Introduction

Germany’s launch of an Industry 4.0 initiative triggered a fashion imitated by countries around the globe. In 2013, the German government introduced the concept of Industry 4.0 in its High-Tech Strategy 2020 and identified it as one of ten major future projects to support a new generation of research and development in industrial technology. German scholars and businessmen consider the concept of Industry 4.0 to be the fourth industrial revolution, dominated by intelligent manufacturing and revolutionary means of production; people can make great use of the combination of computerised information technology and advanced technologies, such as cyberspace and cloud computing, to transform the whole manufacturing industry into an intelligent production system.

Thereafter, many countries – especially those developed countries that intend to regain manufacturing capacity and promote employment, as well as developing countries with ambitions of upgrading their industry structure – have expected to find paths to achieve their goals with the contributions of Industry 4.0 construction. Industry 4.0 has thus gradually become a popular national strategy around the world.

China publicly followed this path of industry upgrading in 2015 with the announcement of the Made in China 2025 strategy. Made in China 2025 is a development strategy that aims to enhance the competitiveness of domestic manufacturing and to foster economic growth driven by advanced manufacturing industries and technical innovations.

For the last 70 years, since the founding of the People’s Republic of China in 1949, China has developed from a large, traditional agricultural economy into an important industrialised one. So far, China possesses one of the most integrated industrial systems in the world and lives up to its reputation as the “world factory” by its total output, providing nearly all kinds of manufactured goods, and its significant role in the global supply chain. At present, all 39 divisions of modern industries are located in China, including 191 subgroups of manufacturing industries and 525 even lower classes of manufacturing industries, according to the International Standard Industrial Classification of All Economic Activities (ISIC) published by the United Nations. This integrated industry system enables China to supply global consumers with almost every kind of goods.

In 1949, agriculture contributed the most to China’s GDP. The secondary industry accounted only for 15.5%, of which heavy industry only took a share of 4.5%. In 2018, however, the...
value-added of China's manufacturing sector was 26.5 trillion Yuan, which is about US $4 trillion (calculated at the exchange rate of that year), and it accounted for almost 30% of China's GDP (Li 2019).

Moreover, according to the databank of the United Nations Industrial Development Organisation, there are 22 major manufacturing industries in China, whose annual value-added rank the highest in the world. In addition, the production of textile, clothing, leather and metals products all account for even more than 30% of the world's total value-added. Currently, China ranks as the top producer of hundreds of manufacturing products, such as steel, copper, cement, chemical fertilisers, chemical fibres, shipbuilding, automobiles, computers, laptops, printers, television sets, air conditioners, washing machines and so on.

In 2018, China's total value-added of its manufacturing industry accounted for 28% of the whole global manufacturing industry; this is the highest of all countries, with the United States accounting for 17% and Japan for 9% during the same period. In 2018, the export volume of China's manufactured goods amounted to 235.2 billion Yuan, that is, nearly 17.5% of the world export aggregate. In the same year, the export of manufactured goods in China accounted for 85.4% of its total exports of goods and services (China Economic Information Service 2019).

However, there are also evident weaknesses in China's industry system. On the whole, China's manufacturing sector is still in the transitional process from “Industry 2.0” to “Industry 3.0”, characterised by electrification and automation respectively, not to mention the higher level of Industry 4.0. There are great differences in not only the automation level among different firms, industries and regions but also great variation among firms as to the role of digitisation and ICT (information and communications technology) used in production processes. China has made remarkable progress in promoting the new type of industrialisation and coordination between industrialisation and ICT, and some domestic industries and firms have increased their investment in information, intelligent technology and human capital. However, while China has a few leading firms in some high-tech industries, the majority of Chinese manufacturing firms are generally latecomers and still in the early stages of applying advanced technologies.

**Misalignments of industrial structure**

China’s manufacturing industries produce the largest quantity of some products worldwide, but its production in high-end chips, electronics, consumer electronics, industrial software and other areas does not meet the basic needs of domestic consumption. The development of high-end equipment manufacturing industry and producer services lags far behind as well. The internationalisation level of Chinese firms is low, as is their management efficiency, which has been amplified in the globalisation age. Moreover, resource- and labour-intensive industries are disproportionately large, while the proportion of technology-intensive industries and production-oriented service industries is relatively undersized for sustainable and coordinated growth for China's manufacturing industrial structure. Moreover, the level of industrial agglomeration and cluster development of domestic firms is insufficient. Redundant investment and overcapacity of production in some industries have made those firms vulnerable to outside challenges.

