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# Unlocking India's Potential in Industrial Revolution 4.0:
## National Innovation System, Demography, and Inclusive Development

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## Abstract

Abstract: Industrial Revolution 4.0 (IR4.0) has many opportunities and important challenges for developing countries such as India. This article takes stock of India's opportunities in harnessing IR4.0 for inclusive development, and the challenges that the revolution presents before the country. It argues that with India's extant capabilities in ICT software development, a youthful demography, and skill development potential, the country can be at the centre of IR4.0 -- becoming the world's skill or talent capital, besides leveraging the potential of the new technologies for closing development gaps. It also summarizes some policy lessons for tapping the potential of India in IR4.0; these include, among others, the need to quickly transform the educational system to make it fit-for-purpose for the digital revolution, step up enterprise-level innovative activity, facilitate the adoption of relevant technologies by MSMEs, closing the digital divide, and evolving a new architecture for social protection designed to protect displaced workers, as well as gig economy workers.

**Keywords**: Innovation, Industrial Revolution 4.0, Inclusive development, demography, skill development

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## 1. Introduction

The rise of new technologies such as artificial intelligence (AI), blockchain, cloud computing, big data analytics, machine learning (ML), internet of things (IoT), 3-D printing -- collectively referred to as Industrial Revolution 4.0 (IR4.0) -- presents a lot of opportunities as well as important challenges for developing countries such as India.[1] Hence, they are attracting the attention of policymakers across the world.

Some of the defining features of IR4.0 technologies, sometimes also called the digital revolution, include their widespread applications across the fields of agriculture, industry, and services. They could bring hugely disruptive consequences, including extensive job losses and potential restructuring of value chains, and hence could shape a new international division of labour. But they also have a very substantial potential for inclusive development and societal transformation, and if leveraged well can have a profound development impact.

Furthermore, IR4.0 is highly driven by skills. Hence, smaller and nimble organizations have an advantage in developing applications. This is the key reason for the success of start-ups in tapping the potential of IR4.0.

Finally, one challenge arises from the speed of their evolution. Unlike the previous industrial revolutions, IR4.0 is evolving and advancing rapidly. For instance, the global market size of the new technologies was expected to rise to $3.2 trillion in 2025 from $350 billion in 2018 (UNCTAD 2021). Another study has simulated that AI alone could add around $13 trillion (or 16%) to global output by 2030 (McKinsey Global Institute 2018).

The COVID-19 pandemic, which has affected a number of economic activities adversely, has actually helped to boost the digital transformation. The rapid evolution of IR4.0 technologies, almost on a real-time basis, leaves little time for developing countries to develop capabilities and adopt them. The first movers in the technology also enjoy a big advantage, as latecomers face huge entry barriers. Countries like India, therefore, need to move very fast to tap their potential if they wish to not be left behind.

As the Information and Communication Technology (ICT) Revolution (or IR3) morphs into IR4.0, this article takes a stock of the opportunities that India has in harnessing IR4.0 for inclusive development, and the challenges that the revolution presents before the country. It argues that, with India's extant capabilities in ICT software development, a youthful demography, and skill development potential, the country can be at the centre of IR4.0 and become the world's skill capital, besides leveraging the potential of the new technologies for closing its own development gaps. It also summarizes some policy lessons for tapping the potential of India in IR4.0.

## 2. India's IR4.0 readiness and relative strengths

Assessments by the United Nations and other international organizations corroborate India's considerable potential in the digital economy, readiness, and other strengths, as summarized below.

***Relatively high level of readiness vis-à-vis the level of economic development:*** India, was found to be the 'greatest outperformer' in terms of the frontier technology readiness index, with a rank of 43, which was 65 positions higher than its rank according to per capita incomes (UNCTAD 2021:26) (Table 1). India has been classified among the countries with high levels of 'Opportunities' but low levels of 'Skills', in terms of IR4.0 indicators of readiness, along with a number of much richer countries such as China, Thailand, and Mexico (UNCTAD 2022:18) (Figure 1).

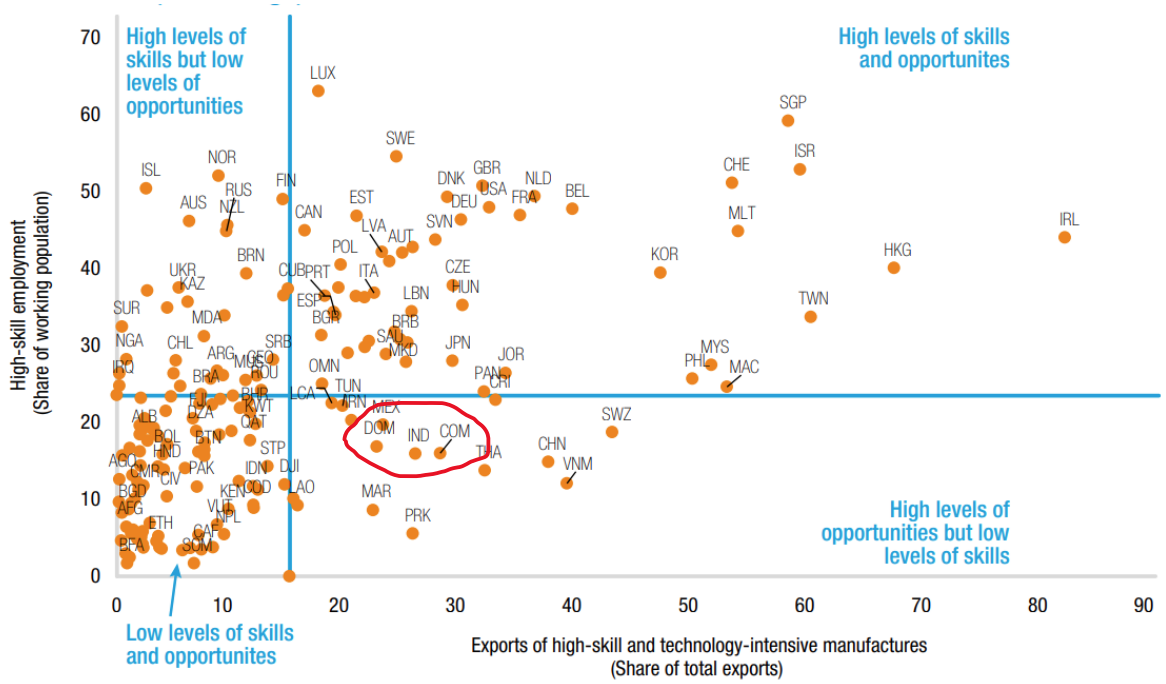
Another assessment, the Asia-Pacific AI Readiness Index 2021, put India 3rd in business readiness, 6th in consumer readiness, and 7th in government readiness (Salesforce 2022). Similarly, a Brookings paper put India among top 10 countries in terms of having a robust technology and research platform, and substantial public/private investments for AI preparedness (Fatima et al. 2022) (Figure 2).

