OECD-WTO Trade in Value Added (TiVA) database, the analysis evaluates India's automotive sector from a value-added perspective. The industrial classification follows ISIC Rev.4, Division 29 ("Manufacture of motor vehicles, trailers, and semi-trailers").

In particular, the indicator EXGR_INT_DVA_PSH (Domestic value added in gross exports of intermediate products, destination partner shares) is employed to examine the share of domestic value added (DVA) embodied in India's intermediate goods exports, by destination country, restricted to direct processing partners ("first-hop" countries). Applying a new AI-based Hierarchical Risk Parity (HRP) clustering method, this study identifies the grouping and temporal transition of partner-country structures that are difficult to capture in traditional aggregate analyses. The results reveal the emergence of new markets and structural realignments in India's export destinations. Notably, the share of African countries such as South Africa and Nigeria has increased significantly, while linkages with the Middle East and ASEAN countries have also expanded.

These findings are consistent with the vision presented by R. C. Bhargava in his book *Getting Competitive: A Practitioner's Guide for India* [1]. Bhargava emphasized that India should move beyond protectionism, foster a market environment driven by efficiency and quality, and cultivate mutual trust and continuous improvement across both management and labor. He highlighted that adopting Japanese-style management practices and strengthening collaboration with local suppliers would enable higher local content ratios, as well as the coexistence of high quality and low cost. The diversification of India's export markets and the growing autonomy of its domestic supply chain, as observed in this study, can be interpreted as the realization of Bhargava's envisioned transformation within the Indian automotive industry.

The remainder of this paper is structured as follows. Section 2 outlines the conceptual framework of global value chains and defines the key indicators used in this study. Section 3 presents time-series analyses of Pure Forward Participation, Pure Backward Participation, and EXGR_INT_DVA_PSH based on OECD TiVA data. Section 4 discusses the theoretical positioning of supply chain upgrading and modularization, referencing the case of supplier development led by Maruti Suzuki. Section 5 applies clustering analysis to country-level time series of EXGR_INT_DVA_PSH, clarifying the multipolarization of export markets and the rise of emerging economies. Finally, Section 6 concludes the paper by summarizing key findings and presenting implications for enhancing the international competitiveness of India's automotive sector.

2. Definition of Indicators Related to Global Value Chains (GVC)

This section explains the definitions of the indicators concerning Global Value Chains (GVC).

2.1 Concept of Global Value Chains (GVC)

A Global Value Chain (GVC) refers to an international division of labor in which the production of goods and services spans multiple countries and regions. Each country specializes in different stages of production—such as component manufacturing, assembly, design, and sales—creating value added (VA) at each stage. The modern automotive industry is a representative GVC-type sector, where a single vehicle is composed of thousands of components, many of which are supplied through multi-country networks. In recent years, India has been integrated into the international production network, not only as a manufacturer of finished vehicles but also as a supplier of automotive components. For example, Indian suppliers export wire harnesses and engine parts to European manufacturers, which are then assembled abroad and sold in third-country markets. Thus, India has become a participant in both the upstream (component supply) and downstream (vehicle export) segments of GVCs.

2.2 Definition of Forward and Backward Participation

In the OECD TiVA framework, Forward Participation refers to the share of a country's domestic value added (DVA) that is embodied in the exports of other countries. In other words, it captures cases where a country's intermediate goods are processed abroad and subsequently re-exported to third countries. For instance, if the Indian supplier Bharat Forge Ltd. exports crankshafts to Germany, which are then assembled into vehicles and re-exported to the United States, the value added originating from India is counted as part of its Forward Participation.

Conversely, Backward Participation refers to the share of foreign value added (FVA) embodied in a country's exports. For example, if an Indian automaker assembles cars using engines imported from Japan and exports the finished vehicles to Africa, the portion of

Japanese value added embedded in the exported cars is included in India's Backward Participation.

However, conventional Forward Participation measures often include multiple re-export stages, leading to potential double-counting of value-added. To address this issue, the concept of Pure Forward GVC Participation is defined as follows:

- Pure Forward GVC Participation (Value): The portion of a country's domestic value added (DVA) that is exported as intermediate goods, processed once abroad, and re-exported to final demand in a third country.
- Pure Forward GVC Participation (Rate): The ratio of Pure Forward Participation value to the country's total exports or total trade.

Examples:

1. Pure Forward Case: Japan → Korea → United States (final consumption). The Japanese components are processed once in Korea and re-exported to the U.S. for final consumption.
2. Excluded Case (Direct Consumption): Japan → Korea (final consumption). No re-export occurs.
3. Excluded Case (Multi-step Re-export): Japan → Korea → United States → Canada (final consumption). Multiple re-exports beyond the first hop are excluded.

Similarly, Pure Backward GVC Participation is defined as follows:

- Pure Backward GVC Participation (Value): The portion of imported intermediate goods (FVA) that is processed once domestically and re-exported.
- Pure Backward GVC Participation (Rate): The ratio of Pure Backward Participation value to total exports.

Examples:

1. Pure Backward Case: India imports components from Japan, assembles vehicles, and exports the finished products to the United States.
2. Excluded Case (Indirect Imports): India imports parts from Thailand that initially came from Japan—these Japanese value-added products are excluded from India's Pure Backward measure.

Both indicators—Pure Forward and Pure Backward GVC Participation—can be accessed from the World Integrated Trade Solution (WITS) database [2]. The definitions used in this study follow the OECD TiVA framework [3]. It is important to note that the World Bank's GVC indicators [4] differ from the OECD definitions in their scope and treatment of re-exports, so direct numerical comparison should be made with caution.

In this study, the indicator EXGR_INT_DVA_PSH from the OECD TiVA database is used as a practical proxy for Pure Forward Participation. This variable represents the share of

domestic value added embodied in intermediate exports relative to gross exports. Its component terms are defined as follows:

- EXGR: Gross Exports
- INT: Intermediate Products
- DVA: Domestic Value Added
- PSH: Percentage Share

The EXGR_INT_DVA_PSH indicator includes both cases where intermediate goods are used for final demand in the partner country and where they are further re-exported. Therefore, it is conceptually broader than Pure Forward GVC Participation. The dataset used in this analysis was obtained from the OECD TiVA Data Explorer (“Trade in Value Added (TiVA) 2023 edition: Principal Indicators, shares [cloud replica]”) [5].

3. Analysis of GVC Data

This section examines the time series changes of key indicators related to India’s participation in global value chains (GVCs), with a primary focus on the automotive manufacturing sector.