**Poor product quality**

Currently, the product quality problem is prominent in China, and it not only leads to concerns of domestic consumers but also keeps foreign consumers away. According to product quality random inspection conducted by China's State Administration for Market Regulation in 2019, the average passing rate for quality sampling inspection of 97 categories of consumer
goods is slightly less than 90% (China State Administration for Market Regulation 2019). The manufacturing industry in China bears a direct quality loss exceeding 200 billion Yuan each year, comparing the indirect loss exceeding 1 trillion Yuan; this loss is hitting downstream industries and contributing to loss of market share and pollution control due to inferior product quality (Zhang 2015). Export products made in China also lack a reputation for high quality in the international market, compared to products from Germany or Japan (Cagé and Rouzet 2015). Foreign demand is determined by expected quality, which is driven by the dynamics of consumer learning through shopping experiences and the country of origin’s reputation for quality. Therefore, a range of quality Chinese firms are permanently kept out of the market by information friction, which causes net welfare loss to Chinese firms and foreign consumers.

**Lack of innovation capability**

There is still a big gap between the innovation capability of Chinese manufacturing firms and that of firms in advanced countries. In 2018, China’s overall R&D spending amounted to 2 trillion Yuan, in which manufacturing R&D expenditure was more than 1 trillion Yuan; the annual growth rate was stable at 10%, based on the published data of the China National Bureau of Statistics. However, the ratio between R&D expenditure and GDP was 2.19% in 2018. Furthermore, the R&D intensity of manufacturing firms (the ratio of R&D investment to their main business revenue) was only slightly over 1.1%, which is far behind the world’s advanced level. For instance, the United States and Japan generally maintain their R&D intensity at around 3%: the indicator for the United States was 2.81% in 2017, and 3.21% for Japan in 2018 (China National Bureau of Statistics 2019). Meanwhile, even in technology-intensive industries such as pharmaceuticals, computers, machinery equipment and electrical equipment, R&D investment of China is lower than that of the United States and Japan. China needs to overcome the bottleneck caused by shortage of core technology that results from backwardness of research and development.

**Low revenue share in global value chains**

The data show that more than 80% of China’s electronic chips depend on imports, which were worth $305.5.1 billion in 2019, and the value is even higher than that of imported crude oil (China General Administration of Customs 2020). China is still entrapped in the “manufacturing–processing–assembly” link with low technical contents and only contributes low value-added to the international division of labour, falling short of competitiveness in sessions with high value-added, such as R&D, design, project contracting, marketing and after-sales service. A much more famous case study reveals that for the wholesale price for an iPhone of the Apple company, which is $178.96, Japan, Germany and South Korea take 34%, 17% and 13% share of the value, respectively, while China has only 3.6%, which is about $6.5 in value, or one thirtieth of the aggregate price (Xing and Detert 2010).

**Harsh competitive pressure**

China’s manufacturing firms have participated extensively in international market competition and have the advantage of providing massive amounts of goods and services to international consumers. Nevertheless, because of the inferiority of the technical capacity and product
Industry 4.0 in China

quality, Chinese firms and products are already at a disadvantage in the world market, especially with regard to the position in global value chains and income share acquired by Chinese firms. Moreover, in recent years, developed countries such as the United States, Germany and the United Kingdom have proposed a “re-industrialisation” strategy focusing on revitalising their domestic manufacturing industry, and their strategies rely on the application of information technology and digital manufacturing technology to seize a new commanding point of manufacturing industry. Therefore, not only do Chinese firms need to adapt to competitive pressure in the global market, but they also need to catch up with the new rival frontier in this emergent tide of internalising manufacturing capacity.

China has already become a manufacturing power evaluated according to multiple dimensions, such as its production and exports and its role in global value chains, but it still has a relatively poor reputation in manufacturing for its relatively low product quality and shortage of technology contents. Additionally, although the overall scale of China’s manufacturing industry is huge, there is significant excess production capacity and redundant investment, and thus the constraints of resources, the use of energy and the environment become the main obstacles to the future development of China’s manufacturing industry.

China’s manufacturing industry has entered a new stage facing two diverging roads, with one way pointing towards a low-level trap and the other pointing towards a bright future. The journey in the second direction needs to be guided by the Industry 4.0 program. This plan will enhance the core competitiveness of enterprises, improve product quality and intelligent manufacturing, because Industry 4.0 will realise the optimisation and automation of the production process. Therefore, the implementation of Industry 4.0 in China is associated with high expectations.

Policy evolution of China’s Industry 4.0 programme

Industrial policy in China

China’s Industry 4.0 programme started with an industry policy plan known as Made in China 2025, which together with previous 5-year plans has taken an important and active role in China’s industrialisation and economic development process for the last 40 years. However, it is always a controversial topic in academic research and policy discussions. It is necessary to explore the role of policy factors in the development of Industry 4.0 in China.

A brief account of the history and features of China’s industrial policy will be helpful to understand why China implemented an Industry 4.0 strategy. China studied the experiences made in Japan and South Korea, especially at their take-off stages, in order to design and implement industrial policy. Academic research has suggested that appropriate industrial policy helped these two countries to achieve very rapid economic growth in the 1950s and 1960s (Sakoh 1984). Rodrik (2010) observed that “the real question about industrial policy is not whether it should be practiced, but how”.