**Table 1: Readiness toward the use, adoption and adaptation of frontier technologies (Rankings)**

| *Country* | *Total* | *ICT* | *Skills* | *R&D* | *Industry* | *Finance* |
|---|---|---|---|---|---|---|
| ***Top 10*** | | | | | | |
| United States of America | 1 | 14 | 17 | 2 | 20 | 2 |
| Switzerland | 2 | 7 | 13 | 13 | 3 | 3 |
| United Kingdom | 3 | 17 | 12 | 6 | 11 | 14 |
| Sweden | 4 | 1 | 7 | 16 | 15 | 16 |
| Singapore | 5 | 4 | 9 | 18 | 4 | 18 |
| Netherlands | 6 | 6 | 10 | 15 | 8 | 23 |
| Korea, Republic of | 7 | 19 | 27 | 3 | 9 | 8 |
| Ireland | 8 | 24 | 6 | 21 | 1 | 87 |
| Germany | 9 | 23 | 16 | 5 | 10 | 39 |
| Denmark | 10 | 2 | 4 | 25 | 21 | 5 |
| ***Selected Transition and Developing Countries*** | | | | | | |
| China | 25 | 99 | 96 | 1 | 7 | 6 |
| Russian Federation | 27 | 39 | 28 | 11 | 66 | 45 |
| Brazil | 41 | 73 | 53 | 17 | 42 | 60 |
| India | 43 | 93 | 108 | 4 | 28 | 76 |
| South Africa | 54 | 69 | 84 | 39 | 71 | 13 |

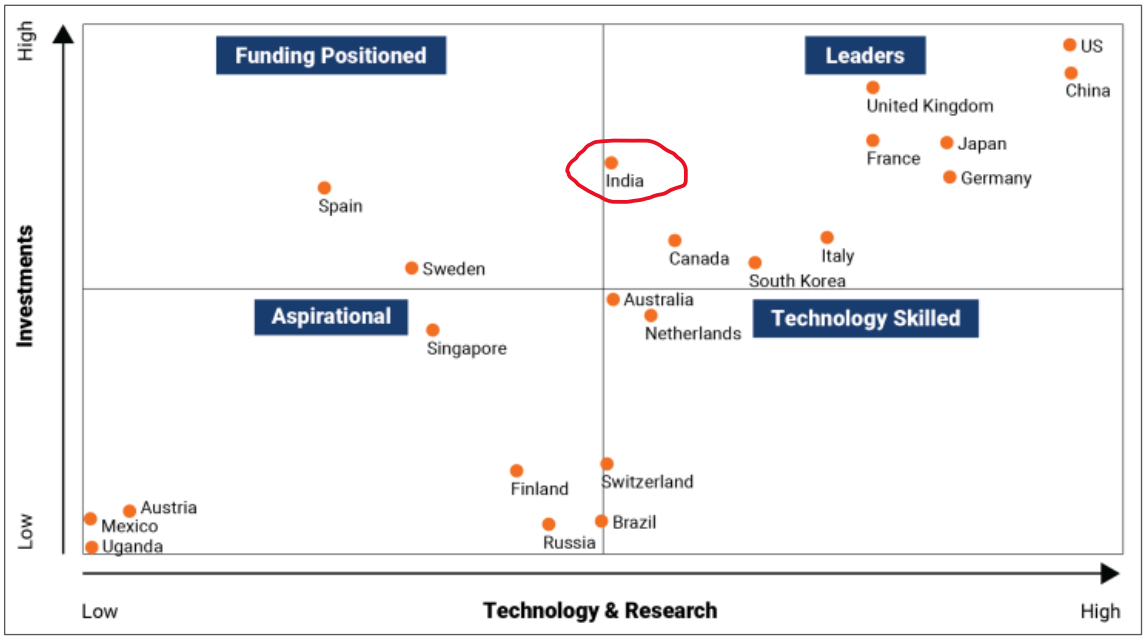
Source: UNCTAD (2021)

**Figure 1: Indicators of readiness to benefit from Industry 4.0**




Source: UNCTAD (2022).

