Empirical Study on Smart Manufacturing's Effective Response to "Deindustrialization"

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Abstract: In the face of the "de-industrialization" issues that have emerged in developed countries such as the United States, the United Kingdom, and France, as well as in sub-Saharan Africa, Latin American countries, and China, this paper, based on theoretical analysis, empirically studies the heterogeneous impact effects of smart manufacturing coupling manufacturing and producer service industries using panel data from 42 countries spanning 2000 to 2014. The research findings indicate that smart manufacturing can effectively couple manufacturing and producer service industries. Firstly, a one-lagged effect of smart manufacturing promotes economic growth by 1.0134%. Secondly, smart manufacturing enhances the global value chain by 2.2860%. Thirdly, a one-lagged effect of smart manufacturing increases GDP per capita by 25.6538%. Furthermore, extensive research shows that smart manufacturing is conductive to carbon emission reduction, which is highly compatible with the high-quality development of manufacturing under the smooth progress of China's "dual carbon" goals. Therefore, this paper proposes policy recommendations: during the "15th Five-Year Plan" period, China should focus on increasing special fund support, accelerating the transformation and upgrading of smart manufacturing, promoting its transition from the infrastructure construction phase to the application phase, and making smart manufacturing the main direction for the high-quality development of China's manufacturing industry, so that China can take the lead in developing a modernized powerful country path that is superior to that of European and American countries in successfully addressing "de-industrialization" on a global scale.

Keywords: smart manufacturing; manufacturing and producer service industries; de-industrialization

1. Introduction

Looking around the world, in the new era of a new round of technological revolution and industrial transformation, economies worldwide are undergoing structural transformation characterized by an increasing proportion of the service sector. The phenomenon of a continuous decline in the manufacturing sector has not only been observed in developed countries such as the United States, Britain, and France, but also in many developing countries, such as sub-Saharan Africa and Latin American nations, where there has been a "premature deindustrialization", leading to the "middle-income trap" [1-2]. As the largest developing country in the world, China has seen the tertiary industry surpass the secondary industry in terms of proportion since 2012. By 2024, the tertiary industry's share had reached 56.720%, 20.2% higher than that of the secondary industry, with the industrial share having dropped to 30.1%. Compared to developed countries, where the manufacturing sector's share began to decline when GDP per capita reached $17,000 in the United States, $19,000 in Japan, and $20,000 in Germany, China has already shown a tendency towards "premature deindustrialization", and this "premature deindustrialization" also exhibits comprehensive and rapid characteristics [3-7]. Historically, in other countries, if the industrialization process is not handled properly, it may lead to conflicts of interest and social crises due to intensified contradictions and even state collapse.

The marginal contributions of this paper lie in three aspects: firstly, it innovatively examines the heterogeneous impact effects of smart manufacturing on both manufacturing and producer service industries. This provides us with a feasible solution to successfully cope with "de-industrialization" by coordinating the different roles of manufacturing and producer service industries in the new era. Secondly, it innovatively empirically studies the heterogeneous effects of smart manufacturing in both traditional manufacturing and producer service industries from three aspects: economic growth, global value chain enhancement, and GDP per capita increase. It highlights that smart manufacturing is a new business form that better achieves the organic integration of manufacturing and producer service industries, and it is necessary to accelerate its promotion. Thirdly, it emphasizes that during the critical period of a new round of technological revolution and industrial transformation, by making good use of smart manufacturing, China can better balance the different roles of manufacturing and producer service industries and can take the lead over European and American countries in finding an effective path for China to successfully cope with "de-industrialization".

2. Literature Review

The research in this paper is related to three types of literature: first, the concept of "de-industrialization" and related literature on the resulting industrial hollowing out; second, related literature analyzing the different roles of manufacturing and producer service industries; and third, related literature on the comparative advantages and characteristics of smart manufacturing.

Firstly, the concept of "de-industrialization" and relevant literature on the resulting industrial hollowing out. The concept of "deindustrialization" was first proposed by Barry B of Northeastern University in the United States and can be summarized as productivity-driven "deindustrialization" and intensity-driven "deindustrialization" [8-10]. As a country transitions from an agricultural economy to an industrial economy and then to a service economy, it must confront the rising output value of the service sector and gradually shift towards the "post-industrial era"[11]. "Deindustrialization" is detrimental to high-quality economic development can lead to industrial hollowing out, resulting in sluggish economic growth and declining industrial competitiveness, and in severe cases, may even trigger economic crises. A fundamental reason for the financial crisis that erupted in the United States in 2008 and further evolved into an economic crisis was the industrial hollowing out caused by "deindustrialization"[12-15].