Since the reform and opening up in 1978, industrial policies have assumed an indispensable role in China’s economic development, especially in manufacturing. Behind the evolution of China’s industrial policy were two driving forces: one is adjustment of the relationship between government and market in the process of market-oriented reform, which has an important influence on the orientation of industrial policy and the choice of policy tools. The second is a change in the main problems faced by the industrial development and the transformation of industrial structure in the rapid development of China’s economy.
Policy portfolio

The “Made in China 2025” strategy is a forerunner of Industry 4.0 policies in China, which puts forward the strategic goal of realising manufacturing power through accomplishing “three steps” by the time of the centenary of the founding of “New China” in 2049. To achieve those strategic goals – of a manufacturing power China has aspired to for several decades – the “Made in China 2025” strategy has defined nine strategic tasks and priorities to be fulfilled and many of them are also the core contents of Industry 4.0 program.

Except for the “Made in China 2025” program, related policies have come out continually. For example, one message of resolution, from a report delivered at the 19th National Congress of the Communist Party of China, is to drive deep integration of the internet, big data, artificial intelligence (AI) and the real side of the national economy. Moreover, five-year plans during those years and yearly work reports from the central government, released on the annual meeting of the National People’s Congress, set the targets and basic structure of practical policies to promote Industry 4.0. Those policies have constantly emphasised the major tasks related to Industry 4.0, such as AI, industrial internet platform, big data, digital economy. Table 33.1 lists some important policies and detailed measures to promote the development of Industry 4.0 in recent years.

Logic of policies related to Industry 4.0

Focus on various aspects of Industry 4.0

Table 33.1 reveals that the various policy measures to develop Industry 4.0 involved different Industry 4.0 content, such as AI, industrial internet, intelligent hardware industry, industrial robot and so on. Moreover, these policies often provide time frames and enact specific requirements for their effectiveness to be realised. In addition, these policy programs usually provide specific measures such as subsidies, tax deductions and exemptions.

The role of those policies

The policy adopted usually tries to incentivise the redistribution of resources among industries or to accelerate the development of Industry 4.0 in certain business activities of private firms in various industries. In other words, it is the kind of policy that promotes the production, investment, research and development, modernisation and restructuring of one industry that would impose restrictions on similar activities in other industries, or the policy instruments for Industry 4.0 would cost the investment in or production of other business activities. Those policies bear the gene of selective industrial policy because of the potential extensive intervention in microeconomic operation, with selection bias, distortion of factors and misallocation of resources as well.

The ambiguous effectiveness of those policies

The effects of those policies are awaiting an evaluation, and the results might be highly controversial. With those selective policies, the limitations of China’s industrial policy system gradually become visible. Although China is promoting the transition of policy from a selective industrial policy mode to competition policy in recent years, this cannot be accomplished in a single step. Therefore, in the case of entering the new stage of economic development, it is urgent
### Industry 4.0 in China

Table 33.1 Timeline and contents of major policies related to Industry 4.0 in China

<table>
<thead>
<tr>
<th>Time</th>
<th>Policy</th>
<th>Main content</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2015</td>
<td>Guiding Opinions of the State Council on Vigorously Advancing the “Internet Plus” Action</td>
<td>Foster the development of AI in emerging industries; promote the key areas of intelligent product innovation; improve the level of intelligent terminal product etc. The main goal is to speed up the breakthrough of the core technology of AI and promote the application of AI in the fields of smart home, intelligent terminal, intelligent automobile, robotics and so on.</td>
</tr>
<tr>
<td>August 2016</td>
<td>Program of Standardization and Quality Improvement in Equipment Manufacturing</td>
<td>By 2020, the standard system in key areas such as intelligent manufacturing and green manufacturing will be fundamentally improved, and the quality and safety standards in those areas will be in line with international standards.</td>
</tr>
<tr>
<td>April 2016</td>
<td>Robot Industry Development Plan (2016–2020)</td>
<td>By 2020, the annual output of industrial robots with six axes and more will reach more than 50,000 units. The annual sales revenue of service robots exceeds 30 billion Yuan; the main technical requirements of domestic industrial robots to reach the level of similar products abroad; and to make breakthroughs on key parts such as the precision reducer, servo motor and driver for robots.</td>
</tr>
<tr>
<td>September 2016</td>
<td>Special Action on Innovation and Development of Smart Hardware Industry (2016–2018)</td>
<td>To create basic resources and innovation platform for AI. AI industry system is basically established; the overall technology and industry development and international synchronisation, application and system-level technology are partially in a leading position in the world.</td>
</tr>
<tr>
<td>November 2016</td>
<td>Guideline on Emerging Strategic Sectors during the 13th Five-Year Plan Period (2016–2020)</td>
<td>Cultivating AI industry ecology, promoting AI technology to all-round integration and penetration of various industries. Specific tasks include: speed up the construction of the AI support system; promote the application of AI technology in various fields, encourage all industries to strengthen the integration with AI and gradually achieve intelligent upgrading.</td>
</tr>
<tr>
<td>May 2018</td>
<td>Industrial Internet Development Action Plan</td>
<td>By the end of 2020, the industrial internet infrastructure and industrial system will be preliminarily built, and five or so of the country’s top-level marking and resolution nodes will be completed, with a registration capacity of more than 2 billion.</td>
</tr>
<tr>
<td>March 2019</td>
<td>Guidance on Promoting Deep Integration of AI and the Real Economy</td>
<td>Grasp the development characteristics of the new generation of AI, combined with the characteristics of different industries and different regions, explore the path and methods of the application and transformation of innovation and construct the intelligent economic form of data-driven, human–computer cooperation, cross-border integration.</td>
</tr>
</tbody>
</table>
for China to give full play to the role of market mechanism, to stimulate innovation, explore the novel direction of future industry and promote the continuous improvement of economic efficiency. China needs to adopt effective industrial policies or competition policies to enhance industrial competitiveness and accelerate the adjustment of industrial structure.

