Industrial robots and manufacturing employment, The Indian Experience”

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Outline

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- Major research questions
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- Conclusions

Renewed interest in the effect of automation and employment

- 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 overestimation of job automatability, as occupations labelled as high-risk occupations often still contain a substantial share of tasks that are hard to automate

Concept of automation

- A *range of technologies* are involved- 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
- 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.

Different types of automation technologies

According to Flamm (1988)

- Robotics
- Machine Tools
- Automated inspection and test
- Automated materials handling
- Process control
- Sensors/actuators
- CAD equipment
- Programmable controllers

Industrial Robots are arguably the most flexible and most sophisticated of all automation machinery, they provide an excellent vehicle for studying how and why leading edge manufacturing technology has penetrated the commercial market place.

Motivations for the study

- 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 be automatable(https://(www.theguardian.com/science/political-science/2017/oct/01/will-robots-bring-about-the-end-of-work,**

  .https://www.oxfordmartin.ox.ac.uk/news/201601_Technology_at_Work_2

- 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 as they have a **large number of blue collar workers doing repetitive manual work.** 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.
- 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).

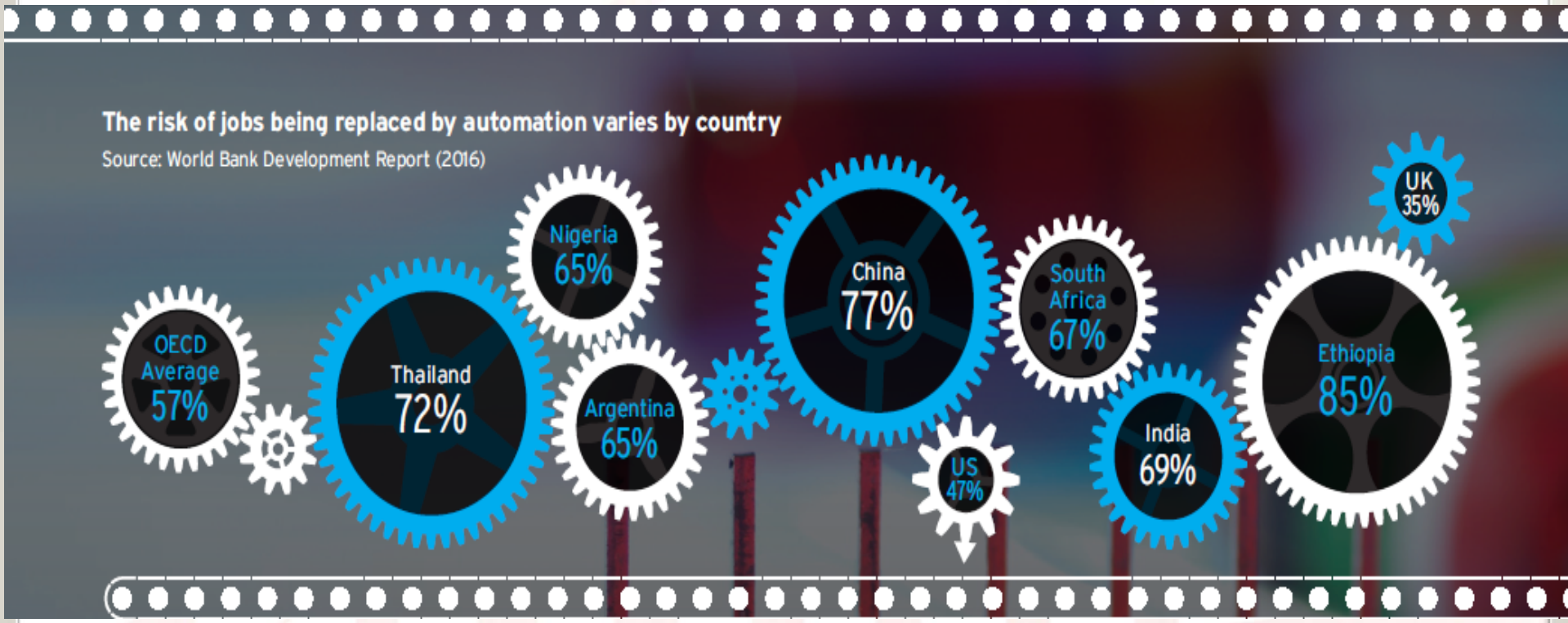
Motivation 1

- Robot apocalypse- automation media narrative primarily in the US but also now in China, India and other developing countries.

- *Empirical research, especially from the USA has shown that automation and technology are responsible for the poor wage growth and inequality bedeviling the American working class in recent decades, and that looming automation will only accelerate and ratchet up these problems.*

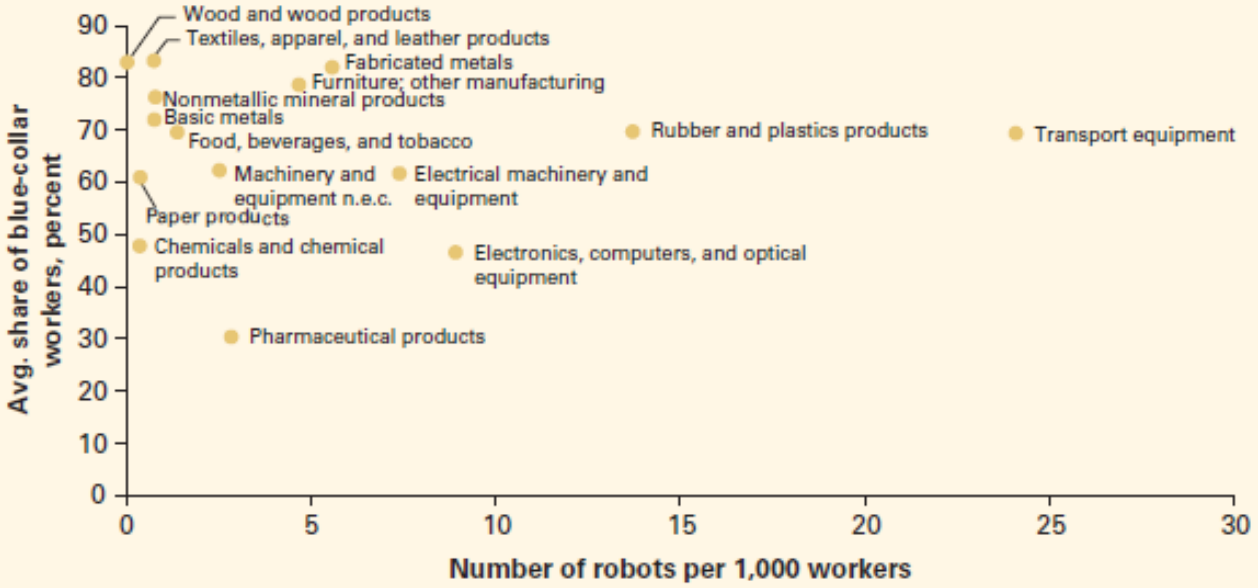
- Recent research by economists Daron Acemoglu of MIT and Pascual Restrepo of Boston University is but the latest fuel for the automation media narrative (Acemoglu and Restrepo 2017).

Automatability of manufacturing employment in India and other countries



Potential risk of robot use in the future given their share of blue collar workers during repetitive manual work

Average shares of blue-collar workers and robots per 1,000 workers, by manufacturing subsector, selected countries, 2011



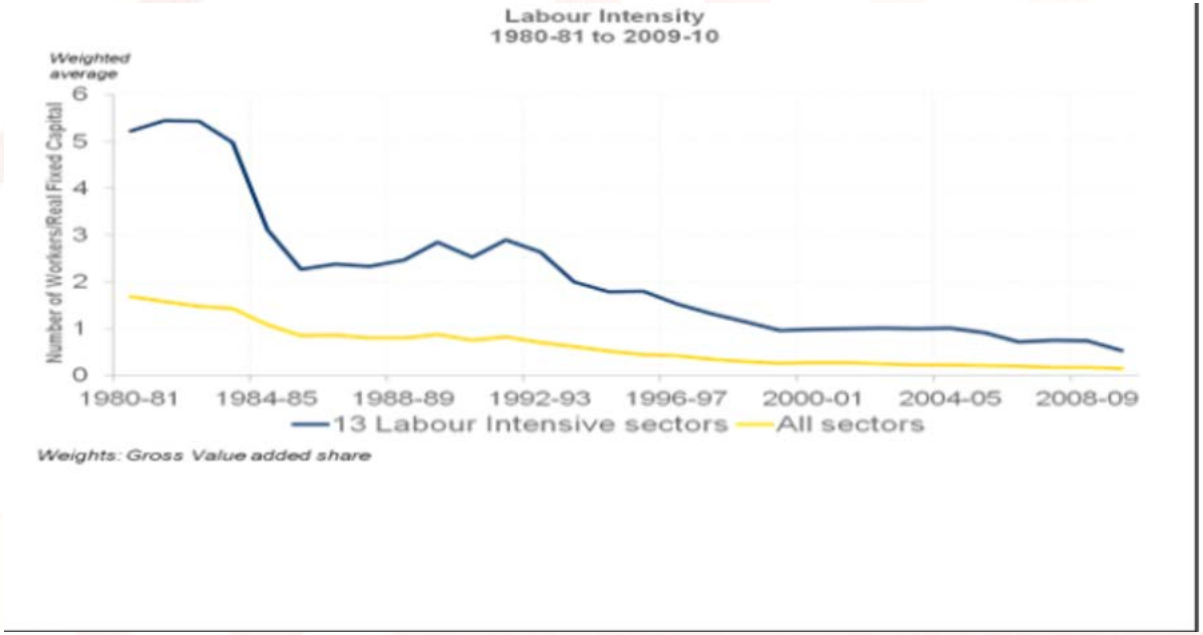
Sources: Calculations based on International Federation of Robotics (IFR) World Robotics database; and University of Minnesota's Integrated Public Use Microdata Series (IPUMS) International database; and United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database.
Note: Average blue-collar shares per subsector are calculated as follows: (1) Country sector blue-collar share is calculated using census data harmonized by IPUMS International. (2) Take simple average of blue-collar shares across 19 countries for which data are available. The sector aggregation is based on International Standard Industrial Classification (ISIC) rev. 3 two-digit classification. n.e.c. = not elsewhere classified.

Motivation 3

- India is placing much emphasis on raising employment through the manufacturing route;
- The size of the manufacturing industry is being raised to at least a quarter of India's GDP by year 2020- *Make in India programme*.
- However researchers have a noted a steady decline in the labour intensity of manufacturing and jobless growth in India's manufacturing sector. One of the explanations for this decline in labour intensity of manufacturing is use of more machines for production- automation

Labour intensity of Indian manufacturing has declined over time

(Source: Sen and Das (2014)



Results of the 6th Economic Census 2013-14

- The 6th Economic Census finds a total of 10.3 million establishments engaged in manufacturing in India, and these employed 30.4 million workers.
- While the number of establishments increased by 28 per cent over the eight years, the number of workers in the sector rose by 19 per cent. This shows that establishments are getting smaller with a decline in average employment per establishment.

