

# **The Transformation and Upgrading of the Chinese Manufacturing Industry: Based on “German Industry 4.0”**

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*German “industry 4.0” strategy provides a reference and inspiration for the development of China’s manufacturing industry. This article analyzes the main problems existing in the development of the Chinese manufacturing industry and the enlightenment of German “industry 4.0” to the Chinese manufacturing industry. The Chinese manufacturing industry can learn from the German “industry 4.0” strategy from the adjustment of the industry structure to the cultivating of strategic emerging industries, from the integration of industrial technology and information technology to industrial technology innovation. “Industry 4.0” will take these policies and measures and enable China to make the necessary transformation and upgrading of its manufacturing industry.*

## **INTRODUCTION**

So far, human history has experienced three stages of the industrial revolution. The first industrial revolution is named “industry 1.0.” “Industry 1.0” originated in the late 18th century with the introduction of manufacturing machinery and, steam power created the era of mechanized production. The second industrial revolution, named “industry 2.0,” began in the 1870s with the division of labor, the production of parts and components separated from product assembly, and the use of electric power. Products began to be produced on a large scale production. This new model of batch production became known as the era of electrification.” Industry 2.0” made possible factory production assembly lines and standardization. The third industrial revolution, named “industry 3.0,” began in the early 1970s and made the transition into the information age. The level of automation in production increased significantly. Since “industry 3.0,” traditional technology has occupied the dominant position in manufacturing industry. Compared with the previous variants of the industrial revolution, “industry 4.0” is based on the successful application of information and communication technology, embedded technology, and powerful Internet

technologies. "Industry 4.0" is the integrated use of Cyber Physical System (CPS), interconnecting the resources, information, goods, and people to create an internet of things and services, then applying this kind of service mode to an industrial field further promoting intelligent and networking manufacturing development.

## **ABOUT GERMAN "INDUSTRY 4.0"**

### **The Meaning of German Industry 4.0**

*In* 2011, Germany hosted the Hannover Industrial Exhibition, and put forward the concept of "industry 4.0." In April 2013 after intense effort by the German government, industry and research institutions the strategic proposal for implementation of "industry 4.0" was issued. In December of the same year, Germany released the standardization roadmap for "industry 4.0." German "industry 4.0" became the German national strategic plan for the year of 2020. German "industry 4.0" is the overall strategy for Germany's future competitiveness. In the field of global information technology, Germany's powerful machinery and equipment manufacturing industry has occupied a significant position. Germany put forward and promoted the "industry 4.0" strategy to strengthen its leading position in the global manufacturing industry by building new standards of intelligent manufacturing. German "industrial 4.0" will have a far-reaching impact on traditional manufacturing industries. It is the combination of information technology and intelligent technology. It will create greater capacity than currently available with the traditional manufacturing industry. It can extend to other areas such as logistics distribution and after-sales services. It will bring more development opportunities than the traditional manufacturing industry and more personalized service to the market. The German "industry 4.0" development goals, that on the one hand are to eliminate the distance between the traditional industrial control and information management technology and, on the other hand, are to build smart and intelligent factories. This means that the future development of industry will enter a smart channel. The robot will get rid of manual operation. Each link from raw materials to production to transportation can be controlled by all kinds of intelligent equipment. Cloud technology is able to connect all of the elements, generate large data and automatically correct any problems during the production.

### **Contents of German "Industry 4.0"**

German "industry 4.0" strategy, in essence, is to establish a new mode of production and industrial structure, based on mechanization, automation and informatization. The main contents are summarized as core, strategy, integration," and the eight measures."<sup>[1]</sup>

"Intelligent + network" is the core of German industry 4.0, which builds intelligent factories through the Cyber Physical system (CPS) to attain intelligent manufacturing. Based on the CPS system, German "industry 4.0" uses "leading supplier strategy", "the leading market strategy" to enhance the competitiveness of manufacturing industry. There are three integration supporting implementation processes. First, pay close attention to the production process and build smart factories with vertical integration of production. Second, pay close attention to the information of the product in the different stages of its life cycle and share the information to achieve the integration of project digitization. Third, pay attention to the realization of the whole social value network and attain the horizontal integration of the German manufacturing industry. German "industry 4.0" uses eight measures to achieve technological standardization and open standard reference systems, to set up a model to manage the complex system, to provide a comprehensive industrial broadband infrastructure, to establish security mechanisms, to innovate the organization and design model, pay attention to the training and continuous professional development, to make sound rules and regulations and to improve resource efficiency<sup>[2]</sup>.