The current status of Industry 4.0 in China

In this section, we use indicators to reflect the status and trend of China’s Industry 4.0 program up until now. Based on the definition and connotation of Industry 4.0, which contains the characteristics of making manufacturing industry more digitalised, internet-based and intelligent, and because of the availability of data, the indicators we have chosen here include the coverage of broadband network, the application of industrial robots, the growth of AI industry and the development of big data industry. If Industry 4.0 is conceived as an organic system metaphorically, then AI is the brain, industrial robots are extended limbs, broadband network is much like the bonds that connect every corner of the system and big data is the blood that flows through the meridians.

Broadband network penetration

Broadband is a key infrastructure of the Industry 4.0 program. Both China’s “Made in China 2025” and Europe’s national Industry 4.0 initiatives have higher demands for broadband networks, because it is essential for intelligent production and smart factories. The construction of Industry 4.0 is based on a continuous stream and large volume of industrial big data, which requires a more powerful capacity of network bandwidth. The information transmission of each link of the industrial value chain or the data transmission of each section within the firm cannot be separated from the broadband network. Additionally, real-time information transmission of numerous industrial equipment, terminals, supply chains and workers in a large network puts forward higher requirements for the stability and the coverage of the network. The closer links between producers and consumers in Industry 4.0, such as the promotion of personalised customisation, the construction of platform economy and digital ecosystem, make the penetration of broadband a prerequisite as well. Due to constraints of data availability, we here use overall broadband penetration as a proxy variable to represent the network infrastructure development of Industry 4.0 in China.

In the past, China’s broadband infrastructure was relatively weak compared to that of other countries. This is reflected in many aspects, such as the fact that most industrial parks have a network barely meets the standards of routine office works, and the result is that the bandwidth, coverage or stability of its internet are inadequate to support modern smart production. However, with the progress of economic development, especially the construction of Industry 4.0, the usage of fixed broadband bandwidth has grown very rapidly. The data in Figure 33.1 reveal that both the total number of network users and the size of fixed broadband users show a steady upward trend of growth, and by 2018 they reached a size of nearly 830 million and more than 400 million people, respectively. In 2019, the ratio of fixed broadband penetration, which is the quantity of fixed broadband users divided by the population of China, had attained 31.1%, which is even higher than the average level of OECD countries according to the White Paper on the Development of China’s Broadband (CAICT 2019).

Broadband networks are accelerating into 5G, recently featuring ultra-high speeds. The low-time delay features of 5G can be used in real-time instruction control, real-time distribution of capital goods, parts assembly and other management and production scenarios. Therefore,
ever-widening industrial application will become an important direction for 5G network construction. Furthermore, the wide connection features of 5G can be used to control the whole life cycle of modern factory’s now ubiquitous digital devices.

Broadband application has expanded from consumption to production, opening a new era of interconnectedness of all business activities. The industrial internet has begun to be applied in the automobile, machinery, aviation and other industries and has extended from the peripheral links of production such as security and logistics to the core and internal links of product design, tooling manufacturing and production control, as well as quality inspection. The rapid popularisation of broadband networks has greatly promoted the integration of the network information technology within the economic and social fields, accelerating the quality revolution of China’s industry, which stands for not only the enhancement of product quality, but also the upgrading of China’s industries.

**Usage of industrial robots**

The widespread application of industrial robots in various subfields of manufacturing industry has become a remarkable fact, reflecting the growth of Industry 4.0, and it is of great significance for the transformation and upgrading of the manufacturing industry in China, as well as the rapid development of other industries. In China, the growing demand for industrial robots is reinforced by ever-increasing labour costs driven by the elapsing demographic dividend, which means the share of the working-age population (15 to 64) is no longer larger than the non-working age share of the population. Therefore, the application and dissemination of industrial robots to improve production efficiency, ensure product quality and reliability and even enhance the optimisation of corporate organisation and labour relations is the rational choice by entrepreneurs. The growth of industrial robots in China is reflected by not only the huge quantity increase of its usage in production, but also the expansion of application scenarios to provide services.