**Figure 2: AI Preparedness in terms of Technology and Investments**




Source: Brookings (2022)

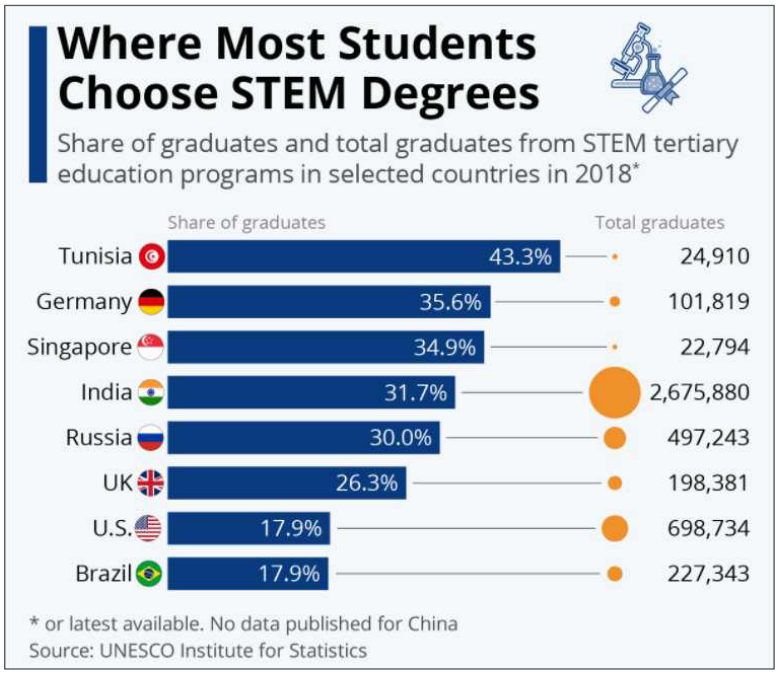
***Leadership in ICT and BPO capabilities:*** One of India's advantages is its ICT software services and business process outsourcing capabilities, which resulted in exports of nearly US$150 billion in 2021. Since its introduction, India has retained the top slot globally in Kearney's Global Services Location Index (GSLI). The software development capabilities provide an important base for upgrading into AI/ML, among other IR4.0 technologies. **India** was put at 17th place in the digital-resonance

ranking.[2] NASSCOM (2022a) puts India at a score of 2.45 (enthusiast) out of a 4-stage AI maturity model.

***The Skills and Demographic Advantage:*** India has a relatively large skills base. India produces over 2.7 million graduates annually, of which nearly 32% are in Science, Technology, Engineering and Mathematics (STEM) -- the types of skills needed for IR4.0 technologies (Figure 3). A McKinsey study puts India (along with Italy and Malaysia) among economies with moderate foundations, noting that the country produces around 1.7 million STEM graduates a year -- more than the total STEM graduates produced by all G-7 countries (McKinsey Global Institute 2018).

NASSCOM (2022a) finds that India was emerging as one of the biggest talent hubs for AI, with a burgeoning number of STEM graduates and digital natives. The abundance of skilled manpower has helped India to attract 40+ Global Capability Centres (GCC) focussed on AI/ML established by multinational enterprises (MNEs). The NASSCOM Survey also found that the rapid growth of AI applications has led to a surge in hiring of AI professionals, resulting in a talent demand-supply gap with a shortage of 200,000 professionals in 2021 (ibid: 31). India can rapidly expand the supply of skilled personnel, due to the demographic sweet spot in which it finds itself.

**Figure 3: Key Producers of STEM Graduates**

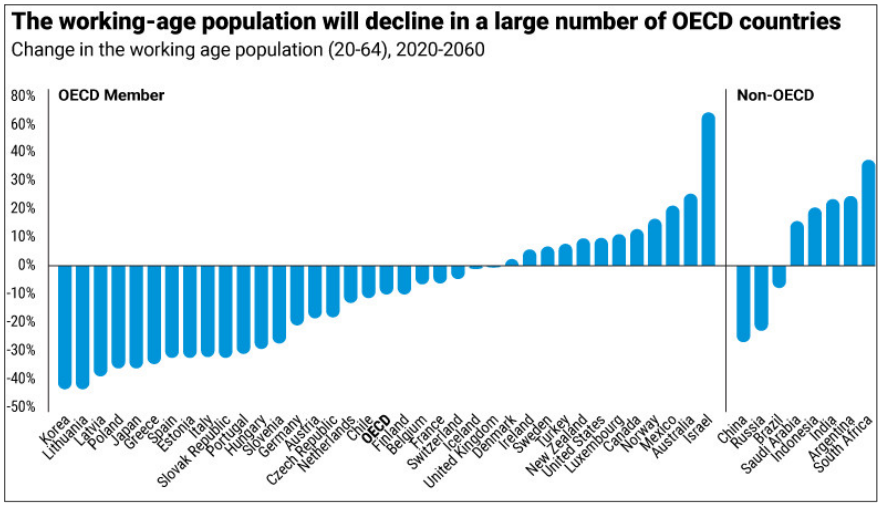



Source: Scoonews (2020)

India's large population base, combined with a relatively low dependency ratio, provides the country with the potential to expand the skills base needed for IR4.0. Unlike the already aged or rapidly-ageing societies of European countries, Japan, China, and the Republic of Korea, India is among the few countries where the proportion of working-age population would be rising in the coming decades (Figure 4).

