The Indian Journal of Labour Economics
https://doi.org/10.1007/s41027-018-0128-1

ARTICLE

Technology and Labour Market: Insights from Indian Manufacturing Sector

Rajarshi Majumder[1]

Abstract
Changes in technology alter the capital–labour ratio in production process and change the magnitude, scale and composition of employment, often beyond recognition. Sometimes, this leads to an enormous expansion of production and employment. Technological change may also hand over many repetitive jobs to machines and decrease demand for low-skill workers, while increasing demand for high-skilled workers to manufacture, program and control these machines. This alters the skill composition of workforce and may worsen the wage gap between skilled and unskilled workers. In this paper, we explore the issue of technological change and its impact on Indian labour market from three angles—impact on aggregate employment, skill composition of workforce and wage disparity. We find a mixed impact of technological change on employment. At industry level, high levels of technological change are associated with moderately high level of employment expansion, but at regional level, high-technological change is accompanied by relatively lower employment growth. As expected, technological progress has been skill biased and wage inequality has increased in both the high technological progress sectors and regions. This increasing polarisation of the labour market is perhaps behind the rising inequality, social tensions and conflicts in India in recent times.

Keywords Technological change · Manufacturing sector · Skill bias · Wage inequality · TFPG

1 Introduction

Economists have long been interested in the effect of technological change on the labour market. Any change in technology basically changes the capital–labour ratio in the production process and therefore changes the magnitude, scale and

✉ Rajarshi Majumder
meriju@rediffmail.com

[1] Department of Economics, University of Burdwan, Golapbag, Burdwan, West Bengal 713104, India

Published online: 29 August 2018

composition of employment. The impact on labour market therefore depends on the type of technological change and its effect on the production process—both in terms of expanse and intensity. Leaps in technology very often change the production process to such an extent that the scale of production itself changes beyond recognition. This leads to an enormous expansion of production and increases employment. The first industrial revolution of 19th century is an example where development of technologies enabled mass production and mass employment of factory workers. Skilled artisans protested development of such technologies as they replaced these skilled artisans with unskilled workers to run the machines (the '*Luddite*' riots of 1811, for example). However, technological change may also lead to handing over many of the repetitive jobs to machines and thereby decreasing demand for low-skill workers. At the same time, it may be accompanied by an increase in demand for high-skilled workers to manufacture, program and control these machines. These changes will alter the skill composition of the workforce and may worsen the wage gap between skilled and unskilled workers. Such technological change is a modern phenomenon, coming into force since the computer revolution after 1950s (Acemoglu 2002).

Direct effects of new technology have mostly been positive through creation of new jobs producing and delivering IT products and services, technology-enabled services and entire new industries, such as software and consumer electronics. On the other hand, most of the negative effects of new technology have not been on the technology sector itself but on employment elsewhere in the economy through substitution of low-skill workers by machines. However, technology has also enabled expansion in size of several sectors like telecommunication, business services, publication and media where new jobs have been created. Thus, technological change both destroys old jobs and creates new ones and the overall impact is hard to hypothesise. However, the impact on the individual worker is immediate and often catastrophic. While skilled workers see a surge in demand and wages, they are under constant threat of their embodied skill becoming obsolete. Unskilled workers are therefore joined by workers whose skills have seen a drop in demand due to change in technology. These displaced workers find it difficult to retrain themselves and find new employment. For example, a skilled typesetter in a printing press during the early 1990s was one of the most highly skilled and paid workers in the publishing process. However as technology changed and publishing software decimated the presses, these workers were suddenly out of job and could never adopt to be typists on a desktop. Similarly, the shop-floor workers losing jobs due to technological changes in the factory could hardly get themselves rehired as computer programmers. Though late, the modern type of capital-deepening technological progress started in India as well and it is crucial to explore its impact on the labour market.

2 Brief Review

Forms of unemployment caused by rapid technological advancement in the processes of production were loosely termed technological unemployment by Keynes during the 1930s when he talked of 'discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour' (Keynes

1930). However, for most of the next 70 years, he seemed to be outvoted by empirical evidence as jobs expanded and real wages increased substantially. This followed up the pattern experienced in the late 19th century when most of the technological progress had been ‘deskilling’ in nature since they broke up the production process into smaller and easier fragments, each different and highly specialised, and thus employing more workers than before, albeit unskilled and able to perform only a fragment of the production chain (none other exemplifies this phenomenon better than the Assembly Line pioneered by Ford Motor Company in 1913).

However, as the century came to a close and real wages plateaued out in most developed countries with a fall in labour share in income becoming pervasive, Keynes’s apprehension resurfaced. Considerable debate has since taken place in academic as well as policy level on the role of technology in the labour market. On one hand are those who argue that technology can create unemployment in the short run but expands employment in the long run (Mincer and Danninger 2000; Lachenmaier and Rottmann, 2011; Coad and Rao, 2011; among others). The other view is that there is a negative association between technological innovation and employment expansion, at least in the long run. Frey and Osborne (2013) argued that close to half of the job categories are at risk of being automated in the next decade or so. Similar views are expressed by Bresnahan (1999), Brynjolfsson and McAfee (2011). This impact is strongly felt first in the manufacturing sector where production process consists of several well-defined, repetitive, routine jobs (the assembly chain for example) and which therefore can be easily automated. The jobless growth in several parts of the globe in recent times has been explained by scholars through this process of declining routine jobs in manufacturing shop-floors (see, for example Charles et al. 2013; Jaimovich and Siu 2012).

The second strand of argument that looks at technological advancements critically speak of the inherent skill bias of advanced technology and its impact on composition of labour force as well as relative wages and ‘returns to education’. Goos and Manning (2007), Atkinson (2008), Goldin and Katz (2009), Autor and Dorn (2013) and several others speak of such polarisation in the labour market since late 20th century.