3.1 Trends in Pure Forward GVC Participation

Figure 1 presents the time-series evolution of the total value of India’s *Pure Forward GVC Participation* in the automotive manufacturing sector. The data were obtained from the WITS GVC Trade Table and its *GVC Visualization* portal [2]. Figure 2 shows the time-series changes in the participation rate (share of domestic value added). The rate rose steadily from approximately 8% in 1995 to 16% in 2020.

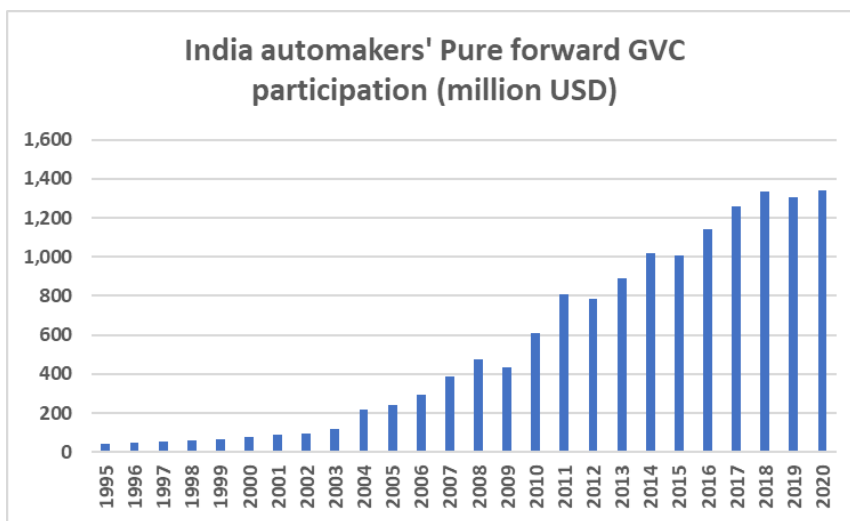


Fig. 1: India’s *Pure Forward GVC Participation* in the automotive manufacturing sector.

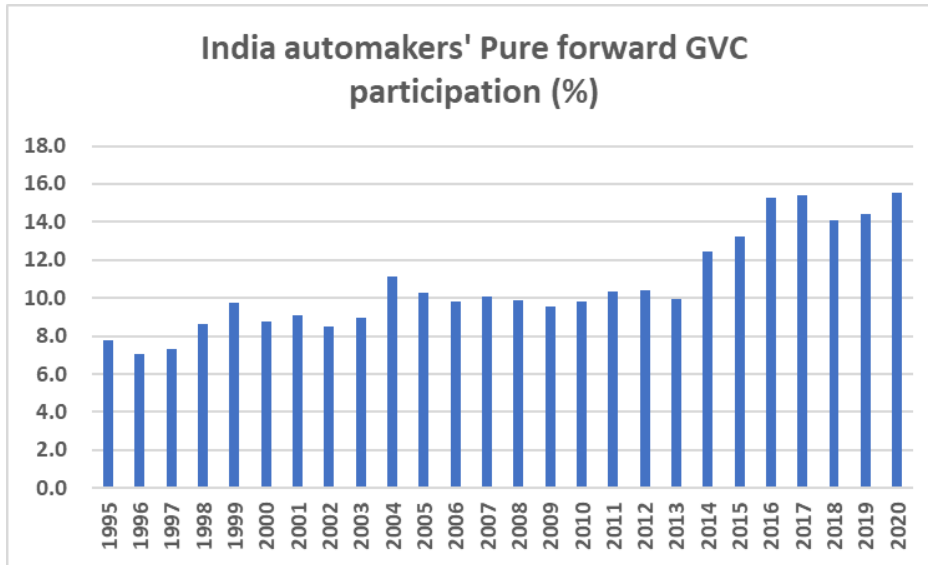


Fig. 2: India automakers' Pure forward GVC participation percentage.

The growth of total *Pure forward GVC participation* can be interpreted as follows:

- 1995–2002: Limited and small-scale participation**
 The level remained nearly flat (around 50–100 million USD). Component exports were limited, with the domestic market being the dominant one. Tier-1 and Tier-2 suppliers had limited international experience.
- 2003–2010: Rapid expansion of component exports**
 Supplier development initiatives by multinational and domestic automakers accelerated. Improvements in quality control, delivery compliance, and cost competitiveness reached international standards. As a result, exports of parts and units that were processed once and then re-exported to third countries increased sharply.
- 2011–2020: Stable growth**
 Values stabilized above 1 billion USD. Indian components became integrated into multiple international OEM production networks. Export destinations have diversified, with an increasing number of shipments to emerging markets.

This study examines the historical lineage of supplier development, which originated from Maruti Udyog Limited (later renamed *Maruti Suzuki India Limited*), an enterprise established in 1981. The technical collaboration with **Suzuki Motor Corporation** in 1982 facilitated technology transfer and local parts procurement, laying the groundwork for India's increased participation in global value chains. Although other domestic and foreign firms also contributed, the origin of India's supplier development can be traced directly to Maruti Udyog [1], [6]–[11].

Since no quantitative data exist specifying the contribution of individual firms to supplier development, this study relies on qualitative evidence. The author (Y. Shirota) interviewed with **Mr. R. C. Bhargava**, Chairman of Maruti Suzuki India, in New Delhi on July 28, 2025. Mr. Bhargava confirmed that the company's supplier development initiatives began with Maruti Udyog under the leadership of **Osamu Suzuki** (former President and later Chairman of Suzuki Motor Corporation, deceased 2024) [9]. Bhargava stated that Osamu Suzuki's most significant

achievement was strengthening the capabilities and international competitiveness of India's Tier 1 and Tier 2 suppliers. This testimony strongly supports the hypothesis that the long-term growth of Pure Forward GVC participation reflects the outcomes of Maruti's supplier development strategy.

The OECD report [12] also supports this interpretation:

"In 2020, the shares of domestic and foreign value added (DVA and FVA) in India's exports vary significantly across industries. While the ICT and service sectors are largely domestically driven, the manufacturing sector relies relatively more on imported intermediates. Nevertheless, in the automotive and transport equipment industries, despite a notable share of imported components, domestic value added still accounts for more than half of total export value."

This indicates that the automotive sector exhibits an exceptionally high DVA ratio compared with other manufacturing industries.

3.2 Changes in Pure Forward and Pure Backward GVC Participation

To examine the structural dynamics of domestic and foreign value added, Figure 3 compares the evolution of *Pure Forward* and *Pure Backward* participation rates.

