Analyzing technology aspect of India’s manufacturing: The global context and future of work

Tandon, Anjali

Institute for Studies in Industrial Development

March 2024

Analyzing technology aspect of India's manufacturing: The global context and future of work

Abstract

Although developed countries lead in technological advancements and adoption, nations in the Global South are not immune to their effects due to increasingly borderless interactions. The extent of transformation will depend on the economic and technological feasibility in the less developed economies suggesting the co-existence of existing technologies even though the technology frontier continues to shift upwards. Therefore, it is intriguing to understand the relative significance of the distinguished technology levels in terms of their employment base and also for different typologies (e.g. employment-intensive, export-oriented, import-dependent, etc.) of the industry.

In the backdrop of the likely non-uniform technology impact across regions and countries and the likely existence of the different levels of technology, the paper has two key objectives. First, to present a balanced view of the possible challenges and opportunities from the technology transition across the regions. However, the linkage between technology (as in innovation) and employment is also influenced by the sector where the firm operates. Technology response of the sector tends to vary due to factors including the richness of technological opportunities, cumulativeness of the knowledge base, or the means to protect the economic benefits of innovation/ technology. The view motivates the second objective to classify the broad manufacturing into sectors by different technology levels, viz., high-, medium-high-, medium-low-, and low-technology, and study their relative significance in employment, value added, export, imports and output in the manufacturing segment of the Indian economy.

The present paper contributes through providing a technology profile of the Indian manufacturing by classifying sectors into four categories, originally based on the R&D intensities as defined by the OECD. The technology categorization takes into account the R&D spending as a proportion of the value added and output of the industry in the ISIC Revision 3 nomenclature. By extending the classification to the more recent ISIC Revision 4 (which is also aligned to the National Industrial Classification 2008 in India), we classify each of the 69 manufacturing sectors reported in the India Input-Output database for a recently available year which are further grouped into 17 sectors for comprehensiveness while also maintaining their distinguished technology categorization, the paper uses the classification in the Indian context. The four technology categories are assessed for their relative significance in terms of supporting employment, exports, imports and output of the manufacturing sectors. Also analyzed in the paper is the sector-level labour productivity, employment intensity, export intensity and import intensity based on the technology classification.

The paper concludes with a broad recommendation in view of the increasing and pervasive use of technology across different parts of the world. In the Indian context, based on the analysis of the Indian manufacturing sectors, strategic interventions are suggested for better performance of the technology sectors and to minimize the frictions between technology and jobs in the future times. Proposals for investment in workforce development activities for effective job creation are discussed.

Analyzing technology aspect of India's manufacturing: The global context and future of work[1]

Anjali Tandon[2]

1. Introduction

Technology is defining the new industrialization through adoption of advanced and intelligent methods in production. While the developed countries are at the forefront of technological advancements and adoption, countries in global south are not insulated from the impact due to borderless interactions through production networks, supply chain, trade, investment and migration contributing to transmission of the changes across regions and national economies. However, the impact is not necessarily uniform across countries and the sectors of production. Despite the emergence of artificial intelligence, machine learning, and robotics, the extent of transformation will depend on the economic and technological feasibility in the less developed economies. This suggests the co-existence of existing technologies even though the technology frontier continues to shift upwards. Therefore, it is intriguing to understand the relative significance of the distinguished technology-levels in terms of their employment base and also for different typologies, such as the employment-intensive, export oriented, import dependent, industries. For instance, a disproportionately low share of the technology-intensive imports would indicate a deficit on the indigenous technology development or R&D. Similarly, the predominance of exports in the low technology categories in an economy indicates the lack of competitiveness in high-tech manufacturing suggesting the need to address the existing barriers. At the same time, the policies favouring technological advancements will also have implications on the future prospects for employment of workers. However, despite the job challenges from technology advancements and upgradation, evidence suggests positive net job-creating effects of innovation as in the EU (Dachs, 2018), or a qualitative transformation in labour demand through skill-biased technological change or polarization of jobs (Acemoglu, 2002, Vashisht, 2018). Given the irreversible nature of technology, the future challenge lies in preparing the workforce to cope with the advancements.

Against this backdrop of the likely non-uniform technology impact across regions/ countries and the likely existence of the different levels of technology, the paper has two key

[1] Another version of the paper is published as Tandon, Anjali (2024). "Analyzing technology aspect of India's manufacturing: The global context and future of work", *The Indian Economic Journal*, Volume 2-A, Special Issue, Contemporary Challenges and Opportunities Before Indian Industries, ISSN 0019-4662, pp 117-138.

[2] Associate Professor, Institute for Studies in Industrial Development (ISID).

objectives. The first objective is to present a comprehensive view on the possible challenges and opportunities from the technology transition and their implications on job creation across the regions. The linkage between technology as embodied in innovation and the employment also gets influenced by the sector where the firm operates (Dachs, 2018). Technology response of the sector tends to vary due to the factors, including the richness of technological opportunities, cumulativeness of the knowledge base, or the means to protect the economic benefits from innovation/ technology (Marsili 2001; Cohen 2010; Dosi and Nelson 2010). In view of the likely impact of technology advancements on future of work, and the mixed evidence on job creation, it becomes imperative to study the existing structure of employment across different technologies. Hence, there arises a need to classify the manufacturing sectors by their technology categories, viz., high-, medium-high-, medium-low-, and low-technology, to assess their job prospects in the economy. The view motivates our second objective to study the relative significance of technology categories in terms of employment, output, income, exports and imports in manufacturing segment of the Indian economy.

Rest of the paper is organized into six sections. Section 2 provides a discussion on the emerging technology shocks that have emerged in the fourth industrial revolution and how the disruptive technology and pressing issues are generally expected to impact workers in countries and more specifically the Indian economy. Section 3 highlights the mixed outcomes of technology on the jobs providing - opportunities and challenges, simultaneously. Section 4 presents the method and approach followed in the paper. The review-based Section 5 links the structural differences across developing regions to the prospects and challenges for jobs from the changing technology frontiers with insights on select regions and sectors. Sections 6 and 7 are analytical in nature with a focus on the technology profile of Indian manufacturing in terms of key economic indicators which are studied at aggregate and sector-level, respectively. Section 8 presents summing-up of the preceding sections and concludes.

2. Technology shock and the channels of transmission

In the new global order, two concurrent developments are at the center stage of the technology revolution and thus define the future of work. These prominently include the role of Industry Revolution 4.0 (IR4), automation, digitalization; and the initiatives to decarbonize the planet. There exists a reasonable possibility of the intersection and overlaps between them. in technology transition. The developing economies lead in the technology spheres. In addition, China has demonstrated an exemplary performance on the IR4 front due to its long-term strategy of heavy investment in R&D, and well-suited institutions aligned with ambitious industrial policy, and the ambition to set the global technology standards (Doshi, 2020). Technological breakthroughs such as the AI, ML, Robotics, IOT, Big data science shift the work frontier between the activities performed by workers and those operated by machines, thereby transforming the world of work. The revolution not only is occurring at a fast pace, but is also disruptive with no room to turn back. Particularly, the manufacturing is increasingly turning 'smart' with the use of sensors and next-generation robots.

The transmission of technology occurs through international trade, industry and investment The impact of automation and digitalization. While on side, technologies such as AI can complement jobs such as in the health sector where precision health diagnostics support opportunities for health care workers, there also exist concerns from the possible reshoring. The potential for reshoring of production occurs from quality control, savings on transportation, and lower inventory costs from domestic operations in the developed world. Consequently, the developing countries will have to reorient to domestic/ regional markets to compensate for the contraction in FDI. Notwithstanding, the threat perception from deindustrialization may not be as large if offshoring contributes to increased transportation of the developed country producers to serve the large developing country markets.

Another driver of the changing future of work is the green growth and the attempts to address the climate change challenge. Essentially, decarbonization presents work opportunities through activities which are energy efficient, consume lower energy, or use cleaner source of energy. Consequently, there is increasing emphasis on renewable energy plans which depend on the use of solar, wind, geothermal, hydrogen as. an integral part of green industrialization. This generates new job opportunities as the demand for workers in renewable energy sector increases. For instance, in the US solar workforce increased by 25 percent in 2016, while wind employment increased by 32 percent (Mellett & Finnell, 2021) (Li, 2022). Clean energy sector jobs in the NZE Scenario soar from 33 to 70 million over 2021-2030, offsetting the loss of 8.5 million in fossil fuel-related sectors. Available estimates for India show that 3.4 million jobs (short and long term) can be created as the country achieves the targeted 500 GW non-fossil electricity generation capacity by 2030 by installing 238 GW solar and 101 GW new wind capacity (CEEW-NRDC-SCGJ, 2022).[3] Of this, the solar sector (utility-scale and rooftop solar) is expected to employ the majority of this workforce with a 77 percent share (85,900) whereas wind accounted for 23 percent share (25,500).[4]

It is estimated that related jobs in clean energy manufacturing will more than double from six million to nearly 14 million by 2030, and "further rapid industrial and employment growth is expected in the following decades as transitions progress". Employees in RE sectors require technical skills, a good grasp of scientific principles for fact-based decision making, and also

[3] Numbers represent jobs created in the wind and on-grid solar energy sectors.
[4] Number of jobs created exceeds that of the workforce needed as one worker can perform multiple jobs.

for monitoring and equipment control. Building a large, skilled workforce is key to meeting net zero targets, but labour and skills shortages in expanding clean energy industries are already creating bottlenecks (IEA, 2023). The distribution of energy workers is spread across economic sectors: over 14 million employees work at utilities and firms providing professional services, approximately 22 million in manufacturing of equipment, 16 million in construction of energy facilities, 9 million in the raw materials sector, and 9 million in related activities such as wholesale trade and energy transport. According to an earlier analysis for the earlier year 2015, it is estimated that scaling up grid-connected solar and wind energy would add a cumulative one million jobs for solar construction workers, installers, maintenance works, engineers, technicians, and plant operators between 2015 and 2022 (NRCD-CEEW, 2015). These jobs include short-term jobs for business development, design and pre-construction, and construction and commissioning, as well as long-term jobs for operations and maintenance and performance monitoring. The sunrise sectors such as semiconductors, batteries, and also material such as lithium provide new job opportunities. The manufacture and installation of green equipment requires vocational training for its fast and inclusive integration, to able to positively impact the likes of rural, informal, women, workers. For example, through solar powered electricity they can overcome constraints on processing crops due to unreliable electricity, solar driers for FPOs, solar pumps for small scale irrigation, solar powered, hydroponic fodder stations , solar reeling machines for reeling of silk yarn vis-a-vis thigh reeling machines (Singhal et al., 2023).