Recently, Vivarelli (2013, 2014) has tried to put forward a nuanced analysis of the link between technological change and labour market by distinguishing between *process innovation* and *product innovation* [an early exposition of this difference and its impact on wage inequality was in Iacopetta (2008)]. While the former is essentially labour displacing in nature, the second creates opportunities for emergence of new products, new firms and therefore new jobs. Using both Marxian and Keynesian theories, he has also shown why counterbalancing market mechanisms like new machinery, lower commodity and labour prices, and new investments that are likely to accompany productivity augmenting process innovations are inadequate to compensate the initial job losses. Empirical estimates found that the net effect varies across economies and sectors (Vivarelli 2013). Technological change captured through firm-level R&D expenditure as a proxy for product innovation on the other hand has a significant employment-enhancing impact, at least for European firms (Vivarelli 2014). However, in a later study, it has been observed that this positive employment effect is of small magnitude and limited to the medium- and high-tech sectors, with no such effect discernible for the low-tech industries (Piva and Vivarelli 2018). This is crucial since the industrial sector of the developing economies are mostly of the low-technology variety and therefore unlikely to reap the job-creating benefits of new technology. Calvino and Virgillito (2016) also concluded that the relation between technical change and employment dynamics through the twin channels of product and process innovation is far from conclusive and depends not only on sectors and economies but also on the level of aggregation applied.

Thus, the evidence so far has been mixed and mostly limited to developed countries. It is therefore important to examine and consider alternative scenarios regarding the possible impacts of technological advancement on the labour market, especially in a large developing country like India.

3 Objective and Methodology

In this paper, we seek to explore the issue of technological change and its impact on Indian labour market from three angles. First is the issue of technological change and employment trends. Towards that, we concentrate on the formal manufacturing sector (units registered under Factories Act and coming under the scope of ASI). We first identify the sectors that have been categorised as advanced technology sectors in the Indian economic context using several broad parameters including, but not limited to, the capital–labour ratio used in production by UNIDO (UNIDO, 2005). This report considered product design capability and process technology of Indian manufacturing and segregated them into three groups—basic technological capability level, intermediate technological capability level and advanced technological capability level.[1] We consider the advanced technology sectors and examine the trends in employment and wages in these sectors to understand how technology is associated with labour market conditions. Thereafter, we use frontier production function approach to measure rate of technological progress during 2000–2010 period in this sector, separately for each of the major states and major industry groups. [This part of technological progress has been taken from earlier work by the author; see Mukherjee and Majumder (2014)]. The second set of data on technical progress can be derived from looking at the trends in fixed capital–output ratio. Sectors/regions can be classified on the basis of K/O ratio to have high-, moderate- or low-technological change over a given period. Thereafter, we may examine whether labour–output ratio has increased/decreased in states/sectors showing higher technological progress. If higher rate of technological progress is associated with lowering of L–O ratio we would infer that the nature of the technological change has been labour saving, leading to negative impact on the labour market. Similarly, the

[1] Industries in these three groups are as follows: Food and Beverages, Metal Forging and Products, Machine Tools and Equipment, Chemicals, Electrical and Electronic equipment, and Light Engineering have Basic Technological capability level; Steel, Pharmaceuticals, Automotive, Petrochemicals have Intermediate Technological capability level; Auto-components, Information Technology products, Telecommunication products have Advanced Technological capability level.

links between rate of technological progress and trends in both labour productivity and wage share in GVA have also been examined. Second is the issue of technological progress and wage disparity. To do that, we concentrate on the same set of rate of technological progress data. But now, we take help of the NSSO surveys on employment to examine the wage disparity within states/sectors and its link with technological progress. More specifically, we examine whether states/sectors showing higher rates of technological progress have witnessed increasing wage disparity within. Third is the issue of technological change and skill demand. This can be examined by looking at the changes in skill composition of new workers over time, for the states/sectors separately.

We use the rate of technological progress for major Indian states and major industry groups from an earlier paper (Mukherjee and Majumder, 2014) to examine its linkage with other variables of interest.

In addition, we derive fixed capital/labour ratio, fixed capital/output ratio and output/labour ratios for the registered Indian manufacturing sector for the period 2000–01 and 2010–11, separately for major Indian states and two-digit NIC groups. This is used to determine the level and trends in technology for Indian industries. As mentioned earlier, sectors were divided into advanced, intermediate and basic Technology groups based on the UNIDO (2005) study. Regions/sectors were divided into high-, moderate-, low-technological progress groups based on the TP figures obtained from the SFA as also from changes in capital–output ratio over 1999–2011 period. Values were converted to 2001–01 constant prices using appropriate price indices. Wages and employment data from the NSSO surveys of 1999–00 and 2011–11 (NSSO 1999, 2011) have been used, and wages were converted to constant 2000–01 prices using appropriate price indices (CPIIW in this case). It may be noted that NSSO 68th round survey on employment and unemployment is the latest available countrywide large sample data on employment and wages in India.

4 Technology and Employment

4.1 Macroaggregates

Before examining the specific trends in the manufacturing sector, let us explore the long-run macroeconomic trends in India. It is observed that the capital—output ratio (ratio of Net Capital Stock to GDP) has shown a secular declining trend over the three decades between 1980 and 2010, coming down from 1.54 to 1.33 during this period, before recovering marginally to 1.37 in 2016 (Fig. 1). The manufacturing sector did not follow this trend during the first two decades and increased from 0.83 in 1981–82 to 1.06 in 1998–99, though with periodic fluctuations. After 1999, this sector too followed the declining trend experienced at the aggregate level and came down to 0.84 in 2011, back to the level it was three decades earlier, and thereafter declining further to 0.81 in 2016.