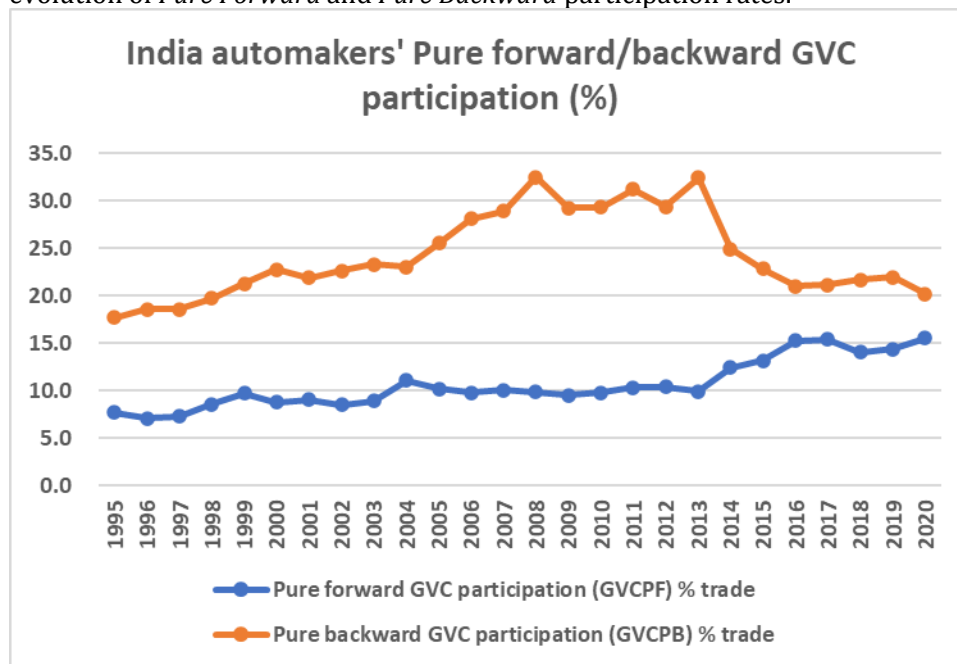


Fig. 3: India automakers' Pure forward/backward GVC participation percentage.

From 1995 to 2020, India's **Pure Forward GVC participation rate** increased steadily from **7.7% to 15.5%**. This indicates that a growing share of domestically produced intermediate goods and components is incorporated into other countries' exports. It reflects the strengthening of India's supply capacity for the multi-plant production networks of international OEMs.

Conversely, the **Pure Backward GVC participation rate** rose from **17.7% in 1995 to over 31% in 2011**, but then declined to **20.25% in 2020**. This decline suggests a reduction in

dependency on imported intermediates and an improvement in local sourcing and domestic manufacturing capability. Since 2014, forward and backward participation rates have converged, implying a structural shift in India’s role within global value chains—from a final assembly base toward a hub for intermediate goods exports with higher domestic value added.

3.3 Dynamics of EXGR_INT_DVA_PSH

Figure 4 illustrates the time-series changes in India’s *EXGR_INT_DVA_PSH* by major partner countries (and selected regions). There are nine destination countries.

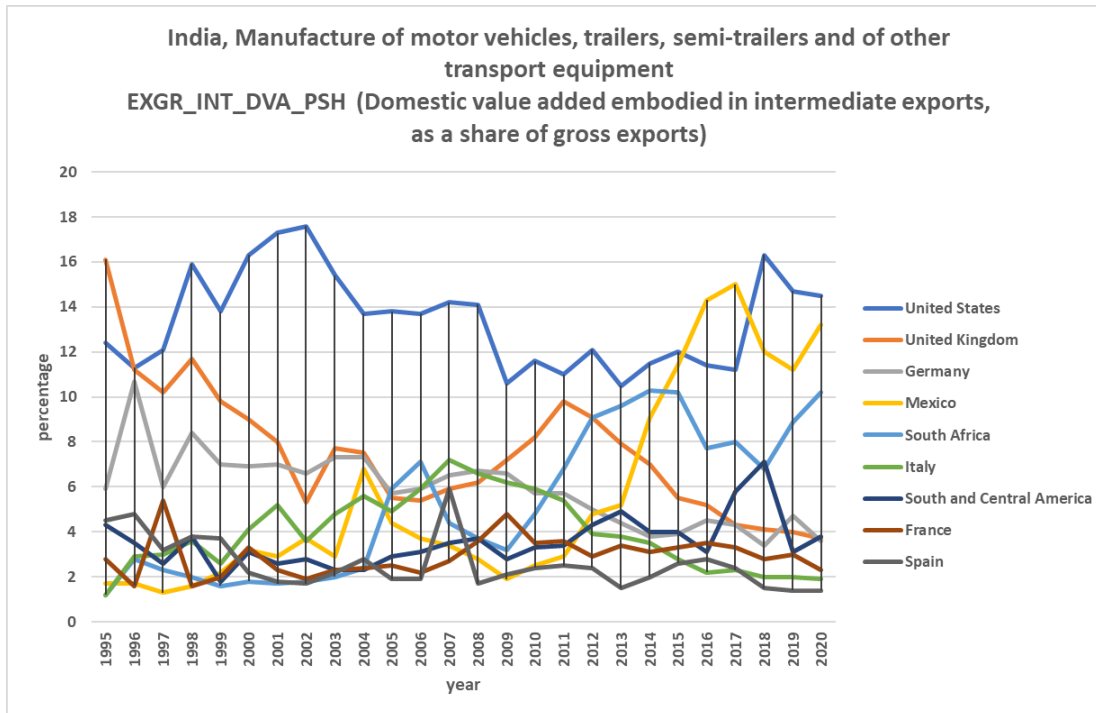


Fig. 4: EXGR_INT_DVA_PSH movements of India to the countries.

The United States consistently maintained the highest share, though after 2015, **Mexico** temporarily surpassed it, ranking first. The dominance of the U.S. market reflects its position as a major importer of Indian automotive parts—especially engine components, wiring harnesses, and cast products—which are used both in vehicle assembly and aftermarket repairs.

The **North American Free Trade Agreement (NAFTA, 1994–2020)** eliminated most tariffs among the U.S., Canada, and Mexico, promoting regional supply chain integration. Under this framework, Mexico became an efficient production and export hub, complementing high-value-added processes in the U.S. and Canada. Major automakers, including GM, Ford, Stellantis, Volkswagen, and Toyota, have established large-scale operations in Mexico, exporting a substantial share of their output to the U.S. market. According to **Inomata** [13], [14], “the full structure of the North American automotive supply chain was transplanted from the U.S. to Mexico.”