Two standard explanations for declining labour intensity

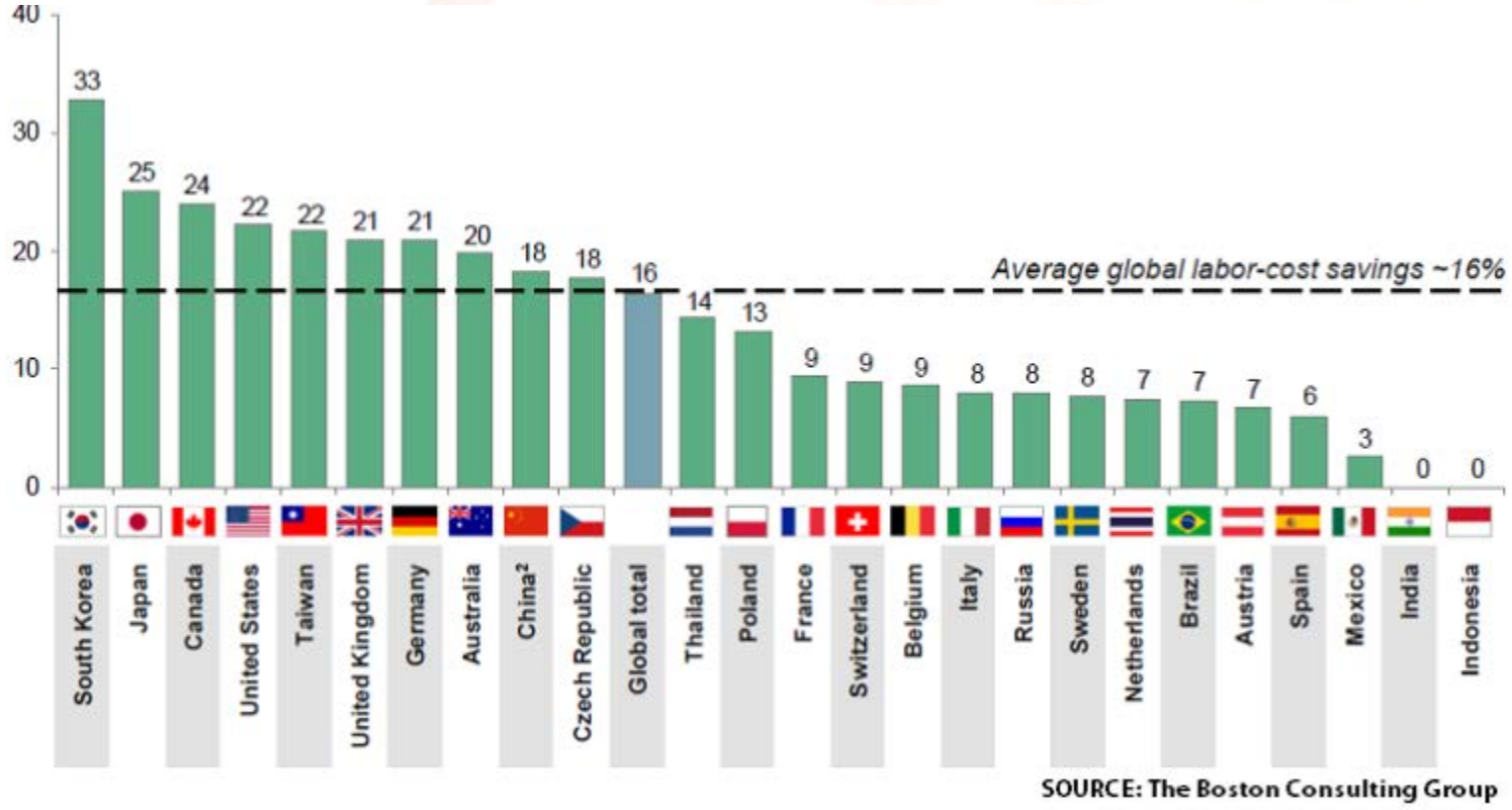
- The first explanation highlights the stringent nature of labour laws in India.
- A second explanation highlights a range of supply-side factors, such as infrastructural bottlenecks, poor skills and low literacy rates among unskilled workers in India as possible reasons for firms substituting labour with capital.

Significance of the research problem:

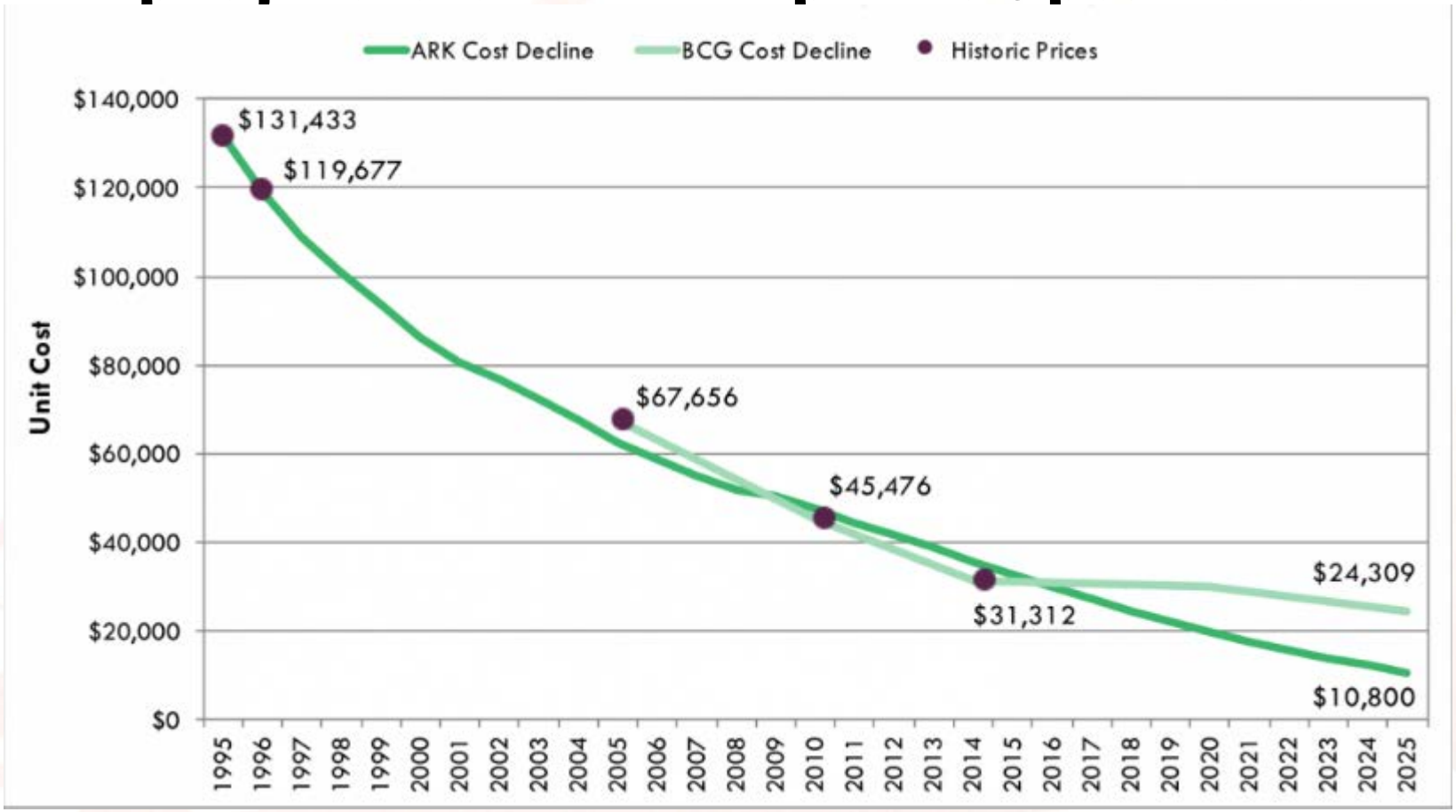
Factors that can increase the diffusion of automation technologies

- 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.

Automation technologies can decrease labour costs by as much as 16 per cent



Price of industrial robots: 1995-2014 and projected decline in prices upto 2025



Major 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.

Methodology and data sources

- The study will be based on a mix of primary and secondary source material.
- In terms of the primary source, the study intends to do a primary survey of *the major industries-that is prone to automation* namely the *automotive industry,* which at the same time is emerging as the leading subsector of India's manufacturing sector in terms of output growth.
- The main secondary source is the annual surveys of the *International Federation of Robotics*

Engagement with the literature on diffusion of robots and its effect on manufacturing 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 show that increased automation has not really resulted in hefty job losses.

Engagement with the literature on automation and employment

- Subset of the literature on technological change and its effect on employment
- Earliest study of automation was by Flamm, Kenneth (1988) 'The Changing Pattern of Industrial Robot Use" in Cyert, Richard and Davis Mowery (ed., 1988), *Impact of technological change on employment and employment and economic growth,* Cambridge: Ballinger, pp. 267-328.

The Flamm study

- One of the earliest studies on the changing pattern of industrial robot use is the one by 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.
- 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.
- His study showed that 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 later 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 have not diffused is 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.

An interesting finding from the Flamm study

- 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.

Inverse relationship between diffusion of robot and manufacturing employment

- 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.**

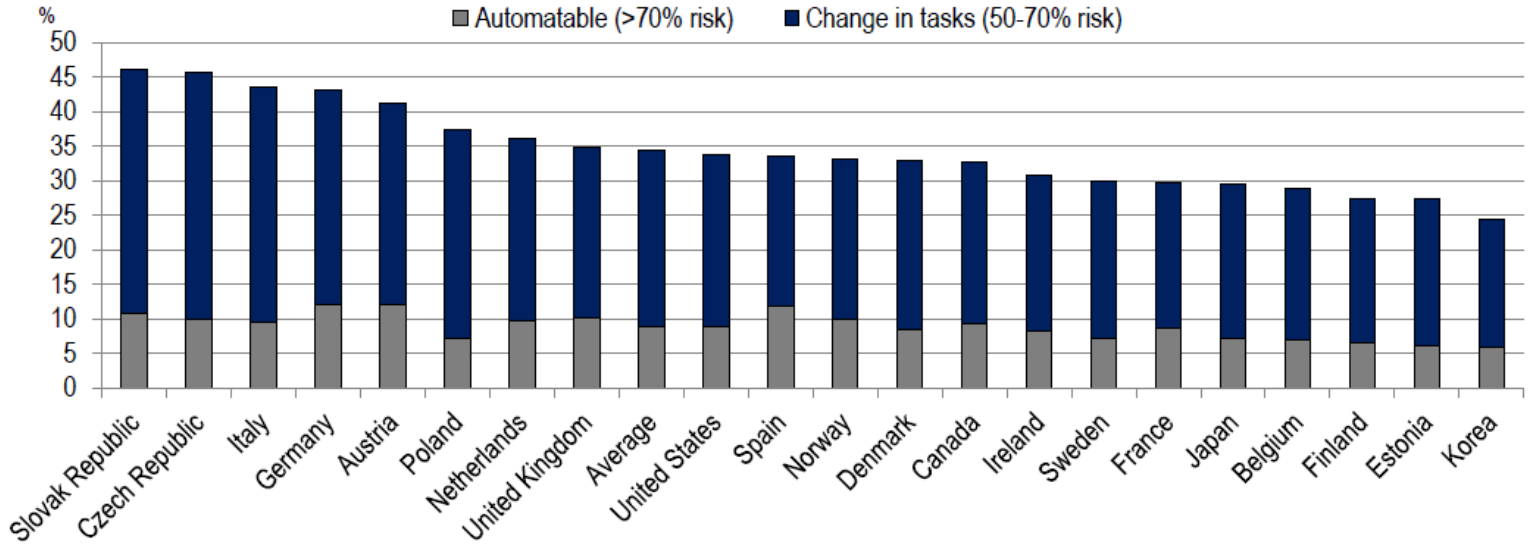
Occupation vs Task-based approach

- However the main problem with these studies is that they consider only very broad occupations and not tasks within occupations.
- In short most of the studies, which found an inverse relationship between automation and emplyment 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 overestimation 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 (2016)

Arntz, Gregory and Zierahn study

- Firstly, they estimate the job automatibility 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 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

Share of workers in jobs, across OECD countries, in jobs at high and medium risk of automation



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

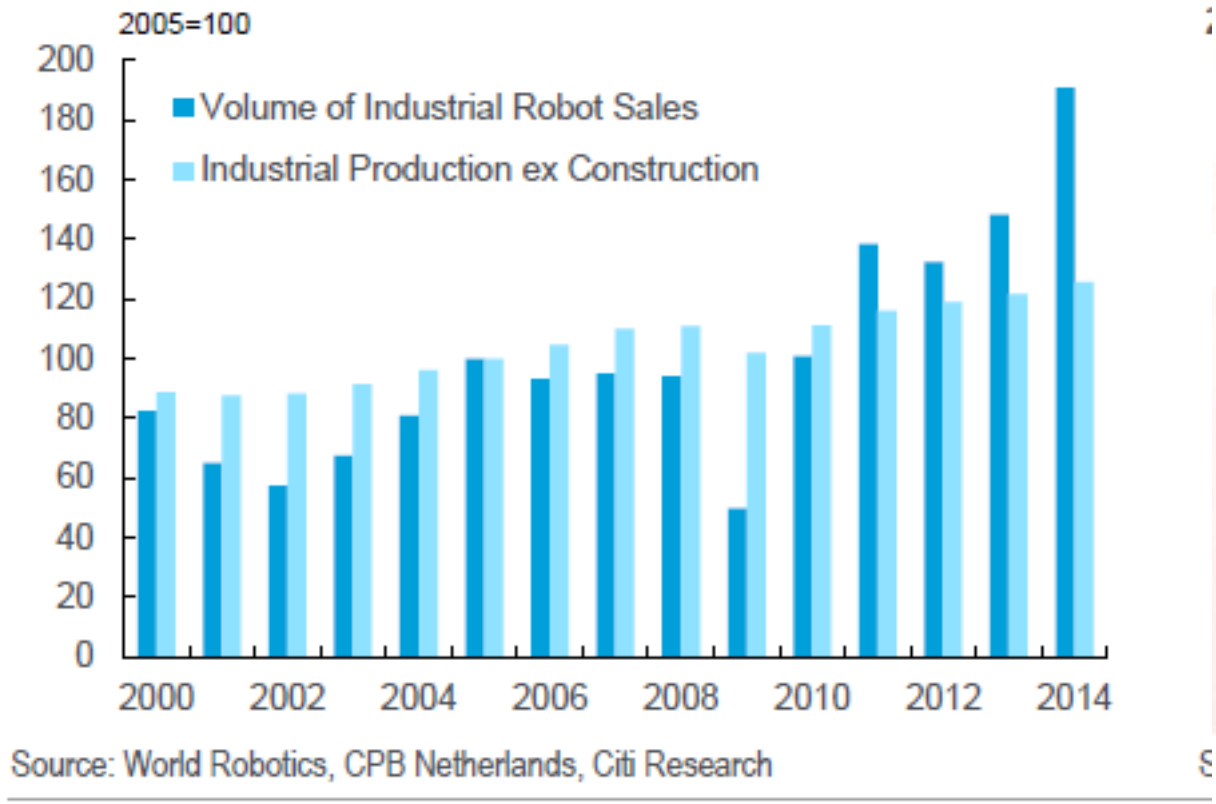
- The second purpose of AGZ study is to critically reflect on the recent line of studies that generate figures on the "risk of computerization" and to provide a comprehensive discussion on possible adjustment processes of firms and workers to automation and digitalization.
- In particular, it is argued 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.