The statistics in Figure 33.2 show that in China the number of industrial robots sold reached 156,400 units in 2018. China has been the largest industrial robot application market in the
In 2017, the sale of industrial robots in China accounted for 35.6% of the global sales figure. In 2019, the size of China’s robot market is expected to reach $8.68 billion, and the average growth rate during the course of 2014–2019 was 20.9%.

Provinces that need a lot of labour have introduced a series of fiscal subsidies and tax abatement to support the application of industrial robots in local firms. For example, Guangdong Province has arranged special funds for the development of industrial robots in its “Special Fund for the Development of Industry and Informationization” and has given the firms the amount of subsidy according to a certain proportion of the purchasing price they paid for industrial robots. Other regions like Shanghai, Hubei and Heilongjiang have also arranged policy support and subsidy for industrial robots’ application. Even cities such as Shenyang, Dongguan and Qingdao have established funds to foster industrial robot application.

**Market size of AI**

AI is a new general-purpose technology, which can be widely applied in the economic and social environment. AI has penetrated different links of production, and it has quietly changed the mode of production process and operations of economic organisation. The application of industrial robots leads to the substitution for human physical strength, while AI technology mainly leads to the substitution of human mental power. Whether for entrepreneurs, middle-level managers or front-line workers, the application of AI technology has liberated labour from cumbersome procedural work, improved productivity and then increased overall TFP (total factor productivity) of the macroeconomy, which ultimately leads to high-quality development of the macroeconomy featuring technology innovation and knowledge-driven progress. High quality is mainly reflected by the enhancement of efficiency, in other words, the growth in labour productivity or TFP.

The data in Figure 33.3 shows that in recent years the AI industry has experienced a strong trend upwards with high growth rates in sales. Its market size has risen from about 11 billion Yuan in 2015 to 57 billion Yuan in 2019, and thus has grown almost five-fold in five years.

![Figure 33.2  Growth of China’s industrial robots’ application](Source: International Federation of Robotics (2019) and Lu and Liu (2019)
The average annual growth rate during this period was about 55%, which is much higher than that of the global average rate of growth in sales, which is about 36% per year in the same period. The total number of AI firms in mainland China (excluding Hong Kong, Macao and Taiwan) is 1,040, which ranks only second to the United States. In addition, the number of AI patents filed by different countries collected by the World Intellectual Property Organization shows that in 2018 (WIPO 2019), China, the United States and Japan already accounted for three-quarters in all patents applied related to AI technology, and China alone took a share of 40%. Moreover, the first half of 2019 has witnessed a total investment of over 47.8 billion Yuan in China’s AI sector (Deloitte Report 2019), which projects an even faster growth of AI industry for China in the near future. With the ever-maturing environment for the development of AI industry, the overall market size of China’s AI industry will reach 200 billion Yuan. At the same time, AI has a significant spill-over effect, which will promote the sustainable development of other related technologies, accelerating the transformation and upgrading of traditional industries.

**Expansion of big data industry**

The development of the big data industry itself is driven by data explosion in industrial production and organisational change, and the promising function of big data to improve efficiency. Additionally, big data communicates with all corners of the Industry 4.0 system and virtual connected related facilitates. Although the big data industry contains hardware facilities, its software dimension, which refers to basic services, technology development and integration applications of different levels, data collection and management, as well as the overall solution of data application, is crucial to the development of Industry 4.0.

Industrial big data has great and far-reaching impacts on the mode of production, operation management and ecological complex of manufacturing industry. The role of industrial big data in the manufacturing industry is mainly reflected in intelligent design and production, networked collaborative manufacturing, intelligent service, personalised customisation and so on. Under the impetus of big data, advanced manufacturing industry will achieve more rapid development, and the level of digitisation and intelligence of traditional industries is expected to be further improved as well.

![](image)

**Figure 33.3 Growth of AI industry**

*Source: CAICT (2020a)*
Since 2015, accelerating the growth of big data industry has become a national development strategy in China. Since then, provincial and municipal authorities have established industrial parks targeted at the development of big data. Meanwhile, along with development strategies of the new generation of information technology, smart city, digital China and so on, digital transformation in the social and economic spheres has been enhanced, the support of big data to industries strengthened and the scope of big data application accelerated.

The industrial application of big data is not limited to the manufacturing industry, and it also includes vast fields such as medical treatment, marketing and public safety etc. As far as Industry 4.0 is concerned, the generation and application of big data run through the whole product life cycle from design, research and development, manufacturing and marketing to after-sales service. By 2019, the sales volume of the big data industry in China amounted to 538.6 billion Yuan, continuing the sustained growth momentum since 2014. In five years, the overall size of the industry tripled, with an average annual growth rate of more than 20%. It is expected that the market size will reach 807.06 billion Yuan in 2021 (China Center for Information Industry Development 2019).