It would have been usual if the labour share in gross output and value added mirrored the trends in K–O ratio, falling when K–O ratio increases and rising when K–O ratio falls. However, labour share, both at the aggregate level and for

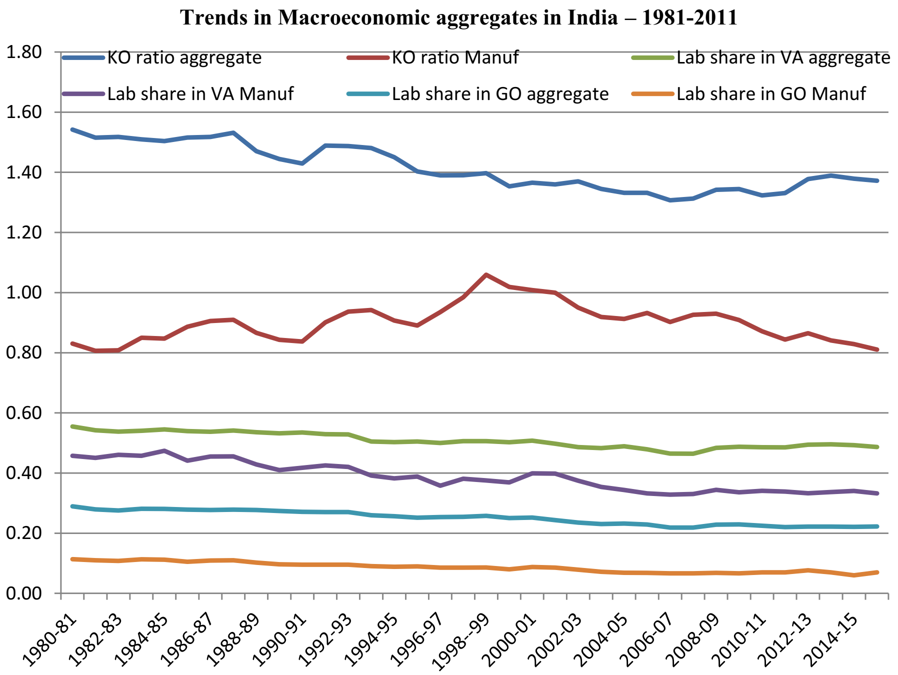

Fig. 1 Trends in macroeconomic aggregates in India—1981–2011. *Source*: India KLEMS database version 2018 (KLEMS 2018)

the manufacturing sector witnessed a secular decline over the three decades under study. Labour share in gross output declined from 0.29 in 1981 to 0.22 in 2016 at the aggregate, and from 0.11 to 0.07 for manufacturing sector. The rate of decline has thus been faster for the manufacturing sector than the aggregate economy. This could have been caused by several factors operating either singly or together, as mentioned below:

(a) A fall in employment size relative to output or rising labour productivity;
(b) Wages rising slower than prices of output;
(c) Wages rising slower than operating surplus (or returns to capital);

All of these point to a worsening labour market situation in the country where employment is not expanding as fast as it should and workers are shortchanged.

With this backdrop, let us now proceed to a more detailed analysis as outlined earlier.

4.2 Level of Technology

As mentioned earlier, manufacturing sector was divided into advanced, intermediate and basic Technology groups based on the UNIDO (2005) study.

Table 1 Growth of workers in manufacturing sector in India—1999–2011—by technology status. *Source:* Authors' calculation based on NSSO (1999, 2011), CSO (1999, 2010, 2016)

Category of industries	Share in employment			Growth rate of employment	
	1999	2011	2016	1999–2011	2011–2016
Aggregate manufacturing sector					
Advanced technology sectors	1.5	1.0	na	−2.9	na
Intermediate technology sectors	0.4	0.6	na	4.0	na
Basic technology sectors	98.1	98.4	na	1.3	na
Aggregate	100.00	100.00	na	1.3	na
Factory sector					
Advanced technology sectors	7.8	7.6	8.1	4.3	1.3
Intermediate technology sectors	14.4	9.5	9.6	0.4	1.3
Basic technology sectors	77.8	82.8	82.3	5.2	1.2
Aggregate	100.0	100.0	100.0	4.6	1.2

Technological backwardness of Indian manufacturing sector is evident from the fact that over 98% of employment is in the basic technology sector (Table 1). It is observed that over the 1999–2011 period, the advanced technology sectors witnessed a negative growth rate of employment and its share in aggregate employment declined from about 1.5% in 1999 to less than 1.0% in 2011. Only the intermediate technology sector has shown a distinctly high employment growth rate during this period, but its share in total employment is so small that it could not pull up the aggregate employment growth rate. Naturally, the basic technology sectors dominated the employment growth figure. It is thus clear that the advanced technology sector cannot be counted upon to expand the labour market by much.

If we concentrate only on the factory sector, the picture is slightly different, but not dissimilar. Here, the highest employment growth rate during 1999–2011 period was exhibited by the basic technology sectors and the lowest by the intermediate technology sectors. But in the next five-year period between 2011 and 2016, employment in all the three sectors had grown almost at the same rate, which was significantly lower than the earlier decade.

It is thus clear that the advanced technology sector is not having any meaningful impact in expanding the size of workforce in the manufacturing sector in India.

Further insights may be obtained by looking at the wage situation (Table 2). It is observed that the growth rate of average (mean and median) wages have been remarkably high in the advanced technology sectors—close to 15% pa in real terms over a 12 year period. During the same period, wages for the manufacturing sector as a whole increased by only 5% pa and have virtually stagnated in the intermediate technology sector. More interesting has been the wage disparity situation. Wage spread has increased in the advanced technology sector as shown by increased CV and increased IQ range of wages, while wage disparity has declined in the intermediate technology sectors.