Secondly, we should attach great importance to the issue of "de-industrialization" and analyze relevant literature on the different roles of manufacturing and producer service industries. China needs to develop the real economy and build a solid foundation for a modern economic system. As a developing country that has entered the era of the service economy, China must attach great importance to the issue of 'deindustrialization.' On the basis of achieving the first centenary goal of building a moderately prosperous society in all respects, China must steadily promote the smooth realization of the second centenary goal by effectively addressing the issue of 'deindustrialization' during this critical period of technological revolution and industrial transformation and by scientifically assessing the roles of manufacturing and producer services [16]. It is essential to avoid following the 'hollowing out of industries' path of developed countries such as the United States, the United Kingdom, and France, and to prevent encountering the difficulties faced by the U.S., which struggled to revitalize its manufacturing industry after the 2008 financial crisis-the path of 'deindustrialization is easy, reindustrialization is difficult' [17].

Thirdly, relevant literature on the definition and characteristics of smart manufacturing. As the leading manufacturing paradigm of the new round of technological revolution and industrial transformation, smart manufacturing is clearly identified in "Made in China 2025" as the main direction for the deep integration of new-generation information technology and manufacturing technology [18]. It is a strategic choice for building an innovative country and reshaping the advantages of the manufacturing industry. Smart manufacturing is an industrial integration complex that integrates communication and computer software information technology from producer service industries into the entire manufacturing process [19]. It not only possesses the characteristics of manufacturing but also seamlessly integrates the knowledge-intensive and technology-intensive features of producer services, embodying the high-quality development of the manufacturing industry. Smart manufacturing can effectively address the existing drawbacks of pure manufacturing or pure producer services, which cannot effectively cope with "de-industrialization". It serves as an important breakthrough in addressing the global issue of "de-industrialization".

3. Theoretical Analysis

With the development of human society, starting from the initial three major social divisions of labor, the refinement of the division of labor in human society has always been accompanied by the improvement of social production efficiency. The ultimate goal of social production is to meet people's ever-growing consumption demands as the fundamental starting point. Therefore, based on human needs and following Maslow's hierarchy of needs theory, people first need to satisfy their demands for agricultural products, then industrial products, and subsequently service products [20]. It is precisely with the improvement of human needs that human society gradually transitions from an agricultural economy dominated by agricultural society to an industrial economy with significantly improved production efficiency. Driven by the increasing spiritual needs of people, the supply of service products is increased, thereby promoting the development of the service economy. In other words, the process of human society transitioning from agricultural society to industrial society and gradually to a service society is driven by the gradual approach of human needs and is an inevitable trend of social development. In this process, more and more countries must face the impact of industrial structure changes on economic growth. Especially since the 1960s, countries, especially developed countries, have experienced rapid development in the service industry, with the proportion of the service industry rapidly increasing. Many developed countries in Europe and America have seen the phenomenon of "de-industrialization," and many economists have found that "de-industrialization" in developing countries is not only related to economic growth but also causally linked to global value chain positioning and the "middle-income trap." This paper integrates industrial theory and service economy theory and, from the perspective of "de-industrialization," studies the mechanism of heterogeneous impact effects of coupling smart manufacturing with manufacturing and producer service industries, highlighting the important practical significance of promoting smart manufacturing in various countries.

3.1. The effects of smart manufacturing on economic growth

Taking China as an example, despite the "paradox of the development of producer service industries" in the past four decades since its reform and opening up, China has still achieved high-speed growth at an average annual rate of 9.39%, relying on the economies of scale of manufacturing [21-23]. Unlike manufacturing, producer service industries, as the 2.5 industry, invest in intangible high-level factors such as knowledge, technology, and experience to produce heterogeneous intermediate goods. Although standardized supply can be achieved, production efficiency still lags behind that of manufacturing, inherently exhibiting the "cost disease" of service industries [24]. If we observe developed countries such as the United States, the United Kingdom, and France, although the proportion of producer service industries has exceeded 40%, they have not achieved a strong boost to their economic growth. Specifically, although these countries have highly developed producer service industries, the domestic "deindustrialization" and industrial hollowing-out still lead to sluggish economic growth, especially the economic depression triggered by the 2008 US financial crisis, was even more pronounced.