Indian exports of automotive components to Mexico are often integrated into vehicles destined

for the U.S. market, allowing Indian-made components—characterized by low import dependence—to maintain a high domestic value-added ratio for India.

The share of **South Africa** also increased markedly, from **1.2% in 1995 to 10.2% in 2020**. This expansion reflects the growth of South Africa as an export base for both African and selected European markets, and the strengthening of the India–South Africa component supply network, supported by historical and economic ties between the two countries.

4. Upgrading of Supply Chains in India’s Automotive Industry

The upgrading of supply chains in the automotive sector has long been a central theme in research on global value chains (GVCs). **Humphrey and Schmitz** conceptualized the process by which suppliers in developing countries enhance their capabilities through the technical and organizational support provided by multinational Original Equipment Manufacturers (OEMs). They categorized this process into four types of “upgrading”: **product, process, functional, and chain upgrading** [15], [16]. The automotive industry represents a prototypical case of a highly integrated GVC. Suppliers must meet stringent requirements concerning quality, cost, and delivery, and in doing so, they are compelled to enhance their technological and managerial competencies.

In parallel, **Gereffi et al.** [17] proposed a typology of GVC governance structures that evolve from **hierarchical integration** to **relational** and **market-based** coordination. As these structures develop, the asymmetry of power between lead firms and suppliers tends to decrease, and direct intervention in production processes becomes less prevalent. In the automotive industry, suppliers were initially incorporated under tight vertical integration by OEMs. However, with the advancement of **modularization** and **international production networks**, the relationships between OEMs and suppliers became increasingly interdependent. In specific component categories, transactions have shifted toward market-based relationships.

A notable case is **Samvardhana Motherson International Ltd.** [18], which was nurtured initially as an early supplier of *Maruti Udyog* and subsequently grew into a global Tier-1 supplier serving manufacturers such as Volkswagen and Mercedes-Benz. The company’s core products—wiring harnesses, plastic components, and interior modules—belong to relatively standardized and modularized domains, which facilitated greater transaction flexibility and global integration.

Regarding modularization, **Sturgeon et al.** analyzed the globalization of the automotive industry from three perspectives: **modularization, network formation, and regional clustering**, arguing that modularization became the foundation for restructuring global supply chains [19]. They also highlighted how suppliers in emerging economies were incorporated into global production systems through modularization [20]. **Inomata** [13] argued that “the transition of the automotive industry from vertically integrated structures to modular forms has disrupted traditional supplier–buyer relations and opened the door for new entrants, including firms from developing countries and other industries.”

The case of **Maruti Suzuki’s supplier development** exemplifies these theoretical frameworks. From its establishment in the 1980s, Suzuki pursued technology transfer and localization in India, nurturing suppliers through long-term partnerships. **Kumar** [21] emphasized that Maruti’s initiatives enabled suppliers to accumulate capabilities through continuous collaboration and guidance from the OEM. He cited examples such as **Visteon** and **Delphi** (global suppliers), **Sona Koyo** and **Krishna Maruti** (Indian joint ventures), and **JBM Group**,

which evolved into system suppliers. Kumar also emphasized the role of the Maruti Centre for Excellence (MACE) in disseminating quality and productivity improvement programs, which significantly enhanced the performance of a wide range of suppliers within India's automotive ecosystem.

Entering the 2000s, market liberalization and the entry of foreign OEMs intensified competition. **Maruti Suzuki** responded by enforcing rigorous quality improvement and cost reduction initiatives, thereby driving capability upgrades among Tier-1 suppliers. As noted by **Sturgeon and Van Biesebroeck (2008)** [20], while modularization and international production networks facilitated greater integration of Indian suppliers into global systems, functional upgrading (i.e., advancement into design and R&D activities) remained limited. Indian firms primarily advanced in product and process domains.

Nevertheless, TiVA data after 2014 reveal a clear shift: the **Pure Backward GVC participation** declined, while the **Pure Forward GVC participation** increased. This trend suggests that India's automotive component industry has gradually shifted away from being import-dependent to exporting domestically produced intermediate goods that add value to foreign markets. Such a shift reflects a **new stage of industrial upgrading**—one characterized by both the deepening of local capabilities and international integration.

5. Multipolarization of Export Markets in India's Automotive Industry

This section examines the evolution of India's export destinations for automotive products, based on empirical analysis. Building on **Inomata's** prior research [13], which compared GVC participation indices for developed and developing economies from 1995 to 2015, this study recognizes that the gap between the two groups has steadily narrowed since the mid-1990s, reflecting the rapid globalization of developing countries. Focusing specifically on India's intermediate goods exports, we analyze the *EXGR_INT_DVA_PSH* indicator from the OECD TiVA database and apply a **Hierarchical Risk Parity (HRP)** clustering method to explore the transformation of global production linkages in the automotive industry.

The analysis covers the period **from 2005 to 2015**, selected for three reasons. First, this was a critical period of rapid growth for Indian auto component suppliers, initiated by the expansion of local procurement centered on **Maruti Suzuki**. Second, from the late 2000s, exports to emerging markets—particularly **ASEAN, Africa, and the Middle East**—increased substantially, marking a structural shift away from dependence on traditional Western markets. Third, using an excessively long time span could obscure this transition, since the 1990s trade liberalization and post-2020 disruptions (such as the COVID-19 pandemic and geopolitical shocks) would introduce unrelated external effects. Although 11 years may appear short, this decade represents the **core period of India's accelerated international integration** within the global automotive value chain, and thus constitutes the analytical focus of this paper.

5.1 Time-Series Analysis of *EXGR_INT_DVA_PSH*

Before conducting the clustering analysis, we first examine the time-series characteristics of *EXGR_INT_DVA_PSH* for major destination countries (Figure 5). The numbers in parentheses represent average shares.

Between 2005 and 2010, the United States remained India's largest destination for domestic value-added intermediate exports, accounting for an average of 13%, followed by the United Kingdom (6.4%), Germany (6.2%), and Italy (6.1%). Non-Western markets, such as South Africa

(4.9%) and Mexico (3.1%), also began to emerge, indicating a gradual expansion beyond Europe and North America.