While the formation of Industry 4 and the decarbonization initiatives started in developed economies early, the developing countries face institutional and financial barriers, in addition to their economic goals, in adoption of Industry 4 technology (Bogoviz et al., 2020). Despite their lagging behind on economic indicators and transitional capability, the technology shocks are transmitted to the developing countries. Borderless transactions occur through production networks, supply chain, trade, investment and migration. Across the regions and economies within the regions.

The issue however is how can we put this transition towards an industry 4 and decarbonized economy to our advantage by ensuring jobs on the pathways to a smart, and green and sustainable economic development.

Earlier studies on India such as Kumar and Pradhan (2003) consider the technology characterisation only in the context of exports. Another by Mani (2000) noted the developing countries to be fast catching upon on through increasing share in high-tech exports, although with high concentration in few countries. While the importance of the high-tech segment and exports cannot be undermined, as also emphasized in a later section 7 of the present paper, it is also important to have comprehensive assessment covering all the technology categories. Employment in high-tech industries is not sufficient to address the wider concerns on poverty providing little evidence on benefits for low-skilled workers suggesting its benign impact of workers in other manufacturing (Lee, 2016; Kemeny and Osman, 2018).[5] Furthermore, considering non-high tech manufacturing is particularly important in the Indian context, where the unorganized with 99percent of establishments, 80 percent of the employment (Ghani et al., 2013), and 90 percent employment is informal. The exceptional persistence of unorganized manufacturing which is also predominantly in the non-high tech category makes it imperative to include all technology categories. Therefore, in this paper the manufacturing is categorized into technology-based categories for analysing their significance through the indicators of economic activity, viz., output, value added, and international trade along with the contribution to employment.

3. Technology and jobs – Opportunities and challenges

The technology influence on the future of work occurs through the emergence of new sectors e.g. Semiconductors, Renewable energy, and the renewal in mature sectors (e.g., machines and machine tools, and automobiles). The transition, manifests through the changing nature and scope of work, wages & income, prospects in future, firm behaviour and public policy. While the process of technological transformation presents new opportunities to be tapped, there are also challenges to be addressed. Technological adoption improves the demand for better goods through rising incomes (labour productivity), more than offsetting the loss of jobs. Productivity gains translate to lower costs, and simultaneously greater incomes support higher demand, ultimately benefitting the jobs.

On the other hand, challenges from greater automation occur through the risk on jobs (from greater automations) in the form of displacement without a return to job, or into low paying jobs or mis-matched jobs. These concerns are serious for countries with large labour force and those with demographic dividend, e.g., India. Under the changing nature of work, the future of work and the required skills needs to be studied in terms of various bifurcations such as gender, education & skills, sectors of activity, nature of work (gig, platform, contingency), migration , income and vulnerability, among others.

The technology outcomes are further contingent upon economic and technical feasibility as the benefit from the adoption of capital-intensive robotics must outweigh the comparative advantage from labour costs in developing countries.

[5] The study by Lee (2016) is based on the US high-tech industries.

4. Analytical approach

For technology categorization the OECD (2011) definition of technology intensity of ISIC Rev 3 activities is used. The classification scheme is a revised version of the earlier definitions. The cut offs points between the four technology categories – low, medium-low, medium-high and high technology – are based on the two indicators, viz., R&D intensity of production and value added. Industries are categorized by ranking the average values of the corresponding indicators against the aggregate OECD average R&D intensities during the period for benchmarking.

In our work, we have revised the underlying nomenclature of manufacturing to ISIC Rev 4 which is fully compatible to the National Industrial Classification (NIC) 2008 (CSO, 2008). The NIC 2008 nomenclature is fundamental to compiling data on Indian manufacturing activity at a disaggregate level. Given the interest in studying the technology profile at the aggregate and sector level, the ISIC industries are mapped to thirteen manufacturing sectors as available in the KLEMS database of the RBI (2022). Additionally, we contribute by disaggregating the broad transport equipment sector into four constituent sub-sectors which are spread across three technology categories, in contrast to their being combined under a single category, disregarding their technology characteristics.

Data and information is sourced from OECD (2011), NIC (2008), Chadha, Saluja, Sivamani (2020), RBI (2022).

5. Regional and sectoral differences of technology outcomes[6]

Globally, the technology opportunities will vary across the regions and countries (ADFB et al., 2018). The extent of technology transformation will depend on the pace of the technology spread and is likely to vary across nations and activities.

5.1 Difference in regional experiences

Differences in economic structures lead to differences in the extent of technology frontiers. The concerns are not limited to developing economics alone. In Europe, the introduction of a (additional) robot reduces employment rate by 0.16-0.20 percentage points; displacing workers that are younger, with middle-level educated, and male. (European Strategy and Policy Analysis System, 2018).

The technological developments in agriculture will benefit more Asia and Africa (32, 51 percent of workers), manufacturing will benefit more European Bank for Reconstruction and Development (EBRD) economies which include the Central, Eastern and South-Eastern Europe, the Southern and Eastern Mediterranean, Central Asia, and Mongolia (30 percent).

[6] This section draws from ADFB et al., 2018

The impact will also vary with regard to service-related activities where the EBRD, Latin America and the Caribbean (60 percent) are expected to be impacted relatively severely/more (ADFB et al., 2018).

The export-led manufacturing can be a tough bet for Africa. With labour costs eroding in Asia, one would expect the assembly-line to shift to Africa. The challenge is posed form AI, due to the influence on economies of scale, thus resulting in reshoring to developed countries. This can lead to loss of jobs. An estimated 126 jobs are lost for every firm that offshores from Africa to America (Banga and te Velde, 2018). The newer I4 related jobs will require better digital integration, where Africa is trailing behind. As also noted in the rising demand for STEM-based skills which have an inadeqaute supply in the region. Nevertheless, opportunities exist through mastering labour-intensive manufacturing. Job prospects can be strenghtened in sectors which are machinized such as the food processing and furniture, where the use of AI is less in comaprison to the more automated and tech-intesive manufacturing such as the automotive and elecltronics.

The prospects for technological adoption are better in developing Asia compared to Africa. Many Asian countries have higher levels of within sector productivity gains than in Africa where much of the is due employing more workers in production. Apparently, in select locations, robot deployment could be economical in more sophisticated sectors such as electronics and automotive sectors which also account for less proportion of jobs. However, the economics of automation will determine the feasibility. For instance, in garments manufacturing, a robot will need much more precision for stitching and handling the cloth, thereby making it deployment uneconomical and making it the application AI technical infeasible.[7]

The emerging Europe may benefit from reshoring of jobs with greater automation, which is already higher than in Brazil, China, Indian and SA.

In the Latin America & Caribbean, where the productivity is stagnant and growth has been moderate, spending in knowledge at early age, and skills for the life-time can be rewarding. With aging population, improving female labour force participation through trainings can offset the reduction in LFPR, thus supporting more jobs. Since most technology skills are transferable across sectors, the workers can be prepared for transition through imparting a combination of soft, technology and cognitive skills.

[7] Pilots for full automation are on in specific sectors such as the textiles and footwear.

5.2 Variations across the sectors

In the past, many Asian economies pursued ELG and industrialization on the strength of low labour costs while also benefitting from the presence of vast informal and women workforce.[8] The Initial expansion of labor-intensive industries such as textiles & apparel, footwear, plastics, electronics assembly which also have an over-representation of informal workers, mostly women, suggests the impact could be more gendered in countries such as China. On the other hand, it is also said that robots are not always only employed for displacing labour, but also to improve efficiency and lower the lags. Thus there is scope for greater mechanization in the labor-intensive sectors through use of sewing machines which will need operators to meet their own large domestic and regional market, rather than the threat of sewing robots. Suggesting the need for training and skilling

However, it has been argued that within the Asian region, Automation will probably first impact the capital-intensive manufacturing; where the present employment is relatively low (pp49). Nevertheless, there remains the possibility that the existing pathways are eroded with Automation to take over the mundane and non-cognitive and riskier tasks such as the mixing of chemicals in the textile industry. Although it can be argued that humans would still be needed to programme the robots, this requires proper training and reskilling, and a more value based design of textiles mandating investment in skill development of the workers.

Similarly, digital platform for services provides work opportunities for the less developed countries, e.g., in accountancy, etc.

While the key to realizing the benefits of technology transaction for all stakeholders is to prepare and participate in the short- to long- run, there exists a wide concerns to how can we keep the tensions between technology and job to a minimum? In this context, we study the technology profile of the Indian manufacturing. We then attempt to look at the technology categories through the job (employment) lense for their relative share in terms of supporting employment and the key characteristics including output, exports and imports. Evaluating the before said manufacturing typologies for their use of varying levels of technology contributes through pointing the dependence on specific technology categories, suggesting the need to strengthen them in future. We try to validate whether the high-tech sectors are also employment supporting, export generating, and import dependent.