Major conclusions from the literature

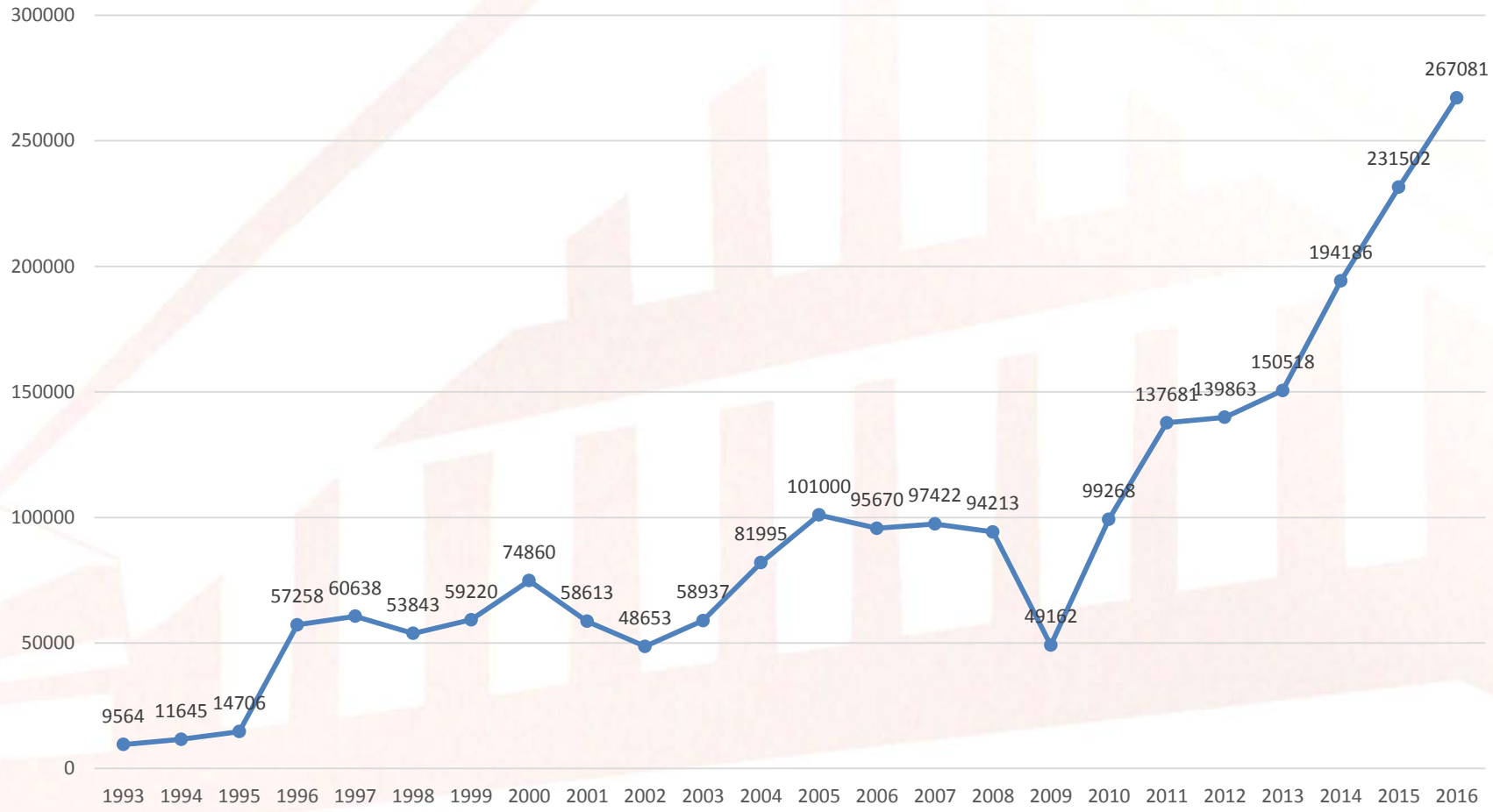
- Industrial robots are basically used in certain specific industries such as automobile, electrical and electronics and metal tending. Even within these industries they are used for certain tasks like spot and arc welding which is both harsh and repetitive for human beings to perform. In fact their 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 of computerization, 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

Empirical findings with respect to India

World-wide sales of industrial robots have outpaced the growth of industrial production



World-wide sales of the number of robots sold has increased since 2009



Estimated annual shipments of industrial robots by regions

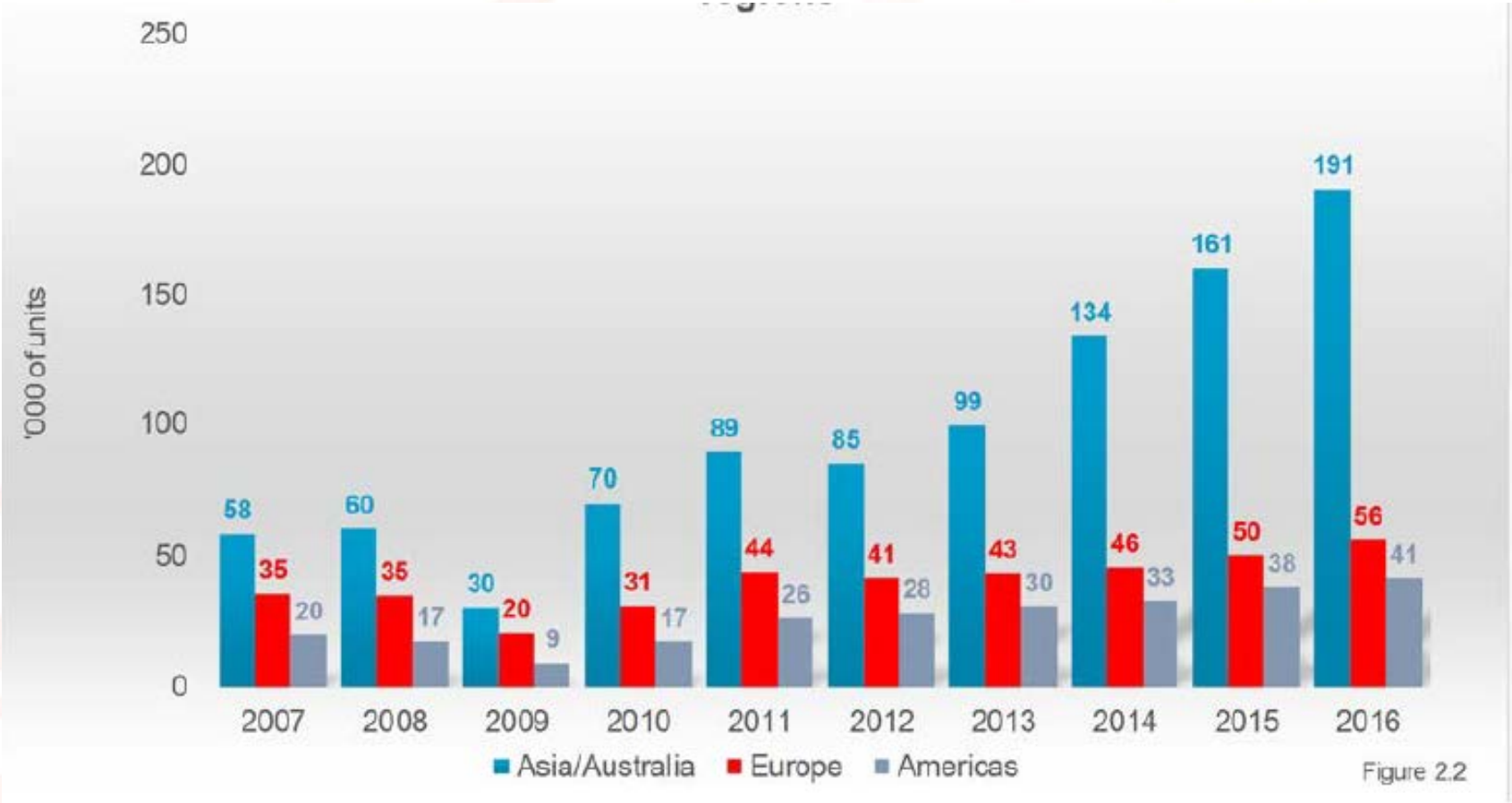
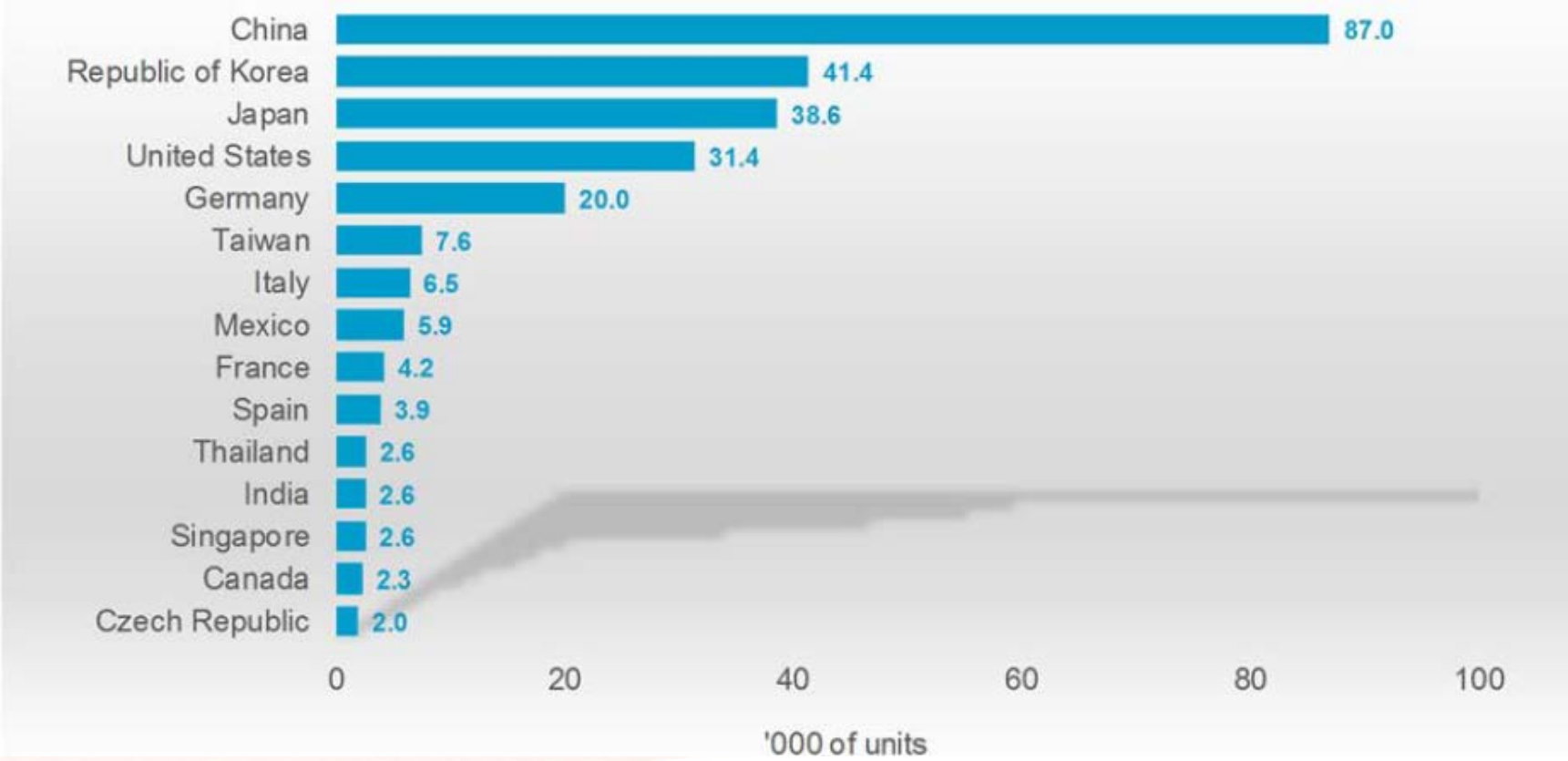


Figure 2.2

Estimated operational stock of industrial robots in largest markets, 2016 (Numbers in thousands)