Smart manufacturing integrates the latest communication technologies into the manufacturing process, enabling the intelligent application of big data, 5G, the Internet of Things, and fuzzy control technology in the manufacturing process. The integration of communication and computer software information services into the manufacturing production process allows for better data analysis and on-site computer management through information technology, increasing the yield of finished products per unit of manufacturing time. Its essence remains to continuously provide tangible manufacturing products to society. Unlike traditional manufacturing, smart manufacturing fully integrates producer services such as communication and information technology into the manufacturing production process. Starting from the front-end organization of production, it utilizes big data and other information technologies to optimize and integrate production resources. During the production process, smart sensors are used to collect and organize first-hand data analyze, process, and handle on-site production data. Issues such as low connectivity in manufacturing links, defective products, and unreasonable processes are identified. Communication information technology and computer software are fully utilized for data simulation and correction. For example, digital twin technology is used to revise, improve, and refine before the production of finished products in manufacturing, significantly reducing the rate of defective products and increasing the yield of qualified products. With the help of computer software, on-site management is better implemented, economies of scale are achieved, and manufacturing efficiency is greatly improved. Agile manufacturing is carried out, which plays a promoting role in economic growth.

Hypothesis 1: The integration of smart manufacturing with manufacturing and producer service industries has a positive impact on economic growth.

3.2. The effects of smart manufacturing on global value chain positioning

In today's economic globalization, with the development of information manufacturing, the decline in tariff levels, and the continuous improvement of international trade and investment environments, the importance of global value chains in a country's economy has become increasingly prominent. More and more countries and their enterprises are participating in global value chains, allocating resources, producing products, and unleashing consumption potential on a global scale. The positioning of global value chains is directly related to value appreciation, technological control, and trade added value [25]. So, can smart manufacturing enhance the positioning of global value chains? According to the smile curve theory, the two ends of the value chain are distributed with producer services, which contain high added value, strong intellectual exclusivity, and are protected by international intellectual property rights. They are a concentrated reflection of the core competitiveness of major multinational corporations in dominating the global market. Due to their knowledge- and technology-intensive exclusive characteristics, they have strong dominance and control over downstream manufacturing. One important reason why the United States can exercise long-arm jurisdiction is that it has a developed producer service industry [26]. Producer service industries are characterized by intellectual exclusivity, protected by international intellectual property laws, and have strong exclusivity towards other countries. Without climbing up the global value chain, China cannot have complete autonomy over industrial and supply chains on a global scale in today's economic globalization, but can only passively participate in the international division of labor. Manufacturing, which is located in the middle of the smile curve, usually has the lowest added value, low proprietary knowledge and technology content, very weak autonomy and controllability, and is mainly subject to high-end producer service industries. Although an increase in the proportion of manufacturing is beneficial to a country's economic growth, if the investment in producer services is too low, the controllability over the country's industrial and supply chains will be weak, and to a certain extent, it will still be subject to others.

Unlike traditional manufacturing, smart manufacturing integrates a plethora of communication and information technologies into the entire manufacturing process. This not only effectively leverages the scale effect of manufacturing to promote economic growth but also fully exploits the unique characteristics of communication technologies such as 5G, big data, artificial intelligence, and the Internet of Things. The knowledge-intensive and technology-intensive features of producer services are reflected in the excess profits brought by technological monopoly. These monopoly profits possess the uniqueness and exclusivity of intellectual property rights, forming a strong exclusivity against other competitors. To some extent, this also achieves smart manufacturing's strong control and dominance over downstream manufacturing links. Compared to traditional manufacturing, smart manufacturing integrates communication, computer software, and information technology producer services; has achieved the transformation and upgrading of traditional manufacturing; and possesses autonomy over the manufacturing industry chain, achieving the goal of climbing to the high end of the global value chain, while well balancing the characteristics of traditional manufacturing and producer service industries.

Hypothesis 2: Smart manufacturing integrates manufacturing with producer service industries, exerting a positive influence on enhancing the positioning within the global value chain.

3.3. The effects of smart manufacturing on GDP per capita

GDP per capita is often regarded as a significant indicator of a country's economic development stage. Typically, the manufacturing sector sits at the base of the "smile curve", generating relatively low added value and having a modest impact on GDP per capita growth. Conversely, producer service industries, as knowledge-intensive and technology-intensive 2.5 industries, are usually positioned at both ends of the smile curve, offering higher added value and contributing positively to a country's GDP per capita increase.