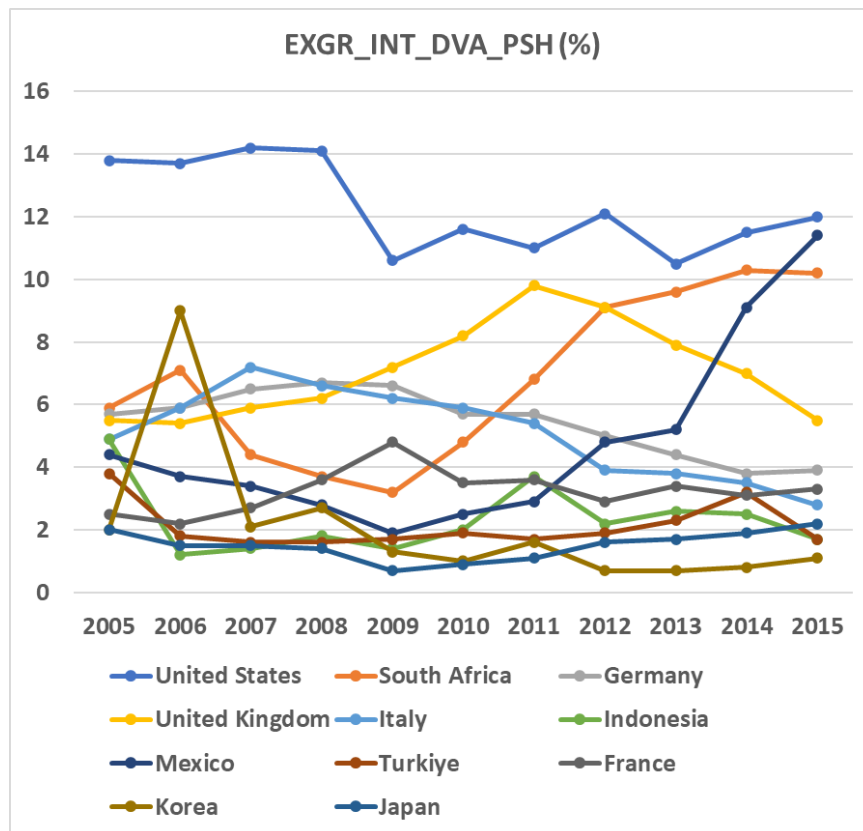


Fig. 5: Movement of EXGR_INT_DVA_PSH (2005 to 2015)

Between 2010 and 2015, notable structural shifts had occurred. The U.S. share fell to **11.5%**, while **South Africa's** rose sharply to **8.5%**, and the shares of **Mexico (6.0%)** increased. In contrast, European countries such as the **United Kingdom (7.9 %)**, **Germany (4.8%)**, **Italy (4.2%)**, and **France (3.3%)** experienced slight declines. Meanwhile, **Thailand (2.8%)** and **Indonesia (2.5%)** emerged among the top destinations, reflecting the expanding intra-Asian trade.

Overall, India's export structure evolved from a Western-centric pattern to a geographically diversified and multipolar configuration involving Africa, Latin America, and Southeast Asia.

5.2 Clustering Analysis of EXGR_INT_DVA_PSH

To identify common patterns in the evolution of destination markets, we applied the **Hierarchical Risk Parity (HRP)** clustering algorithm [22], a hierarchical approach based on distance metrics derived from correlation coefficients. Let ρ represent the correlation between

countries i and j , and $d_{i,j}$ the corresponding distance. The matrix of pairwise distances $\tilde{d}_{i,j}$ is made. Then, they were hierarchically clustered [23] and **quasi-diagonalized** [24] to position countries with similar movement patterns close to one another in the matrix.

$$d_{i,j} = \sqrt{\frac{1}{2}(1 - \rho_{i,j})}$$

$$\tilde{d}_{i,j} = \sqrt{\sum_{n=1}^N (d_{n,i} - d_{n,j})^2}$$

This visualization presents both a heatmap of distances (Figure 6) and a dendrogram representation (Figure 7), where smaller vertical distances indicate greater similarity in temporal dynamics.

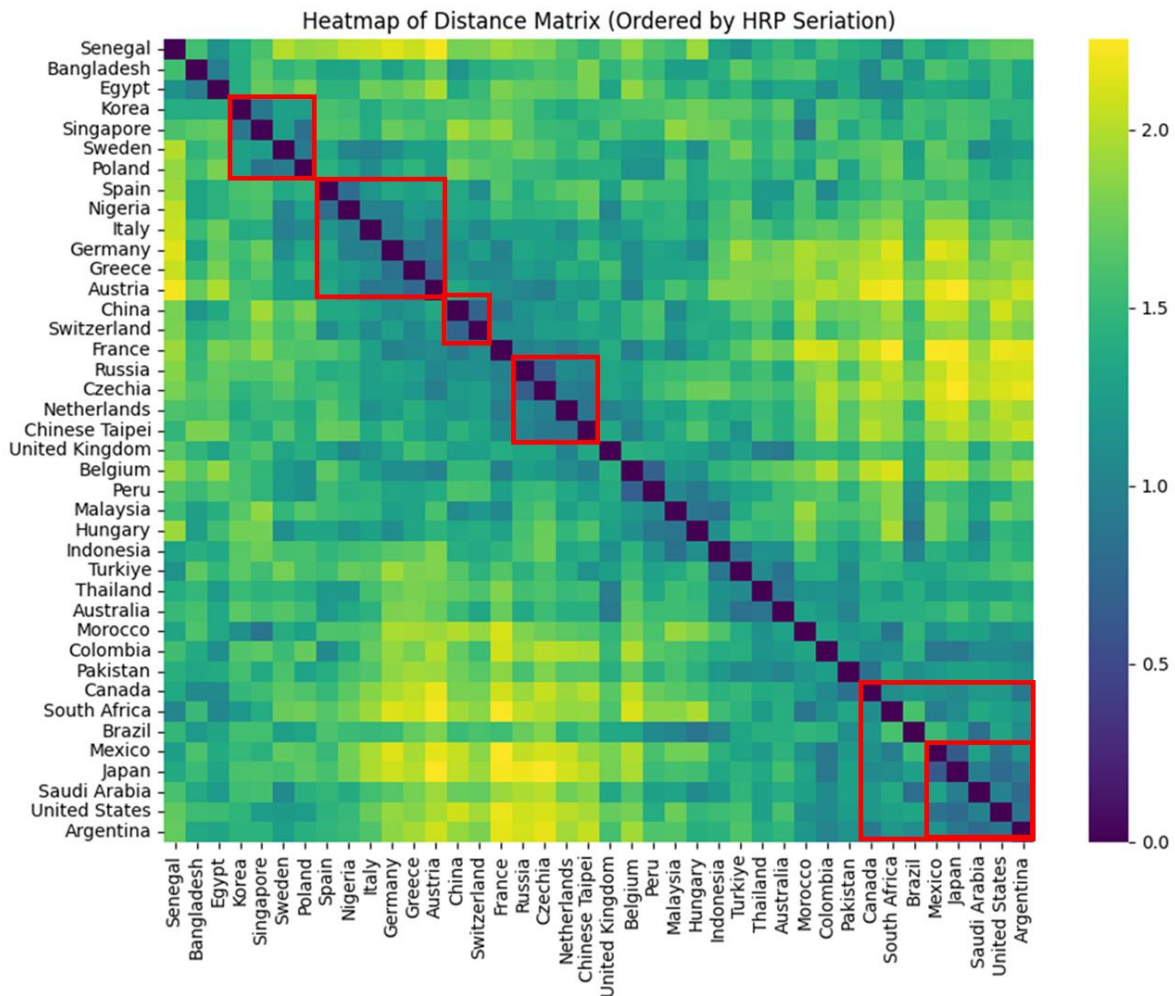


Fig. 6: Heatmap of the distance matrix after quasi-serialization.