German "industry 4.0" will be a very advanced mode of production and industrial development strategy. It will complete industrial production and realize the maximization of efficiency through a top-level design and integration of various techniques. It needs the government, enterprises, and scientific research personnel to cooperate in order to complete an important cause. Germany has always paid attention to the coordinated development of relevant departments and industry, persisted in combining

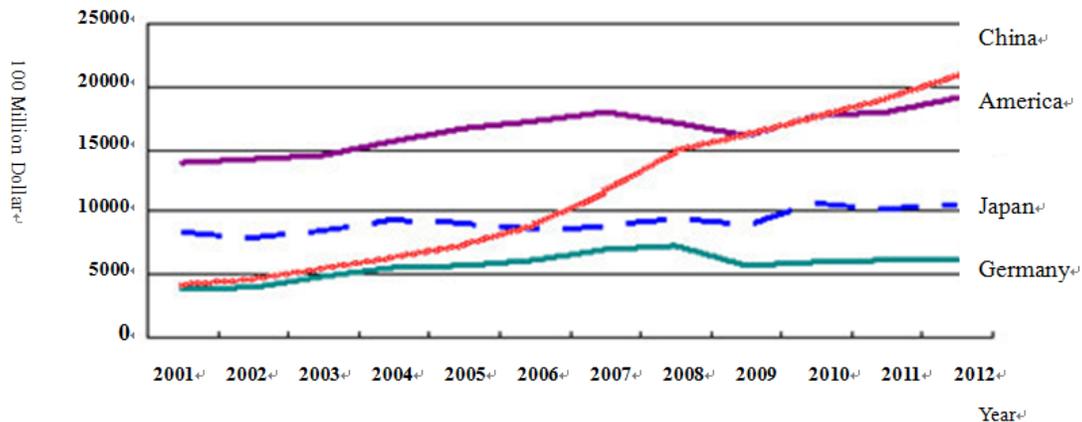
innovative technology with industry, and attached importance to each link of cooperation between production and research. As Germany put forward "industry 4.0," many countries were also stepping up their industrial development projects and strategies for the future. In May 2015, China's State Council issued the "made in China 2025", which arranged and pushed a manufacturing strategy of comprehensive deployment. Development plans and action plans are in line with the German "industry 4.0." However, Germany's implementation of the "industry 4.0" strategy provides a chance to for China's manufacturing industry to learn, transform and to upgrade.

## THE PRESENT SITUATION AND THE MAIN PROBLEMS OF THE CHINESE MANUFACTURING INDUSTRY

### The Achievements Made in Chinese Manufacturing Industry

Manufacturing is the pillar industry of the Chinese economy and is also the main battlefield for upgrading the development of economic quality and efficiency. In the past ten years, China's manufacturing industry has made great progress in gross output and its technical level. Today, China has built a complete range of independent manufacturing systems. There are not only labor-intensive industries, but also capital intensive and technology intensive industries. There are both daily necessities like toys and large equipment such as high speed trains. The products printed with the "MADE IN CHINA" logo can be found all over the world. According to data from the United States economic consulting firm IHS Global Insight, in 2010 China accounted for 19.8 percent of the world manufacturing output becoming the world's manufacturing superpower passing the United States. <sup>[3]</sup> In 2014, the output of Chinese manufacturing accounted for 25 percent of the world total. <sup>[4]</sup> In 2013 the Chinese equipment manufacturing industry's output value exceeded 20 trillion Yuan, more than one third of the total global share. China ranks first in output for 220 out of 500 major industrial products. At present, about 80 percent of the world's air conditioning units, 70 percent of mobile phones and 60 percent of the shoes are made in China. Machine tool production is at 95.9 million units, accounting for 38 percent of the worldwide output. In 2014, China had one hundred enterprises appear in the "Fortune 500", 56 of them are manufacturing industry enterprises (excluding Hong Kong, Macao and Taiwan) China has the second largest number of the world's top 500 enterprises second only to the United States (130) for two consecutive years.