Impacts of Industry 4.0 on China' socioeconomic system

China is promoting the development of Industry 4.0 to solve shortcomings of China's industry in the face of competitive international pressure. Those major problems are mainly reflected in the transformation of industry structure, the improvement of labour productivity, technology innovation and the adjustment of labour structure. Industry 4.0 is ultimately aiming at promoting the high-quality development of the entire economy. In the following, we will discuss the effects of Industry 4.0 on different economic and social variables, and ultimately its impact on economic growth.

A key driver of China's economic development

China's economic growth has entered a new era and faces several new challenges. In recent years, the returns to domestic capital investment have been falling; the shift from the demographic dividend to the human capital dividend takes time, and investment in technological innovation has soared due to a lack of breakthrough innovations. International financial and trade uncertainty has increased and trade conservatism has arisen. Demand-pull policies implemented by China are still not fully launched and are waiting to become effective, because the release of latent demand of domestic consumers is not a short-term issue. Hidden regional market segmentation, local market entry barriers and the substantive gaps in regional economic development have not been significantly reduced. In addition to the current general problems encountered by macroeconomic growth, regional development in China is also facing much more serious divergence in recent years.

Traditional driving forces of economic growth have been unable to meet the urgent demand for high-quality development in the new era of economic growth. The high-quality development of the whole macroeconomy and of regional economies needs a new impetus. Instead of designing a unified index or index system to reflect the development of Industry 4.0 in China and then measuring the driving effect of this index on China's economic growth, we analyse the effects of different components of Industry 4.0 on economic development.

As one of the important components of Industry 4.0, network economy is also a vital link for the development of Industry 4.0 in China. The network economy has now become one of the important new driving factors of Chinese economic growth. The Institute of
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Statistical Science (2019) designed a new economic development momentum index system, which reflects the development of new industries, new commercial activities and new business models in China, and the composite index includes five groups of indicators with equal weight regarding innovation activities, network economy, human capital, industry upgrading and structural transition.

According to the report of the Institute of Statistical Science (2019), in 2019 China’s network economy index has grown six-fold compared to the data of 2014. At the same time, the contribution rate of the network economy index alone to the growth of new factors of economic development composite index has reached 80.5%, which greatly exceeds the contribution of other indexes of economic transformation, structure upgrading and technology innovation.

Moreover, China’s digital economy, which accounted for 36.2% of GDP in 2019, has become a new engine of growth and continues to unleash its dynamism, according to the White Paper on the Development of China’s Digital Economy in 2020 (CAICT 2020a). The report defined the digital economy as the sum of the value-added of the electronic information manufacturing industry, basic telecommunications industry, network industry and software service industry, plus the growth of output and enhancement of efficiency brought by the application of digital technology in other traditional sectors of the national economy. The value-added of China’s total digital economy exceeded 35 trillion Yuan in 2019, according to the data (CAICT 2020b), and its contribution rate to GDP growth reached about 68%.

Effects on upgrading of industry structure

One of the targets of Industry 4.0 is to achieve a new version of industrialisation which will naturally lead to further upgrading and high-quality development within the manufacturing industry, on the one hand, and to the improvement of the share of high-quality industries with respect to the overall manufacturing industry, on the other hand.

The optimisation of the within and between structure of the manufacturing industry will eventually change the landscape of the macroeconomy.
Since 2012, the upgrading of consumption structure represented by the decrease of Engel’s coefficient, advances in internet and other technology, and also the emergence of new economy, have become the main factors affecting the evolution of industrial structure in China. The development of new technologies related to Industry 4.0, including the industrial internet, big data and AI, has promoted the rise of new industries and new business models, which affected not only people’s daily lives but also all aspects of production. It is promoting the upgrading of industrial structure and consumption structure in all aspects.

Driven by the development of Industry 4.0, China’s industrial structure continues to move towards high-end level. The statistics bulletin of China’s National Bureau of Statistics pointed out that the value-added of the high-tech manufacturing industry and the equipment manufacturing industry already accounted for 14.4% and 32.5% of the value-added aggregates in 2019 for enterprises with a yearly main business income higher than 200 million Yuan, which is an average yearly growth rate of 6.9% for their main business income since 1995 (China National Bureau of Statistics 2019). In recent years, the rapid integration of the new generations of information technology into different industries has vigorously promoted the transformation of manufacturing services, resulting in the gradual growth of producer services, and the continued explosive growth of service-oriented manufacturing. The service industry has become a hot spot of innovation and entrepreneurship in the era of Industry 4.0.

