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ROBOT APOCALYPSE DOES IT MATTER FOR INDIA'S MANUFACTURING INDUSTRY ?

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ABSTRACT

The anxiety that technology will displace jobs on a large scale in the near future is flooding both academic and public debates, primarily in the developed world. The recent publication of a study by Oxford Martin School has predicted that a large number of occupations will see an increased rate of automation. Increased automation is likely to have an adverse effect on employment, especially in the manufacturing sector. India has been trying to increase employment through the manufacturing route. But the capital intensity of its manufacturing sector has been showing a steady increase. Employing a comprehensive dataset from the International Federation of Robotics, the study analyses the nature and extent of diffusion industrial robots in Indian manufacturing industry. Instead of an occupation-based approach, the study uses a task-based one, which presents a more accurate picture of the effect of automation on manufacturing employment. The study shows that the operational stock of industrial robots in manufacturing industry has been showing a systematic increase with the density of robots in the manufacturing sector increasing from less than one per 10000 manufacturing employment to almost 10 in 2016. Most of the robot use is confined to the automotive industry and within it, the application area of welding. This task is supposed to be very human unfriendly and so the diffusion of industrial robots does not appear to be having a deleterious effect on manufacturing employment. However, with significant developments in Artificial Intelligence (AI), robots are becoming more flexible and this may lead to automation of a number of tasks, which were previously thought to be non automatable.

Keywords: Industrial automation, Robots, Employment, Technological change, India

JEL Classification: J62, O32, O33, O38

Introduction

The initiation of *Make in India* programme is yet another statement of the desire of the government to increase employment in the country through the manufacturing route. Under this programme, the manufacturing sector is expected to contribute to at least a quarter of India's GDP by 2020. However, recent events and discussions have brought to the fore the pessimism that not much employment possibilities emanate from the sector due to the capital-intensive nature of the manufacturing sector which it had become for quite some time now. The worst fears on this issue have been accentuated with the increasing automation of manufacturing processes elsewhere in the world. Industrial automation is thought to have a deleterious effect on the creation of employment in different sectors of the economy, manufacturing included. This has given rise to an important debate, primarily in the context of developed countries where industrial automation has diffused manifold and that too over a much longer period of time. This debate, although originally in the popular press has now been brought to the formal academic table by the publication and influential and highly cited piece of research by Frey and Osborne (2013). Subsequently, one of the leading academic journals, namely the *Journal of Economic Perspectives,* organised a symposium on the theme 'automation and labour markets' in its summer of 2015 issue[1]. Thereafter there has been a series of studies by academic economists and multilateral institutions such as the OECD as well[2].

In the context, the purpose of the paper is to understand the extent of diffusion of automation technologies in Indian manufacturing and then analyse its effects on manufacturing employment.

The paper is structured as follows. Section 1 discusses the concept of automation and identifies the specific automation technology that we consider in the present study. Section 2 discusses in detail the motivation for the present study and the significance of the issues dealt with. Section 3 delineates the major research questions raised, methodology adopted to answer them and indeed the data sources employed. Section 4 engages itself with the literature on diffusion of automation technologies in manufacturing. Section 5 reports the main findings of our analysis with respect to Indian manufacturing. Section 6 considers the implications of future developments in automation technologies on the conclusions reached in the previous section. Section 7 concludes the study.

1. Concept of Automation

A range of technologies are involved in industrial automation which manifest itself as both hardware and software. Employment implications of these various automation technologies vary considerably. The specific automation technology that has the most direct impact on employment is the use of multipurpose industrial robots. The International Federation of Robotics - IFR for short - defines an

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1 See symposium on 'automation and labor markets', Journal of Economic Perspectives, Vol. 29, Number 3, Summer, 2015, https://www.aeaweb.org/issues/381. The three papers in the symposium are Autor, David H (2015), Mokyr, Vickers, Ziebarth (2015), and Pratt, Gill (2015) (accessed August 24, 2017).

2 See Acemoglou and Restrepo,(2017), Autor(2015), Brynjolfsson and McAfee(2014), Chang, Rynhart, and Huynh (2016), Hallward-Driemeier and Nayyar (2018).

industrial robot as “an automatically controlled, reprogrammable, and multipurpose [machine]” (IFR, 2014). That is, industrial robots are fully autonomous machines that do not need a human operator and that can be programmed to perform several manual tasks such as welding, painting, assembling, handling materials, or packaging. Most other types of automation technologies require a human operator, such as for instance a machine tool, programmable controllers or a CAD equipment. Robots can also perform reliably and consistently in harsh and constrained environments in which a human worker cannot function satisfactorily. Robots therefore represent about the most advanced and flexible form of industrial automation that can be envisioned. So, in the present study, we focus on industrial robots. In addition to industrial robots there are service robots as well. There are two concepts of industrial robots: delivered (flow) and operational stock (stock). Since we are interested in employment implications- our focus is on operational stock of industrial robots in Indian manufacturing. So the concept of industrial automation used is the use of multipurpose industrial robots in manufacturing. Between the stock and flows, our discussion is largely in terms of operational stock of multipurpose industrial robots, as this should give us a more accurate picture on employment implications.

2. Motivation

In recent years, there has been a revival of concerns that automation and digitalisation might, after all, result in a jobless future. The debate has been fuelled by studies for the US and Europe arguing that a substantial share of jobs is at “risk of computerisation”. These studies follow an occupation-based approach proposed by Frey and Osborne (2013), i.e. they assume that whole occupations rather than single job-tasks are automated by technology. It is argued that this might lead to an over estimation of job automatability, as occupations labelled as high-risk occupations often still contain a substantial share of tasks that are hard to automate.

There are essentially a number of reasons as to why an understanding of the relationship between automation and employment is important in the India context. These are:

- World wide there has been an increasing concern or fear on the effect of automation on employment. An extension of the earlier Frey and Osborne (2013, 2017) study on India showed that a whopping 69 per cent of the jobs in India are considered to beautomatable.
- Four industries, such as computers and electronic products, electrical equipment, appliances and components, transportation equipment and machinery are the four industries that are most prone to automation. In many countries including that of India these four industries, and especially the transportation equipment industry has been given much emphasis in the industrialization strategy.
- Automation potential is concentrated in countries with largest population or high wages- India, therefore, is a good candidate, even though currently it is considered to be a low wage country.
- India's recent policy is in terms of raising employment through promoting growth of the manufacturing industry, but hitherto the scenario has been a steady decline in the labour intensity of manufacturing employment (Sen and Das, 2014).
- Most recent data from India's labour bureau showed that there was an absolute decline in employment during the period 2013–14 to 2015–16, perhaps-happening for the first time in independent India. Further, it showed that the construction, manufacturing and information technology/business process outsourcing sectors fared the worst over this period (Abraham, 2017).