Smart manufacturing seamlessly integrates the latest and cutting-edge technologies, such as information and communication technology, fully leveraging the high added value of proprietary technology, enhancing the production value created per unit time by employees, and contributing to the overall development level of society and the increase of GDP per capita. Production services such as information and communication computer software are highly knowledge-intensive, internationally protected by intellectual property rights, and legally obtain excess technical monopoly profits through patents. This can shift traditional manufacturing's price competition to technological competition, significantly increasing added value. Therefore, if traditional manufacturing completes its intelligent transformation, it can fully leverage the role of information and communication computer software production services in enhancing the quality of manufacturing. On the one hand, it can attach heterogeneous production services to homogenized manufacturing products, better meeting consumers' personalized needs. On the other hand, by improving the quality of traditional manufacturing products, it can significantly increase product added value, thereby enhancing individuals' ability to create value and achieving the goal of increasing a country's GDP per capita. To some extent, smart manufacturing may lead to the substitution of machines for workers in traditional manufacturing, and machine production is generally unaffected by environmental factors, working hours, and physical conditions, with a more pronounced scale effect. This can positively promote GDP per capita even with a relative decrease in the number of employees.

Hypothesis 3: Smart manufacturing integrates manufacturing with producer service industries, exerting a positive influence on enhancing GDP per capita increasing.

Therefore, if a country solely focuses on developing manufacturing and increasing its share, although this is beneficial for economic catch-up, it has no significant effect on the goal of industrial upgrading towards the mid-to-high end of the global value chain, and to a certain extent, it is also detrimental to the overall increase in the country's GDP per capita. However, if we learn from the industrial hollowing-out strategies of the United States, Britain, and France, and once we relax our focus on manufacturing and shift our emphasis to producer service industries, although this is beneficial for controlling the high end of the global value chain and increasing GDP per capita, due to the "cost disease" of producer service industries, it is not conductive to a country's economic growth, and there still exists the problem of sluggish economic growth caused by weak manufacturing competitiveness. This article is based on the positive impact of smart manufacturing on economic growth, enhancing global value chain positioning, and increasing GDP per capita. On the basis of demonstrating its mechanism of action, it further conducts empirical analysis to clarify that smart manufacturing is the main direction for the transformation and upgrading of traditional manufacturing, which can ensure that the share of manufacturing does not decrease but increases, effectively addressing the core measure of "deindustrialization".

Considering China as a developing country, this paper representatively selects major countries for comparative analysis. The definition of major countries in this paper adopts the method of Ouyang Yao & Luo Huihua based on land area, population, and economic aggregate[27]. Among the 42 countries in the WIOD database, the top 10 major countries with the highest GDP in 2020 are selected to analyze the proportion of manufacturing and producer service industries. Based on data availability, the input-output table data of various countries published by WIOD is involved in this paper, covering the period from 2000 to 2014.

Between 2000 and 2014, the countries with a continuous decline in the proportion of manufacturing in their major industries were mainly developed countries such as the United States, Japan, Germany, the United Kingdom, France, Italy, and Canada, while the countries where the proportion of manufacturing still increased, especially those represented by countries with economic catch-up, such as China, India, and South Korea as the Table 1. The article further analyzes that between 1961 and 2024, China, South Korea, and India, as the major countries with the fastest annual GDP growth rates, reached 7.92%, 7.03%, and 5.24% respectively, highlighting the positive role played by the high proportion of manufacturing in countries with economic catch-up.

Table 1. Comparison of the proportion of manufacturing industry in major countries from 2000 to 2014.

Major Power	2000	2005	2010	2011	2012	2013	2014	Mean	Growth Gate
United States	0.2276	0.2029	0.1913	0.2027	0.2038	0.2010	0.1995	0.2041	-0.1032
China	0.4621	0.4902	0.5119	0.5146	0.5136	0.5130	0.4999	0.5008	0.0836
Japan	0.3171	0.3210	0.3182	0.3155	0.3125	0.3076	0.3135	0.3151	-0.0064
Germany	0.3306	0.3321	0.3206	0.3366	0.3343	0.3290	0.3275	0.3301	-0.0016
United Kingdom	0.2049	0.1675	0.1500	0.1534	0.1536	0.1548	0.1511	0.1622	-0.2086
India	0.3454	0.3608	0.3759	0.3833	0.3739	0.3653	0.3638	0.3669	0.0622
France	0.2471	0.2162	0.1872	0.1943	0.1892	0.1856	0.1832	0.2004	-0.1891
Italy	0.3203	0.2971	0.2815	0.2892	0.2848	0.2817	0.2800	0.2906	-0.0925
Canada	0.2414	0.2054	0.1924	0.1894	0.1892	0.1891	0.1892	0.1994	-0.1737
South Korea	0.4571	0.4592	0.4938	0.5150	0.5106	0.4995	0.4877	0.4890	0.0697

Data source: WIOD database

Compared to the developed countries where the proportion of producer service industries as the Table 2 was higher than 40% during the same period and showed positive growth from 2000 to 2014, namely the United States, the United Kingdom, and France, where the proportion of manufacturing industries decreased during the same period and had already dropped below 20% by 2014, China and South Korea, which have achieved economic catch-up, did not have a high proportion of producer service industries from 2000 to 2014 2.