**FIGURE 1**  
**2001-12 FOUR COUNTRIES' MANUFACTURING ADDED VALUE**  
**CURVE IN \$100 MILLION**



The pattern of economic globalization has been altered by the rapid development of China's manufacturing industry. In 1990, China's manufacturing industry output accounted for 2.7 percent of the worldwide output and was ranked the ninth in the world. In 2000 it rose to 6.0 percent and ranked the fourth in the world. In 2007 it reached 13.2 percent with a rank of second in the world. By 2010 it was 19.8 percent with the number one ranking in the world (Figure 1)<sup>[5]</sup>.

### **The Main Problems in the Manufacturing Industry in China**

Manufacturing, being a pillar industry of China's economy, has relied on raw materials, labor and other factors to achieve a competitive advantage. This resulted in China becoming the world's largest manufacturing economy. Is the typical "factor driven development model" the cause of the Chinese manufacturing industry to be big but, not strong? There are many problems, such as serious excess capacity in many products, unconscionable industrial structure, relatively backward technology, and lower product quality, lack of core technology, the low level of informatization and a superficial combination with industrialization. China's manufacturing industry is still a resource consumption type, has labor-intensive industries and resides at the low end of the industrial chain.

#### *R&D Funding Levels*

China's R & D investment rose from the year 2008 to 2012. But compared with the United States, Germany, Japan and other manufacturing powers, China's R & D funding input intensity (the ratio of R & D expenditure and gross domestic product) is significantly lower. This shows the percentage of R&D funds for of the world's major 6 countries. In 2014, China's R&D expenditure reached 1,331.2 billion Yuan, an increase of 12.4 percent over the previous year. The intensity of R&D funds increased to 2.09 percent, while Germany's R&D had reached 2.69% in 2008.<sup>[6]</sup> Although China has continued to strengthen R & D investment, R&D funding is still lower than the world average. According to statistics, the proportion of basic research is less than 5 percent in China. This proportion is only one-fourth that of developed countries. Lack of investment in basic research is one of the important reasons for the lack of significant breakthroughs and disruptive innovation. In addition, China's R&D funds are relatively small for the introduction of technology to digest and absorb funds and for the purchase of domestic technology. These funds are more for the introduction of foreign technology. This leads to China's manufacturing industry's lack of innovation.

#### *Lack of Core Technology*

The capability of China's manufacturing industry to independently innovate is not strong. The core technology and top equipment are highly dependent on external sources. The innovation system of the enterprise for the main body is not perfect. Only about 3 out of 10,000 Chinese enterprises have independent intellectual property rights for their core technologies. A number of key parts and components, such as system software and top equipment, rely on imports. The core technology is controlled by others. The data show that 80 percent of their chips were imported into China in 2013. Computer chips have become the largest imported commodity in China recently, more than crude oil. The vast majority of the integrated circuit chip manufacturing equipment and optical fiber manufacturing equipment are also imports. As is known to all, key software and computer hardware equipment are controlled by Microsoft and Intel. Due to the lack of core technology, the large computer production scale is primarily in the processing and assembling business. As a result, the final profit is very low. The same issue exists in the automobile industry. At present, although China is a large producer and consumer of automobiles, the vehicle and parts design, research and development, the core components of the automobile manufacturing are mainly controlled by the Mercedes Benz, GM, Toyota and other multinational companies. Chinese exports of high-tech products are about 90 percent from foreign investment enterprises. The innovation ability is not strong as a result, multinational companies occupy the high-end on the value chain while Chinese enterprises are more likely to be found on the low end of the value chain, typically assembly and general parts manufacturing.