**Impacts on employment structure**

Industry 4.0 is an inevitable choice for a sustainable and high-quality development of China’s manufacturing industry after the disappearance of the demographic dividend. The main effect of Industry 4.0 on employment is the substitution of labour with different skill intensities. The type of labour required for Industry 4.0 is quite different from that of the traditional industries as the former is more inclined to employ high-skilled labour. As a result, not only the aggregate numbers but also the ratio of unskilled to skilled labour may be subject to changes. Therefore, demand for low-skilled labour may decrease, and it will be gradually replaced. The
implementation of Industry 4.0, in time and space, will have significant impacts on the employ-
ment figures and employment structure in China.

The data from the Economy and Information Department of Zhejiang Province in China
(2017) shows that, in Zhejiang Province, with the program of “substitution of labour by robots”,
the aggregate number of industrial employment was reduced by nearly 2 million in the period
2013–2015. As regards another province, the data from Statistics Department of Guangdong
Province (2018) reveals that in 2015, the growth of new robots is 18,000 units, and in 2016 and
2017, the number amounted to more than 20,000 units. Further, in 2018, the growth of new
robots rose to 32,100 units. According to the substitution ratio of one unit of robot for 5 to 10
workers, therefore, a considerable number of workers will be replaced.

In addition, the new method of intelligent and automated production makes the job no
longer limited by a location such as the factory but instead becomes virtual and geographi-
cally flexible, and available to be carried out remotely. Employees will have a high degree of
autonomy to adjust and switch work and life status at any time. Achieving a new mode of
production also means a need for a different education system. Higher education with narrowly
defined majors will not provide enough qualified talent for the new industry, but education that
emphasises multidisciplinary cooperation will bear fruitful results.

Increasing productivity

The implementation of Industry 4.0 will enhance labour productivity and TFP significantly.
According to the German Electronic and Electrical Industry Association, Industry 4.0 can
increase the production efficiency of this industry by 30% (Ding and Li 2014). Industry 4.0 will
revolutionise the design, manufacturing, operation and service processes of the global produc-
tion system, providing multiple benefits such as greater flexibility, swift production, enhanced
productivity, quality improvement, etc. Increasing connectivity between components, machines
and personnel is expected to bring forth a 30% and 25% increase in the speed and efficiency of
production systems, respectively.

According to a sample survey of 1,815 enterprises in ten cities across China, 73% of the
enterprises have a strong willingness to implement intelligent manufacturing. Moreover, accord-
ing to another survey of 308 firms focusing on smart manufacturing, the average productivity
of those 308 firms in 2015–2017 increased by 34%, the average energy utilisation rate enhanced
by 17.2%, the average operating cost reduced by 22 %, the average product development cycle
increased by 32.4% and the average defective product rate dropped by 29.4% (Research Group
on “A New Generation of Artificial Intelligence Under The Leadership Of Intelligent Manu-
facturing Research” 2018).

Promoting overall economic growth

Taking AI as an example, this represents an opportunity not only to revolutionise the manufac-
turing industry, but also to accelerate economic transformation and economic growth. AI can
influence macroeconomic growth in two ways. The first is to utilise its permeability, substitu-
tion, synergy and creativity, which are the four major technology–economic features of the
new generation of information technology; and to promote the growth of various sectors of
the national economy by increasing the efficiency of input–output and accelerating the creation
of knowledge. Finally, it will benefit macroeconomic growth. The second is that the industrial
ecological system boosted by AI technology is infiltrating and affecting the various fields of
the national economy, and its own scale will also grow along with it, boosting macroeconomic
growth as well. Following the first path, the growth in input–output efficiency and knowledge creation will lead to an increase in the overall factor productivity of the macroeconomy and support the high-quality growth that China is seeking. With the second path, the growth of AI and other new generations of information technology industries lead to the expansion of the high-tech sector, which is fully in line with the direction of optimising and upgrading China’s industrial structure. Therefore, the burgeoning growth of Industry 4.0 will stimulate high-quality development in China.

**Future development**

From the above survey, we are aware that China’s Industry 4.0 has made remarkable achievements across different dimensions, and the overall trend of future development is promising. At the same time, the development of Industry 4.0 has promoted the upgrading of China’s industrial structure, improvement of the employment structure and productivity through various innovative functions. Furthermore, China’s Industry 4.0 program has a positive effect on its economic development. However, there are a series of problems which need to be tackled.

**Problems**

**Persistence of quantity shortage**

Although various fields of Industry 4.0 in China have been improved quantitatively after several years of rapid development, there is still a big gap from the frontier to fulfil the demand for further economic development in China. For example, the penetration rate of industrial robots in China’s manufacturing industry remains lower than in advanced countries, and there is much to be done in this new automation age. The data from the World Robotics 2019 International Federation of Robotics revealed that the usage density of industrial robots in China was 140/10,000 in 2018, which stands for 140 units of robots per 10,000 workers in the manufacturing industry. The density of industrial robots in advanced countries, such as South Korea, Japan and Germany, is well above 300/10,000. Especially in South Korea, where the robot density in the manufacturing industry is 774 units per 10,000 workers. Therefore, the penetration rate of industrial robots in China’s manufacturing industry still has much room for improvement. Needless to say, there are also a large number of people and economic units in China not connected to the internet, let alone to a broadband network. The development of China’s AI industry is also still at a low level compared to developed countries.