All these issues motivates us to understand the process of automation that is taking place in Indian manufacturing and its potential and actual effects on manufacturing employment.

Significance of the Study

The rate of diffusion of automation technologies are likely to increase in the manufacturing sector in the near future. The following factors highlight the significance of the study:

- First, a late manufacturing country such as India can skip stages and start with the latest manufacturing technologies.
- Second, with increasing globalization and with increasing pressure on manufacturing companies to be more productive and thereby competitive internationally, the pressure on adopting productivity enhancing technologies are much more now than ever before. According to estimates by Boston Consulting Group (2015), use of robots can decrease labour costs by as much as 16 per cent.
- Third, developments in artificial intelligence and machine learning the nature of tasks that machines can do has seen a quantum jump. For instance industrial robots are now much more intelligent and can perform a wide variety of operations which earlier they could not do.
- Fourth, the declining cost of automation and their increasing supply is still another factor that can hasten the rate of diffusion. Again according to Boston Consulting Group (2015), the average price of industrial robotic systems has declined from US $ 182000 in 2005 to US $ 133000 in 2014 (Sirkin, Zinser, Rose, 2015).

3. Research Questions, Analytical Framework and Data Sources

In the context, the study attempts to answer the following two research questions:

- What has been the rate of diffusion of automation technologies in Indian manufacturing over the period since increasing globalization of India's economy?
- What has been its effect on manufacturing employment? What is the relationship between the rate of diffusion of automation and the intensity of manufacturing employment and also what are the likely trends in this relationship in the years to come when the size and composition of manufacturing is bound to increase and become more sophisticated.

Analytical Framework

In order to understand diffusion of industrial robots in manufacturing we adopt a task-based approach. This is because an occupation may contain several tasks that are not prone to easy automation. So a task-based approach may provide us with a more accurate picture of diffusion. Also in the framework we measure diffusion by the number of operational stock of industrial robots per unit of employment. This framework is due to Arntz, Gregory and Zierahn (2017).

Data Sources

The main data source consulted is annual survey of robotics titled *World Robotics*. The data source presents annual and time series data on the number of delivered robots and its operational stock industry-wise and country-wise. Further, it presents the task-wise distribution of robots within occupations. Data are available over 32 countries including that for India. The data on manufacturing employment is taken from the Annual Survey of Industries. This is available industry-wise upto and including 2014-15.

4. Engagement with the Literature on Automation and Employment

The literature on the effect of automation on manufacturing employment is a subset of the general discussion on effect of technological development on employment creation. There are two different phases in the development of this literature. The first phase is the late 1980s when first of the cross country studies on effect of industrial automation on employment was completed (Flamm, 1988). The second phase is from 2013 onwards with the publication of the Frey and Osborne (2013) study. The publication of this study has unleashed a wave of extreme concern on the deleterious effect of faster diffusion of automation technologies on manufacturing employment. This has spawned a number of studies analysing the effect of automation on employment. These studies in turn can be divided into three groups: the first is a study which analyses the diffusion of industrial robots in a range of countries, the second group of studies show an inverse relationship between the extent of diffusion of automation and manufacturing employment in the sense that increased automation leads to decline in employment and the third group shows that increased automation has not really resulted in hefty job losses. In the following we review these studies in some length.

Diffusion of Industrial Robots in Developed Countries

One of the earliest studies on the changing pattern of industrial robot use is the one by Flamm (1988). He analysed the rate of diffusion of robot use in Belgium, France, Germany, Italy, Japan, Sweden, United Kingdom and the United States during the period 1970 through 1984. His survey focused on two related issues: how and where industrial robots were used in manufacturing and how robot use in the United States compares with manufacturing practices abroad. Robot use is uneven across industries with their use being confined or concentrated in certain specific tasks and industries. Historically, they were first used in hazardous and unpleasant operations associated with metal processing, in relatively small numbers. The Japanese auto manufacturers, after 1975, began to use them in large numbers for spot welding operations on their assembly lines and late in that decade expanded their field of application to arc welding. Their foreign competitors followed suit. In fact, it was welding activities which has hastened the diffusion of industrial robots across the developed world. Since 1980, once again led by Japanese manufacturers, more sophisticated industrial robots began to be used in electrical and electronics industries. Majority of the industrial robots, according to Flamm, are found in electronic assembly and automotive welding. The reasons as to why the use of robots has not diffused are because there are only a handful of major uses in which they are currently a cost-effective solution to manufacturers. In fact, industrial robot use has not shown a secular increase but in fits and starts.

In the context, Flamm is of the opinion that "One would be well advised to be sceptical of technological optimists who, on the basis of broad statistical job classifications for industrial workers, project veritable tidal waves of robots inundating manufacturing in the medium term".

Another interesting finding is that robots diffusion has lagged in the US manufacturing industry when compared to Japan, Sweden and Germany. Cross country variation in the relative prices of capital, labour and other factors of production does not seem to explain the differential rate of diffusion. The shift to more product variety that require a more flexible manufacturing plant may be a more plausible explanation.

Studies Finding an Inverse Relationship between Automation and Employment

One of the studies in this genre is World Economic Forum (2016). The study covered 15 major developed and developing countries based on a large-scale survey of major global employers including 100 largest global employers in each of WEF main industry sectors to estimate the expected level of changes in job families between 2015-20 and extrapolate the number of jobs gained or lost. Automation and technological advancements could lead to net employment impact of more than 5.1 million jobs lost due to disruptive labour market changes between 2015-20 with a total loss of 7.1 million jobs- two-thirds of which are concentrated in the office and administrative job family and a total gain of 2 million jobs in several smaller jobs.

Another study in this category is by McKinsey Global Institute (2017) which covers 46 countries accounting for about 80 per cent of the global labour force. The study showed that almost half of work activities globally have the potential to be automated using current technology. Technically speaking, automatable activities touch 1.2 billion workers and 1404 trillion dollars in wages. China, India, and the United States will account for over half of the automatable jobs. The study also notes that automation's boost to global productivity could be 0.8 to 1.4 per cent annually over decades.