Estimated operational stock of industrial robots by region

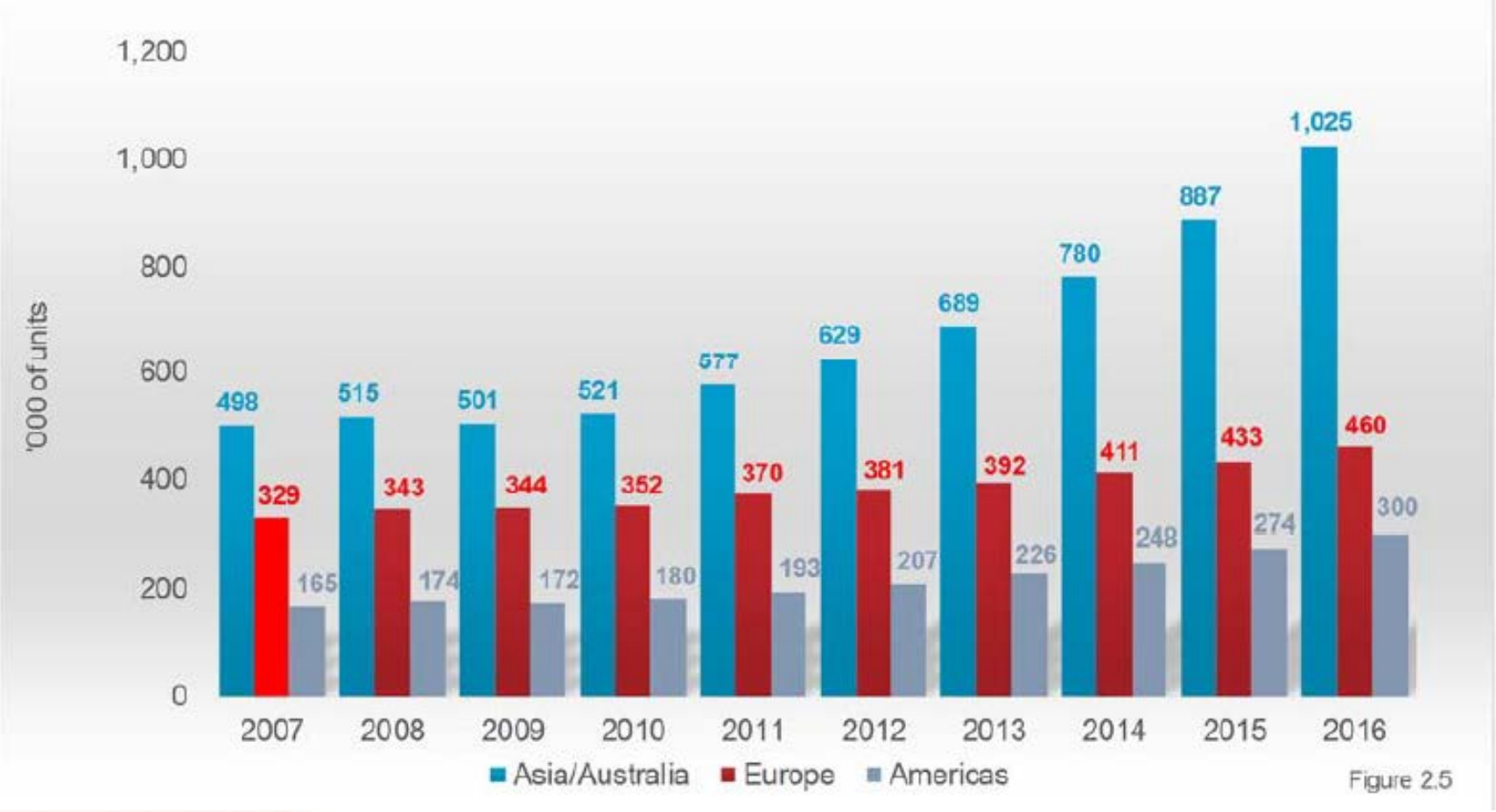
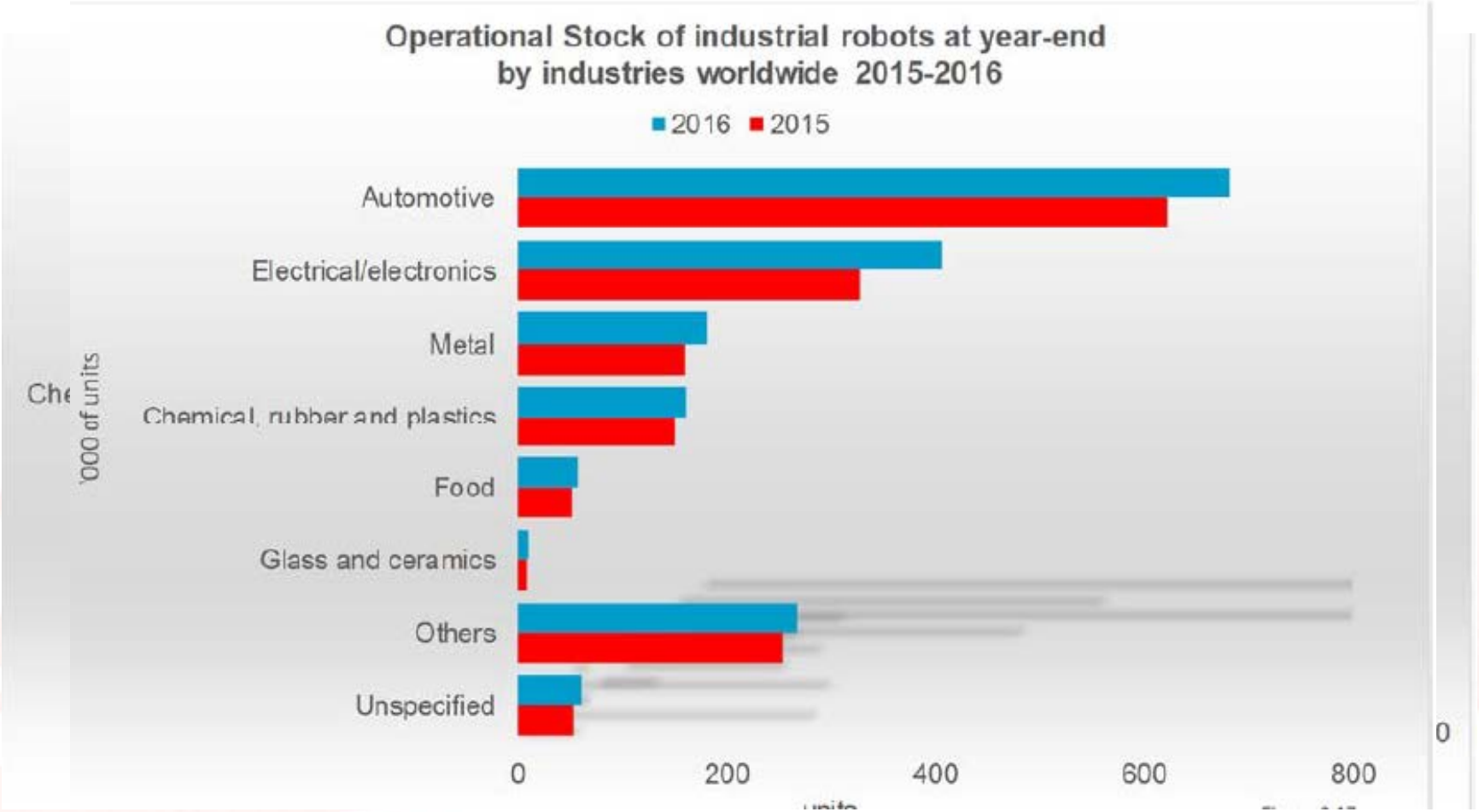
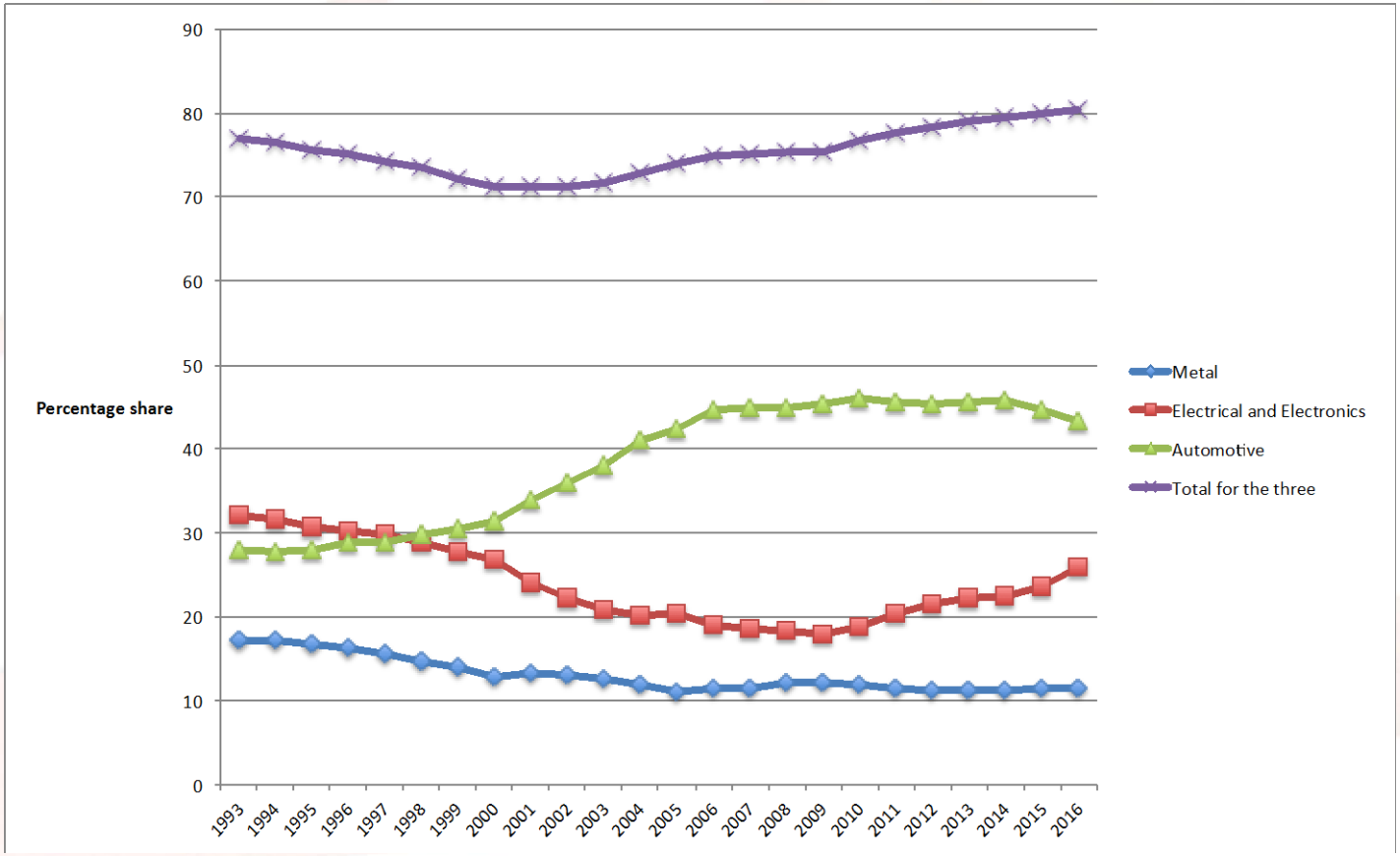