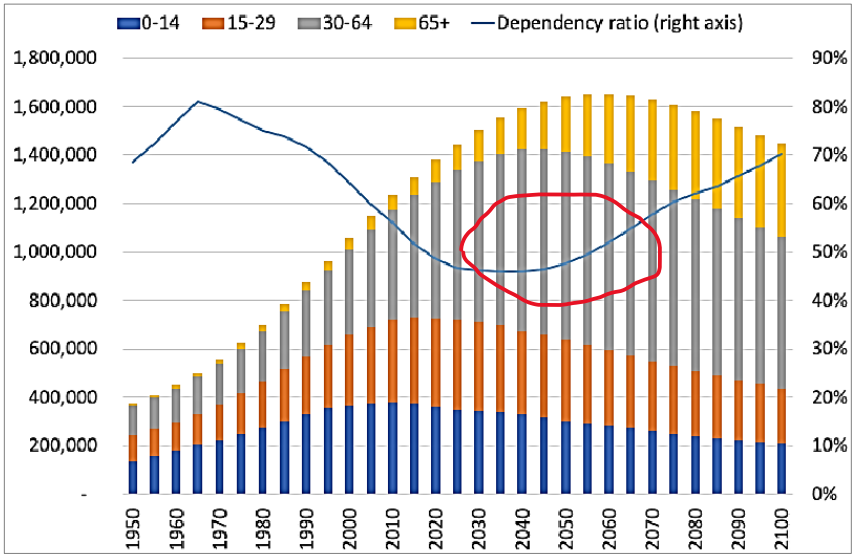
Furthermore, with the large population base passing through a youth bulge in its demographic transition, India would have the largest workforce globally (Figure 5). The favourable demographic window or the demographic dividend that would continue to be available to India for the next couple of decades provides the country with a huge potential to emerge as the key provider of skills globally, beyond providing for its own needs for harnessing IR4.0. This would, however, require substantial investments in skill development, as discussed later.

**Figure 4: Changing proportions of Working Age Population, 2020-2060**




Source: World Economic Forum, https://www.weforum.org/agenda/2020/02/ageing-global-population

**Figure 5: Demographic Transition in India**




Source: UNCT-India Calculations based on UN_DESA (2019).

***Vibrant Start-Ups Ecosystem:*** Given the skill-intensive nature of IR4.0, start-ups with their flexible and nimble organizational structures enjoy an edge over larger organizations riddled with bureaucracy. Many of these start-ups are later acquired by larger corporations, which are better equipped to leverage the revenue productivity of their innovations. India has over the past few years developed a very

vibrant ecosystem covering incubators, infrastructure, and venture capital, facilitated by the Start-Up India Mission of the Indian Government launched in 2016. This ecosystem, considered the third-largest globally after the US and China, has helped establish over 75,000 start-ups recognized by DPIIT, of which over 100 have become unicorns with a valuation over $1 billion (Invest India 2022).

## 3. IR 4.0 and India's Industrial Transformation

India's development trajectory has moved from an agriculture-dominated economy to a services-dominated economy, bypassing the industrial sector (especially manufacturing). While services sector has grown rapidly, it has failed to create jobs in a commensurate manner, leaving agriculture to sustain nearly 45% of the workforce.

Realizing the criticality of the manufacturing sector for creating an adequate number of productive jobs, India is now seeking to harness its potential through the Make-in-India programme. A number of steps have been taken to boost the manufacturing sector, including the production-linked incentives (PLI) scheme announced as a part of the *Aatamnirbhar Bharat* package, announced by the Government to revive the economy in the aftermath of the Covid pandemic.

IR4.0 could play an important role in the success of the industrial transformation strategies of India. This is because global competitiveness is a key factor for success in manufacturing in an open economy context. IR4.0 is emerging as the key driver of manufacturing productivity and competitiveness. The convergence of ICT with Operational Technologies (OT) creates new possibilities for efficient process controls, as well as more efficient product designs, customization, delivery and logistics.

IR4.0 technologies can substantially boost labour productivity, and reduce defect rates and delivery cycle times through real-time management, production optimization, personnel management, data-driven decision making and predictive maintenance, all part of 'smart factories'. IR4.0 technologies could also accelerate the circular economy and green transition of the industry through expanding opportunities for material saving, energy efficiency, waste reduction, and waste recycling possibilities.

Therefore, the adoption of IR4.0 technologies could be a game-changer for productivity and competitiveness in the manufacturing sector. However, the landscape of IR4.0 adoption by Indian industry is highly uneven. There are islands of excellence, for instance, Tata Steel's Kalinganagar plant was nominated by the World Economic Forum (WEF) as a member of the Global Lighthouse Network (GLN), in recognition of its excellence in the adoption of IR4.0 technologies in 2019. In 2021, another Indian company Renew Power joined the GLN, followed by Tata Steel's Jamshedpur facility as well as Hindustan Unilever's Dapada (Dadra and Nagar Haveli) factory joining the league in 2022, out of some 100 plants worldwide.[3]

A NASSCOM (2022a) study finds that starting from a low base, AI investments in India are growing at a CAGR of 30.8%. The potential value added from AI use on India's GDP by 2025 was estimated to be of the order of US$ 450-500 billion. As much as 60% of AI-led value addition is expected from consumer goods & retail, banking, financial services & insurance, energy & industrials, automotive manufacturing, and health care. NASSCOM also finds that a unit increase in AI intensity can increase the total factor productivity growth by 0.05%.

While larger companies are gradually gearing up to tap the potential of IR4.0 technologies for productivity enhancements of their operations, there is a serious risk of MSMEs getting left behind. Given the fact that MSMEs form the backbone of Indian industry, employing 111 million people, their inability to harness the productivity-enhancing potential of IR4.0 technologies threatens to marginalize them further and aggravate the inequalities (ISID 2021a). This is a serious challenge requiring policy attention from both the government and industry.