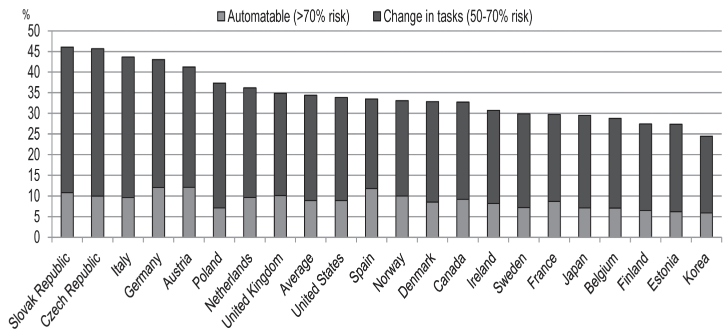
A more systematic study of the diffusion of robots in US manufacturing is done by Acemoglu and Restrepo (2017). In specific terms the study analysed the impact of robot use on the US labour market during the period 1990 through 2007. Using a model in which robots compete against human labour in the production of different tasks, they show that robots may reduce employment and wages, and that the local labour market effects of robots can be estimated by regressing the change in employment and wages on the exposure to robots in each local labour market—defined from the national penetration of robots into each industry and the local distribution of employment across industries. Using this approach, they estimate large and robust negative effects of robots on employment and wages across commuting zones. They supplement this evidence by showing that the commuting zones most exposed to robots in the post-1990 era do not exhibit any differential trends before 1990. The impact of robots is distinct from the impact of imports from China and Mexico, the decline of routine jobs, offshoring, other types of IT capital, and the total capital stock (in fact, exposure to robots is only weakly correlated with these other variables). According to their estimates, one more robot per thousand workers reduces the employment to population ratio by about 0.18-0.34 percentage points and wages by 0.25-0.5 percent.

Occupation *Vs* Task Based Approach

However, the main problem with these studies is that they consider only very broad occupations and not tasks within occupations. In short, they follow the occupation-based approach of Frey and Osborne (2013). Very often the assumption that whole occupations are automated by technology are invalid, rather, it is only that single job-tasks are prone to automation. This may lead to an over estimation of job automatability as occupations labeled as high-risk occupations often still contain a substantial share of tasks that are hard to automate. An important cross country study that has considered a more task-based approach is by Arntz, Gregory and Zierahn (2017).

The Arntz, Gregory and Zierahn (AGZ) study serve two purposes. Firstly, they estimate the job automatability of jobs for 21 OECD countries based on a task-based approach. In contrast to other studies, AGZ take into account the heterogeneity of workers' tasks within occupations. Overall, they found that, on average across the 21 OECD countries, only 9 percent of jobs are automatable- significantly lower than those predicted by Frey and Osborne (2017) and reported in World Bank (2016). The threat from technological advances thus seems much less pronounced compared to the occupation-based approach. Further, the study found heterogeneities across OECD countries. See Figure 1. For instance, while the share of automatable jobs is 6 per cent in Korea, the corresponding share is 12 per cent in Austria. Differences between countries may reflect general differences in workplace organisation, differences in previous investments into automation technologies as well as differences in the education of workers across countries.

The second purpose of AGZ study is to critically reflect on the recent line of studies that generate figures on the "risk of computerization" and to provide a comprehensive discussion on possible adjustment processes of firms and workers to automation and digitalization. In particular, it is argued that the estimated share of "jobs at risk" must not be equated with actual or expected employment losses from technological advances for three reasons. First, the utilisation of new technologies is a slow process, due to economic, legal and societal hurdles, so that technological substitution often does not take place as expected. Second, even if new technologies are introduced, workers can adjust to changing technological endowments by switching tasks, thus preventing technological unemployment. Third, technological change also generates additional jobs through demand for new technologies and through higher competitiveness.



Note: Data for the United Kingdom corresponds to England and Northern Ireland. Data for Belgium corresponds to the Flemish Community.

Figure 1: Share of Workers in Jobs, across OECD Countries, in jobs at High and Medium Risk of Automation

Source: OECD (2016).

The main conclusion from the above study is that automation and digitalization are unlikely to destroy large numbers of jobs. However, low qualified workers are likely to bear the brunt of the adjustment costs as the automatibility of their jobs is higher compared to highly qualified workers. Therefore, the likely challenge for the future lies in coping with rising inequality and ensuring sufficient (re-)training especially for low qualified workers.

A still another study (Graetz and Michaels, 2017) using cross country data on robot adoption by the International Federation of Robotics (the same data source used in our study), analyses robot adoption within industries in 17 countries during the period 1993 through 2007. Employing panel data on robot adoption within industries in these countries, and new instrumental variables that rely on robots' comparative advantage in specific tasks, it is found that increased diffusion of robotic technology contributed approximately 0.37 percentage points to annual labour productivity growth. Simultaneously, it has raised total factor productivity and wages, and lowered output prices. Further, the estimates suggest that robots did not significantly reduce employment, although they did reduce low-skilled worker's employment share.

In sum, the following inferences can be drawn from the studies that we have reviewed here:

- Industrial robots are basically used in certain specific industries such as automobile, electrical and electronics and metal tending. Even within these industries they are used for certain tasks like spot and arc welding which is both harsh and repetitive for human beings to perform. In fact, their usage does not seem to have diversified into other manufacturing industries over the last four decades;

- Studies which have analysed the relationship between diffusion of automation and employment have got results which are diametrically opposite. Some studies have got an inverse relationship between the two variables, while others have not detected any such relationship. Careful analysis of the former studies, show that they have used an occupation based approach while dealing with employment as opposed to a task based approach. An occupation based approach tends to exaggerate the impact of automation on employment as there are many tasks within an occupation that are not automatable; and

- The proxy that is used for identifying automation has varied across studies. Some studies define automation in terms ofcomputerization, while others identify it in terms of use of industrial robots.
- All the studies, without exception, refer to the situation in developed market economies. None of the studies refer to any of the developing countries.

Thus our engagement with the literature shows that there is a real case for a study analyzing the relationship between automation and manufacturing employment in the context of a late industrializing country such as that of India. Further, in our study, we define automation in terms of its highest form, namely the use of industrial robots and we use a task based approach to its effect on employment, this we feel will provide us with better and meaningful results on the effect of automation on manufacturing employment.