Table 2 Trends in wages in India across sectors—1999–2011. *Source:* Authors' calculation based on NSSO (various years)

Categories	Growth rate of		CV in wages		Change in IQ range
	Mean wage	Median wage	1999–00	2011–12	
Advanced technology sectors	14.9	18.2	1.00	1.23	18.3
Intermediate technology sectors	0.6	−0.7	1.62	1.24	−2.5
Basic technology sectors	4.3	5.7	1.36	1.34	2.4
Aggregate	4.6	5.4	1.39	1.37	3.0

It is thus clear that the advanced technology sector has created wage disparity in the labour market while at the same time had a marginal impact on the employment situation.

4.3 Technical Progress

Indian formal manufacturing sector registered 15% per annum output growth during 2000–10, compared to just 8% during the 1980s. Historically, most of the growth in manufacturing output in developing economies is attributed to increased input use and India was no exception. However, in recent decade, productivity growth has picked up and it is generally perceived that technical progress is the main driving force behind productivity growth, especially in manufacturing industries. During the last decade, TP was 0.6% per annum at the aggregate level (Table 3). Rate of TP was negative in the non-durables sector and manufacture not classified. TP was negative also in the intermediate goods sector while machinery and equipment sector had the highest TP during this decade. It is noteworthy that the two sectors which experienced technical progress in recent times have witnessed significant inflow of both domestic and foreign capital in the last decade and entry of multinational corporations in a big way. So it has gained access to improved technology and output growth has taken place along with substantial technological progress. The consumer non-durables and intermediate goods sectors on the other hand are dominated by domestic small- and medium-sized firms with lower capital intensity and hence have witnessed negative technical progress in the last decade.

At the regional level, rate of technological progress was highest in the central region, followed by southern and northern states (Table 4). Only in the eastern states, rate of technical progress was negative in the last decade.

4.4 Impact on Labour Market

What has been the impact of such technological change on the labour market? To explore that, we have segregated the manufacturing sector into three groups. We identify high-technological change sectors as those where rate of technological progress and change in capital–output ratio has been more than half standard deviation higher than the average for the sector in aggregate. Low-technological

Table 3 SFA-based technical progress and labour–output ratio of registered factory sector in India—industries (average across states). *Source:* Authors' calculation based on CSO (various years)

States	Rate of technical progress 2000–10	Output–worker ratio (Rs. Lakh per worker) constant 2000–01 prices			Change in O–W ratio (% pa)	
		2000–01	2010–11	2015–16	2000–10	2010–15
Food and beverages	−0.5	14.5	29.4	40.9	10.3	7.8
Tobacco	0.2	2.6	4.4	5.8	6.9	6.4
Textiles	3.7	8.3	14.4	16.7	7.4	3.2
Textile products	−3.8	5.9	6.7	7.9	1.5	3.6
Leather products	0.3	8.7	8.2	11.1	−0.6	7.1
Wood products	−1.5	6.0	16.8	18.8	18.1	2.4
Paper products	0.3	13.4	19.9	28.9	4.9	9.0
Publishing and Media	−0.4	13.4	19.9	23.6	4.9	3.7
Coke and carbon	−1.7	167.1	522.7	449.9	21.3	-2.8
Basic chemicals	−0.6	29.1	42.4	55.7	4.6	6.3
Rubber and plastic	−3.9	15.1	25.3	28.6	6.8	2.6
Non-metallic minerals	−1.4	9.4	13.0	16.0	3.8	4.6
Basic metals	1.1	22.2	55.4	67.0	14.9	4.2
Metal products	−0.3	10.0	19.4	22.3	9.4	3.0
Electrical Equip	−0.2	20.2	37.5	44.3	8.6	3.6
Non-electrical Equip	−0.2	15.7	31.5	40.9	10.1	6.0
Transport Equipment	1.7	19.8	35.0	42.4	7.7	4.2
Product groups						
Non-durables	−0.2	10.8	23.6	34.8	11.8	9.5
Durables	1.3	8.5	12.3	15.9	4.5	5.9
Intermediates	−0.5	23.4	45.5	57.9	9.5	5.4
Machinery and Equip	1.0	18.6	34.8	44.9	8.7	5.8
Others	−2.2	20.4	43.6	54.8	11.4	5.2
All industries	0.6	15.2	30.9	40.3	10.3	6.1

change sectors are those where rate of technological progress and change in capital–output ratio has been more than half standard deviation lower than the average for the sector in aggregate. The sectors lying in between are the moderate-technological change (TC) sectors. We observe that the three groups have almost similar shares in total manufacturing sector employment.[2] However, growth of workers during both 1999–2011 and 2011–16 periods has been highest in the low

[2] These three groups are as follows: Food & Beverages, Textile products, Leather products, Paper products, Publishing & Media, Metal products in the High Technological change group; Tobacco products, Textiles, Wood products, Non-metallic Mineral products and Basic Metals in the Moderate Technological change group; Coke, Basic Chemicals, Rubber & Plastic, Electrical & Electronics equipment, Machine tools & Equipment, and Transport Equipment in the Low Technological group.