## 4. IR4.0 and Inclusive Development and Societal Transformation

IR4.0 technologies can be very helpful for societal transformation and inclusive development. This potential is of particular relevance for India. As India celebrates the 75$^{th}$ Anniversary of its Independence in 2022, there are many achievements in socio-economic development, yet some development gaps also persist. The inequalities of opportunities or basic amenities, such as drinking water, sanitation, education, health, and electricity, along rural-urban, rich-poor, or gender lines continue to persist, although remarkable improvements have been made in recent years in closing these gaps (Kumar 2022). In recent years India has also tried to exploit the potential of the digital revolution or IR4.0 technologies for closing these gaps and fostering inclusive development.

To harness digital technology for societal transformation and inclusive development**,** the Indian Government adopted a comprehensive **Digital India** programme in 2015, covering 9 goals and 30 digital themes implemented by multiple ministries, that are expected to create a digital economy of between US$800 billion to $1 trillion by 2025. This will be roughly 18-23 % of India's GDP (India, Meity 2019). These 9 broad goals, which are aligned with the Sustainable Development Goals (SDGs), are summarized below:

- IT Infrastructure: universal broadband coverage and software capabilities for the future
- E-Governance: digital identity, Government Electronic Marketplace (GeM), digital land records, digital urban governance, direct benefit transfers (DBT)
- Healthcare for all: digital health records, COVID management app, public health insurance, health delivery
- Education: Digital education platform, content delivery, and learning
- Energy for all: digitally-enabled access, smart grid, renewables

- Financial services: UPI digital payments interface, flow-based lending, and credit underwriting
- Agriculture/ doubling farmers income: crop insurance pay-outs, e-NAM
- Manufacturing: e-enabled trade, Open Network for Digital Commerce (ONDC), shared platforms for transportation, integrated logistics, manufacturing automation and IOT-based advanced analytics, electronics and semiconductor manufacturing
- Jobs and skills: skill-building, online talent marketplaces, digitally-enabled jobs

The digital ecosystem is guided by creating presence-less, paper-less, cash-less, data-driven service delivery by linking them through open standards and interfaces collectively referred to as India Stack.[4] Some of the highly visible and successful platforms include:

- *Aadhar* the digital identity for nearly 1.3 billion people, covering 99% of India's population, which has also served as an identity marker for 410 million Jan Dhan bank accounts facilitating direct benefit transfers (DBT) helping to save resources and avoiding leakages;
- Government e-Marketplace (GeM), the government e-procurement system launched in 2017 linking more than 4 million suppliers including MSMEs and women entrepreneurs;
- the highly successful Covid and vaccine management app, COWIN, besides public health delivery and insurance under *Ayushman Bharat*;
- UPI, a highly successful mobile app based digital payments interface that accounts for over 60% of all digital transactions in the country;
- a digital platform TReDS to facilitate MSMEs by financing their receivables;
- National Agriculture Market or e-NAM, an online trading platform for agricultural commodities in India, that can be used by farmers, traders and buyers;
- the upcoming Open Network for Digital Commerce (ONDC) that could provide an e-Commerce platform for MSMEs.
- There is also an Application Programming Interfaces (APIs) Setu to build interoperable digital platforms for seamless governance delivery.[5]

The Indian Government has also drawn up an ambitious manufacturing programme for electronics and semiconductors under the Semiconductor Mission, with a budget of US$ 10 billion. Five proposals, with a projected investment of over $20 billion, have been lined up for the manufacture of microchips in the country as a part of the Mission.[6] There is also Skill India mission for skill development programmes.

It has been argued that digital empowerment can redefine the education system, transform the agriculture ecosystem, and health care, and drive the productivity of MSMEs to the levels of big companies (Zainulbhai 2022; Sawhney 2021).

Indian start-ups are also helping to exploit the potential of the digital revolution for inclusive development. Several of them are active in financial inclusion, edtech, and health care, among others. Some of them have also started exporting software. For instance, the Postman API Platform, developed by an Indian start-up, is used by more than 17 million developers and 500,000 companies, including 98% of Fortune 500 companies.[7]

To sum up therefore, IR4.0 technologies can be helpful in enhancing inclusivity of the access to public services including in rural areas. However, they cannot substitute for the public (or private) investments required for closing the gaps in physical and social infrastructure, such as roads, hospitals, and schools. Therefore, there is no room for complacency and public (and private) investments should continue to receive the same priority as before.

## 5. Threats and Potentially Disruptive Consequences

Like previous industrial revolutions, IR4.0 also has potentially disruptive consequences; one needs to be aware of these, and take steps to minimize their incidence. The challenges in the case of IR4.0 include widespread risk of job losses as machines begin to displace workers, new forms of work, widening of inequalities within and between countries, and possible restructuring of global value chains to the disadvantage of developing countries like India.

***Employment effects and new forms of work:*** IR4.0 is likely to lead to creative destruction, with the loss of some jobs and the creation of others. There is a lively debate about the extent of possible job losses (see for instance, Autor and Solomons, 2018; Acemoglu and Restrepo 2020). There have been some studies, including those by OECD, that have found that up to 50% of jobs in 32 industrialized countries are vulnerable to substitution with automation.[8]

A Forrester (2022) study finds that as many as 69% of India's jobs are under threat from automation by 2040. This observation is based on perception surveys; it may appear to be alarming, but it refers to potential threats. The actual incidence may depend on a number of factors. There are others that suggest a more moderate level of vulnerability. For instance, a survey conducted by the World Economic Forum (2018) suggests a decline of 0.98 million jobs and a gain of 1.74 million jobs. A McKinsey (2018) study based on extensive simulations has found that although AI adoption is likely to displace 18% of workers, it would also help to gain 17% more jobs on account of gains from augmentation (+5%), innovation and redeployment (+10%), reinvestment (+1%) and global flows (+1%), leaving the net effect on employment to be just -1%.