5. Main Findings with Respect to India

The operational stock of industrial robots in manufacturing has been increasing both in the world and in India. In India, it has increased from just 70 in 2000 to 16026 in 2016. See Figure 2. The operational stock has been increasing by 44 per cent per annum during the same period. According to the International Federation of Robotics (2017), there are five major markets representing 74 per cent of the total sales volume in 2016. These are China, Korea, the United States, and Germany. China has now become the largest with a share of almost a third of the total market in 2016. At a total sale of 87000 robots, the total number of industrial robots sold in the country is almost equivalent to the total number of industrial robots sold in Europe and America together. Apart from China, the other important markets for industrial robots are, Taiwan, Thailand and India. In India, sales of industrial robots increased by 27 per cent in 2016 to reach 2627 units. Estimated worldwide operational stock of industrial robots in 15 largest markets is presented in Figure 3.

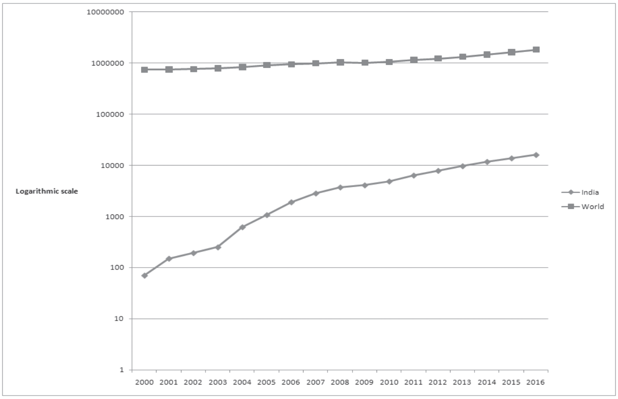


Figure 2: Trends in Operational Stock of Industrial Robots in the World and in India (in thousands)

Source: International Federation of Robotics (2017).

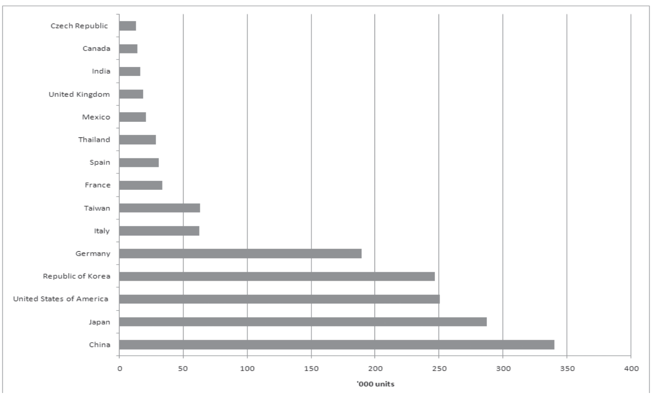


Figure 3: Estimated Worldwide Operational Stock of Industrial Robots in 15 Largest Markets 2016

Source: International Federation of Robotics (2017).

Despite having the largest operational stock of robots, in terms of density of it, China is still below the world average. India appears to have the lowest density although there is some underestimation of it due to the estimation of employment in the organised sector. This will be made clear in our own estimates of the density of industrial robots.

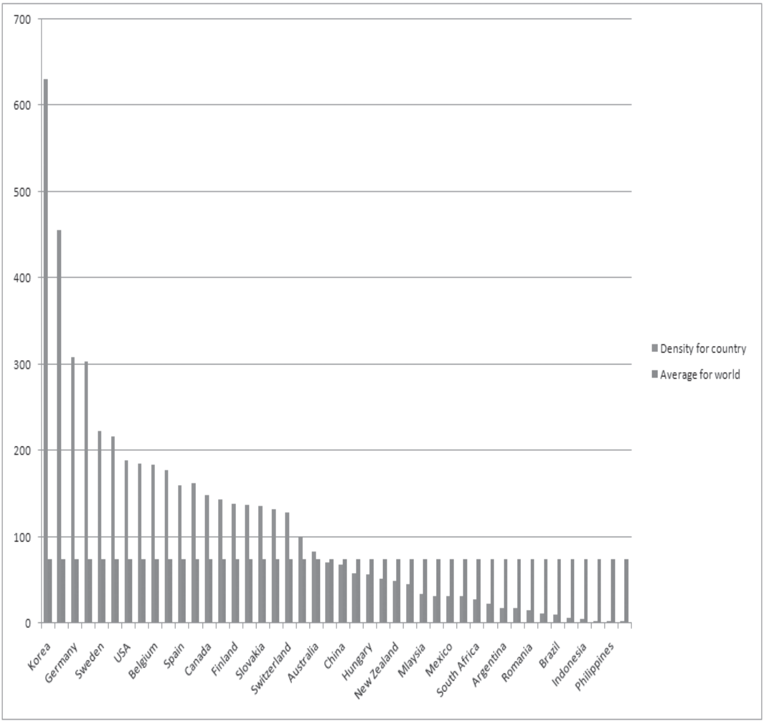


Figure 4: Density of Industrial Robots across both Developed and Developing Countries, 2016

Source: International Federation of Robotics (2017).

The Republic of Korea has by far the highest robot density in the manufacturing industry since 2010 (See Figure 4). 631 industrial robots were in operation in 2016 per 10,000 employees. The rate has been increasing from 311 units in 2010 due to continued installation of a large volume of robots since 2010 particularly in the electrical/ electronics industry and in the automotive industry. Singapore follows with a rate of 488 robots per 10,000 employees in 2016. Due to a very low number of employees in the manufacturing industry - some 240,000 employees are estimated by ILO - and a large number of installed robots, the robot density is very high. About 90% of the robots are installed in the electronics industry in Singapore, which has increased its number of robot installations significantly in recent years.

Now we analyse the industries and the tasks within these industries where the robots are being used. It will be instructive to analyse whether this has undergone any changes compared to what was observed by Flamm (1988) during the late 1980s. Three industries account for about 80 per cent of the operational stock of industrial robots: metal, electrical and electronics and automotive. See Table 1. Within the three, the automotive industry itself accounts for about 43 per cent- in fact it is the only industry which has increased its share. What is most interesting is the fact that the same industry accounted for the largest share in the 1980s as well (Flamm, 1988). We now analyse the tasks or application areas within these industries where industrial robots are used. See Table 2.