Table 4 Technical progress and labour–output ratio of registered factory sector in India—states (average across industries). *Source:* Authors' calculation based on CSO (various years)

States	Rate of technical progress 2000–10	Output–worker ratio (Rs. Lakh per worker) constant 2000–01 prices			Change in O–W ratio (% pa)	
		2000–01	2010–11	2015–16	2000–10	2010–15
Andhra Pradesh	1.0	8.0	21.7	27.8	17.0	5.7
Assam	0.0	9.5	19.7	22.6	10.8	3.0
Bihar	3.0	14.7	26.0	30.3	7.6	3.3
Chhattisgarh	4.1	19.3	38.7	46.3	10.0	3.9
Gujarat	4.0	23.1	53.4	63.5	13.1	3.8
Haryana	2.3	20.5	33.0	46.4	6.1	8.1
Himachal Pradesh	3.3	21.8	39.3	53.5	8.1	7.2
Jharkhand	0.3	14.4	49.7	53.1	24.6	1.4
Karnataka	3.0	12.9	30.8	37.4	13.9	4.3
Kerala	2.6	10.2	16.4	29.5	6.2	16.0
Madhya Pradesh	0.1	19.2	32.8	47.3	7.1	8.9
Maharashtra	3.1	22.6	42.8	55.9	8.9	6.1
Orissa	−1.1	13.4	26.4	43.0	9.7	12.6
Punjab	1.9	12.6	20.1	24.8	6.0	4.6
Rajasthan	4.1	17.5	29.1	40.2	6.6	7.6
Tamil Nadu	2.0	11.2	19.4	23.8	7.4	4.5
Uttar Pradesh	4.3	16.1	30.6	38.4	9.0	5.1
Uttarakhand	1.5	17.0	29.7	53.0	7.4	15.7
West Bengal	1.8	8.6	26.3	35.8	20.6	7.2
Regions						
Central	1.8	17.4	32.2	41.5	8.6	5.8
East	−0.6	10.6	28.2	36.8	16.7	6.1
North	1.0	16.7	28.3	41.1	7.0	9.0
South	1.1	10.3	21.8	27.8	11.1	5.5
West	0.8	22.8	47.6	59.4	10.9	5.0
All India	0.6	14.8	30.7	40.1	10.7	6.2

TC sectors, followed by the high TC sectors (Table 5). Growth of output has also been highest in the low TC sectors during the first decade. As a result, elasticity of workers with respect to output has been highest in the high TC sectors and least in the low TC sectors during 1999–2011 (Table 6). However, in the next period, output growth in high TC sectors has outstripped employment growth by far, and as a result, elasticity of employment has been lowest in this sector.

Table 5 Growth of important indicators of registered factory sector in India across TC groups *Source:* Authors' calculation based on CSO (various years)

Categories	1999–2011				2011–2016			
	Fixed capital	Workers	Output	Wages	Fixed capital	Workers	Output	Wages
High-technological progress sectors	10.3	5.4	10.6	8.1	10.1	1.9	7.1	10.7
Moderate-technological progress sectors	10.0	3.1	12.1	4.4	7.3	1.6	4.2	9.6
Low-technological progress sectors	8.0	6.1	13.2	7.1	7.0	3.3	5.9	10.5
High-technological progress states	14.7	4.1	12.1	7.6	11.8	−0.2	4.0	8.5
Moderate-technological progress states	9.2	5.2	11.9	6.3	7.8	2.9	6.6	11.0
Low-technological progress states	9.3	4.9	14.3	6.6	11.0	3.5	6.2	11.5
Aggregate	10.3	4.8	12.7	6.6	9.8	2.4	6.0	10.7

Table 6 Technological change and employment elasticity of registered factory sector in India. *Source:* Authors' calculation based on CSO (various years)

Categories	Elasticity of workers with respect to output		Share in employment	
	1999–2011	2011–2016	1999–2011	2011–2016
High-technological progress sectors	0.51	0.27	33.5	32.9
Moderate-technological progress sectors	0.26	0.38	34.3	33.2
Low-technological progress sectors	0.46	0.55	32.2	33.9
High-technological progress states	0.33	−0.06	21.0	18.4
Moderate-technological progress states	0.43	0.44	49.7	50.8
Low-technological progress states	0.34	0.56	29.3	30.8
Aggregate	0.38	0.40	100.0	100.0

To examine the regional dimension of the issue, we have segregated the states into three groups—high TC, moderate TC and low TC—as before.[3] The picture that emerges is slightly different from what we observed at the NIC level. At the regional level, growth of workers and elasticity of employment with respect to output was highest for the moderate TC regions during 2000–11, which incidentally also has the highest share of manufacturing sector employment. Employment growth and elasticity of workers with respect to output were lowest for the high TC regions. In the next period, employment growth was highest for the low TC regions and negative for the high TC regions. As a result, elasticity was also highest for the low TC regions and negative for the high TC regions.

If we go into further detail, it is observed that the highest employment growth has taken place in the low TC sectors of high TC states and the least employment growth has taken place in the moderate TP sectors in moderate TC states (Fig. 2).

Going into NIC/region-specific analysis, it is observed that the highest employment growth has occurred during 2000–16 period in the recycling sector of southern region (Fig. 3). This was followed by apparel industries in northern, central and eastern India; wood products in northern India; leather products and metal products industries in central India; electrical and electronic machinery and equipment and chemical industries in northern India.

We thus find a mixed impact of technological change on the employment situation. At the industry level, sectors that have shown high levels of technological change have also witnessed moderately high level of employment expansion, though employment growth has been highest in the low-technological change sectors during the first 15 years of this century. But at the regional level, states where technological change has been high are also the ones with lowest growth of workers. There are thus separate factors at work at spatial and industry level and it would require further

[3] The states in the three groups are: Andhra Pradesh, Madhya Pradesh, Orissa, and Punjab in the High Technological Change group; Chattisgarh, Himachal Pradesh, Jharkhand, Kerala, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh, and Uttarakhand in Moderate Technological Change group; Assam, Bihar, Gujarat, Haryana, Karnataka and Bengal in Low Technological Change group.