6. Technology profile of Indian manufacturing

The classification of manufacturing sectors based on technology shows that a larger number of sectors belong to the lower technology stratum jointly comprising of the of the low- and

[8] Korea in the 60s, Japan in the 70s, ASEAN4 tigers (HK, Korea, Singapore, Taiwan) in the 80s, China in the 90s.

medium-low tech categories with 10 of the 17 sectors (Table 1). Further, these sectors predominantly belong to the labour-intensive category suggestive of their importance from employment perspective, particularly for the workers with low level of the skills, and specifically in the unorganized segment. The low tech manufacturing includes sectors which are resource-based and use primary products, e.g., food processing and textiles. The medium-low tech manufacturing is material-intensive e.g., petroleum products which are intensive users of coal as a raw material. The medium-high tech manufacturing includes heavy machinery and capital goods. The high tech manufacturing makes use of advanced technological expertise and engineering skills.

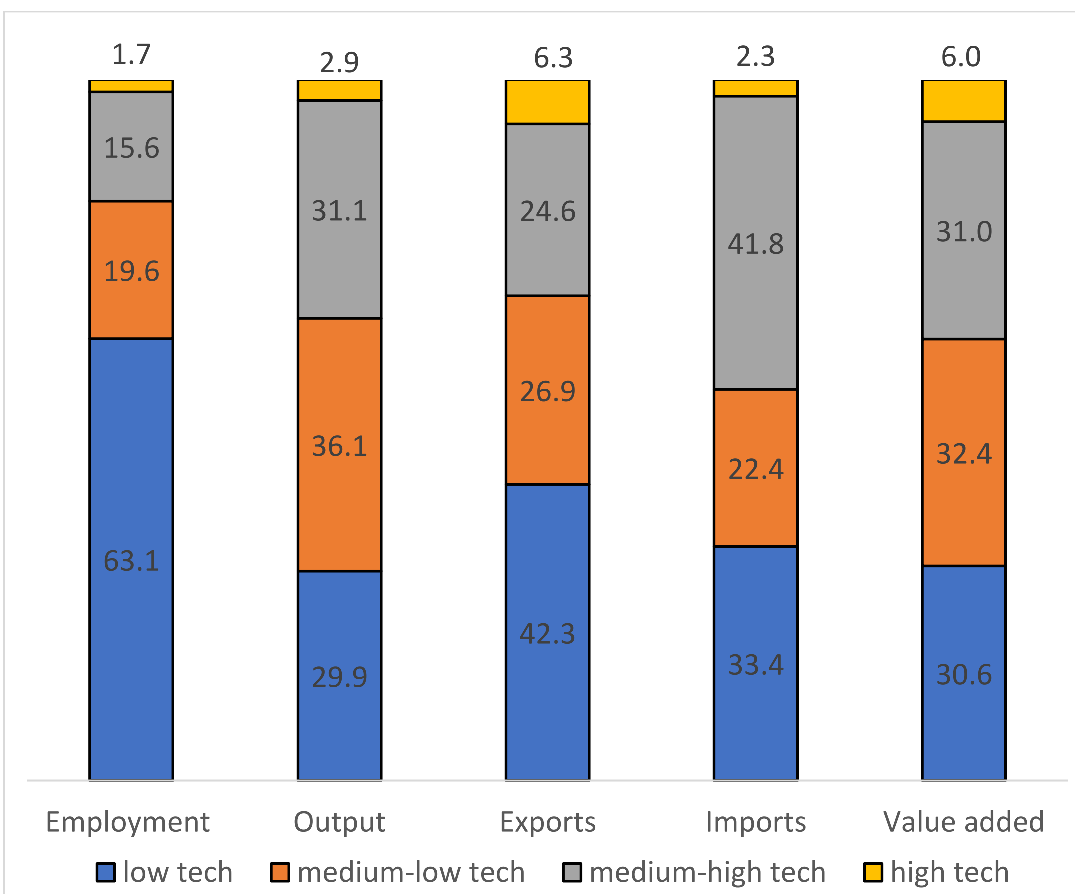
Table 1: Technology-based classification on Indian manufacturing

Low technology (LT)	1. Food Products, Beverages and Tobacco	Labour-intensive
	2. Manufacturing, nec; recycling	Labour-intensive
	3. Pulp, Paper, Paper products, Printing and Publishing	Labour-intensive
	4. Textiles, Textile Products, Leather and Footwear	Labour-intensive
	5. Wood and Products of wood	Labour-intensive
Medium-low technology (MLT)	6. Basic Metals and Fabricated Metal Products	
	7. Coke, Refined Petroleum Products and Nuclear fuel	
	8. Other Non-Metallic Mineral Products	Labour-intensive
	9. Rubber and Plastic Products	
	10. Ships and boats	
Medium-high technology (MHT)	11. Chemicals and Chemical Products	
	12. Electrical and Optical Equipment	Labour-intensive
	13. Machinery, nec.	
	14. Motor vehicles	
	15. Rail	
High technology (HT)	16. Aircraft and spacecraft	
	17. Pharmaceuticals	

6.1 Employment, output and value added

The technology profile of manufacturing is analyzed from the technology-based distribution of key indicators of economic performance as shown in Figure 1. The low-technology segment stands apart with a high share in total manufacturing employment. This is followed by lesser employment significance of the remaining technology categories, which is also observed to decline as the technology-level increases. Unlike the skewed employment distribution which is more concentrated at the bottom of the technology pyramid, the production structure is relatively balanced across the bottom-three technology categories with a relatively low significance of the high tech category overall. Nearly two-thirds of the production belongs to the medium technology category of goods. Specifically, the medium-low tech category accounts for a higher production share of 36.1 percent compared to 31.1 percent share of the medium-high tech goods. A similar distribution is also noted for the value added component of the manufacturing sectors where the contribution of medium technology segments is the highest.[9] In all the three distributions of employment, output, and value added, the high-tech goods have low significance. This however does not undermine the importance of the high tech goods within manufacturing and the overall economy as also discussed in Section 7.4.

Figure 1: Technology-based profile of select economic indicators (percent distribution)



[9] In fact, no significant change in the distribution is noted from that in the past (Kumar and Pradhan, 2003).

6.2 Exports under the technology categories

The technology profile of manufactured export shows a substantial proportion of exports with more than two-fifths under the low tech category (Figure 1). Although the share is lower than in the past (Kumar and Pradhan, 2003), the low tech category continues to dominate the overall export basket. This is suggestive of the continued reliance on resource-based exports. At the same time, relatively lower share of the low-tech exports than observed earlier at the turn of century is suggestive of a shift towards other technology categories in the export basket.

The representation of high tech category is higher in exports when compared to other indicators viz., employment, output, value added, and imports. However, at 6.3 percent the share of the high tech exports, even though higher than in than in the past, continues to be substantially lower when compared to other emerging markets and developed countries. According to World Bank Indicators, the high technology exports from India constituted 6 percent in the year 2001. Although the share of high-tech exports has increased during the later period from the years 2018 to 2020, the reversal in the recent year of 2022 shows that the jump was perhaps temporary due to the China+ policies of the countries during the pandemic. Also, India's share of high tech exports in the overall export basket of goods is comparably low against many other countries including Malaysia (52 percent), Singapore (55 percent), Korea (36 percent), China (30 percent), UK (24 percent), USA (20 percent), Japan (18 percent), and Germany (15 percent) (World Bank, 2023).[10]

The comparison of technology-based distribution of the output and exports shows a mis-match. The low tech category has a disproportionately higher representation in exports than the corresponding share in output. This not only shows greater the dominance of the low tech segment in the export basket but is also indicative of the competitiveness of select exports within this category from India (refer to Section 7 for sector-level details).

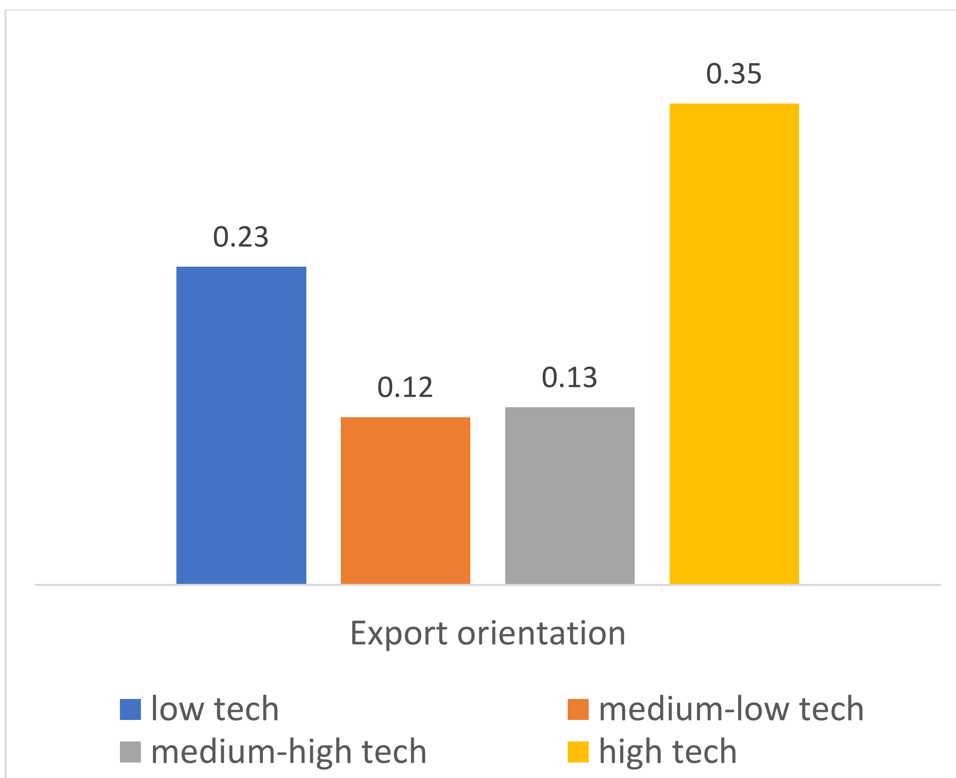
Further, the technology categories are also observed to vary with regard to their export orientation i.e., export as percentage output, a measure of outward trade. The high tech exports have comparatively strong export orientation, followed by the low tech category (Figure 2). The products from the sectors within the latter category are characterized by the high level of differentiation while also having close substitutes. Considering India's niche in specific low tech products, it is not surprising that nearly a quarter (23 percent) of output in the low tech category serves the global market through exports. These sectors mostly comprise of the traditional activities also having a predominance of the micro, unorganized,

[10] Figures within parenthesis are the share of high tech exports of the corresponding country and correspond to the year 2021.

and SMEs, further underscoring their importance in employment considerations in a technologically dynamic world.