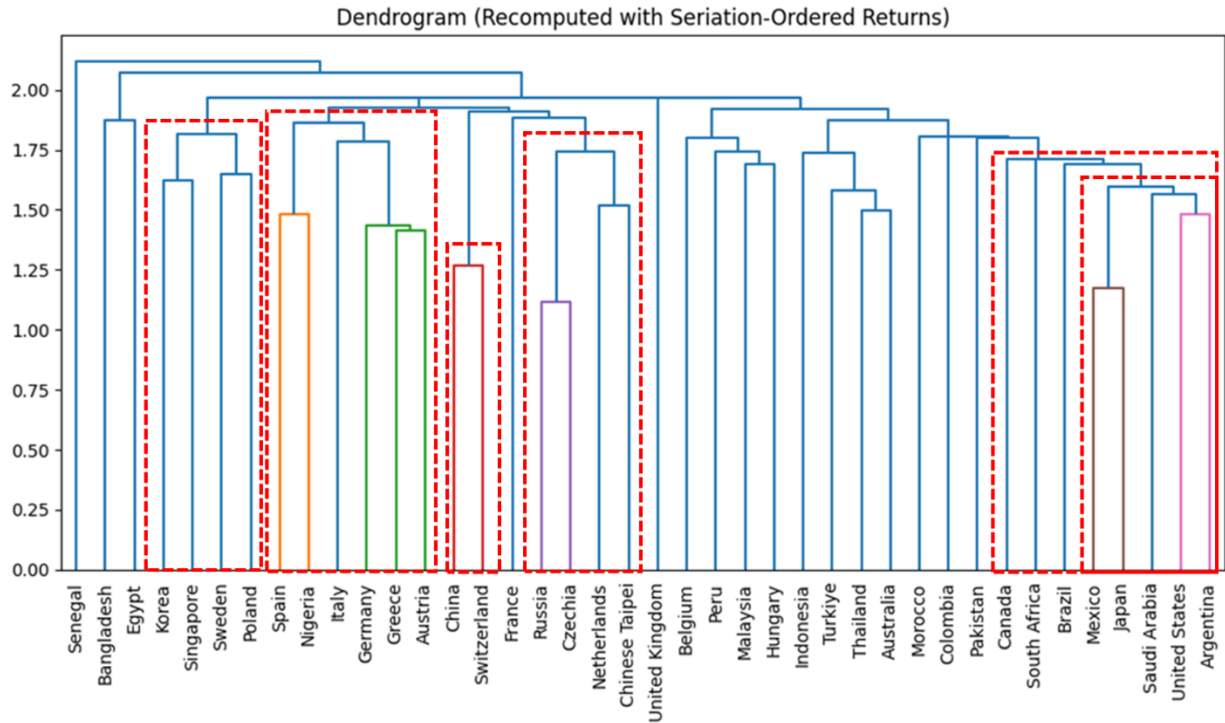


Fig. 7 : Clustering result dendrogram.

The dataset comprises the top 40 destination countries by *EXGR_INT_DVA_PSH* value in 2005, using annual return values from 2005 to 2015 as inputs. The HRP clustering procedure organizes countries into coherent groups, allowing us to interpret stable co-movement patterns regardless of arbitrary threshold choices.

The dendrogram reveals the closest pairs of countries as **(1) Russia and the Czech Republic**, and **(2) Mexico and Japan**.

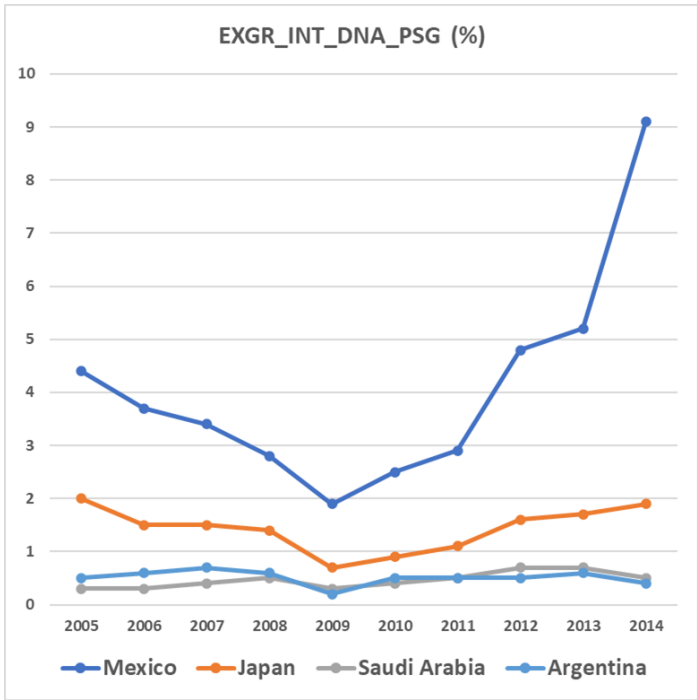


Fig. 8: Movement patterns from Argentina to Mexico.