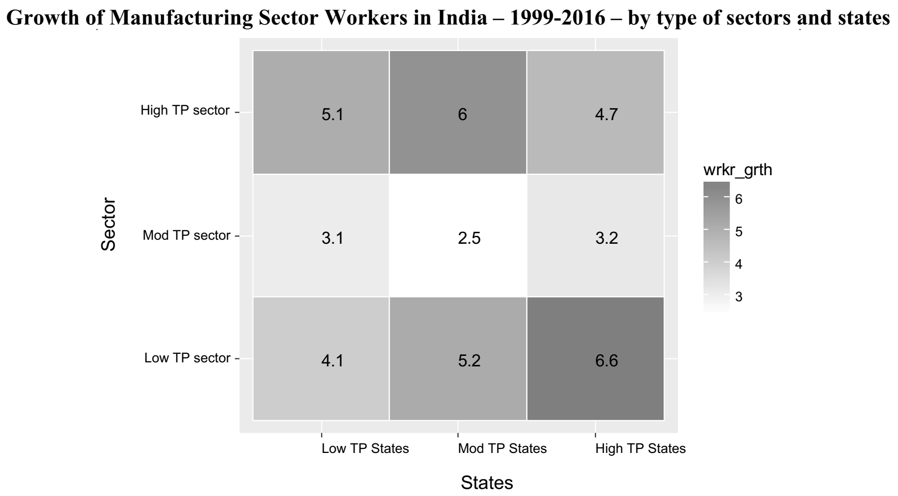

Fig. 2 Growth of manufacturing sector workers in India—1999–2016—by type of sectors and states. Note: figures indicate growth rate per annum; sector/state groups are as explained in text. *Source*: Authors' calculation based on CSO (various years)

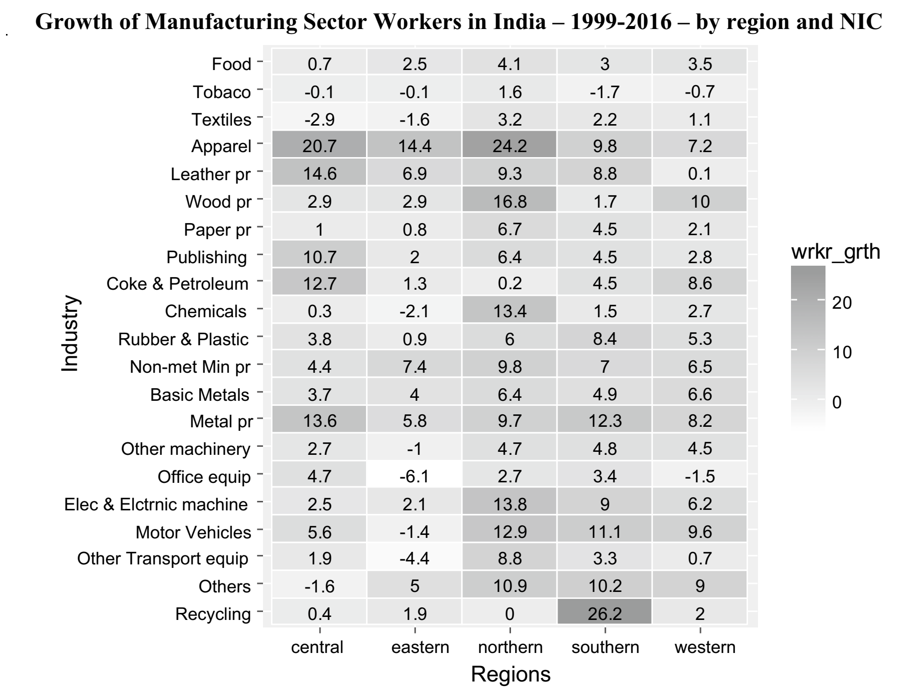

Fig. 3 Growth of manufacturing sector workers in India—1999–2016—by region and NIC. Note: figures indicate growth rate per annum. *Source*: Authors' calculation based on CSO (various years)

Table 7 Growth of workers in manufacturing sector in India—1999–2011—by Education groups *Source:* Authors' calculation based on NSSO (1999, 2011)

Categories	Growth of workers by years of schooling			
	< 8 years	8–11 years	12–14 years	> 15 years
High-technological progress sectors	2.5	0.1	10.1	11.5
Moderate-technological progress sectors	1.0	4.7	9.5	7.6
Low-technological progress sectors	1.4	4.2	15.2	9.4
High-technological progress states	−5.2	1.4	14.2	12.4
Moderate-technological progress states	0.7	1.0	10.8	8.7
Low-technological progress states	5.2	4.9	11.2	9.3
Aggregate	1.6	2.8	11.7	9.5

detailed study at specific state and industry level to better understand the exact process and pattern of link between technological change and employment in context of Indian manufacturing sector, which is beyond the scope of this rudimentary analysis.

5 Technological Progress and Inequality

It has also been mentioned in the literature that technological progress of the current form may exacerbate income equality in the society through skill bias and wage disparity in the labour market [see, for example, Acemoglu (2002), Rotman (2014), Basu (2016)]. We may examine these issues in light of Indian experience. The impact of technological change on the skill composition of workers is interesting. It is observed that over the 1999–2011 period, skill composition of workers has improved substantially with highest growth in workers with 12–14 years of formal education, closely followed by workers with at least a graduate degree (Table 7). Workers with less than 8 years of formal schooling have shown the lowest growth rate (1.6%). Within such an optimist picture, we find that both the high-technological sectors and regions have shown a relatively higher growth of better educated/skilled workers compared to the low TC sectors and regions. It is thus clear that a skill bias is at work and the high TC sectors/regions are creating relatively higher demand for more educated and skilled workers.

This is supported by movements in the wage scenario as well. Average wage has increased in the high TC sectors and regions at relatively higher rates compared to sectors/regions showing moderate or low-technological change (Table 8). At the same time, wage inequality has increased in both the high TC sectors and regions, as evident from the rising CV and Gini coefficient of wages, whereas wage inequality has come down in the moderate and low TC sectors and regions.