The export orientation of the medium tech categories is relatively low. The sources of comparative advantage can be traced within specific sectors or the products manufactured therein. For instance, within the medium-high tech category, a significant proportion of the automobile production is exported. As much as 24 percent of the 22 million vehicles produced was exported during the year 2021-22 (IBEF, 2022). The Indian automobile industry is endowed with strong engineering skills and low cost expertise, which has attracted leading manufactures of the world, thereby contributing to development as an export hub. Likewise, in the medium-low tech category, exports of specific auto components such as shafts, bearings, and fasteners are supported by a large number of domestic players, lower costs that are 10-25 percent lesser than in Europe and Latin America, and the advantage from domestic steel production as an input (IBEF, 2023).

Figure 2: Export orientation of the technology categories

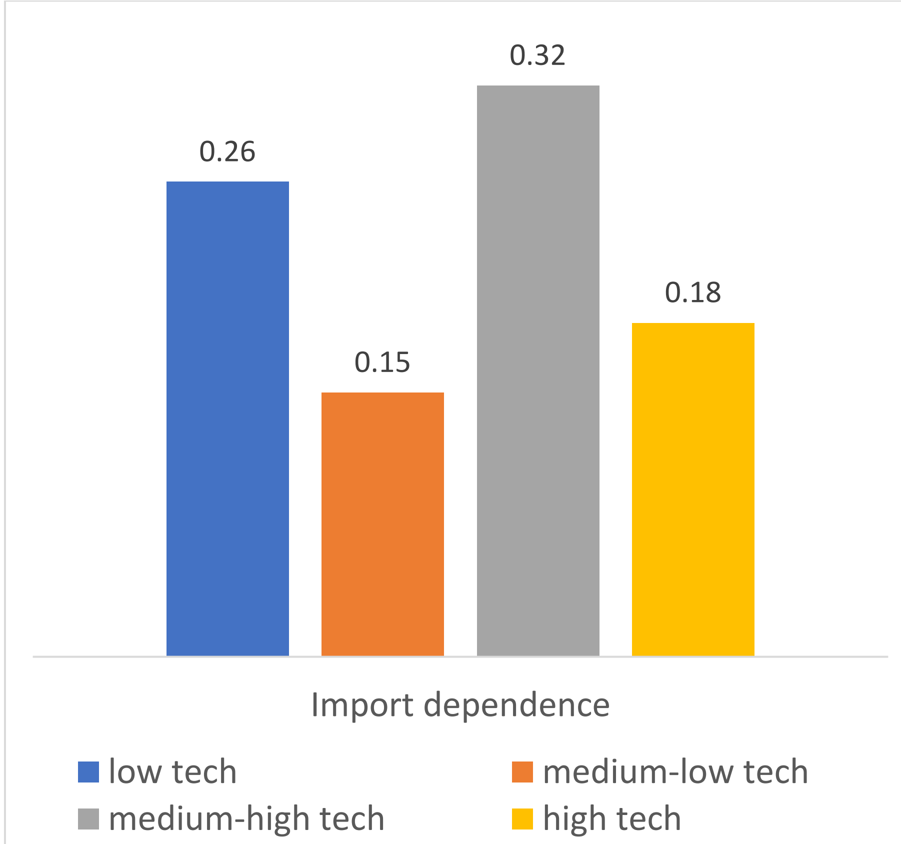


6.3 Imports of the technology categories

The technology profile of manufactured imports is distinct from that of employment, output, value added, and exports. Approximately two-thirds of the imports belong to the medium tech category jointly comprising of the medium-high and medium-low tech categories (Figure 1). Interestingly, the combined share of medium-high and medium-low tech imports is comparable to the corresponding share in output. A bifurcation of the medium tech imports is insightful as the sub-distribution is even more uneven with the predominance of the medium-high tech imports. This shows the deficit in domestic capacity/capability for the manufacture of capital goods sectors. Even more concerning is to note that the imports of low-tech goods alone account for one-third of total imports of goods. This is suggestive of the lack of domestic capacity in the low-tech category despite the availability of a vast labour force and a legacy of the low-tech industries such as the textiles and footwear which are characterized by presence of SMEs and clusters. The import share of high-tech category is relatively low.

Likewise, the export orientation, another measure of openness is the import dependency measured as the ratio of import-to-output. The value of the ratio is highest for the medium-high tech imports (Figure 3). The category essentially covers capital goods where the dependency on imported machinery and equipment has been high. Many studies have attributed this to the low levels of domestic R&D in general and also in terms of lagging participation specifically by agents such as the government, business, and higher education (NITI Aayog, 2021; Reddy and Subhash, 2020). At the same time, import dependency can also be ascribed to inadequacy of raw material and natural resources, or the need for inputs which cannot be substituted through domestically produced inputs. Some of these explanations are differently relevant for the low, medium-low, and high tech category. Despite the technology-related homogeneity within the sectors comprising each of the four technology categories, variations are also likely to exist on other accounts such as traditional presence, international competition, global value chains, infrastructure, etc. Therefore, a sector-specific discussion within each of the technology categories becomes important, and is the subject of the following section.

Figure 3: Import dependence of the technology categories



7. Sector-level profile of technology

A technology-based sector-level disaggregation of the contribution to key economic indicators is given Table 1 and the Figures 2-5. The discussion primarily maintains focus on highlighting the changes in technology as expected to occur in the constituting sectors of the four technology categories, and the likely effect on demand for workers and skills.

7.1 Low-tech manufacturing

The low tech manufacturing such as the textiles, textile products, leather and footwear, and food processing sectors have significantly high employment shares at 25.1 percent and 18.8 percent of the total manufacturing employment (Figure 4). The textiles, leather and footwear sector is particularly also important due to its significance in output, value added, exports and output within the low tech category (Figures 5-7). Despite the ability in traditional industries such as the textiles, for producing items over the entire range of woven wear and knitwears at low cost with desired quality, Indian manufactures are facing challenges due to fragmented operational capacity constraining their ability to emerge as a world-class producer. Operating at sub-optimal scales prevents from realizing the economies of scale, thereby giving edge to other producing countries such as China and Bangladesh. Also, majority of the capacity belongs in the powerloom sectors where the technology is obscelent in comparison to the integrated mills which account for a smaller capacity, even though with modern technology. Competing countries have gained competitiveness through focus on product development e.g. fabrics with specialized treatments, faster turnaround time for sample designs, and investment in design and sampling labs (Chellasamy and Sumathi, 2006). Automation, particularly of the weaving sector, offers the benefit off supplying fine quality fabrics, at low cost and in reduced time. Technological obsolensce has resulted in the export of yarn from India to other countries for weaving on the most modern machines where the value addition is higher. Global majors use machines with superior specifications on speed and wider widths, and high insertion rates exceeding 2000-2500 meters per minute and widths of up to 3.8m, compared to insertion rates of around 350 to 650 meters per minute and widths up to 2.3m in India (Sanghvi, 2007). Moreover, there are also concerns in meeting the environmental and labour standards.

Another sector in the low tech category the miscellaneous manufacturing, comprising of various sub-sectors such as the gems and jewelry, and toys among other industries, is a source of employment particularly in the unorganized segment given its labour-intensive nature. The sector has the largest contribution to exports and imports within the low tech category (Figure further underscoring its forex earning potential and import dependency. Particularly, the gems & jewelry sector has witnessed increasing mechanization to achieve manufacturing at scale, consolidation for greater variety and designs, and standardization through the hallmarking of gold. Although greater mechanization has increased the need for operators and designers, the traditional goldsmith workers are unable to compete as they do not have access to formal trainings. The miscellaneous manufacturing in also inclusive of the toy industry which has undergone a transition by shifting from simple mechanical toys towards electronic and science-based toys requiring higher scale of operation and also the skills. This is particularly challenging for the predominantly micro-sized units that are almost entirely positioned in the unorganized segment.