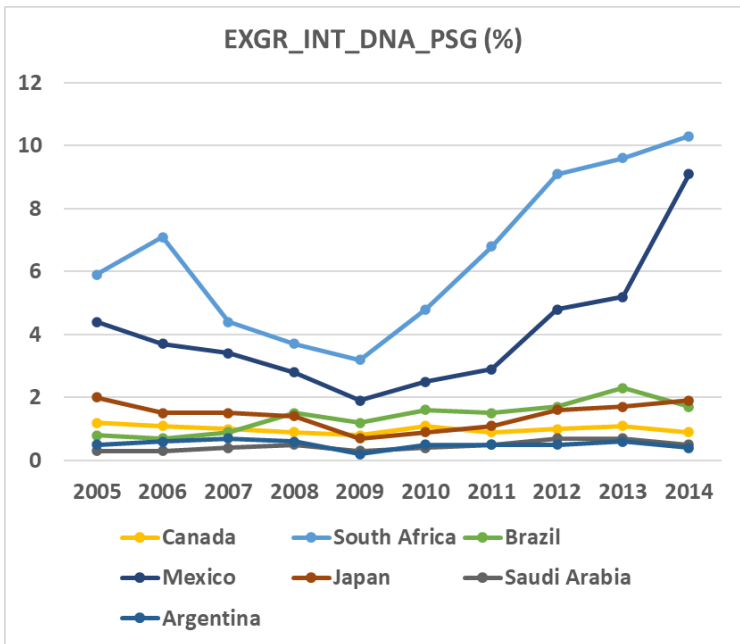


Fig. 9: Movement patterns from Argentina to Canada.

Figure 8 illustrates the time-series evolution of $EXGR_INT_DVA_PSH$ for Mexico and Japan—both exhibiting similar *V-shaped* recovery patterns, though Mexico’s growth magnitude is larger. Figures 9 to 12 further present clusters exhibiting shared dynamics.

- **Argentina–Mexico Cluster (Figure 8):** Displays a V-shaped pattern, indicating post-2009 recovery from the global financial crisis.
- **Argentina–Canada Cluster (Figure 9):** When the threshold is broadened, South Africa joins this cluster, showing robust post-2009 growth.
- **United Kingdom Cluster:** Characterized by a bell-shaped trajectory (see Figure 5).
- **Taiwan–Russia Cluster (Figure 10):** The pattern for Russia exhibits a mountain-shaped trajectory, but overall shows a slight upward trend.

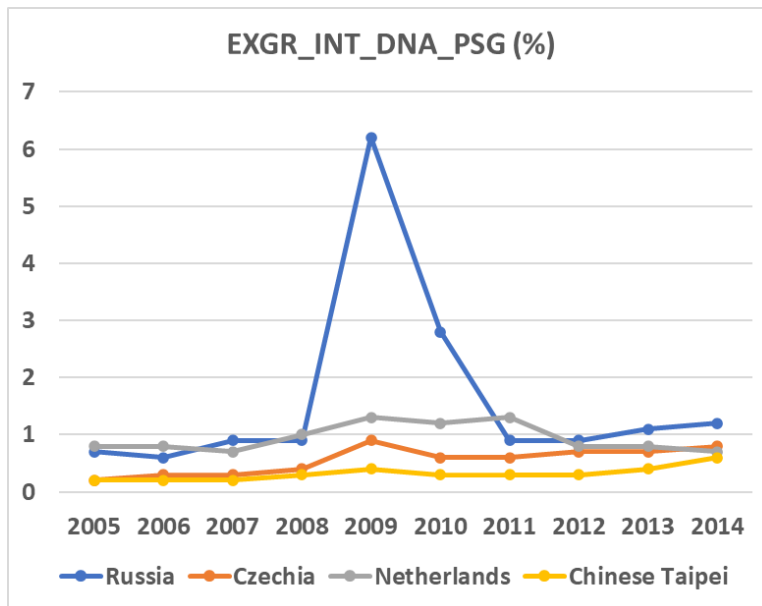


Fig. 10: Movement pattern of Taiwan–Russia Cluster.

The clusters discussed so far represent those with increasing tendencies. China and Switzerland display similar, zigzag-shaped patterns, with almost no significant movement. Next, we examine the patterns of countries exhibiting declining trends. In the dendrogram (Figure 7), the countries located to the left of Austria show downward tendencies. We focus on two such clusters below and illustrate their temporal variation patterns.

- **Austria–Spain Cluster (Figure 11):** This cluster indicates a **declining trend toward European markets**. In particular, the decreases observed for **Germany** and **Italy** are pronounced. Since **Nigeria’s** value also declined after **2012**, it was grouped within this cluster.
- **Poland–Korea Cluster (Figure 12):** Includes Korea, Singapore, Sweden, and Poland, all showing gradual decreases.

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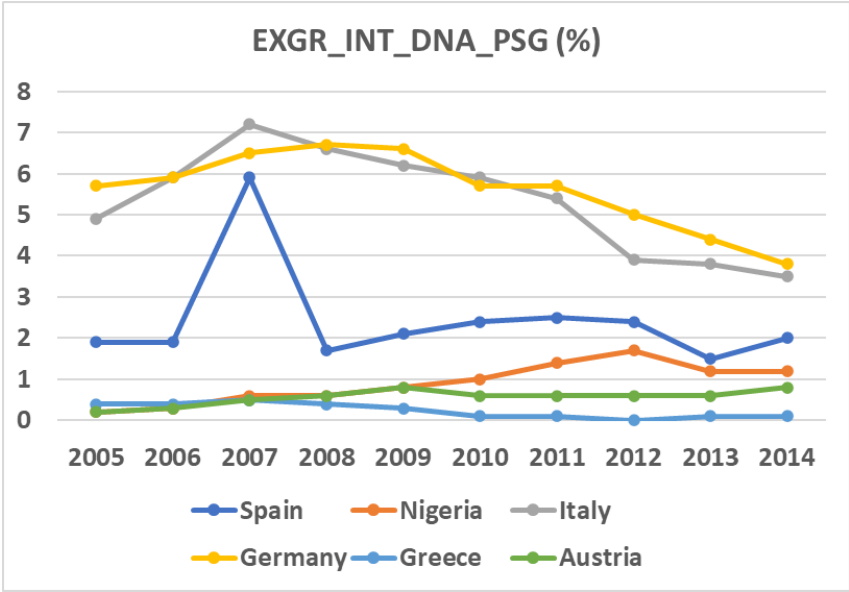


Fig. 11 : Movement pattern of the Austria to Spain cluster.