Therefore, the new technology may not lead to huge job losses in net terms, but it will create different types of jobs, and will therefore lead to a lot of restructuring of labour markets. The labour demand will rebalance from unskilled workers in favour of highly skilled workers. The impact is likely to unfold gradually, as the adoption of the new technology speeds up.

While job losses in net terms may not be substantial, it is clear that a large segment of workers are threatened to lose their jobs, especially those involved in semi-skilled and repetitive jobs. Policymakers will need to address the challenge of rehabilitating and redeploying these workers, with alternate work and reskilling. Social protection frameworks in the country will also need to be strengthened, to smoothen the transition from one job to another after reskilling.

Also, digital technologies are leading to new forms of work that are different from traditional employer-employee-based contracts, including the so-called gig economy or online platform workers. Gig economy workers work as partners of the platform and earn directly from its customers, for instance, as Uber drivers or Urban Company technicians.

The number of workers that are part of the gig economy is rising rapidly. According to ILO, India accounts for 8% of platforms globally, making it the second largest in the world after the US (Uma Rani 2021). Already 7.7 million people are working on these platforms in India, and their number is expected to rise to 24 million by 2029-30 (NITI Aayog 2022). As they are not employees, they do not have a social security cover usually provided by the employers. Hence, they are highly vulnerable to the shocks that may affect their business (as the Covid pandemic did). This creates new challenges for policymakers, to create new forms of social protection for this class of workers.

***Widening inequalities within and between countries:*** As observed earlier, new technologies are becoming an important source of widening inequalities within and between countries. IR4.0 tends to accentuate the inequalities created by the digital and skill divides (UNESCAP 2018). Within the country, inequalities are rising due to the premium commanded by professionals trained in IR4.0 technologies, while semi-skilled workers face threats of job losses. Also, the rise of technology entrepreneurship tapping IR4.0 is creating a new breed of billionaires, with the country having over 100 unicorns, of which as many as 22 were minted just within the first half of 2022 (Invest India 2022). Meanwhile, gig economy workers not having a social security cover remain vulnerable to shocks, as during the Covid-19 lockdowns.

Inter-country inequalities are also likely to widen, with leaders and early adopters of technology racing ahead to exploit the potential, and other countries lagging further behind. The digital revolution benefits early movers in a very disproportionate manner. As a result, the pioneers of new technologies have deeply entrenched themselves in their respective markets, forming near-monopolies. The five big tech companies, namely Apple, Microsoft, (Google parent) Alphabet Inc., Amazon.com Inc., and (Facebook parent) Meta Platforms Inc., all headquartered in the US, collectively added more than $2.45 trillion in their market valuation in 2021 alone![9] The galloping valuations of these companies are reflective of the market power of their pioneering innovations in the digital economy.

Never in history have a handful of companies wielded so much market power and concentration of economic power. This market power becomes a formidable entry barrier for new entrants. This is leading to a trend of techno-nationalism. China, for instance, does not allow the American big tech

companies in its territory, to facilitate entry of Chinese companies. Other countries are also trying to restrict the operations of Chinese telecom equipment manufacturers, fearing security concerns.

## Reshoring of Global Value-chains and new international division of labour

One of the big concerns arising from the evolution of IR4.0 relates to the possible restructuring of global value chains. In the past, global value chains (GVCs) were outsourced to developing countries, to leverage labour cost differences among other locational factors.[10] Robotization of production tends to neutralize the labour cost advantage enjoyed by developing countries. Furthermore, many products can be produced by 3-D printing anywhere.

On the other hand, with the digital revolution, services can be delivered from anywhere. Hence, Baldwin (2019) has argued that manufacturing may become non-tradeable, while services could become more tradeable due to IR4.0. The reshoring of global value chains is, therefore, a real possibility, and can affect the export prospects of developing countries.

Dachs and Seric (2019) observed stagnation in the growth of offshoring since 2010, but found that reshoring or back-shoring was not yet a common trend -- limited to only 4% of all manufacturing firms in Europe. Ferrantino and Koten (2019) observe that IR4.0 technologies have an uncertain effect on GVCs. They may reduce the length of supply chains by encouraging reshoring or nearshoring of manufacturing production. On the other hand, they may strengthen GVCs by reducing coordination and matching costs. Besides robotization, the trend of nearshoring has been accentuated by other factors, such as the US government's support for domestic manufacturing and sourcing, the EU's Carbon Border Tax (Knizek et al 2022).

Therefore, IR4.0 technologies may lead to the reorganization of global manufacturing, reshoring of outsourced production back to home countries, and thus diminishing the role of developing countries in the international division of labour. The COVID-19 pandemic has exacerbated this trend; though the overall impact is not yet apparent in a big measure, it is likely to shape up gradually (Panwar et al 2022).

In India's case, the impact of the reshoring may be limited, given the fact that the country has not yet been integrated too deeply with the GVCs (outside a few product categories, such as pharmaceuticals and textiles). But it may affect the prospects of future integration with GVCs and attracting outsourced production that India is eying with its current emphasis on strengthening the manufacturing sector. In the short run, a more important factor driving the reorganization of GVCs may be the strategies of MNEs to diversify their sourcing strategies on a China+1 basis, which India can well take advantage of.