Table 2. Proportion of producer service industries in major countries from 2000 to 2014

Major Power	2000	2005	2010	2011	2012	2013	2014	Mean	Growth Rate
United States	0.4238	0.4288	0.4254	0.4204	0.4234	0.4268	0.4290	0.4254	0.0037
China	0.1804	0.1728	0.1721	0.1709	0.1747	0.1767	0.1821	0.1757	-0.0262
Japan	0.3600	0.3615	0.3541	0.3536	0.3549	0.3549	0.3512	0.3557	-0.0118
Germany	0.3578	0.3712	0.3655	0.3554	0.3515	0.3530	0.3528	0.3582	0.0011
United Kingdom	0.4072	0.4166	0.4288	0.4284	0.4276	0.4292	0.4338	0.4245	0.0426
India	0.2459	0.2588	0.2601	0.2597	0.2730	0.2833	0.2920	0.2675	0.0879
France	0.3863	0.4061	0.4165	0.4102	0.4132	0.4152	0.4175	0.4093	0.0596
Italy	0.3550	0.3637	0.3666	0.3624	0.3651	0.3672	0.3708	0.3644	0.0265
Canada	0.3721	0.3767	0.3815	0.3776	0.3771	0.3793	0.3780	0.3775	0.0143
South Korea	0.2690	0.2621	0.2470	0.2384	0.2379	0.2399	0.2409	0.2479	-0.0784

Data source: WIOD database

Based on this, this paper further clarifies that the proportion of manufacturing and the proportion of producer service industries in major countries tend to fluctuate in opposite directions. Countries with a high proportion of manufacturing typically experience higher economic growth rates. China, India, and South Korea have all achieved economic catch-up in history. Meanwhile, countries such as the United States, the United Kingdom, and France, which have a high proportion of producer service industries, occupy higher positions in the global value chain, far surpassing the catch-up countries with a high proportion of manufacturing, namely China, India, and South Korea. The United States, the United Kingdom, and France are high-income countries with GDP per capita exceeding $40,000, while China and India are developing countries with GDP per capita below $12,700 and have not yet overcome the "middle-income trap". South Korea, as a rising star, has successfully overcome the "middle-income trap" and reached the level of a developed country with a GDP per capita of $32,250 due to its economic catch-up. It is one of the East Asian countries that China should learn from [17]. Therefore, overall, major countries that often achieve economic catch-up typically have a high proportion of manufacturing; while countries with a high proportion of producer service industries often occupy higher positions in the global value chain, have higher GDP per capita levels, and enjoy a higher overall standard of living. As a developing country, China needs to continue to achieve economic catch-up and build itself into a manufacturing powerhouse on the one hand; on the other hand, it needs to quickly break free from the control of developed countries over China's industrial and supply chains through the global value chain, climb to the mid-to-high end of the global value chain during the 14th Five-Year Plan period, and enhance China's autonomy in its industrial and supply chains. At the same time, China needs to further increase its GDP per capita, achieve common prosperity, and successfully overcome the "middle-income trap".

4. Empirical Analysis of the Effective Response to "De-industrialization" by Coupling Smart Manufacturing with Manufacturing and Producer service Industries

China is currently in a critical period of overcoming the "middle-income trap". Scientifically studying the impact of coupling smart manufacturing with manufacturing and producer service industries is of great significance for China to successfully cope with "de-industrialization". Taking the 42 countries in the World Input-Output Database (WIOD) as a sample, this study explores the universal laws worldwide and addresses the issue of "premature de-industrialization" that has emerged in China. It contributes to China's role as a developing country that takes the lead in successfully exploring the coupling of smart manufacturing with manufacturing and producer service industries worldwide effectively addressing "de-industrialization".