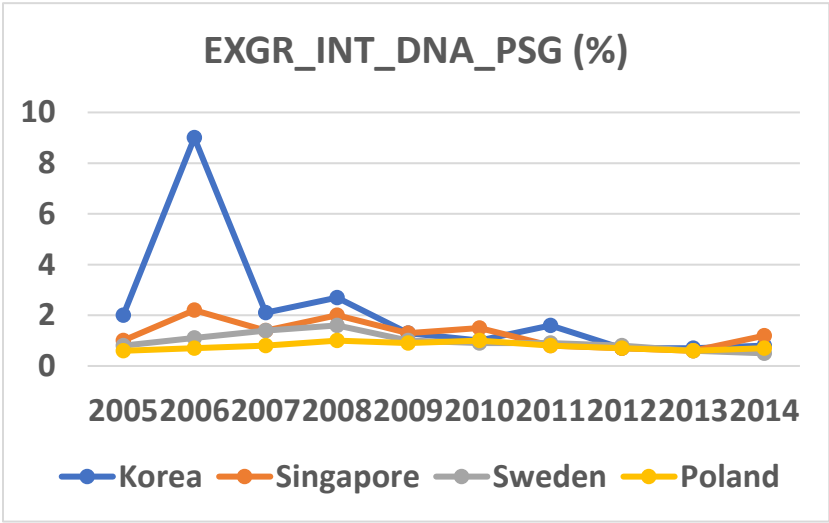


Fig. 12: Movement pattern of the Poland-Korea cluster.

The transition is thus clear: whereas **exports from 2005 to 2010** were dominated by the U.S. and European markets, by **2010–2015**, emerging destinations such as South Africa, Mexico, Thailand, and Indonesia gained prominence. Because correlation-based distances standardize the data, HRP clustering captures the similarity of fluctuation patterns rather than the magnitude of change. Countries positioned to the **right** of the dendrogram—such as Mexico and South Africa—show strong upward tendencies, while those on the **left**, including Germany and Italy, exhibit downward movements. This outcome aligns closely with the raw data observations (Figure 5), confirming a **shift from Euro-American concentration toward multipolar engagement with emerging regions**.

5.3 Factors Enabling Modularization and Market Diversification

We now turn to the underlying causes of these structural changes in India's export composition. Since the 2000s, international production systems have undergone significant transformations, driven primarily by the widespread adoption of information technologies and the **global standardization of design processes**. These developments enhanced interoperability and established shared standards across firms and countries, allowing products to be decomposed into **modules** that could be independently designed, manufactured, and recombined.

Inomata [13] emphasized that modularization represents a structural turning point for the automotive industry, enabling production specialization and international division of labor at the component or process level. Major component manufacturers, such as Denso, Bosch, and Delphi, have increasingly integrated themselves into global supply chains on a modular basis, producing standard components that are usable across various platforms and markets. Moreover, the institutional process of **standardization** has reduced coordination costs among firms and regions, enhancing reliability and efficiency across borders [25]. In parallel, the decline in transportation and communication costs since the post-war era has facilitated the geographic fragmentation of production, allowing each country to specialize in specific stages of manufacturing [26].

As shown earlier (Section 5.1), from 2005 to 2015, India's export destinations shifted dramatically—from Western markets to a diversified portfolio including ASEAN and African economies. Combined with the observed evolution of *Pure Forward* and *Pure Backward* participation rates (Figure 3), this suggests a shift in India's position within the GVC—from the **"front-end of the West"** to the **"front-end of ASEAN"**.

This realignment was influenced by several external shocks: the **2008 global financial crisis**, which depressed U.S. demand, and the **European sovereign debt crisis** around 2010, which slowed European imports. However, the deeper driver was technological: IT advancements and design standardization that enabled modularized production and, consequently, the global dispersion of automotive component manufacturing. The process was further reinforced by domestic supplier development initiatives led by **Maruti Suzuki**, which strengthened local learning capabilities. As **Hoshino** [14] noted, participation in global production networks requires the tacit transfer of know-how through close interpersonal contact. In Mexico, for instance, integration into U.S. automotive networks resulted in both the transfer of production systems and heightened entry barriers for local firms.

In manufacturing-based developing economies, **supplier capability enhancement** and **modularization** are thus twin pillars for sustainable industrial upgrading—a conclusion strongly supported by the Indian experience.

6. Conclusion

This study utilized OECD TiVA data and clustering analysis to examine the evolution of India's participation structure in global value chains (GVCs) within the automotive industry from 1995 to 2015. The results demonstrate that Indian automotive component suppliers have strengthened their competitiveness through three key dimensions:

1. Enhancement of Domestic Parts Self-Sufficiency

The decline in *Pure Backward GVC Participation* indicates a reduction in foreign dependency for intermediate goods and services. This improvement reflects the rising

- local sourcing ratios, successful quality control and process optimization, as well as the tangible impact of supplier development programs targeting Tier-1 and Tier-2 firms.
2. **Expansion of Component Supply Capabilities**
The steady increase in *Pure Forward GVC Participation* reveals that Indian-made components and intermediate goods have become more deeply embedded within international production networks. This development rests upon long-term domestic capability accumulation initiated by **Maruti Udyog** (later *Maruti Suzuki*), whose supplier development initiatives laid the foundation for technological and organizational upgrading throughout the industry.
 3. **Diversification of Export Markets**
The clustering analysis of *EXGR_INT_DVA_PSH* data reveals that, while India's export destinations were predominantly concentrated in North America and Europe during 2005–2010, by 2010–2015, they had expanded to include **Africa, Latin America, and ASEAN countries**, achieving geographical multipolarity. Such diversification has mitigated market concentration risks and enabled India to capture growing demand in emerging economies.

Both external factors and internal drivers drove these transformations—including the 2008 global financial crisis, the European debt crisis, and the 2009 ASEAN–India Free Trade Agreement—and the advancement of information technologies, design standardization, and the spread of modularized production systems. Together, these developments have provided an institutional and technological foundation for strengthening the international competitiveness of India's automotive component industry.

In summary, India's automotive sector has moved beyond its earlier role as a final assembly base. It has re-positioned itself as a **value-adding supplier hub** within global production networks.

The findings of this study highlight India's capacity to elevate its position in the GVC hierarchy while proactively integrating emerging markets into its export structure.

From a policy perspective, several implications emerge. Foremost among them is the **continuation and institutional reinforcement of supplier development policies**. As the case of *Maruti Udyog/Suzuki* illustrates, sustained technical assistance, quality training, and human resource development programs for Tier 1 and Tier 2 suppliers are essential to strengthening domestic value creation. Public policy should therefore provide targeted financial incentives, training subsidies, and institutional frameworks that encourage long-term supplier upgrading. Such measures will not only enhance domestic self-sufficiency but also deepen India's integration into high-value segments of global value chains.

Acknowledgements

This research was partially supported by the **GEM Project, Gakushuin University (FY2025)**. The author expresses sincere gratitude to **Mr. R. C. Bhargava**, Chairman of Maruti Suzuki India, for granting the interview that greatly informed this study, and to **Mr. Kenichi Ayukawa**, Executive Fellow at Suzuki Motor Corporation, for facilitating the arrangement.

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