Figure 2.5

Industry-wise operational stock of industrial robots – World-wide



Industry-wise distribution of operational stock of industrial robots



Operational stock of industrial robots by task-world-wide

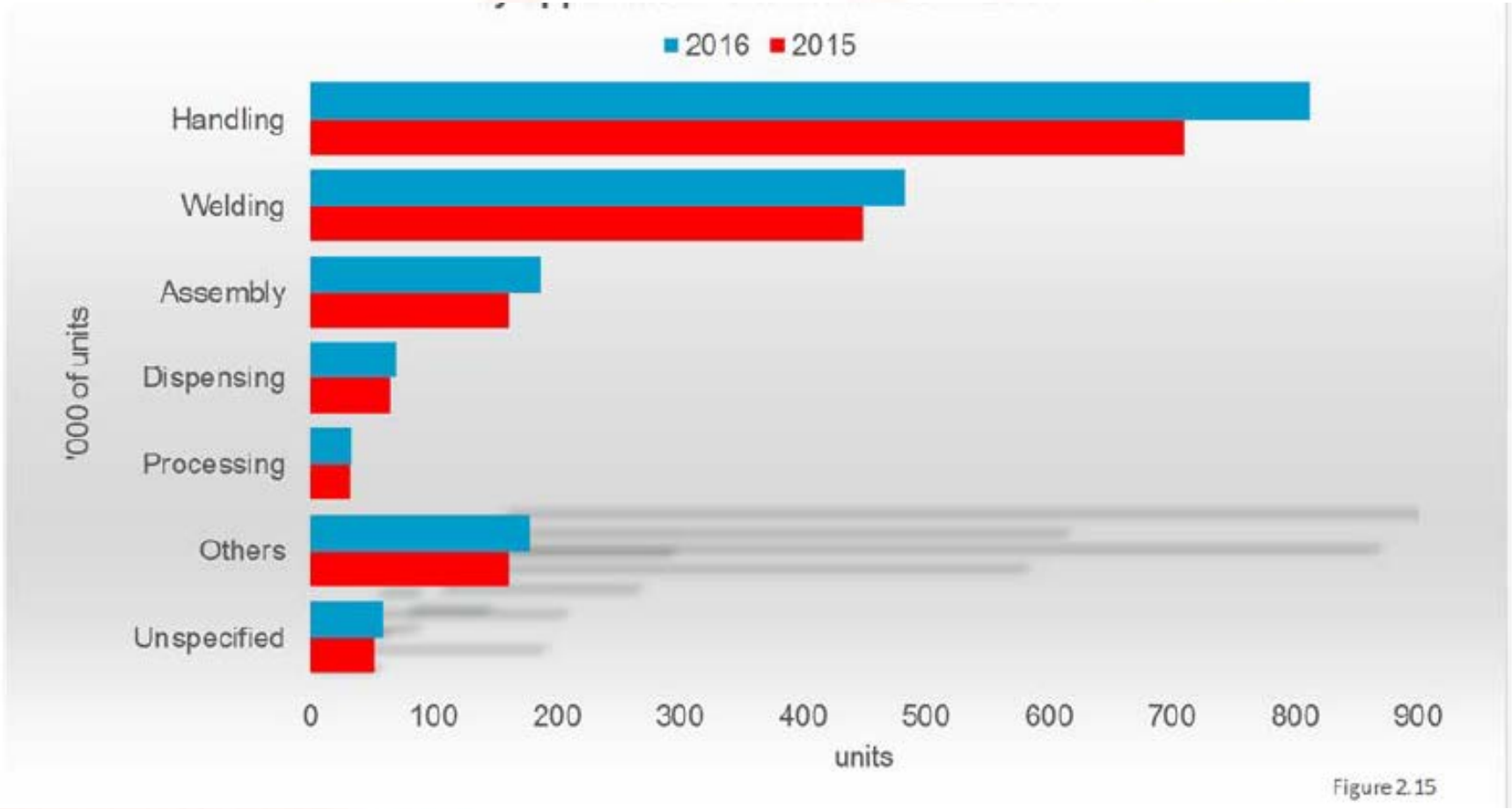
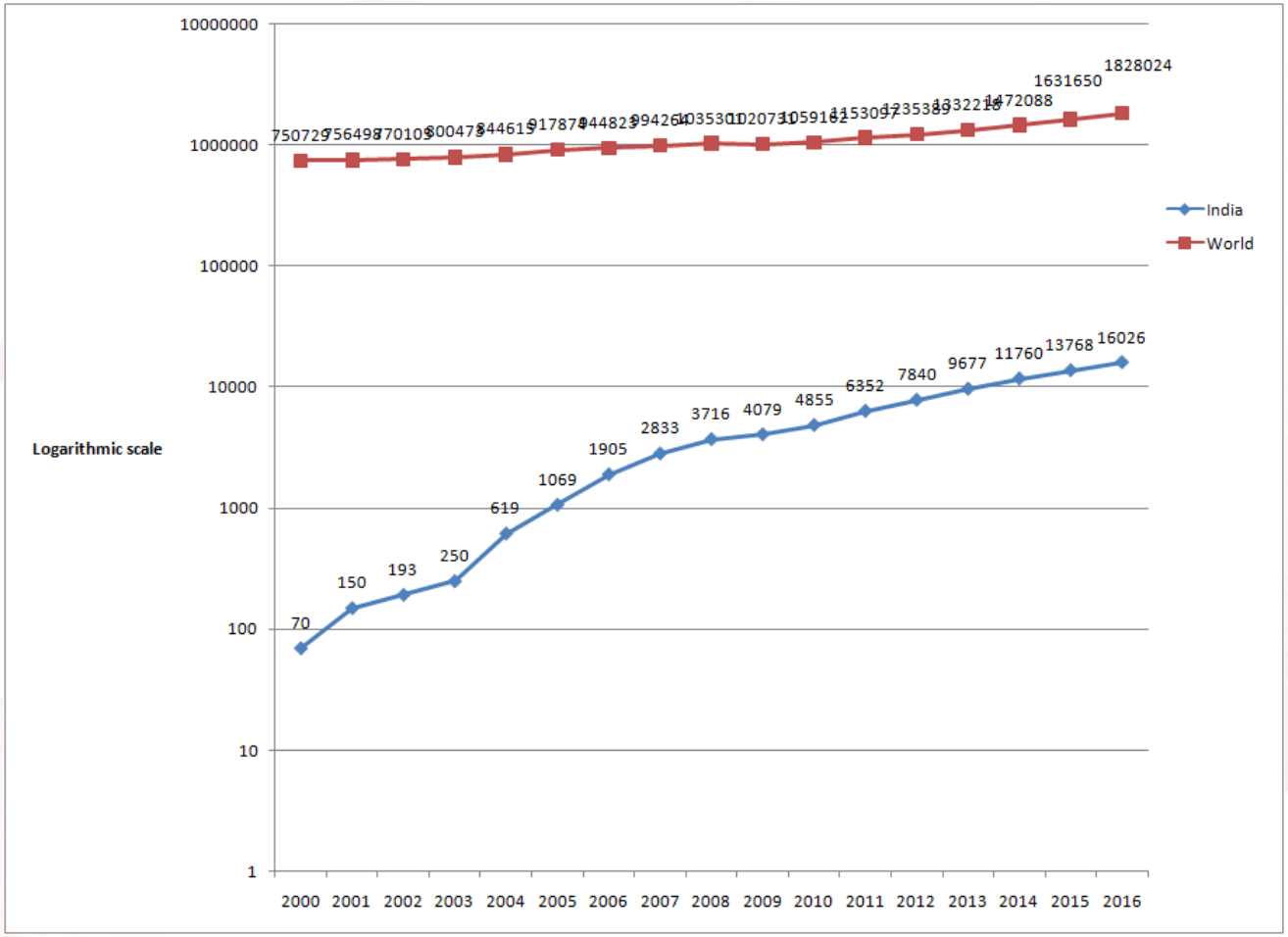
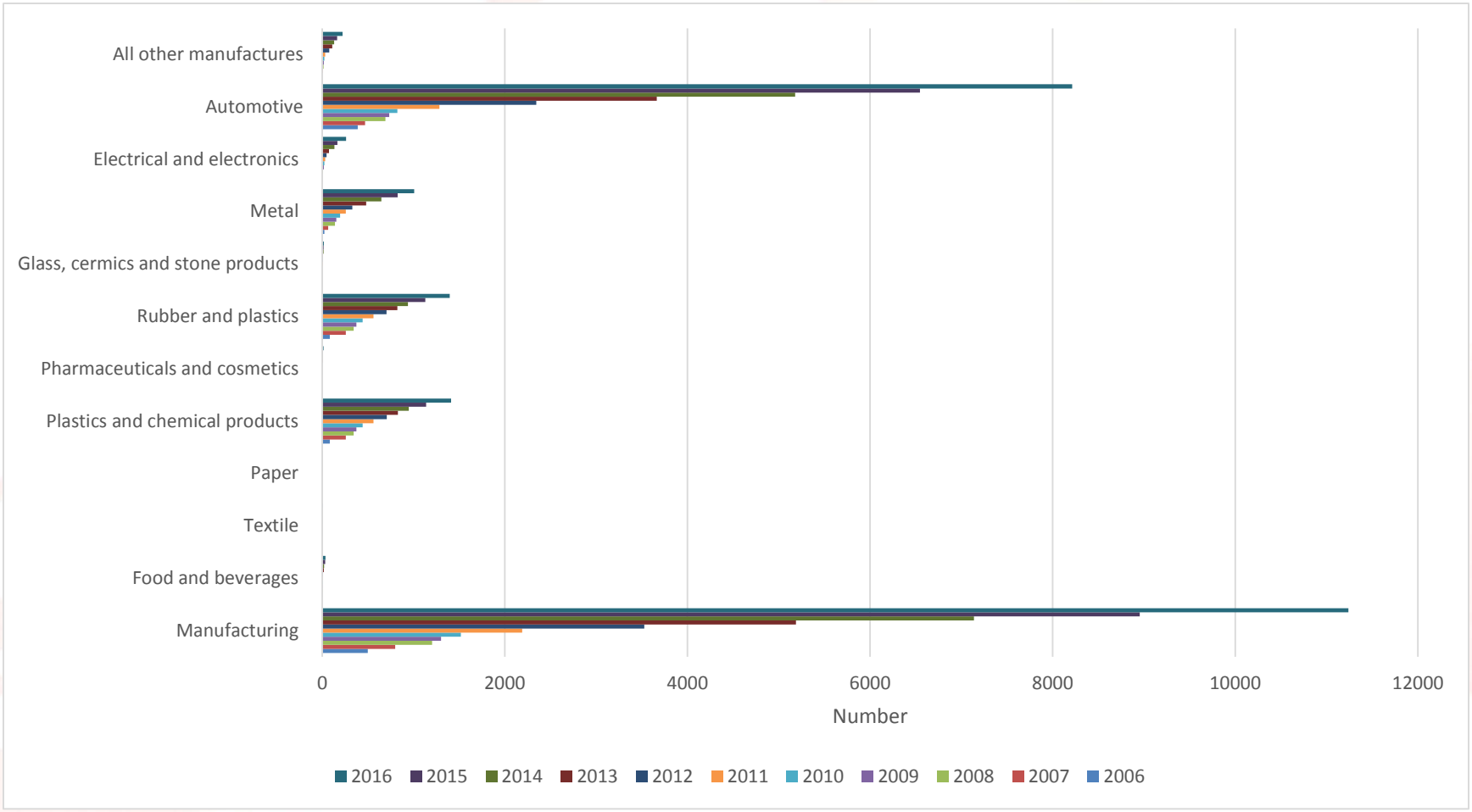