Table 1: Industry-wise Distribution of the Operational Stock of Industrial Robots (percentage shares)

	Metal	Electrical and Electronics	Automotive	Total for the three
1993	17.07	31.97	27.83	76.86
1994	17.16	31.63	27.76	76.55
1995	16.77	30.77	27.97	75.52
1996	16.25	30.20	28.74	75.20
1997	15.62	29.74	28.89	74.25
1998	14.75	28.95	29.84	73.53
1999	13.91	27.76	30.53	72.20
2000	12.90	26.83	31.47	71.20
2001	13.20	24.06	33.98	71.24
2002	12.96	22.24	35.96	71.17
2003	12.66	20.91	38.11	71.68
2004	11.87	20.04	40.95	72.86
2005	11.06	20.46	42.43	73.95
2006	11.36	19.02	44.59	74.98
2007	11.54	18.63	44.95	75.13
2008	12.16	18.23	44.90	75.30
2009	12.19	17.92	45.26	75.38
2010	11.97	18.78	45.92	76.67
2011	11.55	20.42	45.57	77.54
2012	11.28	21.51	45.44	78.23
2013	11.16	22.18	45.58	78.92
2014	11.21	22.48	45.76	79.45
2015	11.55	23.58	44.71	79.84
2016	11.46	25.77	43.21	80.43

Source: Computed from International Federation of Robotics (2017).

Table 2: Task-wise Distribution of Industrial Robots in World Manufacturing 2011-2016 (percentage shares)

IFR Class	Application area	2011	2012	2013	2014	2015	2016
110	Handling operations/Machine tending	41.3	44.3	43.6	47.1	48.4	47.4
111	Handling operations for metal casting	1.0	1.1	0.9	0.9	1.1	1.5
112	Handling operations for plastic moulding	6.9	7.5	6.9	8.1	8.4	6.9
113	Handling operations for stamping/ forging/bending	0.8	0.9	0.7	1.0	0.9	0.9
114	Handling operations at machine tools	3.9	4.4	5.6	4.2	5.6	5.1
115	Machine tending for other processes	1.9	1.5	1.4	1.0	1.6	0.9
116	Handling operations for measurement, inspection, testing	1.6	0.6	1.0	0.7	0.7	0.5
117	Handling operations for palletizing	2.8	3.3	3.2	3.3	3.9	3.5
118	Handling operations for packaging, picking and placing	7.5	9.7	7.2	12.2	10.7	10.0
119	Material handling n.e.c	15.0	15.2	16.7	15.6	15.3	18.0
120	Handling operations/machine tending unspecified						
160	Welding and soldering (all materials)	28.9	28.4	28.0	26.2	23.9	22.1
161	Arc welding	12.7	13.2	12.8	11.2	9.8	8.6
162	Spot welding	14.9	14.7	13.5	13.0	12.5	11.6
163	Laser welding	0.4	0.2	0.3	0.2	0.2	0.2
164	Other welding	0.5	0.2	1.2	0.9	0.6	0.7
165	Soldering	0.5	0.0	0.0	0.8	0.9	0.9
166	Welding and soldering unspecified						
170	Dispensing	4.2	4.0	4.9	3.6	3.6	3.3
171	Painting and enamelling	2.8	2.7	2.8	2.4	2.1	2.3
172	Application of adhesive, sealing material or similar material	0.9	1.0	1.2	0.4	0.6	0.3
179	Dispensing others/Spraying others	0.5	0.2	1.0	0.8	0.9	0.6
180	Dispensing unspecified						
190	Processing	1.4	2.0	1.8	2.5	2.1	1.3
191	Laser cutting	0.1	0.5	0.2	0.2	0.3	0.1
192	Water jet cutting	0.1	0.1	0.2	0.2	0.1	0.1
193	Mechanical cutting grinding/ deburring/milling/polishing	0.6	0.9	1.1	1.8	1.4	0.7
198	Other processing	0.6	0.5	0.3	0.3	0.3	0.3

Source: International Federation of Robotics (2017).

The use of industrial robots are concentrated in two main tasks: handling/machines tending and welding and soldering. The single largest application or task where robots are used is welding, and within it, arc and spot welding. In fact, there is a remarkable stability in the tasks where robots are used in the late 1980s and now. The only difference is that more of them are used for the same kind of tasks. The only task that has improved its share is in material handling and machine tending which shows that industrial robots are primarily used for those tasks which are difficult for human beings to perform.

Firms employ robots to automate specific tasks - many of them harmful to human health. The range of automatable tasks is continuously increasing and will continue to increase through advances in vision and end-effector technologies[3]. But this does not imply that jobs will be wiped out.

We now turn our attention to the Indian case. As seen earlier in Figure 2, the operational stock of industrial robots have shown some tremendous increase from just 70 in 2000 to 16026 in 2016. However, the growth rates of it has been fluctuating. Although there has been a fall in growth rates it has been in double digits. See Table 3. The share of manufacturing sector has been rising steadily and now accounts for about two thirds of the operational stock. It is also interesting to note that the number of robots being used in both construction and Education/ R&D has also shown some impressive increases. However, the industry-wise usage to a certain extent is coloured by a large number of robots whose usage cannot be ascribed to any specific sector.

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3 In robotics, an **end effector** is the device at the end of a roboticarm, designed to interact with the environment.

Table 3: Trends in Operational Stock of Industrial Robots in India

(Number)

	All Industries	Manufacturing	Electricity, Gas and Water supply	Construction	Education R&D	Other manufacturing	Unspecified
1999	50	0	0	0	0	0	50
2000	70	0	0	0	0	0	70
2001	150	0	0	0	0	0	150
2002	193	0	0	0	0	0	193
2003	250	0	0	0	0	0	250
2004	619	0	0	0	0	0	619
2005	1069	0	0	0	0	0	1069
2006	1905	497	0	6	5	0	1397
2007	2833	799	0	14	8	0	2012
2008	3716	1201	0	15	8	0	2492
2009	4079	1302	0	16	10	0	2751
2010	4855	1517	0	16	11	0	3311
2011	6352	2189	0	17	17	1	4127
2012	7840	3526	1	18	23	1	4270
2013	9677	5189	1	27	40	1	4417
2014	11760	7138	1	29	53	1	4536
2015	13768	8953	1	30	62	1	4718
2016	16026	11237	1	30	82	1	4671

Source: International Federation of Robotics (2017).

Manufacturing sector accounts for the lion's share of delivered robots as well as indicated by Table 4.