## 6. National Innovation System for Tapping the Potential

Tapping the potential of the new digital revolution, covering an entire spectrum of economic and social activities, would require extensive preparations by all different stakeholders of the national innovation system, including the government, business enterprises, educational and research institutions, and society at large. While a number of initiatives have been taken by the Indian Government, a larger action agenda is needed for exploiting the potential. Such an agenda for action is outlined below.

*Making skill-generation activities fit-for-purpose:* The availability of skills is a critical ingredient for success in IR4.0. India needs to completely revamp the educational system to produce the type of skills that are needed. India's excellence in the ICT software and business process outsourcing industry owes its success to the creation of infrastructure for producing computer software professionals by the early 1980s, following recommendations of a series of government committees, including the Bhabha Committee of 1963, the Electronics Committee Chaired by Dr V.A. Sarabhai in 1966, and the National Conference on Electronics of March 1970 (see Kumar 2001).

A similar moment is upon us to reimagine the educational and training system of the country in tune with the needs of the digital revolution. This would include revamping secondary and higher education to design thinking and problem solving, and introducing coding in schools, besides improving the quality of education at all levels. The seats in secondary schools, colleges, and higher education institutions need to be rebalanced in favour of Science, Technology, Engineering and Mathematics (STEM) vis-à-vis traditional humanities and arts disciplines. Even within IITs and other engineering institutions, there is a need to rebalance the seats in favour of computer science, AI, data science, machine learning, and algorithm-related courses, against traditional engineering disciplines such as civil, mechanical or chemical engineering.

The National Education Policy 2020 does emphasize multidisciplinary education, vocationalization, STEM, and strengthening technical education with a focus on cutting-edge areas like AI, big data analysis, and machine learning, among others, that would be critical for harnessing IR40. It also envisages Digital Universities that would enable students to design a more personalized and flexible education. It also recognizes the need to avoid the commercialization of education, and the importance of providing affordable quality education. The need for enhancing R&D activity through a National Research Foundation is also emphasized.

These changes will help the Indian education system produce graduates that would be needed, rather than those who cannot find a job. Given the demographic advantage that will last for the next two decades, India has the opportunity to not only meet its own requirements for skills for IR4.0 deployment, but also fill the global skills gap owing to a rapidly declining working-age population in several countries of Europe and East Asia.

The government is also paying attention to skill development through Skill India mission. The National Skill Development Corporation is approaching the skill gaps by expanding public-private

collaboration, initiating pathways for international mobility, and increasing women's participation in the labour force. In parallel, leading India-based IT organizations have started focusing on skill-development programs to meet the demands of the digital era.[11]

The private sector could also come forward to establish new educational and training institutions, that would augment the capacity to produce graduates with the AI/ML capabilities to meet the growing requirements. WEF (2018) finds extensive evidence of rising demand for AI and ML specialists, big data specialists, process automation experts, information security analysts, user interface designers, robotics engineers, and blockchain specialists, among others.

A programme for reskilling and upskilling people displaced by the incipient technology revolution would also be needed, and should be run by the government and industry. Given the growing scarcity of skills that are fit-for-purpose, the industry is learning to reinvent strategies for recruitment, training, and retention of talent.[12] India should exploit its favourable demography for meeting the challenge of skills shortage by quickly expanding the supply.

To sum up, we recommend a big expansion in the public-funded education and training sector through raising the national education spending to 6% and above (from the current level of 4.4%), to provide affordable, quality education in the emerging AI/ML-related fields through a reformed education and skill development framework. This would pay rich dividends to the country, in terms of harnessing the potential of IR4.0 for its own inclusive development, besides becoming the skill capital of the world.

***Closing the digital divide:*** Broadband internet access is the most critical infrastructure for digital transformation. Although internet users in India per 100 people have grown 2.4 times (from 25.3 to 61) between 2015-2021, access to fixed broadband subscriptions has lagged behind other developing countries (World Bank 2021). Therefore, the highest priority has to be accorded to expanding universal broadband coverage. Access to broadband internet should be treated as the basic infrastructure like electricity or drinking water. Recognizing the criticality of this, the Indian Government has adopted the National Broadband Mission that aims to provide 100% Broadband connectivity in all villages, 55% fiberization of mobile towers (up from 30%), an average broadband speed of 25 mbps, and laying 30 lakh kilometres of optic fibre by December 2022.[13]

***Facilitation and Extension Services for MSMEs:*** Given the productivity-enhancing potential on IR4.0 technologies, it is important to ensure that MSMEs are not left behind in their adoption. For this, the Government, industry associations, and self-help groups could start some kind of extension services for MSMEs in key clusters, to demonstrate key applications of new technologies.

The Technology Facilitation Centres run by the MSME Ministry of the Indian Government could be retrofitted with IR4.0 technologies (Kant 2021). 30 centres of excellence have been established by the Ministry of Electronics and Information Technology (Meity) to support 4000 technology-focused Start-Ups (Rajendra Kumar 2021). These centres could also facilitate MSMEs in their adoption of digital technologies.