4.1 Variable Selection and Model Setting

This paper conducts an empirical study using panel data from 42 countries in the World Input-Output Database (WIOD). Based on the input-output tables of these 42 countries in WIOD, it sorts out variables such as smart manufacturing, manufacturing share, and producer service industry share as explanatory variables. To better control key variables that affect economic growth, this paper selects consumption, exports, foreign direct investment (net inflow), foreign direct investment (net outflow), manufacturing employment share, and producer service industry employment share as control variables. The reasons for choosing these control variables in this paper are as follows: drawing on the research of Mao Zhonggen & Sun Hao, and Yin Jielan, consumption is selected as a control variable; drawing on the research of Chen Xiaohua et al., Sun Bowei & Zhang Bowei, Lv Yanfang et al., exports are selected as a control variable; drawing on the research of Shen Guoyun, Liu Huizheng & Han Qi, Li Lianbo, foreign direct investment (net inflow) and (net outflow) are selected as control variables; drawing on the research of Wu Hao & Li Meng, Yu Zhengmao & Xu Dengyao, manufacturing employment share and producer service industry employment share are selected as control variables. This paper uses panel data and, to control for country and year differences, incorporates country-year fixed effects analysis [28-36].The variable data sources are listed in Table 3 and the descriptive statistics of main variables are as the Table 4.

Table 3. Variable Selection and Data Sources

Variable Name	Variable Description	Data Source
Economic growth rate	Gross national product annual growth rate	World Bank WDI Database
Global value chain positioning	Based on the GVC_Position indicator constructed by Koopman et al. (2010) and measured using the method of Ma Yingying (2019)	Calculated based on the WIOD input-output table
GDP per capita	Annual GDP per capita	World Bank WDI Database
Rate of intelligent manufacturing	Based on the method of Liu Fu and Zhao Xiaofei (2021), calculate the portion of communication services and computer programming consulting and related services from WIOD that are input into the manufacturing industry.	Calculated based on the WIOD input-output table
Proportion of manufacturing	Proportion of manufacturing output in total output	Calculated based on the WIOD input-output table
Proportion of producer service industry	The proportion of output from producer service industries in total output	Calculated based on the WIOD input-output table
Final consumption	Annual final consumption expenditure	World Bank WDI Database
Exports of goods and services	Annual export value of goods and services trade	World Bank WDI Database
Foreign direct investment (Net Outflow)	Annual net outflow of foreign direct investment	World Bank WDI Database
Foreign direct investment (Net Inflow)	Annual net inflow of foreign direct investment	World Bank WDI Database
Proportion of employment in manufacturing	Proportion of manufacturing employment in total employment	International Labour Organization
Proportion of producer service industry	The proportion of output from producer service industries in total output	International Labour Organization

Meanwhile, this article presents descriptive statistics for the main variables:

Table 4. Descriptive statistics of main variables

Variable Name	Observation	Mean	SD	Min	Max
Economic growth rate	630	0.2812	0.3612	-1.4838	1.4230
Global value chain positioning	630	0.0032	0.0266	-0.0986	0.0888
GDP per capita	630	27385.8800	22210.1000	443.3142	118823.6000
Intelligent manufacturing rate	630	0.0067	0.0033	0.0013	0.0200
Proportion of manufacturing industry	630	0.2706	0.0890	0.0004	0.5150
Proportion of producer service industry	630	0.3657	0.0861	0.1662	0.7748
consumption	630	8.70E+11	1.89E+12	3.31E+09	1.44E+13
Exports of goods and services	630	2.89E+11	3.93E+11	2.93E+09	2.46E+12
Foreign direct investment (net outflow)	630	307.7667	177.2305	1.0000	614.0000
Foreign direct investment (net inflow)	630	307.6365	174.4266	1.0000	607.0000
Proportion of employees in the manufacturing industry	630	0.1662	0.0482	0.0500	0.3128
Proportion of employees in producer service industry	630	0.2468	0.0329	0.1361	0.3249

This article constructs an econometric model as follows:

① Econometric model of the impact of smart manufacturing on economic growth:

$$gdpgrowthrate_{it} = \alpha 1 + \beta_1 iamanufacturing_{it} + \beta_2 control1_{it} + \varepsilon 1_{it} \quad (1)$$

In the econometric model (1), $gdpgrowthrate$ represents the economic growth rate; $iamanufacturing$ represents the rate of intelligent manufacturing; subscripts i represent 42 countries, t represents the years from 2000 to 2014. The control variables in model (1) include final consumption, exports of goods and services, net outflow of foreign direct investment, and net inflow of foreign direct investment, $\varepsilon 1$ represents unobserved residual terms. To further highlight the impact of intelligent manufacturing on economic growth, this paper conducts comparative analysis with traditional manufacturing and producer service industries in the empirical research process. Therefore, model 1 is compared with models (2) and (3) simultaneously:

$$gdpgrowthrate^{'}_{it} = \alpha 1^{'} + \beta^{'}_1 manufacturing_{it} + \beta^{'}_2 control1^{'}_{it} + \varepsilon 1^{'}_{it} \quad (2)$$

In the econometric model (2), $manufacturing$ represents the proportion of traditional manufacturing, and this econometric result is compared and analyzed with the smart manufacturing results from model (1).

$$gdpgrowthrate_{it} = \alpha 1^{''} + \beta^{''}_1 producerservice_{it} + \beta^{''}_2 control1^{''}_{it} + \varepsilon 1^{''}_{it} \quad (3)$$

In the econometric model (3), $producerservice$ it represents the proportion of producer service industries. This econometric result is compared and analyzed with the results of smart manufacturing from model (1).