Table 4: Trends in the Number of Delivered Robots

	All Industries	Manufacturing	Electricity, Gas and Water supply	Construction	Education R&D	Others no manufacturing	Unspecified
1999	50	0	0	0	0	0	50
2000	20	0	0	0	0	0	20
2001	80	0	0	0	0	0	80
2002	43	0	0	0	0	0	43
2003	57	0	0	0	0	0	57
2004	369	0	0	0	0	0	369
2005	450	0	0	0	0	0	450
2006	836	497	0	6	5	0	328
2007	928	302	0	8	3	0	615
2008	883	402	0	1	0	0	480
2009	363	101	0	1	2	0	259
2010	776	215	0	0	1	0	560
2011	1547	672	0	1	6	1	866
2012	1508	1337	1	1	6	0	163
2013	1917	1663	0	9	17	0	227
2014	2126	1949	0	2	13	0	162
2015	2065	1815	0	0	0	0	250
2016	2627	2284	0	0	0	0	343

Source: International Federation of Robotics (2017).

However, within the manufacturing industry, much of the robot installations are in four industries, namely automotive, electrical and electronics, metal, chemical, rubber and plastics. There has been a 27 per cent increase in the number of delivered robots in 2017 compared to 2016 and on an average, it has increased by 64 per cent per annum during the period under consideration.

An analysis of the industry-wise operational stock of industrial robots show that it is very much concentrated in the automotive industry followed by plastics, rubber and chemical products and in the metal industry. The pattern that one observes in India is very similar to the international pattern that we observed earlier. In short, within India it is the growth of the automotive industry which explains largely the growth of robotic installations.

Task-based installations: Once again, the pattern that we observe in India is exactly the same as we have observed internationally (Table 5). Basically, robot usage is confined to two tasks, namely welding and soldering, and handling and machine tending. Within the former it is almost entirely concentrated in arc and spot welding. This is followed by material handling where in material handling for plastic moulding and at machine tools accounts for the second largest share. This was more or less the pattern observed historically even in developed countries.

This finding has very deep implications for employment. Industrial robots, are hitherto used for tasks where it is inhospitable for human labour and where much precision is required.

However, in order to understand the employment implications of robot use, one has to analyse in detail, the density of robots per unit of employment.

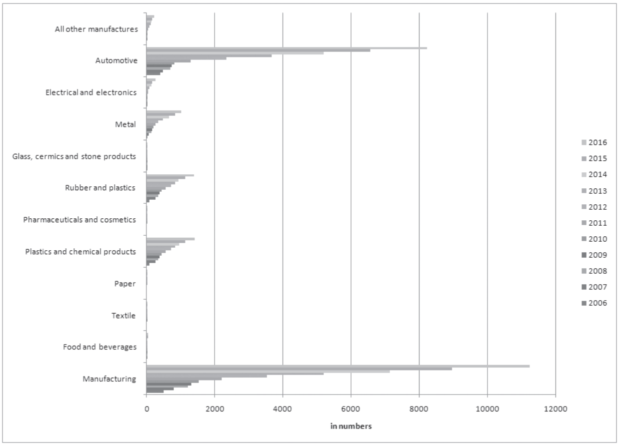

Figure 5: Industry-wise operational stock of industrial robots in India, 2006-2016

Source: International Federation of Robotics.

Density of Robots : We had earlier noted that the density of robots in India is one of the lowest among robot using countries. The density is an important indicator of the labour displacing effect of industrial robot use. We provide here two different estimates of density: first is the density of robots in the manufacturing industry and second is its density in the automotive industry. Both are showing an increase, although as expected, it is much higher in the automotive industry than the general manufacturing industry.

How does the density of robots in India compare with other countries? This is attempted in Table 6.

Table 5: Task Based Operational Stock of Industrial Robots in India, 2011-2016

Task	2011	2012	2013	2014	2015	2016	CAGR 2011-2016
Handling operations/Machine tending	2,101	2,531	2,903	3,404	3,948	4,760	18%
Handling operations for metal casting	44	58	62	68	93	111	20%
Handling operations for plastic moulding	538	676	790	905	1,097	1,387	21%
Handling operations for stamping/forging/bending	78	91	100	109	117	158	15%
Handling operations at machine tools	390	440	472	519	622	789	15%
Machine tending for other processes	42	48	51	51	51	51	4%
Handling operations for measurement, inspection, testing	6	8	8	9	9	10	11%
Handling operations for pelletizing	49	63	74	87	99	114	18%
Handling operations for packaging, picking and placing	29	47	63	65	78	90	25%
Material handling n.e.c	925	1,100	1,283	1,591	1,782	2,050	17%
Handling operations/Machine tending unspecified							
Welding and soldering (all materials)	2,720	3,561	4,775	6,095	7,324	8,800	26%
Arc welding	1,707	2,354	3,073	3,736	4,415	5,264	25%
Spot welding	938	1,125	1,602	2,250	2,780	3,380	29%
Laser welding	9	15	25	27	34	38	33%
other welding	55	56	62	69	82	102	13%
Soldering	11	11	13	13	13	16	8%

(Cont'd...)

Task	2011	2012	2013	2014	2015	2016	CAGR 2011-2016
Welding and soldering unspecified							
Dispensing	640	776	982	1,127	1,286	1,392	17%
Painting and enamelling	467	582	740	847	924	1,015	17%
Application of adhesive, sealing material or similar material	136	155	190	219	231	233	11%
Dispensing others/Spraying others	37	39	52	61	131	144	31%
Dispensing unspecified							
Processing	90	130	172	223	235	259	24%
Laser cutting	5	6	7	8	8	9	12%
Water jet cutting	5	7	7	9	11	16	26%
Mechanical cutting/grinding/deburning/milling/polishing	21	37	73	109	117	133	45%
Other processing	59	80	85	97	99	101	11%
Processing unspecified							
Assembling and disassembling	71	93	139	184	261	366	39%
Fixing, press-fitting	61	83	129	170	229	328	40%
Assembling/mounting/inserting	5	5	5	10	10	16	26%
Disassembling							
Other assembling	5	5	5	22	22	22	34%
Assembling and disassembling unspecified							
Others	113	129	147	206	240	271	19%
Cleanroom for FPD	5	5	5	5	5	6	4%
Cleanroom for semiconductors							
Cleanroom for others							
Others	108	124	142	201	235	265	20%
Unspecified	617	620	559	521	474	178	-22%
TOTAL	6,352	7,840	9,677	11,760	13,768	16,026	20%

Source: International Federation of Robotics.