Figure 2.15

Estimated operational stock of Industrial Robots in the World and in India

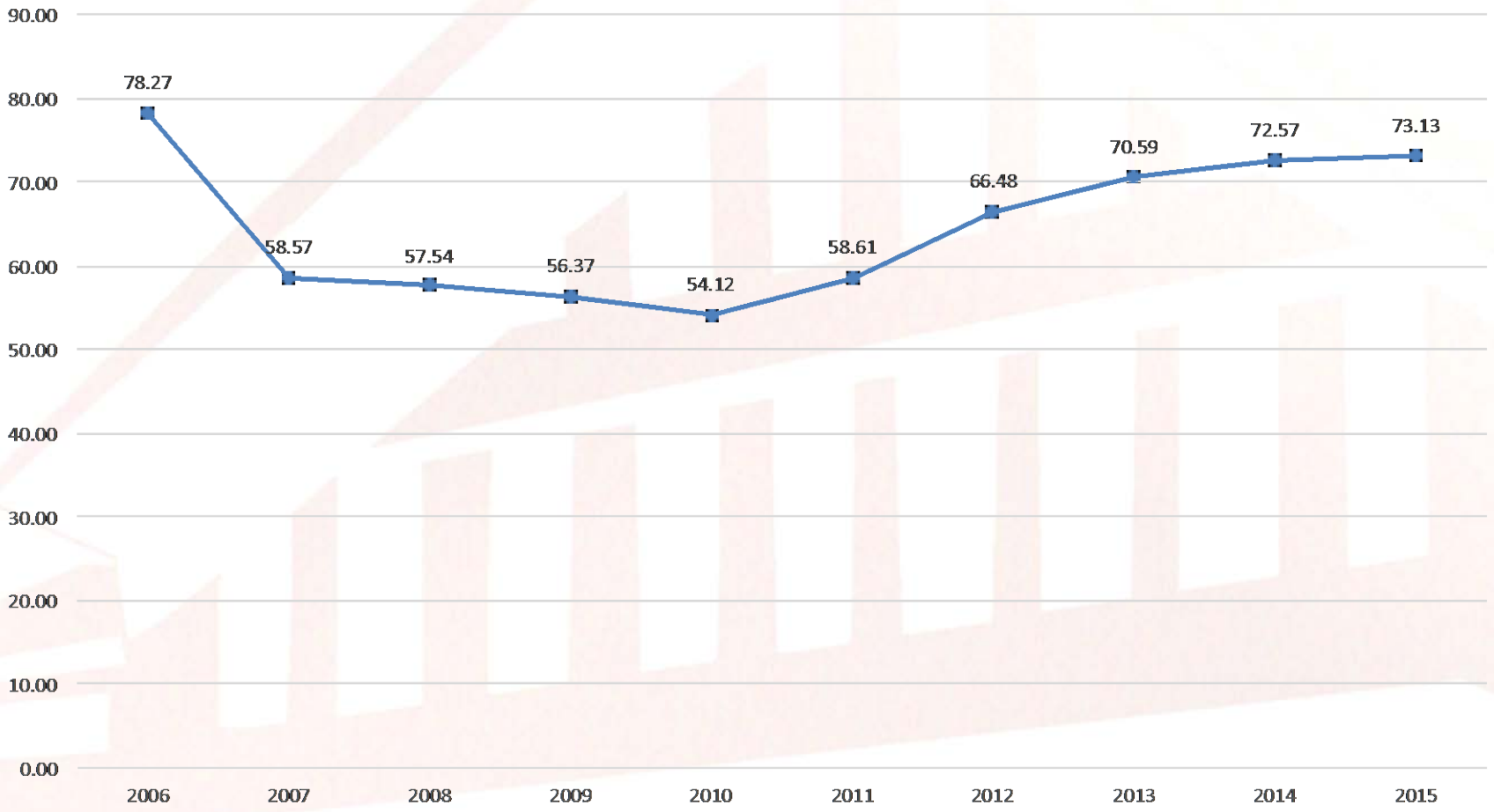


Distribution of industrial robots in India- industry-wise, 2006-2015

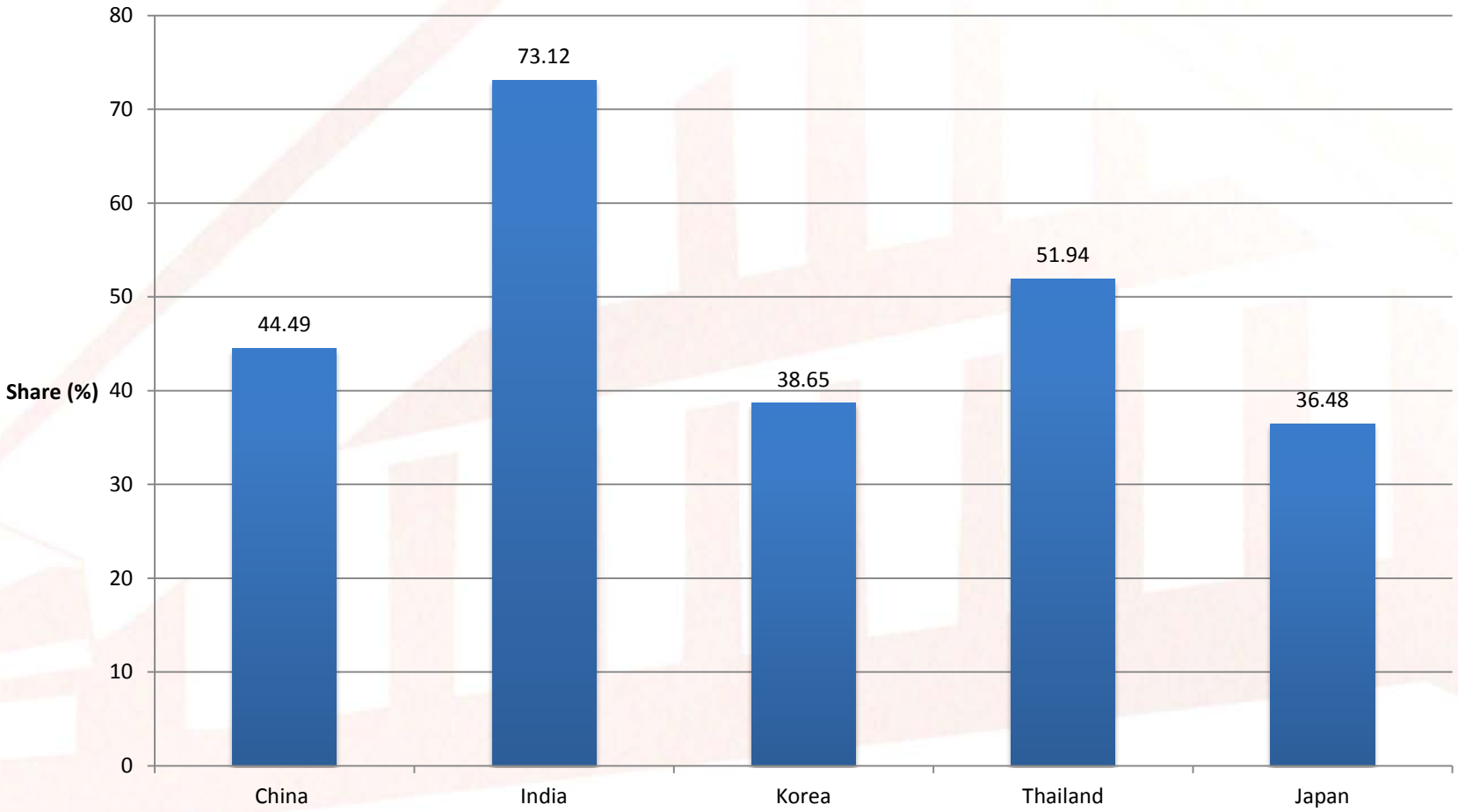


Automotive industry is the most automated manufacturing industry in India

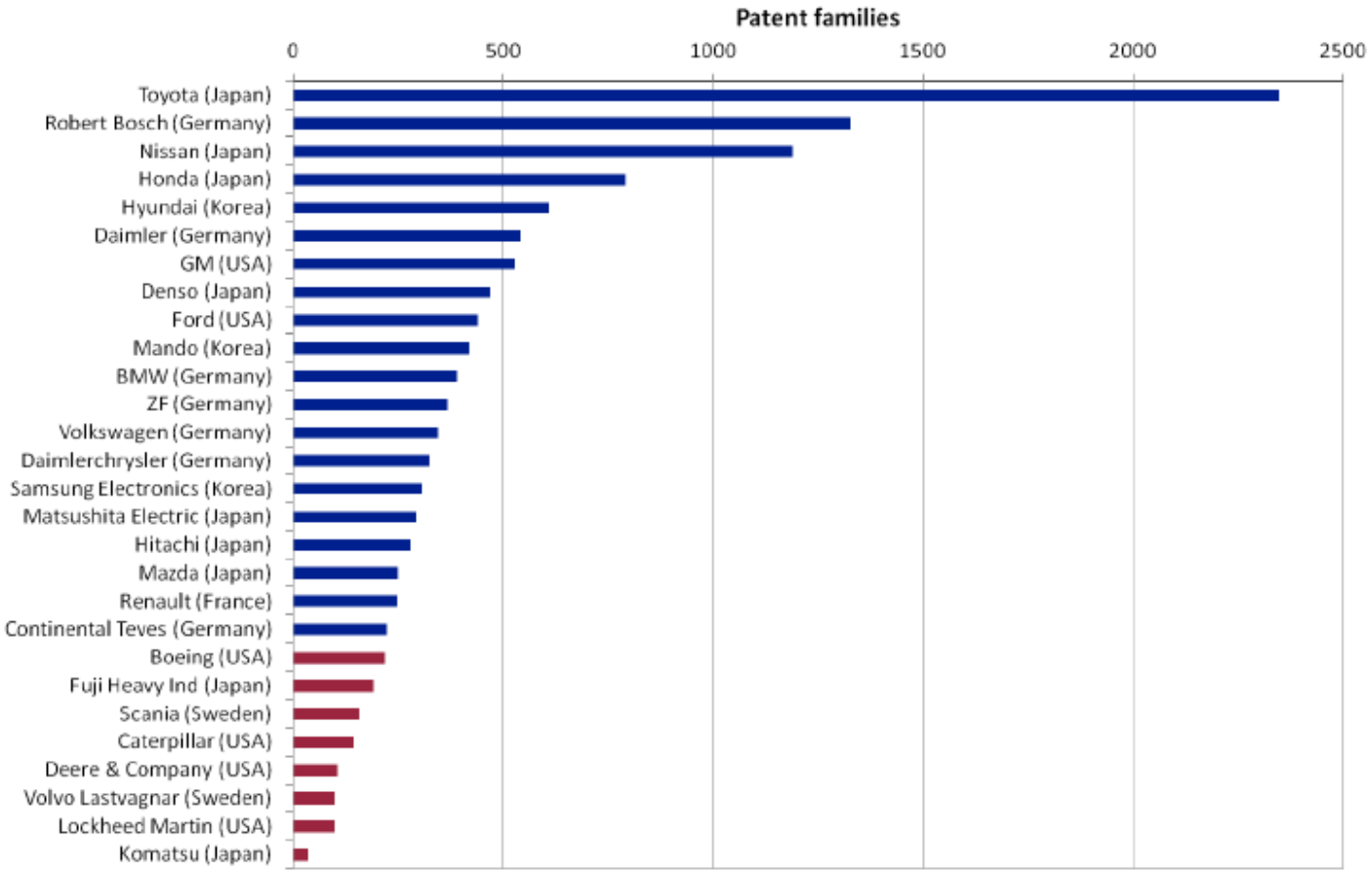
(Share of operational stock of industrial robots in the total operational stock of industrial robots)



Share of automotive industry in automation in Asian Economies



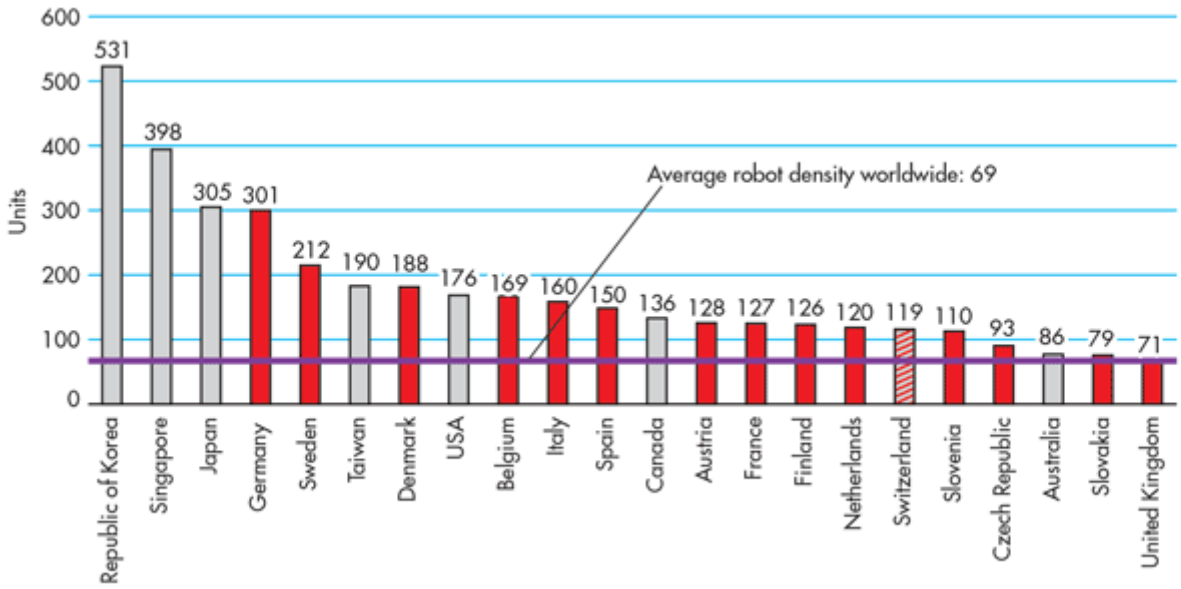
Robotic technology is largely created by automotive firms