Recently some research institutes were transformed into enterprises allocating more funds, human resources and management from the common technology to the applied technology and commercial areas. The research and development of industrial generic technology has been weak. At the same time, colleges, universities, scientific research institutes and enterprises have different evaluation mechanisms and interest orientations. The differentiation may be serious between their innovation activities. The rate of research achievements transformation is only 10 percent, far below the level of 40 percent in developed countries.

#### *Less of Internationally Renowned Brands*

On the whole, "made in China" has certain advantages. But quality brand name, high tech and high value added products are mainly from foreign enterprises. For brand name products the proportion of products with independent intellectual property rights is not high in China. There are few Chinese world-renowned brands and international competition is difficult. There is a large gap between foreign brands and China's independent brands, whether it is in the brand value or market visibility. The lack of international brands causes China's international status and economic profits to decline and also places the Chinese manufacturing enterprises in a weak position with respect to the international division of labor. For example, a 16g version of iPhone4 retails at a price of \$499 in the U.S. The parts account for about \$255 and are delivered mainly from Japan, Korea, the Philippines and China Taiwan region. The patents and design account for nearly \$150. The total of logistics, wholesale and retail, is approximately \$80. The remaining \$12 is China's share for assembly. Shenzhen Foxconn takes a profit of \$4, and the rest is owned by industrial workers, trade management. The mainland of China only earns \$8 in total profits. A rich brand premium is taken by foreign enterprises and, in sharp contrast; China enterprises can only earn a meager processing fees.

Chinese enterprises have serious shortages in brand design, brand building and brand maintenance. In 2014, out of the world's top 500 brands, mainland China only accounted for 29 brands far below the United States, France and Japan. China's manufacturing competitiveness is not strong with respect to world famous brands and their development. China's product quality and technical standards are not high.

#### *Large Gap of the Level of Information Technology*

At present, developed countries have entered the new stage characterized by integrated manufacturing and information technology as well as the applications of digitization and networking. For example, the world leader in manufacturing and information technology is Germany. And Germany has begun to promote the "industry 4.0" strategy. China has not attained the same level as Germany. Chinese industrial enterprises as a whole are still in "industry 2.0." They need to narrow the gap between "industrial 2.0" and "industrial 3.0" and then develop to the "industry 4.0" level. China's level of construction of information infrastructure and applications lag behind the developed countries. In 2012 China's network readiness index (NRI index) was 4.03 and ranked fifty-eighth in the world, lower than the United States, Japan, Germany, South Korea and other countries. Due to the government's increase in constructive investment, the 2014 index of information technology development reached 66.56 in China.<sup>[7]</sup> Compared with the world's developed countries, there is still a considerable gap. In addition, the enterprises' intention to use information technology to transform the traditional mode and process of production is low. The majority of the region and the industries still produce in the primary stage or in a partial application mode. The human resources of information technology and information security is seriously insufficient.

The development of the manufacturing industry informatization is not balanced yet in China, it shows that: (1) the degree of informatization among different industries has a large gap. The degree of informatization is relatively high in petrochemical and steel industries, while the degree of informatization is relatively low in the textile and light industries. (2) Informatization varies by enterprise scale. The informatization level of large and medium-sized state-owned manufacturing enterprises is higher than that of small and micro-sized enterprises. (3) Due to the economic differences, there is different informatization for manufacturing industries in different regions in China.