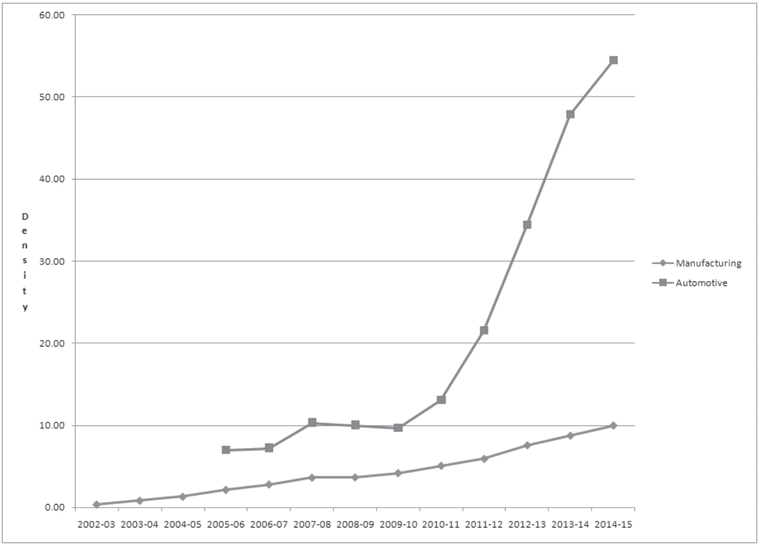

Figure 6: Trends in Density of Industrial Robots in India, Manufacturing *vs* Automotive Industry

Source: International Federation of Robotics (2017) and Central Statistical Organization (2015).

Table 6: Extent of Diffusion of Automation Technologies in India Compared with other Countries, 2015

(Density of industrial robots per 10000 manufacturing employment)

	India	China	Brazil	Thai-land	Malay-sia	Korea	Japan
Manufacturing	10	49	11	52	33	531	305
Automotive	54	392	125	859	281	1218	1216
All other industries	1	24	5	22	22	411	213

Source: International Federation of Robotics (2017).

This once again confirms the proposition that India has one of the lowest densities of robot usage even compared to her Asian counterparts. Although the robot usage in her automotive industry is much higher.

Since the automotive industry in India is dominated by affiliates of MNCs, and given the fact that the parent MNCs has a much longer history and experience with respect to the usage of industrial robots in various manufacturing operations, it is only natural that their affiliates in India with newer vintage plants will be using industrial robots (Table 7).

Table 7: Industrial Robots usage in MNC Affiliates in India's Automotive Industry

	Name of plant	Number of industrial Robots	Number of Employees	Density of robots
Ford Motor India	Sanand, Gujarat	453	2500	1812
Hyundai Motor India	Irugattukottai, Tamil Nadu	400	4848	825
Volkswagen India	Chaken, Pune	123	2000	615

Source: Company sources.

It is seen that the robot density of these state-of-the art plants are significantly higher than the average for the Indian automotive industry discussed earlier. Even the domestic automotive manufacturers such as the Tata Motors (See Box 1) are deploying industrial robots although on a density basis much lower.

Box 1

Tata motors uses industrial robotics and automation for production. Reports reveal that the production force in Tata Motors came down by 20%. At the same time its turnover increased by 250%. In a single plant in Pune, Tata is said to have installed 100 robots.

Source: Tata Motors.

Highly labour intensive industries such as paper and wood products, textiles, non-metallic products, food products, metal products and machinery etc are the least automated. The most automated industries such as the automotive industry, rubber and petroleum, basic metals and chemicals, are less labour-intensive. So the effect of automation (read as the use of industrial robots) has only an insignificant effect on the quantum of employment in the manufacturing industry.

- **Production of Industrial Robots in India:** Some of the world's leading firms in factory automation such as Fanuc, Kuka, Gudel and ABB have manufacturing and sales operations in India which can hasten the diffusion of industrial robots even in non-traditional industries. One of them, has even established a training academy or college in the Indian city of Pune for training young engineering graduates in robotics which can hasten the process of diffusion of industrial robots in manufacturing industries. Further, TAL Manufacturing Solutions, a subsidiary of Tata Motors Ltd. has launched its much-awaited TAL Brabo robot in two variants, with payloads of 2 kilos and 10 kilos, priced between INR 5 to 700000. Indigenously developed, the TAL Brabo is apparently solution, developed to cater to micro, small and medium enterprises, as well as for large scale manufacturers who require cost competitive automated solutions in manufacturing. Designed and styled in-house at TAL Manufacturing and Tata Elxsi respectively, Tata AutoComp manufactured some of the critical components of the robot. Conceptualized to complement human workforce and perform repetitive, high volume, dangerous and time consuming tasks, the TAL Brabo robot, can be deployed across industries. Having successfully tested the TAL Brabo in over 50 customer work streams hitherto. TAL Manufacturing is ready to supply these robots, inter alia, to several sectors including Automotive, Light Engineering, Precision Machining, Electronics, Software Testing, Plastics, Logistics, Education, Aerospace and Engineering.

6. Implications of Impending Automation on Traditionally Labour –intensive Industries

One of the most labour intensive industries in India is the cotton textile industry, especially the making of ready made garments. The "Sewbot" technology, being developed by Softwear Automation (an US company), aims to automate the entire clothes-making process. However, the technology is very highly priced that its diffusion in the textile industry will take years to fructify. There are four processes that go into making an item of clothing, (i) picking up the item, (ii) aligning it, (iii) sewing it; and (iv) disposing of it. Of these, only the sewing has so far been automated, and the sewing machine came in a long time ago. The other parts of the process are still done more quickly and more cheaply by humans. In fact, as can be seen from Figures 7a and b, the most automated industry in India, the automotive industry accounts only for about 10 per cent of the manufacturing employment in the country. Within this industry, we had already seen that only certain specific tasks are automated.