Figure 4: Sector-wise employment distribution across technology categories

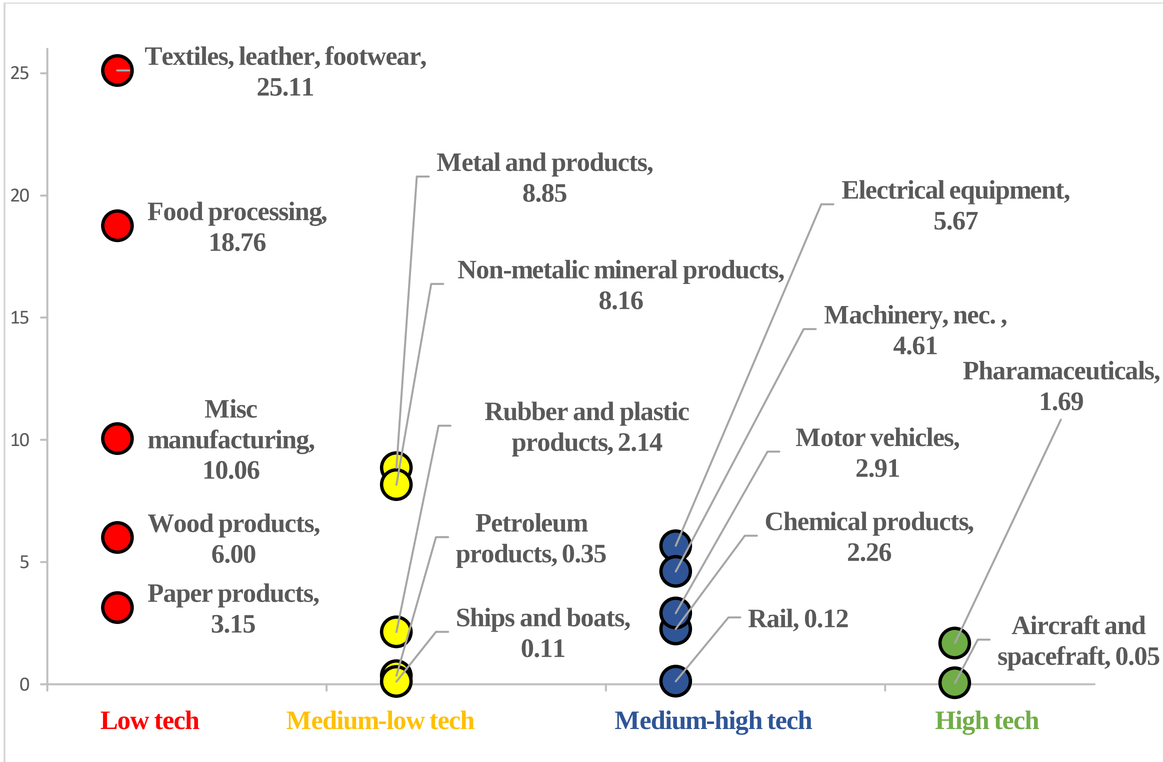

25
20
15
10
5
0
Textiles, leather, footwear, 25.11
Food processing, 18.76
Misc manufacturing, 10.06
Wood products, 6.00
Paper products, 3.15
Metal and products, 8.85
Non-metalic mineral products, 8.16
Rubber and plastic products, 2.14
Petroleum products, 0.35
Ships and boats, 0.11
Electrical equipment, 5.67
Machinery, nec. , 4.61
Motor vehicles, 2.91
Chemical products, 2.26
Rail, 0.12
Pharamaceuticals, 1.69
Aircraft and spacefraft, 0.05
Low tech
Medium-low tech
Medium-high tech
High tech