### *Being Unreasonable in Industrial Structure*

An unreasonable industrial structure is an important factor restricting a large and strong “Made in China” image. This unreasonableness is reflected in two aspects. One is that the industry types are mainly focused on energy resources industries and labor intensive industries such as the coal, iron and steel, non-ferrous metals, and oil. Thus high-tech industries like electronic information, high-end equipment manufacturing, new energy and so on, comprise a relatively low proportion of manufacturing. Based on “The Statistical Communique on National Economic and Social Development in China in 2014,” equipment manufacturing industry was above the scale for industrial value added in China by 30.4 percent. However, this proportion was 41.9 percent in the United States, 43.6 percent in Japan and 46.4 percent in Germany.<sup>[8]</sup> Light industry, such as textile manufacturing, was sizable but the proportion of mechanical and electronic manufacturing was significantly lower than that of the developed industrial countries. The second aspect is that the proportion of processing trade enterprises is too large in China. Although the processing trade expands “made in China” in the international market and participation in international division of labor, the goods of the processing trade are mainly the labor-intensive products at the low-end of the value chain and lack core technology. There are certain difficulties realized in the manufacturing industry chain extension and perfection. At present, high quality products, high technology content and high value-added products are less prominent than the resource consumption, extensive production and labor-intensive products of China's industrial structure. The industrial structure is not reasonable, so that the industry upgrades slowly.

## **THE ENLIGHTENMENT OF GERMAN "INDUSTRY 4.0" TO CHINA'S MANUFACTURING INDUSTRY TRANSFORMATION AND UPGRADING**

A strategic decision to adopt German “industry 4.0” provides a path for advanced manufacturing industrial development with clear goals and practical measures. Following this path will result in the upgraded transformation of China’s manufacturing industry.

### **Bring New Ideas to the Development of China's Industrialization and Urbanization**

"Industry 4.0" emphasizes the integration of information technology and manufacturing technology to change the current mode of industrial production and service. At the same time “industry 4.0” can make production and delivery more flexible. Solving the challenges facing Chinese manufacturing, such as efficient energy usage and personnel structure, is important to enable the development of Chinese industry. First, intelligent factories can meet the personalization needs of customers; at the same time unearth new ways and new business models to create value. It can bring development opportunities for start-ups and small firms, and the downstream service industries can also benefit from it. Second, the efficiency of resources utilization can be improved significantly by the use of the CPS. Third, the intelligent manufacturing pays more attention to the workers’ professional skills of design, management and digitization. The flexible way of production organization can prolong the workers' careers and make for a more balanced work and life. "Industry 4.0" can synchronously optimize the industrial structure, energy utilization and talent structure. It provides a new path for China's development of industrialization and urbanization.

### **Bring New Driving Force for Transformation and Upgrading of China's Manufacturing Industry**

“Industry 4.0” uses the CPS to carry out technical innovation, upgrade the industry competitiveness using intelligent manufacturing, drive the development of the manufacturing service industry, producer services and a batch of strategic emerging industries. This thinking can bring a new driving force for transformation and upgrading of China's manufacturing industry. First, production based on the CPS intelligent digitization can greatly shorten the time from product design to launch. This development of independent innovation will alter the path of China’s manufacturing output. It will allow China’s manufacturing enterprises to avoid the fierce competition from the Association of Southeast Asian Nations (ASEAN), India and Latin America for the low-end industrial chain. Second, "industry 4.0" can

eliminate the traditional industry boundaries and restructure the industry chain. It can promote both the upstream and downstream enterprises and accelerate the transformation and upgrading of manufacturing services. Third, the CPS technology will promote the development of strategic emerging industries, such as industrial robots, 3d printers and the production equipment industry, as well as the development of producer services such as the information industry, new material industry and industrial design.<sup>[9]</sup>

### **Pay Attention to the Core Technology and the Leading Role of Large Enterprises to Industrial Transformation and Upgrading**

German "industry 4.0" strategy aims to control the supply of new technical products and the industry commanding summit, by means of developing the modern equipment manufacturing industry. This will create an advantage in the field of advanced technical services. The core technology is still the key to shape the competitiveness of industry. The overall development and upgrade of the industry can be promoted with the innovation of core technology. In the process of carrying out the "industry 4.0" strategy, the German government puts particular stress on technical strength and the market influence of extra-large German companies, such as Siemens, to promote CPS technology products to be the standard for manufacturing in the future. It is worthwhile to study the methods of promoting new strategies and the implementation of new technical standards by leaders in the industry. That is, big companies mobilize resources to promote the cultivation and development of their markets while small and medium-sized enterprises and research institutions will have more power to be involved in the technology innovation team. The Chinese government will be in charge of the planning and direction.