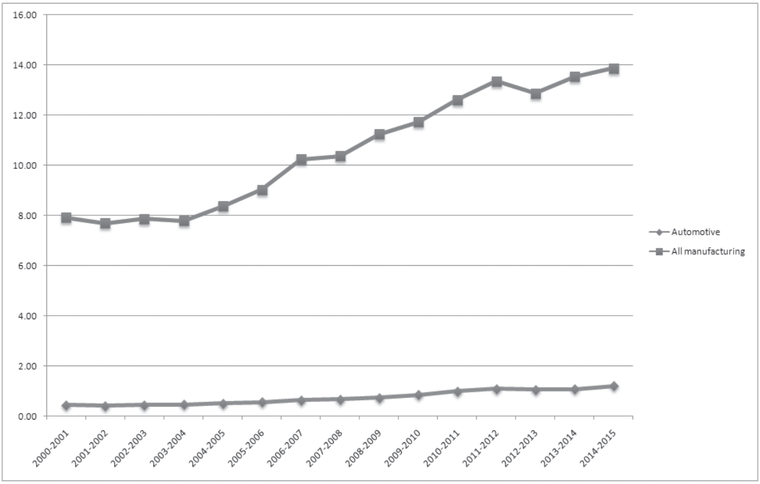

Figure 7a: Trends in Employment in India's Automotive Manufacturing Industry

Source: Computed from Annual Survey of Industries.

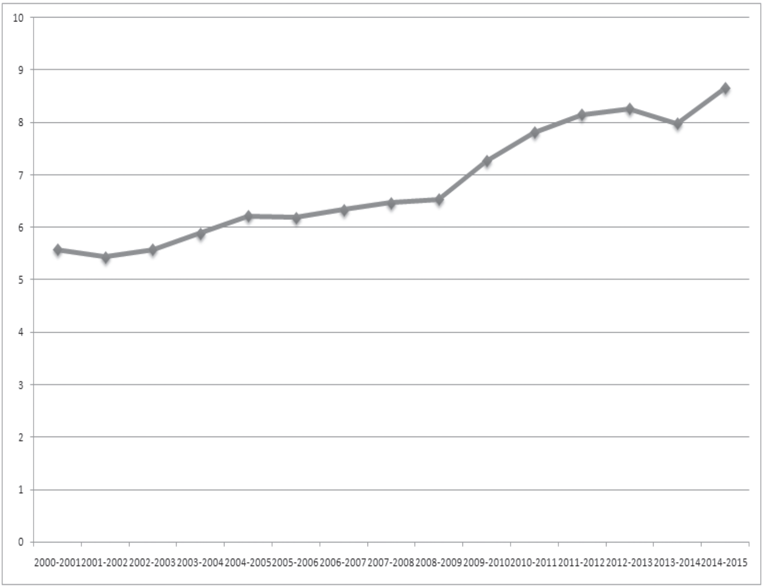

Figure 7b: Share of Automotive Sector Employment in Total Organised Manufacturing Sector Employment

Source: Computed from Annual Survey of Industries.

However, automation technologies are fast improving with the significant developments in the following three areas: (i) Artificial Intelligence (AI) and machine learning- especially a technique known as deep reinforcement learning; (ii) a number of technologies relevant to the development of robotics are improving at exponential rates; and (iii) China's AI boom (Figure 8). The country's tech industry is shifting away from copying Western companies, and it has identified AI and machine learning as the next big areas of innovation. Chinese investors are now investing heavily into AI-focused start-ups, and the Chinese government has signalled a desire to see the country's AI industry blossom, pledging to invest about $15 billion by 2018. A combined effect of these three can make industrial robots more intelligent and being capable of performing tasks, which are hitherto impossible for robots to perform. Further, the entry of China can make robots much cheaper as well increasingly the probability of it being affordable to even to newer industries as against traditional adopters of robotic technology such as the automotive industry. Faster adoption of these new automation technologies can have deleterious effect on employment intensities in Indian manufacturing- for instance in the labour intensive industries such as textiles and clothing.

Further, there are eight technologies, the improvements in which will have a strong positive effect on faster diffusion of automation technologies:-

- Exponential growth in computing performance
- Improvements in electromechanical design tools and numerically controlled manufacturing tools
- Improvements in electrical energy storage
- Improvements in electronics power efficiency
- Exponential expansion of the availability and performance of local wireless digital communications
- Exponential growth in the scale and performance of the Internet
- Exponential growth of worldwide data storage
- Exponential growth in global computation power

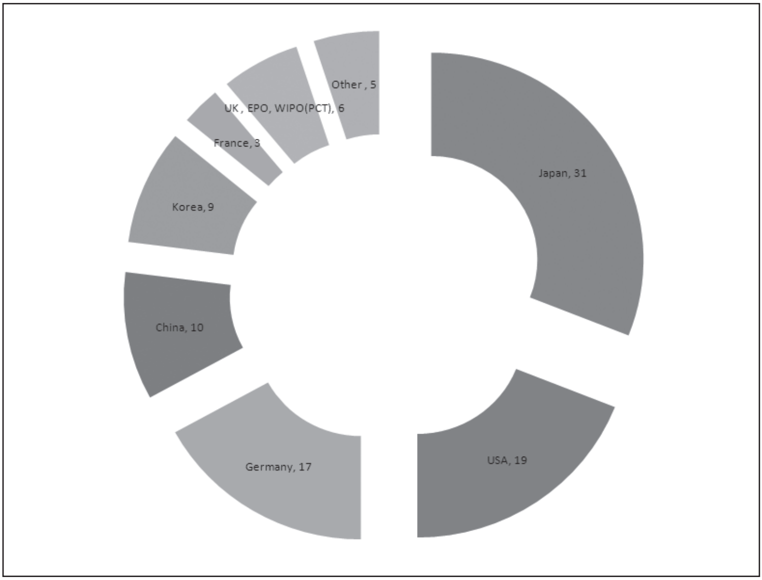

Figure 8: Percentage Distribution Patents Granted in Robots and Autonomous Systems, 2014

Source: Intellectual Property Office (2014).

7. Concluding Remarks

In this study, we have analysed the possible links between diffusion of automation technologies and employment. Automation technology is narrowly defined in terms of the highest form of automation- namely the use of industrial robots- primarily because of the availability of good quality data on the use of automation technologies at the level of tasks within occupations. Analysis of the data shows that, although the density of robots has increased its usage is restricted to one or two manufacturing industries- the automotive industry being the most important user. Within the automotive industry, the use of industrial robots is concentrated in tasks, which are historically speaking less labour intensive. So, for the present, automation does not pose a threat to manufacturing employment. However, with the fast developments in technology, the situation can change. So there has to be a policy on automation for an abundant labour economy such as that of India's.

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