Figure 5: Sector-wise output distribution across technology categories

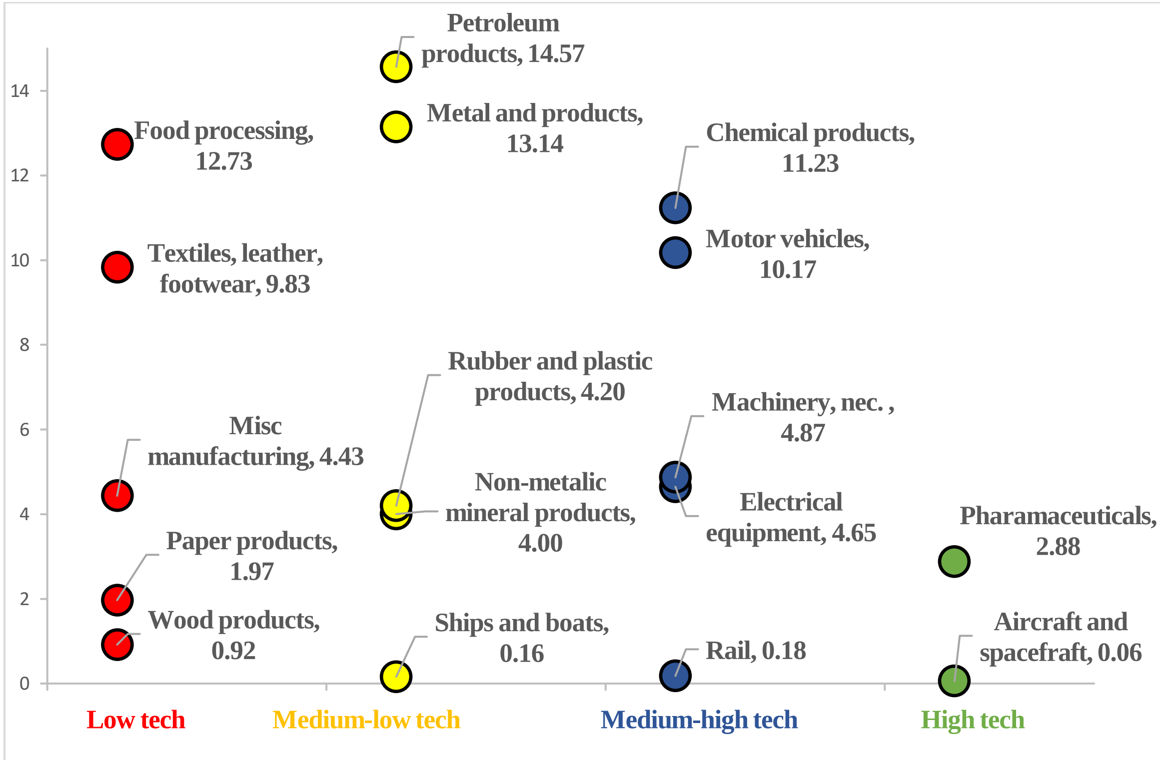


Figure 6: Sector-wise export distribution across technology categories

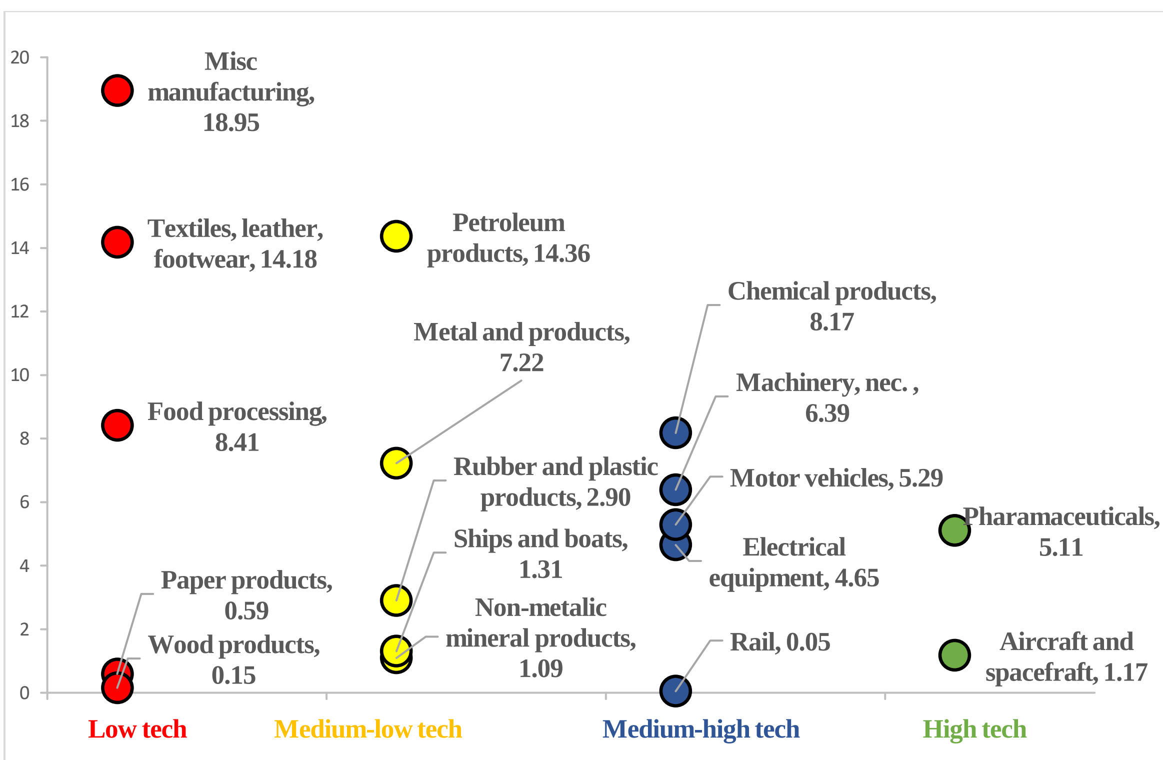


Figure 7: Sector-wise distribution of value added across technology categories

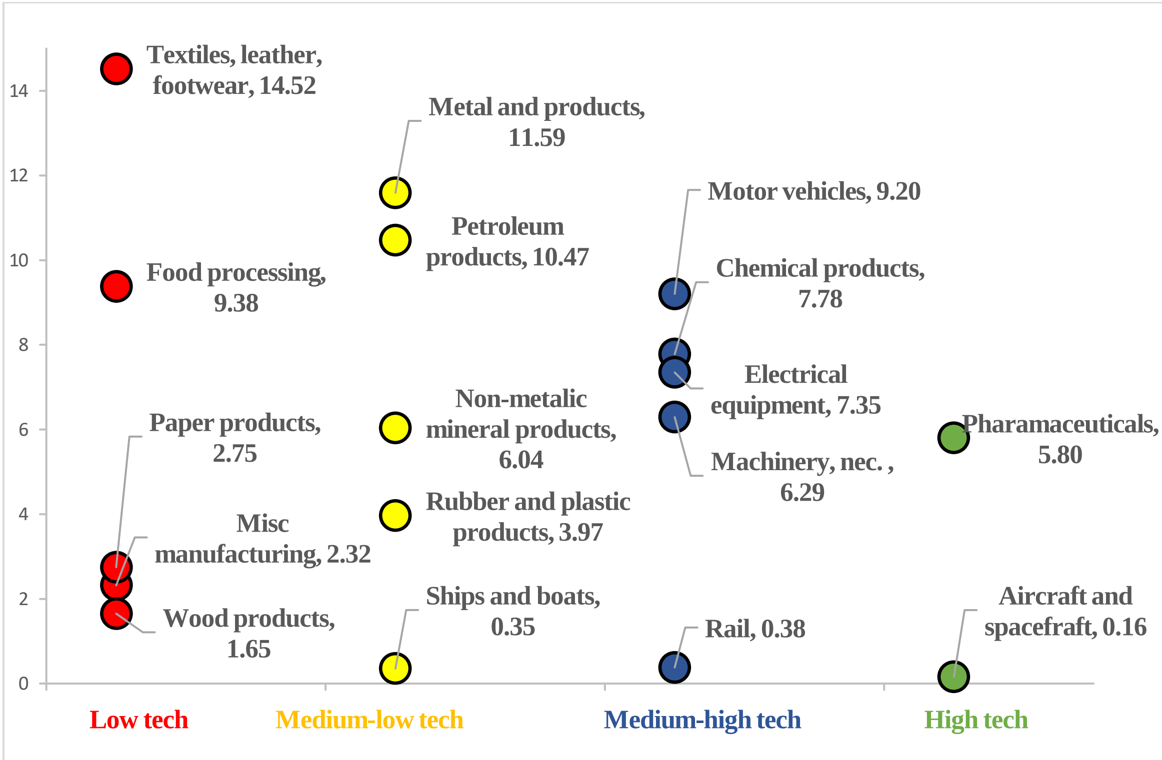
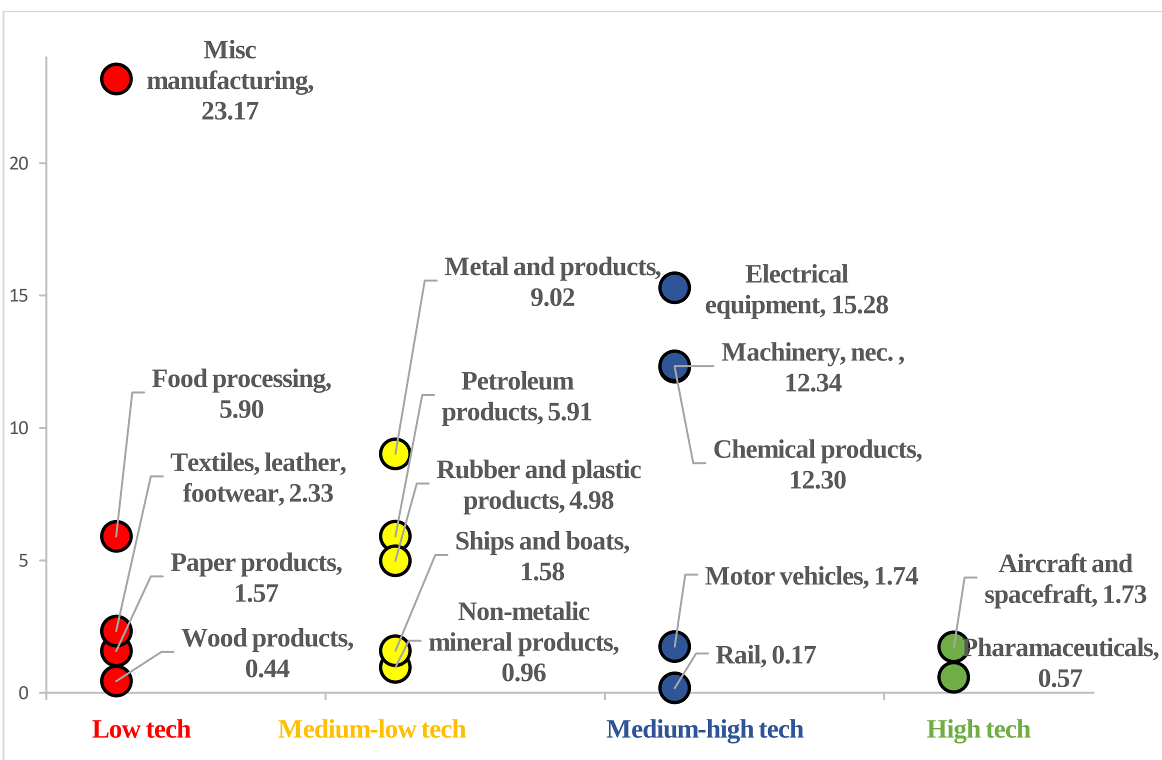


Figure 8: Sector-wise import distribution across technology categories



Technology upgradation: Worker benefits and challenges

The low tech manufacturing also has a characteristic labour-intensive nature of operations and relatively low productivity of labour (refer to Section 7.4) emphasizing the need to improve worker productivity for competitiveness. Technology upgradation improves productivity which benefits through lower price of goods leading to increase in demand ultimately creating more jobs. The improvements in labour productivity also contribute to better wages further raising the demand for goods, thereby workers through more job opportunities with the increase in domestic output. Even though, the introduction of advanced technologies such as the robotics cannot be completely ruled out in specific activities such as textiles and garment manufacturing, it is unlikely that there will be an immediate mass substitution of labour through such applications in India. Notwithstanding, greater automation is needed for large-scale production and to meet the strict time-lead requirements of the foreign retailers as the manufacturers become more competent to execute orders for more complex garments such as suits, jackets and underwear as witnessed in other countries, e.g., Bangladesh and Vietnam.[11] Therefore, from an employment perspective, the key to competitive performance of the industry and job opportunities is related to upgradation of the worker skills. However, these traditional industries are constrained to up-skill workers, and lack in providing trainings to productivity and quality managements, and the shortage of managerial staff and trainers for trainings as also corroborated in a report by the KPMG (2020). Also, even though placed at the bottom of the technology spectrum, the low-tech industries such as the manufacture of footwear stand in need of technology benchmarking and environment management for upgradation of plants and for solid waste management (KPMG, 2020). Therefore, introduction of new(er) technologies is an inevitable situation, even though breakthrough technologies is not an immediate challenge.
Since employment generation in textiles is strongly linked to exports, the need to leverage exports cannot be understated (Research and Information System, Kumar, 2019). Technology upgradation in the domestic industry will enhance the potential to capture overseas markets benefiting domestic employment. It is also noted that the potential for automation is not the same across all sub-sectors within textiles. To illustrate, in China while weaving and spinning have witnessed automation, cutting and sewing processes have been

[11] In both countries, Bangladesh and Vietnam, increasing automation is associated with job loss of select worker categories such as female workers. However, the resulting competitiveness of the business has helped through greater international order ultimately supporting greater workers than before. However, emerging challenges include the shortage of skilled workers, emphasising the need to enhanced the knowledge and skills of the workers and prepare them to handle the automation technologies (Faruk, 2023, Apparel Resources, 2019, Ullah and Akhter, 2021, FemLab)

less affected suggesting that widespread automation is not supported due to lower economic feasibility (ILO, 2016b). In India too, the high cost of ‘sewbot’ technology prevents from its fast and smooth diffusion (Mani, 2019). However, in the medium-term deployment of sewing robots may register an increase with the decline in their costs, thereby impacting the workforce. Therefore, there is need to prepare the workers for transition to other activities, and to train and equip them to become compatible for the introduction of breakthrough technologies in the long-run.

The comparatively high export orientation vis-a-vis the two medium tech categories underscores the needs to maintain competitiveness through acquiring skills that match international standards. This will also improve the returns to labour. In fact, worker trainings and compatibility to the modern techniques of production, not necessarily involving top-end technology, is much needed in view of the international evidence which shows that trade has been associated with job loss in labour-intensive industries (OECD, 1994, 1996). This also exposes the primarily rural unorganized and micro enterprises, which are constrained with insignificant capital stock and the limited access to finance, to the need for improving their labour productivity and capital intensity of the production integrating a generally better technology.

Better technology also supports opportunities for women employment (UNCTAD, 2013). The higher levels of technology are associated with improved capital intensity which tends to improve the employment prospects for women workers than in the labour-intensive industries. More specifically in the context of the broader unorganized manufacturing activity, the argument for a stronger influence of the endowment of female workers, particularly in the capital-intensive segment, is supported due to the possible substitution of the female worker for male worker (Tandon, 2024 forthcoming). It is argued that male worker in the unorganized manufacturing may not be having distinctly different skills (than their female counterparts); even though the female workers are generally paid lower based on gender differentials (Tandon, 2022).

Table 2: Sector-wise economic characteristics across technology categories

	Employment	Output	Exports	Imports	Value added
Low technology					
Food Products, Beverages and Tobacco	18.76	12.73	8.41	5.90	9.38
Manufacturing, nec; recycling	10.06	4.43	18.95	23.17	2.32

Pulp, Paper, Paper products, Printing and Publishing	3.15	1.97	0.59	1.57	2.75
Textiles, Textile Products, Leather and Footwear	25.11	9.83	14.18	2.33	14.52
Wood and Products of wood	6.00	0.92	0.15	0.44	1.65
Medium-low technology					
Basic Metals and Fabricated Metal Products	8.85	13.14	7.22	9.02	11.59
Coke, Refined Petroleum Products and Nuclear fuel	0.35	14.57	14.36	5.91	10.47
Other Non-Metallic Mineral Products	8.16	4.00	1.09	0.96	6.04
Rubber and Plastic Products	2.14	4.20	2.90	4.98	3.97
Ships and boats	0.11	0.16	1.31	1.58	0.35
Medium-high technology					
Chemicals and Chemical Products	2.26	11.23	8.17	12.30	7.78
Electrical and Optical Equipment	5.67	4.65	4.65	15.28	7.35
Machinery, nec.	4.61	4.87	6.39	12.34	6.29
Motor vehicles	2.91	10.17	5.29	1.74	9.20
Rail	0.12	0.18	0.05	0.17	0.38
High technology					
Aircraft and spacecraft	0.05	0.06	1.17	1.73	0.16
Pharmaceuticals	1.69	2.88	5.11	0.57	5.80

7.2 Medium-Low tech manufacturing

Turning to low-medium technology category, the metal and non-metallic product sectors have significant employment contributions of 8.9 percent and 8.2 percent, respectively. More specifically, their constituting industries such as the iron and steel, aluminum, and cement have been the center of policy attention over the past decade due to the energy-intensive nature of their feedstock and/or operations. Particularly, the basic metal and fabricated metal product sector is also important due to its high share in output, value added, imports, and exports within the category. The coke, refined petroleum product and nuclear fuel is another important sector due to significant share in output, value added, exports, and imports, though not as much for employment. In fact, exports of petroleum products have the second highest proportion in the export basket, following exports of engineering goods from India.