Type of industrial robots sold in India

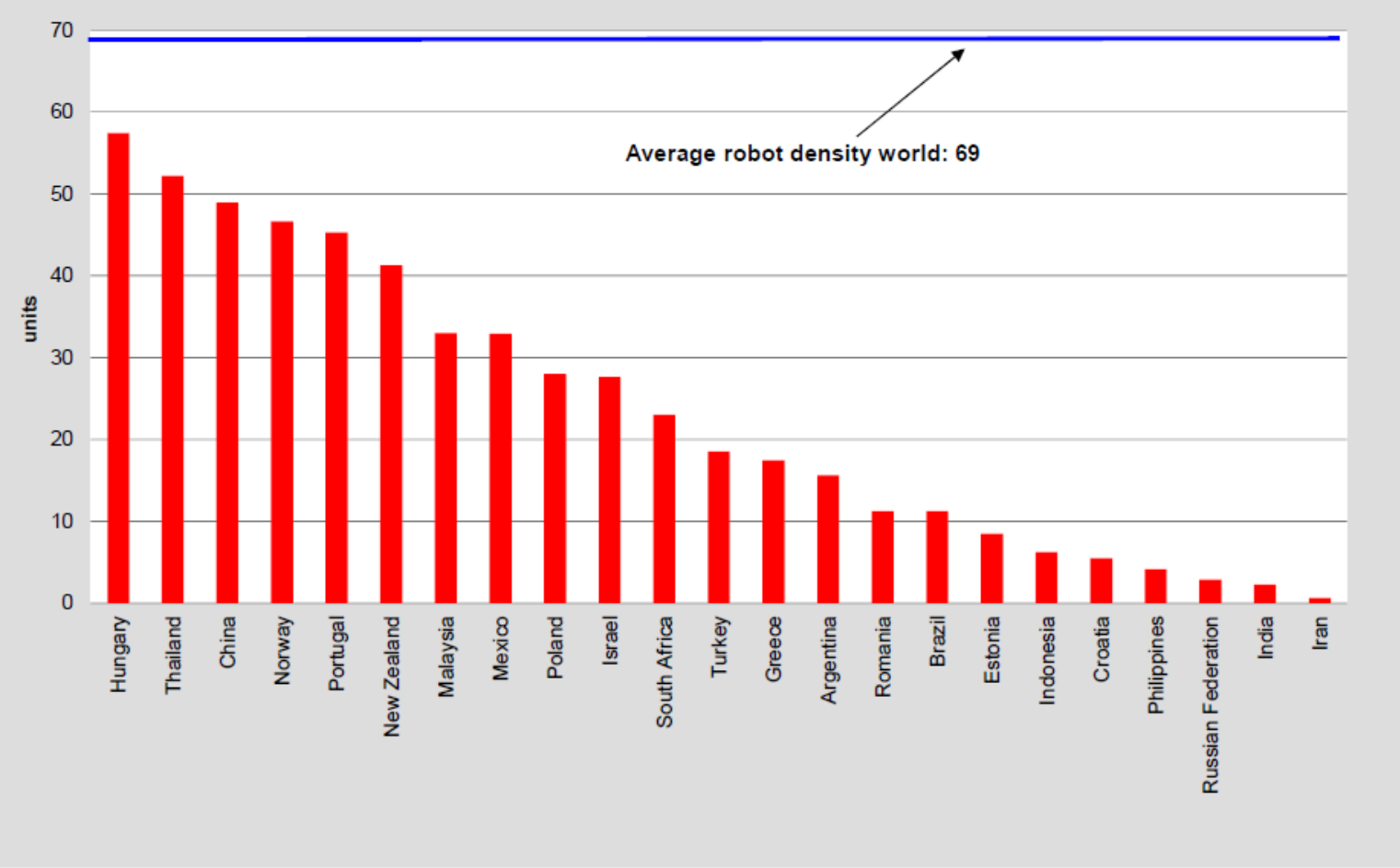
Year	2010	2011	2012	2013	2014	2015
Types of robot by mechanical structure	units	units	units	units	units	units
Articulated	704	1,406	1,339	1,752	1,985	1,842
Linear/cartesian/gantry	69	132	152	139	137	203
Parallel	1	4	8	6	1	
SCARA	2	5	9	20	3	20
Others (cylindrical, others)						

Diffusion of industrial robots across countries, 2015 (Above world average)



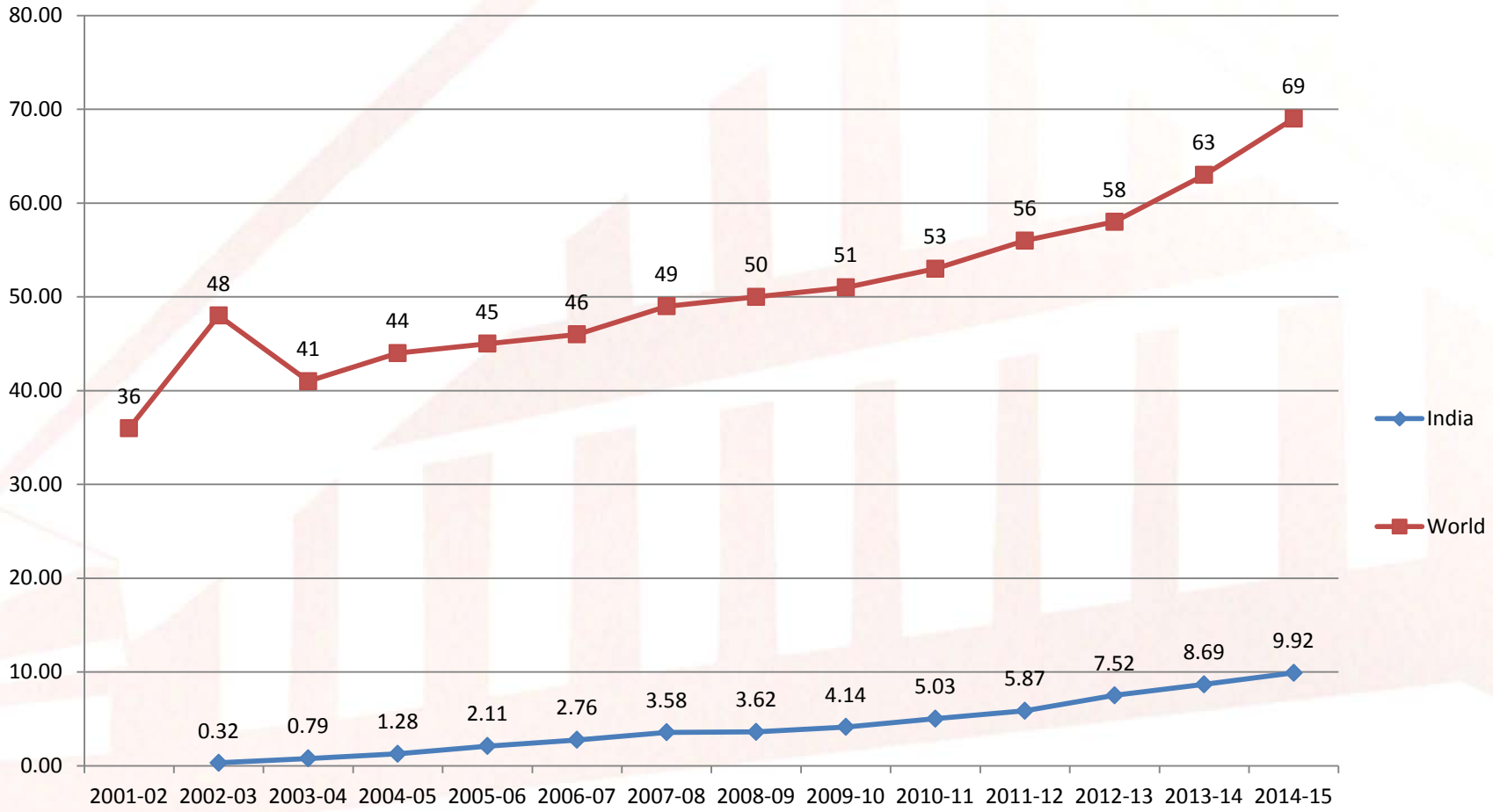
Diffusion of industrial robots across countries, 2015

(Below world average)



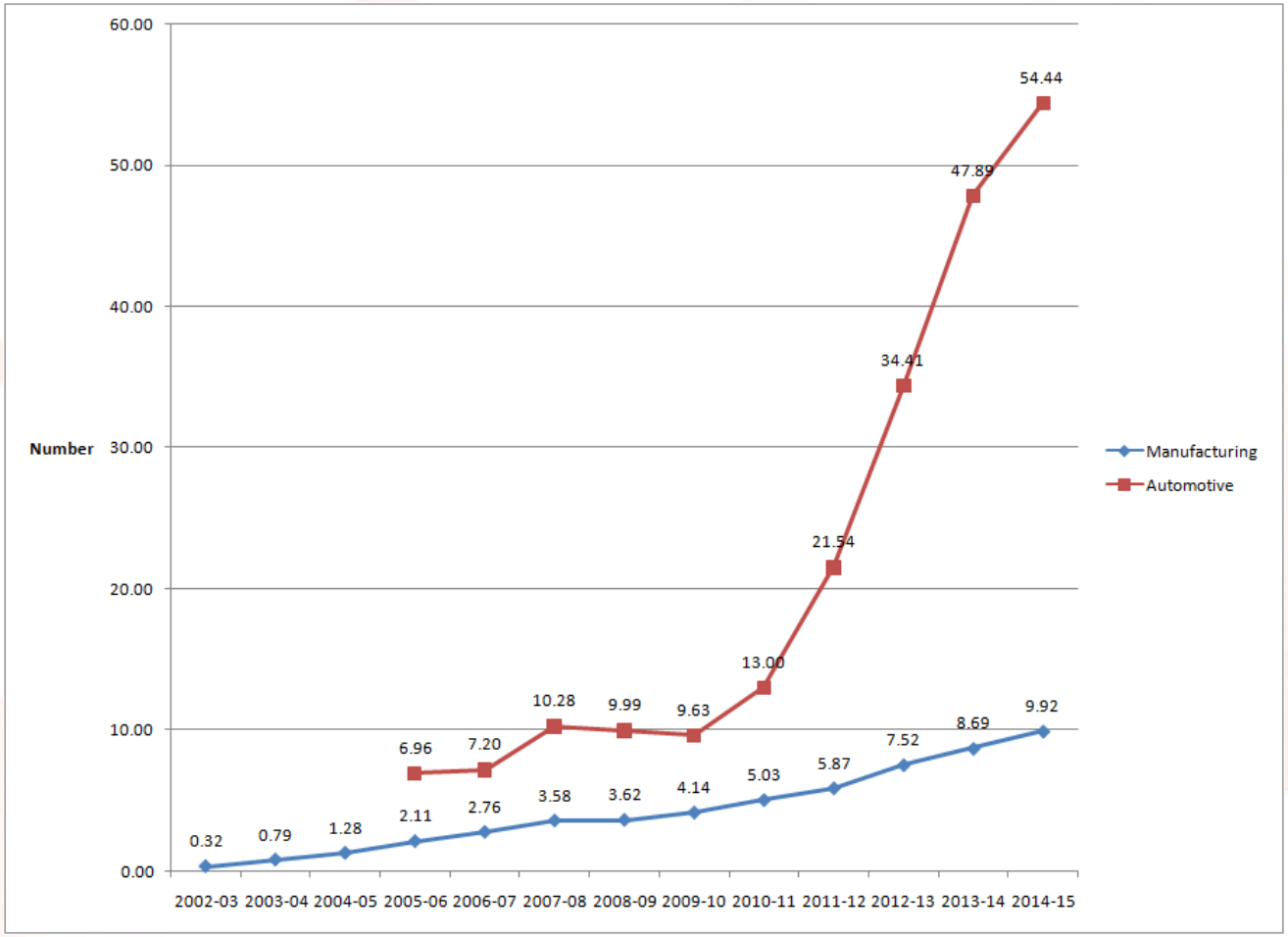
Extent of diffusion of automation technologies in World and Indian manufacturing

(Density of Industrial Robots per 10000 manufacturing employment)



Extent of diffusion of automation technologies Indian manufacturing

(Density of Industrial Robots per 10000 manufacturing employment)



Illustrations of industrial robots use by Indian automotive manufacturers

- 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.

Industrial Robot use in MNC affiliates in Indian 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

Extent of diffusion of automation technologies in Indian manufacturing in comparison with other countries, 2015

(Density of Industrial Robots per 10000 manufacturing employment)

	India	China	Brazil	Thailand	Malaysia	Korea	Japan
Manufact-uring	10	49	11	52	33	531	305
Automotive	54	392	125	859	281	1218	1276
All other industries	1	24	5	22	22	411	213

Distribution of operational stock of industrial robots in India by tasks

Application area	2010	2011	2012	2013	2014	2015
Handling operations/Machine tending	**1,622**	**2,101**	**2,531**	**2,903**	**3,404**	**3,948**
Handling operations for metal casting	26	44	58	62	68	93
Handling operations for plastic moulding	432	538	676	790	905	1,097
Handling operations for stamping/forging/bending	67	78	91	100	109	117
Handling operations at machine tools	323	390	440	472	519	622
Machine tending for other processes	37	42	48	51	51	51
Handling operations for measurement, inspection, testing	5	6	8	8	9	9
Handling operations for pelletizing	29	49	63	74	87	99
Handling operations for packaging, picking and placing	17	29	47	63	65	78
Material handling n.e.c	686	925	1,100	1,283	1,591	1,782
Handling operations/Machine tending unspecified						
Welding and soldering (all materials)	**1,937**	**2,720**	**3,561**	**4,775**	**6,095**	**7,324**
Arc welding	1,228	1,707	2,354	3,073	3,736	4,415
Spot welding	644	938	1,125	1,602	2,250	2,780
Laser welding	6	9	15	25	27	34
other welding	48	55	56	62	69	82
Soldering	11	11	11	13	13	13
Welding and soldering unspecified						
Dispensing	**443**	**640**	**776**	**982**	**1,127**	**1,286**
Painting and enamelling	320	467	582	740	847	924
Application of adhesive, sealing material or similar material	94	136	155	190	219	231
Dispensing others /Spraying others	29	37	39	52	61	131
Dispensing unspecified						
Processing	**72**	**90**	**130**	**172**	**223**	**235**
Laser cutting	1	5	6	7	8	8
Water jet cutting	5	5	7	7	9	11
Mechanical cutting/grinding/deburning/milling/polishing	20	21	37	73	109	117
Other processing	46	59	80	85	97	99
Processing unspecified						
Assembling and disassembling	**42**	**71**	**93**	**139**	**184**	**261**
Fixing, press-fitting	33	61	83	129	170	229
Assembling/mounting/inserting	5	5	5	5	10	10
Disassembling						
Other assembling	4	5	5	5	22	22
Assembling and disassembling unspecified						
Others	**103**	**113**	**129**	**147**	**206**	**240**
Cleanroom for FPD	5	5	5	5	5	5
Cleanroom for semiconductors						
Cleanroom for others						
Others	98	108	124	142	201	235
Unspecified	**636**	**617**	**620**	**559**	**521**	**474**
TOTAL	**4,855**	**6,352**	**7,840**	**9,677**	**11,760**	**13,768**

Share of various automatable tasks in the installation base of industrial robots in India

(Based on shares in operational stock)

	Welding and soldering (all materials)	Handling operations/Machine tending	Dispensing	Unspecified	ling and disass	Others	Processing	Total
2010	39.90	33.41	9.12	13.10	0.87	2.12	1.48	100
2011	42.82	33.08	10.08	9.71	1.12	1.78	1.42	100.00
2012	45.42	32.28	9.90	7.91	1.19	1.65	1.66	100.00
2013	49.34	30.00	10.15	5.78	1.44	1.52	1.78	100.00
2014	51.83	28.95	9.58	4.43	1.56	1.75	1.90	100.00
2015	53.20	28.68	9.34	3.44	1.90	1.74	1.71	100.00

Domestic production of industrial robots

- Major robot manufacturers are present in India:

- ABB India
- Gudel India
- Kuka
- Fanuc

- Further, the presence of Japanese, Korean and German automotive manufacturers will result in importation of industrial robots
- Specialised training institutes for diffusion of robotic technology has been established. For instance, Iconics Research and Training Institute(http://www.irti-robotics.com/about.php) at Pune.