### **Attach Importance to Talent Cultivation in Manufacturing Industry According to the Trend of Technology Development**

The main point of German "industry 4.0" strategy is the profound transformation of the man-machine relationship. By replacing manual operation with a machine, CPS enables the main focus of the worker to turn to the aspect with higher additional value. This will greatly increase the demand for knowledge and skills of laborers. It reminds us that in terms of human capital investment the accumulation and cultivation of knowledge and skills and the adaptation should be a major focus. In order to improve knowledge-based and professionally skilled human resource competitiveness, China's talent structure needs to be guided to learn and adapt to change.

## **THE SUGGESTIONS TO MATERIALIZE THE TRANSFORMATION AND UPGRADING OF CHINA'S MANUFACTURING**

China needs to speed up the transformation and upgrading of the production chain to advance the "made in China" branding. We can draw lessons from German "industry 4.0" strategy, seize the technology and market opportunity brought by this industrial revolution. Promoting the growth of the industry with more competitive products, at the same time rely on innovation to form unique manufacturing technologies will achieve industry upgrading and leapfrog development.

### **Optimize the Industrial Structure and Cultivate the Growth Point of Strategic Emerging Industry**

A particular emphasis should be on pushing the integrative development between the manufacturing industry and the service industry based on the advanced industries in developed and industrialized countries. In the process of transforming and adjusting the industrial structure, China can draw lessons from developed countries' industrialization strategies such as technical development trends and marketing rules and policy measures. Based on the actual situation in different Chinese industries a step-by-step upgrade of the industrial structure to promote optimization is necessary. To upgrade industrial structure and to enhance the level of manufacturing industrial development there should be an updating of the design, branding and supply chain management. The transformation of manufacturing industry can give rise to a number of emerging industries developing rapidly.<sup>[10]</sup> We should take this opportunity to find and

cultivate new industry growth points based on the key technologies of digital, intelligent and networked manufacturing.

### **Division of Industry Chain for the Future to Extend the Range of the Transformation**

The future production form will be different from the traditional assembly line or centralized machine production. Intelligent equipment and the organization will lead to the factors of production, the organization pattern of production, even the market supply and demand to significantly change. This requires, on the basis of developing an intensive economy, to pay special attention to the scope of transformation from the factors of production structure extending to the fields of supply structure and demand structure. The development strategy must adjust the economic structure and emphasize the coordinated development of the national economy. It must balance the diverse interests among individuals and urban/rural regions, industry and government. The development strategy must achieve a long-term sustainable national economy by speeding up the transformation of economic development.

### **To Encourage Enterprises to Take the Lead- the Government, the Enterprises and the Research Institutes of Colleges Should Collaborate to Promote Technology Innovation and Market Development**

China has a large manufacturing base and the potential market is big. It should fully arouse the enthusiasm of the scientific research institutes and enterprises to transform China's manufacturing industries to speed up technologic research and industrialization such as the industrial software, production process control and management system, intelligent industrial facilities, and the industrial internet. China should pay more attention to fostering intelligent manufacturing to satisfy the needs of Chinese industrial development rather than being dependent on developed countries for these. Large enterprises should increase investment and lead in coordinating government, enterprises and the research institutes for the technological innovation. They should explore the path of upgrading manufacturing to take advantage of different manufacturing technologies.<sup>[11]</sup> Large companies should promote technological innovation and explore the markets to attract small and medium-sized enterprises (SMES) to follow up, to give full play to the role of market resource allocation.

### **Under The Government Leading, Promoting the Programming, Construction and Execution of Intelligent Manufacturing Technical Standard**

The degree of manufacturing industry informatization and automation varies in China. Industrial software has been internalized by the production facilities and is incompatible with each other. Integration is difficult. Some enterprises and trade unions have tried to put forward multiple sets of technical standards, but because of the lack of adequate technology and market power, they have not been widely recognized. This would require the government to play a bigger role, driving the large enterprises to create and spread the technical standard planning related to intelligent manufacturing and to activate the market demand and attract all kinds of social groups to actively promote technological innovation.

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