②Econometric model of smart manufacturing's impact on enhancing the positioning effect of global value chains:

$$manupositioning_{it} = \alpha 2 + \beta_3 iamanufacturing_{it} + \beta_4 control2_{it} + \varepsilon 2_{it} \quad (4)$$

In the econometric model (4), $manupositioning$ it represents the positioning of the manufacturing industry in the global value chain; other aspects are similar to model (1). The control variables in model (4) include net outflow of foreign direct investment and net inflow of foreign direct investment, $\varepsilon 2$ represents unobserved residual terms.

$$manupositioning_{it} = \alpha 2^{'} + \beta^{'}_3 manufacturing_{it} + \beta^{'}_4 control2_{it} + \varepsilon 2^{'}_{it} \quad (5)$$

In the econometric model (5), we compare the impact effects of traditional manufacturing and smart manufacturing on

the positioning of global value chains.

$$manupositioning_{it} = \alpha 2^{''} + \beta^{''}_3 producerservice_{it} + \beta^{''}_4 control2_{it} + \varepsilon 2^{''}_{it} \quad (6)$$

In the econometric model (6), we compare the impact effects of producer service industries and intelligent manufacturing on the positioning of global value chains.

③ Econometric model of the impact effect of smart manufacturing on improving GDP per capita:

$$gdpper_{it} = \alpha 3 + \beta_5 iamanufacturing_{it} + \beta_6 control3_{it} + \varepsilon 3_{it} \quad (7)$$

In the econometric model (7), $gdpper$ represents GDP per capita, and the control variables include the proportion of manufacturing employees, the proportion of producer service industry employees, net outflow of foreign direct investment, and net inflow of foreign direct investment. $\varepsilon 3$ represents the unobserved residual term.

$$gdpper_{it} = \alpha 3^{'} + \beta^{'}_5 manufacturing_{it} + \beta^{'}_6 control3^{'}_{it} + \varepsilon 3^{'}_{it} \quad (8)$$

In the econometric model (8), we compare the impact effects of traditional manufacturing and smart manufacturing on the increase of GDP per capita.

$$gdpper_{it} = \alpha 3^{''} + \beta^{''}_5 producerservice_{it} + \beta^{''}_6 control3^{''}_{it} + \varepsilon 3^{''}_{it} \quad (9)$$

In the econometric model (9), we compare the impact effects of producer service industries and intelligent manufacturing on the increase of GDP per capita.

4.2 Empirical research results on the impact of smart manufacturing on economic growth

Based on the current large-scale construction of smart manufacturing, there may be a lag effect. This paper constructs a distributed lag model and employs the Almon polynomial method to determine the lag period. It is determined that smart manufacturing has a first-order lag on economic growth; there is no lag term for smart manufacturing in global value chain positioning; and smart manufacturing has a first-order lag on GDP per capita. This paper further tests for collinearity, and the variance inflation factors are all less than 10, indicating no collinearity. Drawing on the methods of Graetz & Michaels, this paper uses the growth rate of the logarithm of the sum of new robot installations and robot usage stock in various countries published by the International Federation of Robotics (IFR) as an instrumental variable [37]. The F-statistics for weak instrumental variables in the first stage are all greater than 10, indicating that the instrumental variables meet the correlation requirement; the Hansen statistic fails to reject the null hypothesis that the instrumental variables are exogenous, indicating that the instrumental variables are valid.