Tatas have developed their own robots- the TAL Brabo

- 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 – 7 lakhs. Indigenously developed, the TAL Brabo is a 'Made in India' 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.

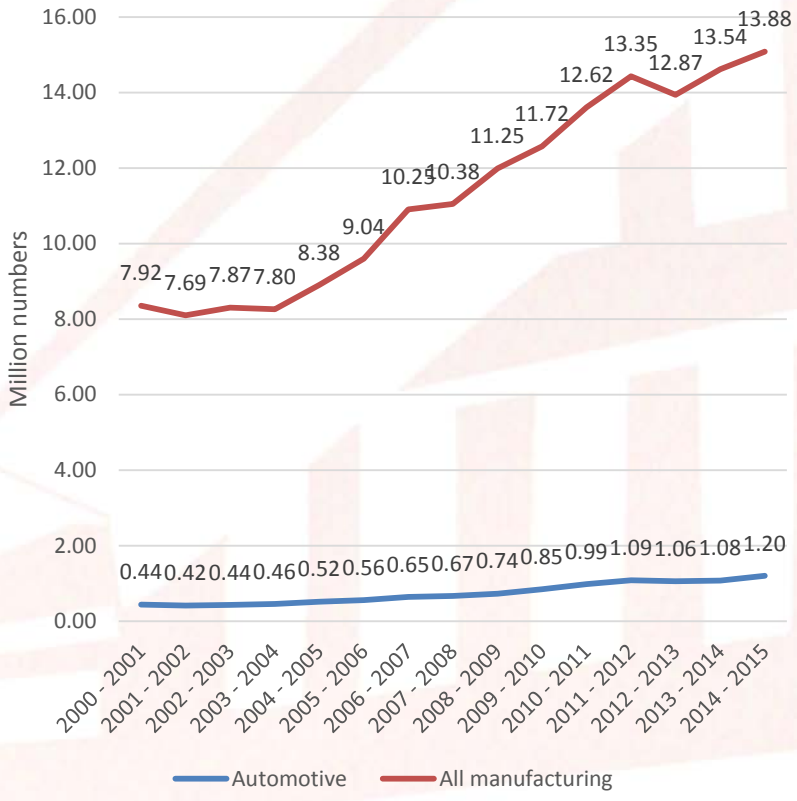
- Designed and styled in-house at TAL Manufacturing and Tata Elxsi respectively, Tata AutoComp manufactured some of the critical components of the robot. Conceptualised to complement human workforce and perform repetitive, high volume, dangerous and time consuming tasks, the TAL Brabo robot, can be deployed across industries.

- Having successfully tested the TAL Brabo in over 50 customer work streams so far, TAL Manufacturing is ready to supply these robots to several sectors including Automotive, Light Engineering, Precision Machining, Electronics, Software Testing, Plastics, Logistics, Education, Aerospace and Engineering among others, simplifying industrial manufacturing, improving quality and productivity.

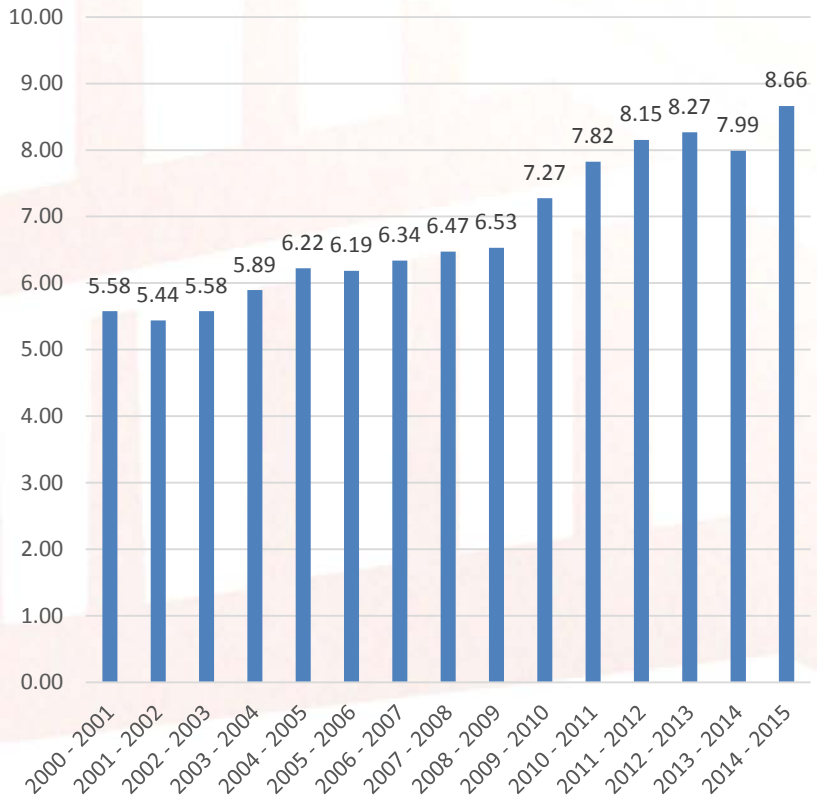
Trends in employment in the manufacturing industry and in automotive industry

(in million numbers)

Manufacturing and automotive employment



Share of automotive employment(%)



Labour intensity and automation

- 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.

Automation and employment in the textile and clothing industry ?

- 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

- 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.”

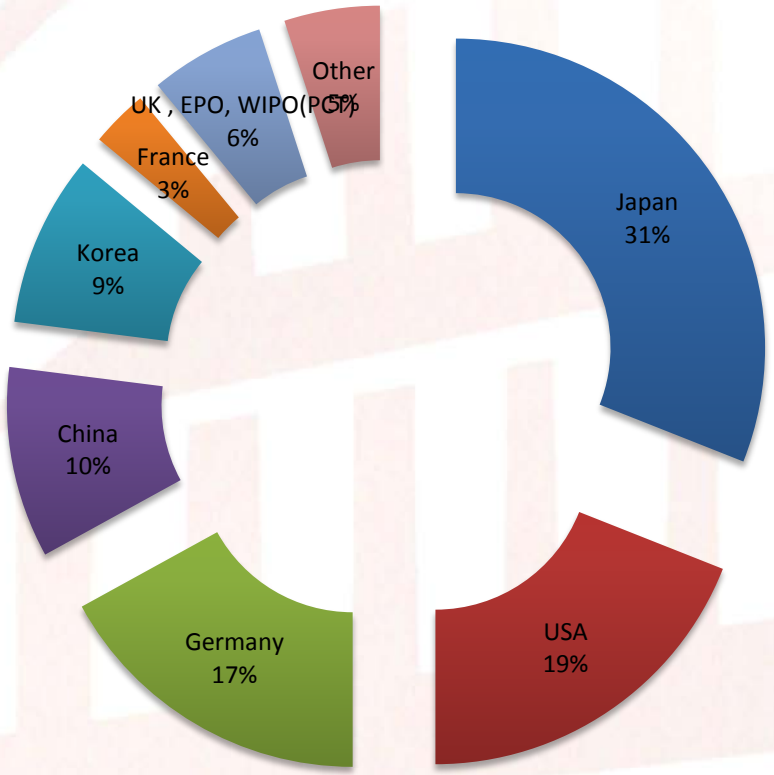
Future of automation

- However automation technologies are fast improving with the significant developments in the following three: (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. 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 pouring money 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.
- 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.

Eight technologies, the improvements in which can contribute to development of robotics

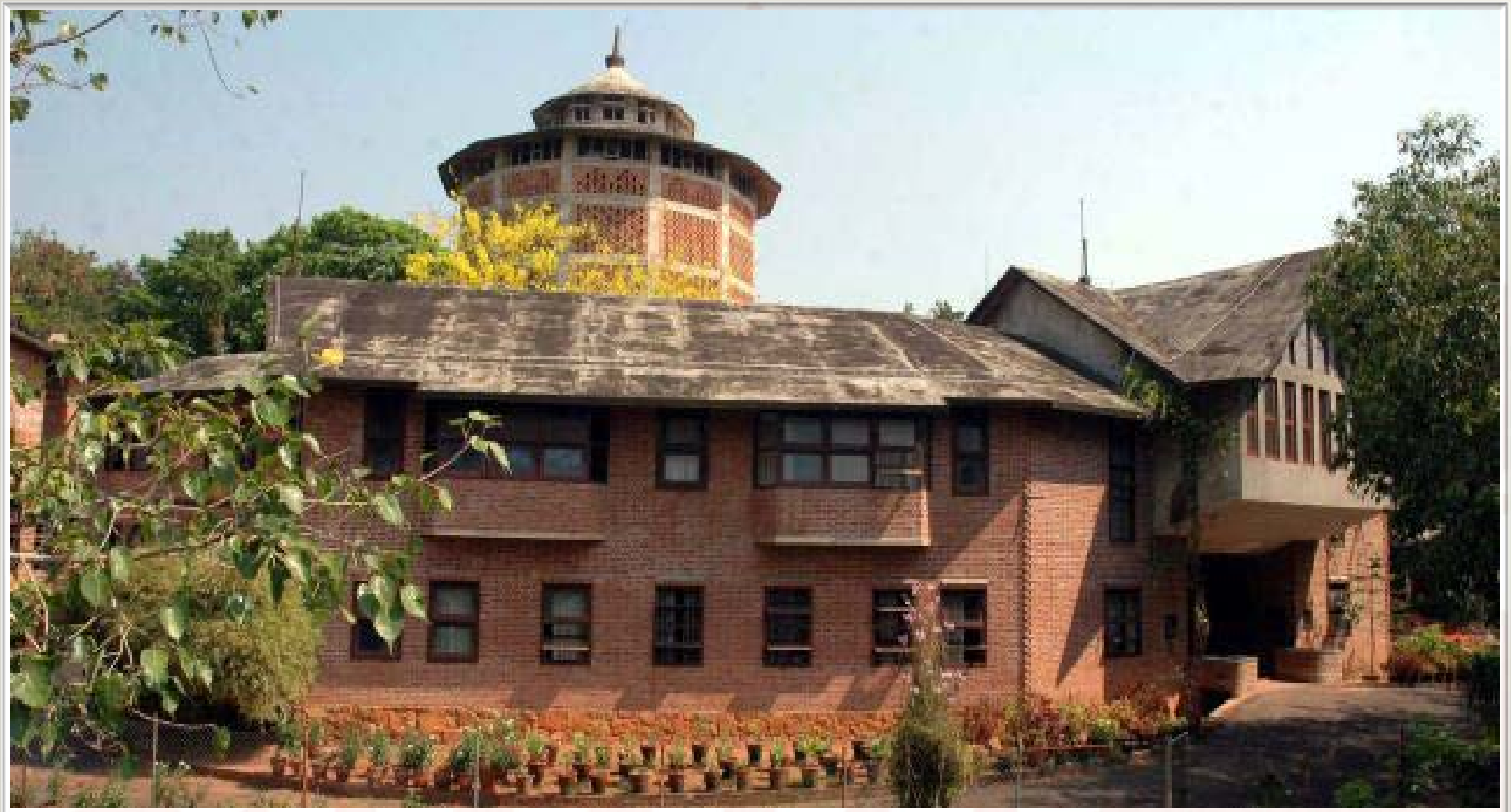
1. Exponential growth in computing performance
2. Improvements in electromechanical design tools and numerically controlled manufacturing tools
3. Improvements in electrical energy storage
4. Improvements in electronics power efficiency
5. Exponential expansion of the availability and performance of local wireless digital communications
6. Exponential growth in the scale and performance of the Internet
7. Exponential growth of worldwide data storage
8. Exponential growth in global computation power

Emergence of China as a leading producer of robotic technology



Conclusions

- 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 have 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 are 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 a labour abundant economy such as that of India's.



Thank you…