The rubber & plastic sector though relatively less proportionate in the economic parameters, is noted for potential to provide future jobs. India's is the third largest producer of rubber globally. Quality production of rubber products creates a scope for export expansion in future (Skill Development Council). The rubber industry provides key components for the automobile industry where nearly 61 percent of auto tyres and tubes are consumed, thus making its sustained growth important for competitiveness of downstream buying industries. Another 10 percent of the rubber is consumed as cycle tyres, followed by rubber dipped goods contributing to another 8 percent of the rubber consumption (Jadeja, 2018). The rubber industry is highly segregated with mostly micro-sized units that find it challenging to keep with the pace of business changes through prioritizing on technology and product invitation. Other limitations occur in the form of talent management, inventory managements, logistic costs and competition. The plastic industry is predominantly characterized by MSMEs constituting 85-90 percent of 50,000 processing and converting in the country. The plastic industry is uniquely placed through its contribution to circular economy. As waste management becomes important at par with the product itself, opportunities for work emerge for plastic waste segregators and machine operators for recycling and processing of the waste.

Another sector namely the ships and boats manufacture is relatively less significant within the overall medium-low category.

The technology implications of India's pathways to decarbonization deserve concentered attention. Under the nationally determined commitments (NDCs) the energy intensity of the GDP will reduce by 45 percent by the year 2023, from the 2005 level; and the country will achieve net zero emissions (NZE) by 2070. Consequently, the government has introduced many energy conservation initiatives backed by technology changes in industries. Therefore, the workers in industries, particularly in the industries with significant emissions contribution such as the iron and steel, need to be prepared to take-on the green jobs that have been emerging under the decarbonization scenario which has witnessed emerging technologies or the retrofitting of brownfield technology to achieve energy efficiencies mandated through programmes such as the Perform Achieve and Trade (PAT) programme introduced in 2011.

7.3 Medium-high tech manufacturing

Within the medium-high tech category, the electrical and optical equipment, machinery nec. have high employment shares. The category also includes capital-intensive industries such as industrial machinery, automobiles which mainly operate in the organized manufacturing segment where their structural expansion is generally supported by availability of regular and skilled workers (Tandon, 2024 forthcoming). Another sector namely manufacture of motor vehicles despite its characteristic large-sized firms in the organized segment is dependent on the supply of ancillaries and components from the SMEs in the medium-low tech category where the level of skill required is relatively low. However, these upstream supplying sectors also face the pressure to enhance competitiveness and quality due to their supply chain integration.

India's manufacture of chemical products is rated fairly competitive on some fronts and lagging on others. For instance, cost of labour and utilities is among the lowest when benchmarked against six global peers, while the Indian chemical industry is lagging on availability of R&D talent and in terms of domestic feedstock availability (McKinsey, 2023). This in contrast to some key changes observed internationally. Globally, chemical manufacturers are using technological innovation to meet strategic requirements for improving operational efficiency through automated monitoring and preventive maintenance, sustainable performance through tracking of key performance indicator (KPI) to minimize energy usage, and optimize production thereby reducing carbon footprint of the industry (Prestowwod, 2022). The digital transformation through automation in process and equipment is unlikely to leave Indian manufacturers in isolation, who will have to adopt better technology in their production line.

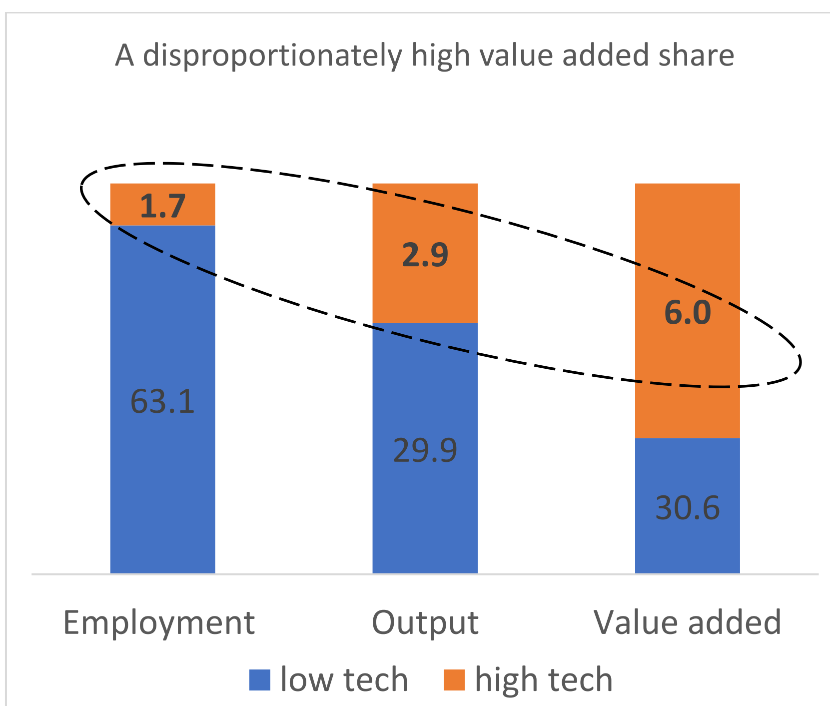
7.4 High tech manufacturing

Despite a relatively low significance in comparison to the other three technology categories, the high tech manufacturing is important due to its faster growth also for other reasons as highlighted in this sub-section. The value addition of the industries belonging to the high tech segment is higher than the matured low tech industries where the competition is intense leading to low margins (Kumar and Pradhan). Also, the technology intensive industries have the benefit of significant inter- and intra-industry externalities (Lall, 1999). Further, broad-basing the exports to more high tech exports lowers export instability, increases value added, enhances forex earnings, and supports growth through multiple channels (Samen 2010). Also, firm-level studies have shown that employment generation is not confined to low-technology labour-intensive sectors (Mehta, 2016). The observation, particularly in the context of pharmaceutical industry further substantiates views of eminent development scholars including Lall (2001) and Rodrick (2008) emphasizing on the importance of high tech industries in achieving structural transformation with better outcomes on income, employment, and the sustained growth.

Figure 9 shows a comparative distribution among the low tech and high tech categories. It can be seen that despite relatively low importance in overall employment, the high tech manufacturing contributes disproportionately to the output and value addition. While the low tech manufacturing employs 36 times more than the high tech manufacturing, the scaling factor for output, exports, and value added of the low tech and high tech manufacturing is progressively smaller at 10 times, 7 times, and 5 times, respectively. The low employment shares are attributed to the significant employment of skilled workers when compared to the predominantly unskilled work force employed in the low tech labour-intensive industries. This is reflected in the higher labour productivity of the high tech which is observed to be 3.6 times more than in the low tech manufacturing further validating their value addition potential in the economy.

At the same time, high tech industries are sensitive to issues such as capital required to finance R&D, and patent rights for which the private sector needs to be incentivized. In this regard, it needs to be mentioned that a shift of the structure with a stronger presence of the high tech segment would require concerted efforts with strategic involvement of the State. In the recent past, the development of Covid 19 vaccines has indeed demonstrated the success of collaborative research between public and private organizations.

Figure 9: Significance of high tech category



Notes: Distributional structure between low and high tech only. Figures are the shares in total manufacturing.

Within the high tech category, the success of Indian pharmaceuticals employing 2.5 million, is globally recognized. India is acclaimed as "pharmacy of the world", and ranks

3rd in the volume of pharmaceutical production while also accounting for a high R&D intensity of the sector in comparison to the national average. Export intensity of pharmaceutical is as high as 54 percent and the FDI is 3.3 percent of the equity between the period 2000-01 to 2020-21.

8. Summing-up and conclusions

The increasing pervasiveness of technology is inevitable for a progressive and sustainable economic development. A technology-enabled manufacturing helps to improve the quality, cost and the process of manufacturing. Also, under the growth and sustainability agenda, firms tend to improve energy efficiency and consequently lower the related emissions, which also has technology implications emerging from the decarbonization efforts. The industry 4.0 technologies are being implemented with the advances in the form of artificial intelligence (ai), internet of things (iot), big data, machine learning (ml). Their adoption and integrations contributes to efficiency and precisions in the manufacturing process through production under controlled and monitored environment. These advancements increase the demand for science, technology, engineering, and mathematics (STEM) skills in the workers. Therefore, the workers, particularly the blue-collar workers, are likely to be impacted due to their low knowledge of the emerging concepts. In the absence of a ready workforce with technology compatible skills, the transition can negatively impact the workers. Despite the challenges, it is also recognized that not all technologies disrupt all industries in the same manner and a the same time across regions/countries, suggesting that the lag-periods can be used to prepare for the future transition. This provides space to work on improving the worker skills so as to minimize the employment shock from application of new and emerging technologies.

To assess the specific areas in the Indian context, the National Manufacturing Policy with the targeted expansion of manufacturing GDP share to 25% by the year 2025, makes it important to assess the technology profile of Indian manufacturing. This paper uses a bottom-up approach to provide a technology-based classification of the manufacturing activity. Beginning with the disaggregated-level, each of the sectors is classified into one of the four technology categories, which are then aggregated to develop a technology profile of the broad manufacturing.