**Low technology capacity of domestic producers**

In a few key areas of Industry 4.0, and for some important infrastructure equipment in manufacturing industries, domestic firms in China have up until now been unable to provide suitable products. Even if they could provide them, the technical level of those products is much lower than the advanced international standards. Take industrial robots as an example: the biggest four producers of industrial robots accounted for 60% of the market share in China. However, all of them are foreign companies, while China’s domestic brands account for less than 10% of the market share, and their products are mainly concentrated on the middle and low end of the value chain of the robot industry (China Robot Industry Alliance 2018).

Even in an optimistic environment with booming growth prospects, sales of domestic brand industrial robots rose only 20% in 2017, which is well below the average growth rate of the
whole industry (China Robot Industry Alliance 2018). While the foreign capital, joint venture brand industrial robots gradually reduce their prices, most domestic robot enterprises earn profits mainly by providing services of application rather than the sales of final goods of robots. There is another example. At present, most of the AI innovations in China focus on the application of technology, and there is still a big gap from the world’s leading level. Moreover, the key components and parts of China’s smart manufacturing system rely mainly on imports, such as high-performance servo motors in the field of industrial robots, high-precision reducers, functional components in the field of computer-numeric-control machines and lasers of the core components of 3D printers. On the whole, China’s smart manufacturing industry emphasises the production and manufacturing services, but they neglect the design and management components, which leads to obstacles to the further development and application of Industry 4.0.

**Negative effects of designed industrial policies**

A number of Industry 4.0 policies have been designed and implemented in China, but they are essentially formulated according to the paradigm of selective industrial policy. Those industrial policies are easily influenced by administrative intervention, which is not quite adaptive to the market economy law of Industry 4.0. The room for unnecessary intervention of those industrial policies is vast, at both the industrial and the firm level. All in all, this kind of policy model will even produce adverse incentives to firms’ market behaviour and innovation. Therefore, as regards the policy system of Industry 4.0, China should strengthen the cooperation of government, industry and university, maintaining and strengthening firms’ basic role in the market economy.

**Policy recommendations**

In order to overcome important obstacles encountered in the development of Industry 4.0, and to realise its stable and rapid economic growth in the future, China needs to make further efforts in the following respects.

**Replacement of selective industrial policies with competition policy**

In the present stage of China’s economic development, the relationship and weights between industrial policy and competition policy should be adjusted and redefined, to avoid the accumulated resource misallocation caused by the former. The main target is to establish the priority and fundamental role of competition policy, and the key is to install a coordination mechanism between competition policy and industrial policy, with the industrial policy not distorting market competition. The Industry 4.0 policy system of China should pay more attention to functional rather than selective investment programs to avoid the misallocation of production factors and utilise functional industrial policy to stimulate an ideal market mechanism. Even in the fields of natural monopoly, externality, public goods and so on, the application of functional industrial policy should be strengthened, while the scope for selective industrial policy should be continuously and greatly reduced.

**Support of small and medium-sized enterprises**

Compared with state-owned enterprises and large private enterprises, China’s small and medium-sized enterprises (SMEs) lack financial and material resources to take an active role
in the course of Industry 4.0 development. At the same time, they can easily be bypassed by various policies. These factors lead to the unfavourable position of SMEs in Industry 4.0 construction. However, SMEs already occupy a very important position in China’s national economy. The national income and employment created, as well as exports conducted, by those enterprises are crucial to economic growth in China. Therefore, the inclusion of them in the Industry 4.0 road map amounts to a large part of the success or failure of Industry 4.0.

In an attempt to give full recognition to the role of small and medium-sized manufacturing enterprises, policy support, a certain amount of financial funds and technical assistance are needed. For those SMEs, on the one hand, they should make full use of the policy support to improve the foundation of smart production; on the other hand, they should actively learn the advanced production mode and adopt organisational forms designed by the German Industry 4.0 strategy, actively cultivating their own potential advantages of personalised production and forming their own core competitiveness.

Providing high-quality human capital

Simple and routine mechanical work will progressively be replaced by precision and intellectual work with higher value-added production. At the same time, it sets higher requirements for workers' knowledge and skill ability. Industry 4.0 not only means a substantial replacement of low-skilled labour for high-skilled labour, but its future development also needs more high-quality human capital. Otherwise, it will not be able to establish the software and hardware basis of the network economy, not to mention the application of industrial robots, the promotion of research and development of AI and their industrial applications, and the promotion of big data industry. Consequently, more attention should be paid to the personnel training and actively to promote vocational education, improve and update training system in time, provide retraining for present personnel and build up human resources with advantages in knowledge and skills needed by Industry 4.0.

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