The industry associations and chambers should also come forward to raise awareness and provide facilitation services for IR4.0 adoption for their members, especially for raising competitiveness; adoption for its own sake should be discouraged, in view of potential labour displacement consequences. Some industry groups are coming forward in that direction. NASSCOM, for instance, has created AI for India mission to focus on drivers of change, and has begun to recognize the AI Gamechangers.[14]

***Boosting innovative activity***: Innovation is very critical for harnessing the potential of IR4.0. India needs to step up the proportion of national income spent on R&D, from 0.7% gradually to over 2%. Furthermore, an increasing proportion of this R&D activity should be undertaken by the industry. Only about 30% of the GERD is spent by business enterprises, despite the generous tax incentives offered by the government.

Indian enterprises could leverage their software development, chip design, and frugal engineering capability, and leverage the national innovation system (NIS) in the country, comprising the centres of excellence in advanced technology applications like the Indian Institute of Science (IISc), IIITs, and IITs -- as MNEs have been doing through their Global Capability Centres (GCC) located in the country.

Evidently, India is emerging as the key destination for AI innovation. India ranked 8$^{th}$ globally in terms of AI patents filing for 2020. (Although over 5000 AI patents have been filed over the past decade, 63% of granted patents belong to MNEs.[15]) India's rank in the *Global Innovation Index 2022* moved up to 40$^{th}$ rank globally, up from 81$^{st}$ in 2015 (WIPO 2022).

What can be done to boost the R&D activities of Indian enterprises? Given the strategic importance of innovative activity, governments in developed countries spend billions of dollars on R&D subsidies given to national enterprises to shore up their competitiveness. Subsidies up to 50% of project costs have been made non-actionable under the World Trade Organisation (WTO) rules. In India, R&D activities have been encouraged mainly through tax deductions. It is arguable that partial funding for specific R&D projects undertaken by business enterprises may be desirable to develop products or processes, thus strengthening competitiveness or meeting developmental goals.

Another policy to promote local innovation could be to protect minor innovations through the so-called utility models or petty patents. The experience of several East Asian countries such as Japan, South Korea, Taiwan, and China, suggests that petty patents could be effective means of encouraging domestic enterprises to undertake minor adaptive innovations and foster an innovation-based rivalry among them (Kumar and Joseph 2022).[16]

***Fostering the Start-Up culture:*** Start-ups are at the vanguard of leveraging IR4.0 technologies in India. Recognizing this, the Indian Government launched in 2016 the Start-Up India mission, that provides facilities to recognized start-ups. The Indian start-up ecosystem is considered to be the third largest in the world, after the US and China, having produced over 74,000 registered start-ups and more than 100 unicorns (Invest India 2022). We need to constantly foster start-ups with a more enabling ecosystem, including by providing ready to use (plug-n-play) facilities and scaling them up

facilities, not only in big cities but also in tier-2 and -3 cities. The District Industries Centres, which had been created to foster MSMEs, could be revamped as District Incubation Centres.[17]

***Strengthen social protection:*** As discussed above, IR4.0 could lead to the displacement of many workers, especially those involved in semi-skilled jobs, besides creating a new class of workers called gig-economy workers or platform workers. Therefore, there is a need for strengthening the social protection system in the country, to take care of those affected adversely including through reskilling.

The gig economy work is expanding rapidly, and needs a new framework for social protection that covers them for shocks, besides the usual needs of health and life insurance. This is an agenda which is yet to be addressed satisfactorily.[18] Furthermore, the new technology revolution is aggravating within-country inequalities, given the huge skill premium and emergence of technology billionaires, on the one hand, and workers displaced through automation on the other.

A mechanism needs to be developed for the redistribution of massive incomes / profits made by technology entrepreneurs with the bottom billions if socio-economic inequalities were to be contained (Roy 2021). One possibility could be a tax mechanism for super normal profits to support the vulnerable sections of the population on the receiving end of the digital revolution.

## 7. Concluding remarks

To sum up, it is critical for India to harness the potential of IR4.0 for its inclusive and sustainable development, although much of the discussion in the country has generally focused on its potentially disruptive consequences on the future of work and the possible reshoring of global value chains. India's attempt to catch up with manufacturing through Make-in-India would also critically depend on its ability to leverage IR4.0, given that the new technologies are becoming key drivers of productivity and global competitiveness.

Recognizing its potential for inclusive development and societal transformation, the Indian Government has developed a comprehensive vision to harness the digital revolution, through such measures as e-governance, direct benefit transfers, delivery of services, management of Covid-pandemic, financial inclusion, digital payments, and electronic platforms for government procurement and e-Commerce, that are empowering the MSMEs. Some of these interventions have proven to be successful globally.

The national innovation system of the country needs to be geared to tap the opportunities presented by the IR4.0. The skill-intensive nature of the new technologies lends an advantage to countries passing through a youth-bulge phase in their demographic transition, such as India, especially when major economies in Europe and East Asia are rapidly ageing, if not already aged. India needs to quickly transform the educational system to make it fit-for-purpose for the digital revolution, to produce skills that are in short supply to meet not only its own needs but position itself at the centre of the IR4.0 as the skill or the talent capital of the world.

India also needs to step up its innovative activity, particularly the enterprise-level R&D activity, through such measures as partial funding of R&D and adopting a second-tier patent system. MSMEs would need to be supported in harnessing the productivity-enhancing potential of IR4.0 through extension and facilitation services run through self-help groups and industry associations.

Given the potentially disruptive consequences of new technologies, like previous technological revolutions, a new architecture for social protection designed to protect displaced workers, as well as gig economy workers, and to contain inequalities from aggravating would be needed. Finally, a whole-of-society approach involving all the stakeholders working in a coordinated manner would be needed to tap the full potential of IR4.0, rather than leaving it to the government alone.

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## Notes

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