It is thus clear that the sectors/states showing relatively higher rate of technological progress have witnessed slower growth of employment, changes in skill composition of workers biased towards the upper ends and rising wage inequality.

Table 8 Trends in wages across manufacturing sector in India—1999–2011 *Source:* Authors' calculation based on NSSO (1999, 2011)

Categories	Growth rate of		CV in wages		Gini coeff of wages 1999–00	Gini coeff of wages 2011–12
	Mean wage	Median wage	1999–00	2011–12		
High-technological progress sectors	8.1	2.1	1.14	1.16	0.40	0.42
Moderate-technological progress sectors	4.4	3.8	1.02	0.93	0.44	0.38
Low-technological progress sectors	7.1	2.2	1.64	1.37	0.51	0.49
High-technological progress states	7.6	5.2	0.98	1.76	0.42	0.48
Moderate-technological progress states	6.3	2.5	1.85	1.44	0.49	0.45
Low-technological progress states	6.6	0.9	1.14	1.09	0.47	0.45

6 Concluding Comments

Our brief analysis suggests that the present situation in Indian labour market is tense and at a critical juncture. Macrogrowth of the last two decades has not translated into expansion of employment. Changes in production processes and technology, especially in the manufacturing sector, are being accompanied by stifling employment growth for a large part of the economy and the so-called high-tech sectors are unable to pull up the job scenario. Added to this is a widening skill composition of workforce accompanied by rising wage disparity, again mainly in the sectors and regions which has witnessed high-technological progress during the study period. This has much wider social and political ramifications. As Casey (2018) shows, technological breakthroughs may increase growth rates of output per worker but leads to higher long-run unemployment and decreases share of workers in income. Also, such labour-saving technological progress is inefficient because labour is not scarce in the developing countries. This is likely to lead to a substantial mismatch between labour market demands and the outturn of the education/training system of developing countries, resulting in high educated unemployment and shortage of specific skills and hence skill premium in labour market existing simultaneously. In fact, signs of these are already visible in India and many other countries (McGuinness and Redmond 2017). One likely fall-out is massive youth unemployment, social unrest, political tension and instability, scenes already witnessed in the MENA countries during 2010–12, what later came to be known as the *Arab Spring*. Apart from the issue of lack of employment, rising wage disparity fuels overall income inequality, especially in large and populous developing countries like India, and is also a potent source of social conflicts. In addition, there are issues of technological progress outpacing the skill/training capacity of new and existing workers, who find themselves ill-equipped to work on the *latest* machines, systems or software within a short time period. Once deemed redundant, they find it hard to get back jobs at par with previous ones and are forced to go down the occupational ladder.

Such potential pitfalls and dangers notwithstanding, automation and artificial intelligence are being pushed in a big way in research laboratories across the globe and it would be no time before the tremors would be felt in developing countries like India. What should be the likely counterbalance in this situation? While it cannot be expected that the chariot of technological progress will halt at the door and the genie of the bottle can be put back in, society and state must first acknowledge the possibilities of shocks associated with the current form of technological progress. Once it is accepted that several negative impacts do exist, adequate counterbalancing measures and safety nets must be put in place. The first thing to avoid is a drastic fall in wage share in income because it leads to a drop in *effective demand* (a la Keynes) and disincentivises producers to increase output and employment. One way to do that is adoption of a universal basic income policy and India would do well to look at this option more seriously now than ever. Second, since the impact varies across sectors, policies should be specific and not blanket ones. For example, while process innovation may be encouraged in relatively small high-technology sectors, product innovation may be encouraged in dominant low-technology sectors. Encouraging competition through *ease-of-doing-business* policies should be supplemented by expansionary fiscal policies that augment final demand and improve infrastructure. Participation in the global value chain should also be closely monitored to judge whether they are leading to positive employment growth or not. Third, the channel of human capital formation should be given a hard and balanced look. At present, we are yo-yoing from a system which is mostly blind to labour market signals to a system that envisages college pass-outs as nothing but potential workers, tuned to the demands of corporate India. While factoring in labour market demand profile is good, it is equally crucial to understand the importance of fundamental and applied research in basic and social sciences. For it is these that expand the frontier of knowledge and drives technological progress in the long run, while at the same time marks the path of human and social progress. And for those who would still fall prey to technology-driven unemployment, there must be a substantial reskilling and technological training framework in place so that these workers may be redeployed after a short spell.

Unless policy makers respond quickly to these new challenges, an unthinkable polarisation will occur in the labour market and will shape the society at large where a countable few will control vast majority of wealth and income while the countless many will be desolate, destitute and desperate. As The Economist points out:

> "The rise of the middle-class—a 20th-century innovation—was a hugely important political and social development across the world. The squeezing out of that class could generate a more antagonistic, unstable and potentially dangerous politics."
> [*The Economist*, Jan 18th 2014]

It is time that we wake up to the impending catastrophe.

References

Acemoglu, D. 2002. Technical change, inequality, and the labor market. *Journal of Economic Literature* 40(1): 7–72.

Atkinson, A.B. 2008. *The changing distribution of earnings in OECD countries*. Oxford: Oxford University Press.

Autor, D., and D. Dorn. 2013. The growth of low skill service jobs and the polarization of the US labor market. *American Economic Review* 103(5): 1553–1597.

Basu, Kaushik. 2016. Is technology making inequality worse?", World Economic Forum Agenda, 2016/01. Available from https://www.weforum.org/agenda/2016/01/is-technology-making-inequality-worse/. Accessed on 31 July 2018.