A technology-based analysis supports policy through insights on the distinguished attributes as relevant. In general, barring few exceptions, the low-tech manufacturing sectors tend to be resource-based, medium-low tech sectors are material-intensive, medium-high tech sectors incorporate heavy machinery, while the high tech sectors make use of are advanced technological expertise, engineering skills, and precisions manufacturing skills. Analyzing the technology categories for their importance in terms of select economic indicators, highlights significance of the low-tech segment through a higher contribution to employment and exports. This suggests that leapfrogging to breakthrough technologies, e.g., mass deployment of robots in textiles and footwear production, if it happens unprepared, is likely to cause a disturbance for the vast workforce employed therein in the absence of technology-compatible worker skills. At the same time, given the declining international competitiveness of the prominent sectors in this category (West, 2020), e.g. textiles, the scope for modernization remains high under a scenario with emphasis on labour-intensive manufacturing as a source of job creation. Therefore, from an employment perspective of technology applications, there is an urgent need to up-skill the workers in low tech manufacturing.

The import share of medium tech manufacturing is high. Viewed along with the high output share of the medium tech manufacturing, this underscores the shortages on domestic production of the medium tech goods, including that of capital goods. Therefore, domestic expansion and indigenous development of the medium tech manufacturing will contribute to improved *Atmanirbharta* of the economy. This can be achieved through strategic interventions for encouraging tech-manufacturing capabilities through indigenous innovations. A stronger domestic manufacturing will also advantage through passing direct signals to the skilling ecosystem on the kind of labour demand in future.

For the high tech manufacturing, the challenges are of a different nature. These goods are high-value low-volume and the products are complex in nature. Thes unique challenges of high tech manufacturing can be met through detailed engineering, adhering to stringent quality requirement as part of complex press which often involve working with rare/exotic materials, and continuous updation of technology and its absorption. The manufacturing requires highly skilled manpower which is trained through exhaustive training, trial and guidance. The curriculum for engineering and diploma courses should also be revised to impart more employability which will further strengthen domestic manufacturing while creating much-needed jobs in the category.

In conclusion, while recognizing the job creation potential of the manufacturing (Tandon, 2024), it is equally important that the policies fostering industrial development in the country are also accompanied with effective policies for worker transition so that the job and income risks are minimized. Therefore, it is required to prepare the society through skilling, reskilling and upskilling for a more technology-enabled manufacturing in the future. In the absence of an appropriate transition mechanism for the workers, particularly for those working in low tech category, the technology-related anxiety of the Indian manufacturing cannot be refuted upfront.

References

Acemoglu, D. 2022. Technical Change, Inequality, and the Labor Market. Journal of Economic Literature, Mar., 2002, Vol. 40, No. 1, pp. 7-72.

AfDB, ADB, EBRD, IDB (African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, Inter-American Development Bank). 2018. *The Future of Work: Regional Perspectives.* Washington, DC.

Apparel Resources. 2019.

Banga, K. and Dirk Willem te Velde. 2018. Digitalisation and the future of manufacturing in Africa. Supporting Economic Transformation (SET).

Bogoviz,A.V., Vladimir S. Osipov, Marina K. Chistyakova, Maxim Y. Borisov. 2018. Comparative Analysis of Formation of Industry 4.0 in Developed and Developing Countries, Chapter in

Central Statistical Organisation. 2008. National Industrial Classification, 2008.

Chadha, R, Saluja, M R, and Sivamani, G. 2020. Input Output Transactions Table: India 2015-16. Brookings India Discussion Paper, January 012020.

Chellasway, P. and Sumathi, N. (2006). Indian Textile industry. Accessed Online at https://www.fibre2fashion.com/industry-article/543/indian-textile-industry

Cohen, W.M. 2010. Fifty Years of Empirical Studies of Innovative Activity and Performance. In *Handbook of the Economics of Innovation,* ed. B.A. Hall and N. Rosenberg, 129-213. Amsterdam: Elsevier.

Council on Energy, Environment and Water (CEEW), Natural Resources Defense Council (NRDC) and Skill Council for Green Jobs (SCGJ). 2022. India's Expanding Clean Energy Workforce. Report.

Dachs, A. 2018. The impact of new technologies on the labour market and the social economy. Science and Technology Options Assessment, European Parliamentary Research Service

Dasgupta, S. 2018. Indian shipping industry – An ocean of opportunities.

Development, 27: 1769-1786

Dosi, G., and R. Nelson. 2010. Technical Change and Industrial Dynamics as Evolutionary Processes. In *Handbook of the Economics of Innovation,* ed. B.A. Hall and N. Rosenberg, 52-126. Amsterdam: Elsevier.

Ejaz Ghani, E.,William R. Kerr and Stephen D. O'Connell. 2013. The Exceptional Persistence of India's Unorganized Sector. Policy Research Working Paper 6454. World Bank.

Elena G. Popkova, Yulia V. Ragulina, Aleksei V. Bogoviz (Eds.) Industry 4.0: Industrial Revolution of the 21st Century. pp 155-164.

European Strategy and Policy Analysis System. 2018. Global Trends to 2030: The Future of Work and Workplaces. ESAPS Idea Paper Series.

Faruk, Nabil Bin. 2023. The Impacts of the Automation on the Man-based Labor within the Apparel Industry of Bangladesh.

ILO. 2016. *ASEAN in Transformation: Textiles, Clothing and Footwear*. ILO.

In David O'Connor & M. Kjöllerström (Eds), *Industrial development for the21st century* (pp. 7–28). Hyderabad: Orion Printers.

India Brand Equity Foundation. 2022. Automobile exports of INDIA. Accessed online at https://www.ibef.org/blogs/automobile-exports-of-india

India Brand Equity Foundation. 2023. Auto components industry report.

Jadeja, V. 2022. Opportunities and challenges for the Indian rubber industry.

Kemeny, T and T. Osman (2018). Research Policy, Volume 47, Issue 9, Pages 1729-1740

KPMG (2020). White Paper – Footwear Industry in India, TCSP: Technology Cluster Manager, Technology Centre System Program (TCSP), Office of DC MSME, Ministry of MSME.

Kumar, N and J P Pradhan.2003. Export Performance of Indian Enterprises in Knowledge-based Industries: Recent Trends, Patterns and Implications. RIS-DP # 42/2003.

Lall, S. 1999. 'India's Manufactured Exports: Comparative Structure and Prospects', *World*

Lall, S. 2001. *Competitiveness, technology and skills.* Cheltenham: Edward Elgar.

Lee, Neil and Rodríguez-Pose, Andrés (2016) *Is there trickle-down from tech? Poverty, employment and the high-technology multiplier in US cities.* Annals of the Association of American Geographers, 106 (5). pp. 1114-1134.

Mani, s. (2000). Exports of High Technology Products from Developing Countries: Is it Real or a Statistical Artifact. UNU/INTECH Discussion Papers, ISSN 1564-8370.

Mani, Sunil. 2019. "Robot Apocalypse How Will Automation Affect India's Manufacturing Industry*?". Economic and Political Weekly*. Vol LIV. No. 8. Pp. 40-48.

Marsili, O. 2001. *The Anatomy and Evolution of Industries: Technological Change and Industrial Dynamics*. Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

McKinsey & Company. 2023. India: The next chemicals manufacturing hub, March.

Mellett, E. and Finnell, J. (2021). Skills you need to succeed in green energy and sustainability jobs. Leaders in Energy.org. https:// leadersinenergy.org/ skills-you-need-to-succeed-in-green-energy-andsustainability-jobs/.

Mukherjee, A. and B S Harsh. 2021. Maritime pollution and the shipbreaking industry – challenges and mitigation-options.

Natural Resources Defense Council (NRDC) and Council on Energy, Environment and Water (CEEW). 2015. Clean Energy Powers Local Job Growth in India, Interim report, February.

NITI Aayog. 2022. India Innovation Index, 2021.

OECD. 1994.

OECD. 1996.

OECD. 2011. ISIC REV. 3 Technology Intensity Definition, OECD Directorate for Science, Technology and Industry, Economic Analysis and Statistics Division.

Prestwood, J. 2022. What Technologies Can Chemical Manufacturers Use?

RBI (2022). India KLEMS Database.

Reddy, K. and Subash S. 2020. Will COVID-19 Change the Landscape of Financing Innovation in India?. Economic and Political Weekly, Vol lV no 22, November 28.

Research and Information systems. 2019. Robotisation of Textile Sector in China: Impact and Imperatives, Policy Brief No 88, August.

Rodrik, D. (2008). Industrial development: Some stylized facts and policy directions.

Samen, S. 2010. A primer on export diversification: Key concepts, theoretical underpinnings and empirical evidence. Growth and Crisis Unit World Bank Institute.

Sanghvi, K. 2007. Challenges in Weaving Automation. Accessed Online at https://www.fibre2fashion.com/industry-article/1805/challenges-in-weaving-automation

Singhal, Prachi, Mousumi Kabiraj, Kalyani Krishna, Anubha Sharma, and Shaily Jha. 2023. Unlocking Sustainable Livelihood Opportunities for Rural Women: A Case Study of Mainstreaming Women in Clean Energy-Powered Livelihoods. New Delhi: Council on Energy, Environment and Water.

West, J. 2020. India squanders its comparative advantage. East Asia Fourm, July 10.

Tandon, A. 2022. "Inter-industry wage differentials in India manufacturing", *Economic and Weekly*, Special Article, Volume LVII No 38, September 17, pp 39-45. 2022.

Tandon, A. 2024 Forthcoming. Labour and Capital Use in Indian Manufacturing. Routledge.

Ullah, Mohammad Sahid and Rawshon Akhter. 2021. Automation of the Readymade Garment Sector in Bangladesh: Who is paying the price?

UNCTAD. 2013. Impact of the global slowdown on India's exports and employment, United Nations.

Vashisht, P. 2018. Destruction or Polarization: Estimating the Impact of Technology on Jobs in Indian Manufacturing. The Indian Journal of Labour Economics, The Indian Society of Labour Economics (ISLE), vol. 61(2), pages 227-250, June.

World bank. 2023. World Development indicators. Accessed online