Bresnahan, T.F. 1999. Computerisation and wage dispersion: An analytical reinterpretation. *The Economic Journal* 109(456): 390–415.

Brynjolfsson, E., and A. McAfee. 2011. *Race against the machine: How the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy*. Lexington, MA: Digital Frontier Press.

Calvino, Flavio and Maria Enrica Virgillito. 2016. The Innovation-employment nexus: A critical survey of theory and empirics. LEM Papers Series 2016/10, Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy. Available from https://ideas.repec.org/p/ssa/lemwps/2016-10.html. Accessed on 27 July 2018.

Casey, Gregory. 2018. Technology-driven unemployment. Brown University Working paper. From www.brown.edu/academics/economics/candidates/sites/brown.edu.academics.economics.candidates/files/Casey%2C%20Greg%20_%202017%20_%20Tech%20and%20u.pdf. Accessed on 31 July 2018.

Charles, K.K., E. Hurst, and M.J. Notowidigdo. 2013. Manufacturing decline, housing booms, and non-employment: A technical report, NBER Working Paper No. 18949, National Bureau of Economic Research.

Coad, Alex, and Rekha Rao. 2011. The firm-level employment effects of innovations in high-tech US manufacturing industries. *Journal of Evolutionary Economics.* 21(2): 255–283.

CSO. 1999. Annual survey of industries, summary data for factory sector—1999–2000. Available from www.mospi.nic.in/mospi_asi.htm. Accessed on 12 May 2008 and 17 May 2013.

CSO. 2010. Annual survey of industries, summary data for factory sector—2010–2011. Available from www.mospi.nic.in/mospi_asi.htm. Accessed on 27 May 2017 and 17 May 2018.

CSO. 2016. Annual survey of industries, summary data for factory sector—2015–16. Available from www.mospi.nic.in/mospi_asi.htm. Accessed on 17 July 2018.

Frey, C.B. and M.A. Osborne. 2013. The future of employment: How susceptible are jobs to computerisation? Working Paper, Oxford Martin School, University of Oxford. Available from https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf. Accessed on 12 Aug 2017.

Goldin, C., and L.F. Katz. 2009. *The race between education and technology*. Cambridge: Harvard University Press.

Goos, M., and A. Manning. 2007. Lousy and lovely jobs: The rising polarization of work in Britain. *The Review of Economics and Statistics* 89(1): 118–133.

Iacopetta, Maurizio. 2008. Technological progress and inequality: An ambiguous relationship. *Journal of Evolutionary Economics* 18(3): 455–475.

Jaimovich, N., and H.E. Siu. 2012. The trend is the cycle: Job polarization and jobless recoveries. Tech. Rep., NBER Working Paper No. 18334, National Bureau of Economic Research.

Keynes, J.M. 1930. Economic possibilities for our grandchildren in *Essays in Persuasion*. New York: W.W. Norton & Co., 1963, pp. 358–373. Available from http://www.executiveshift.org.uk/images/site_graphics/downloads/John_Maynard_Keynes.pdf. Accessed on 18 Aug 2017.

KLEMS. 2018. India KLEMS database—2017. Available from http://rbidocs.rbi.org.in/rdocs/content/docs/KLEMS27032018.xlsx. Accessed on 31 July 2018.

Lachenmaier, Stefan, and Horst Rottmann. 2011. Effects of innovation on employment: A dynamic panel analysis. *International Journal of Industrial Organization* 29: 210–220.

McGuinness, Seamus, Konstantinos Pouliakas and Paul Redmond. 2017. How Useful is the Concept of Skills Mismatch? IZA Discussion Paper No. 10786. Available at SSRN: https://ssrn.com/abstract=2979934. Accessed on 12 Jul 2018.

Mincer, J. and S Danninger. 2000. Technology, unemployment, and inflation. NBER Working Paper No. 7817. National Bureau of Economic Research.

Mukherjee, Dipa, and Rajarshi Majumder. 2014. Efficiency and Regional Comparative Advantage: Revisiting the Factory Sector in India. *The Journal of Industrial Statistics* 3(1): 1–22.

NSSO. 1999. Unit level records on survey on employment and unemployment in India 1999–2000, NSS 55th round—July 1999–June 2000. National Sample Survey Office, Government of India

NSSO. 2011. Unit level records on survey on employment and unemployment in India 2011–12, NSS 68th round—July 2011–June 2012. National Sample Survey Office, Government of India

Piva, Mariacristina and Marco Vivarelli. 2018. Is innovation destroying jobs? Firm-level evidence from the EU. *Sustainability* 10(4):1279. https://doi.org/10.3390/su10041279. Available from http://www.mdpi.com/2071-1050/10/4/1279. Accessed on 25 July 2018.

Rotman, David. 2014. Technology and inequality. MIT Technology Review, Nov–Dec 2014. Available from https://www.technologyreview.com/s/531726/technology-and-inequality/. Accessed on 31 July 2018.

The Economics. 2014. The onrushing wave, [The Future of Jobs briefing, 18-01-2014, available from https://www.economist.com/news/briefing/21594264-previous-technological-innovation-has-always-delivered-more-long-run-employment-not-less. Accessed on 17 Oct 2017.

UNIDO. 2005. Indian Manufacturing Industry: Technology Status and Prospects. UNIDO Technology Paper Series 04–2005. Available from https://www.unido.org/sites/default/files/2009-04/Indian_manufacturing_industry_technology_status_and_prospects_0.pdf. Accessed on 12 Aug 2017.

Vivarelli, M. 2013. Technology, employment, and skills: An interpretative framework. *Eurasian Business Review* 3(1): 66–89.

Vivarelli, M. 2014. Innovation, employment and skills in advanced and developing countries: A survey of economic literature. *Journal of Economic Issues* 48(1): 123–154.