4.2.1 Smart manufacturing effectively counteracts the "de-industrialization" effect-empirical results of economic growth

This article adopts the measurement method of intelligent manufacturing from Liu B & Zhao X F [38]. The method involves the sum of direct and indirect inputs, meaning that the direct and indirect inputs of service sectors used by various manufacturing sectors represent the complete consumption of service sectors by manufacturing sectors. The specific calculation formula is as follows:

$$servitization^{complete} = \alpha_{ij} + \sum\nolimits_{k=1}^{n} a_{ik} a_{kj} + \sum\nolimits_{s=1}^{n} \sum\nolimits_{k=1}^{n} a_{is} a_{sk} a_{kj} + ..., \quad (10)$$

where $servitization^{complete}$ represents the service input level of manufacturing industry j (measured by the complete consumption coefficient). The first term on the right side of the formula represents the direct consumption of the service sector by the manufacturing sector; the second term represents the first indirect consumption; the third term represents the second indirect consumption; and so on, with the $n+1$nth term representing the nth indirect consumption. The sum of these terms is the complete consumption. The intelligent manufacturing measured in this article is calculated based on the portion of communication services, computer programming and design consulting, and related services input into the manufacturing industry in the World Input-Output Database (WIOD). Due to space limitations, the specific results are not listed here and can be provided upon request.

The distributed lag model indicates that economic growth is influenced by both the current period and the lagged periods of smart manufacturing

$$SC = \ln(\frac{RSS}{n}) + \frac{k+2}{n}\ln(n) \quad (11)$$

Where RSS is the residual sum of squares, k is the length of the lag period, (k+2) is the number of parameters in the model, and n is the sample size. The testing process is as follows: add lag variables to the model one by one until the SC value no longer decreases, that is, select the lag period k that minimizes the SC value.

Table 5. Empirical results of the impact effect of smart manufacturing on economic growth

Explained variable		Model 1	Model 2	Model 3	Model 4	Model 5
		2SLS	System GMM	Fixed effect	Mixed OLS	Mixed OLS
Explanatory variable	Intelligent manufacturing rate	-0.0763*	-0.8546	-1.1343***		
		(0.0453)	(0.3188)	(0.1696)		
	First-order lag of intelligent manufacturing rate			1.0134***		
				(0.1829)		
	Manufacturing industry share				1.341***	
					(0.1550)	
	Proportion of producer service industry					-1.2220***
						(0.1760)
Control variable	Whether to control	yes	yes	yes	yes	yes
	Constant term	0.0053	0.0081	0.0644***	0.7900**	1.3020***
		(0.0036)	(0.0054)	(0.0644)	(0.2490)	(0.2680)
	R-squared	0.0507	0.0054	0.1493	0.142	0.108
	Observed value	588	588	588	630	630

Note: ( ) indicates robust standard error; ***, **, * represent significance at the 1%, 5%, and 10% levels, respectively.

The results from models (1), (2), and (3) in Table 5 clearly illustrate the empirical impact of smart manufacturing on economic growth: during the process of smart manufacturing transformation and infrastructure construction, a significant amount of capital is required, which has a negative effect on current economic growth. However, once this negative effect is experienced during the current period of smart manufacturing transformation and enters the next period, it demonstrates a very significant positive multiplier effect of smart manufacturing on economic growth, fully highlighting the powerful role of smart manufacturing in enhancing the "de-industrialization" effect - economic growth. In June 2021, China elevated the digital economy to a national strategy, and the effective integration of the digital economy with the real economy, such as manufacturing, is an important application scenario for smart manufacturing. That is to say, if China's traditional manufacturing can transform as soon as possible with the support of government special funds and policies for smart manufacturing transformation, it can fully leverage the positive promoting effect of smart manufacturing on the "de-industrialization" effect-economic-economic growth, creating excellent conditions for China's economy to continue to take off during the "15th Five-Year Plan" period.

Compared with the empirical results of smart manufacturing on economic growth, if we solely focus on the effect of traditional manufacturing on economic growth, the results from model (4) in Table 5 indicate that traditional manufacturing has a very significant positive effect on economic growth. In contrast, the results from model (5) show that producer service industries have a significant negative effect on economic growth. This research finding precisely validates the reality that when major economies such as China, India, and South Korea have a relatively high proportion of manufacturing, they achieve economic catch-up; whereas when major economies such as the United States, the United Kingdom, and France have a relatively high proportion of producer service industries, their economic growth is sluggish. This research conclusion suggests that during the process of industrial transformation and upgrading, China should still pay attention to and maintain a relatively stable proportion of manufacturing in its transformation strategy to prevent the negative effects of a too rapid and excessive decline in the proportion of manufacturing on economic growth. This indicates that accelerating the development of smart manufacturing, increasing the proportion of manufacturing, and preventing "de-industrialization" are very beneficial for China's economy to maintain medium-to-high-speed growth on the new journey towards the second centenary goal and are important prerequisites for continuing to implement the national catch-up strategy. This is the best defense plan for China to better cope with economic suppression and blockade from developed countries such as the United States.

Unlike manufacturing, producer service industries have a significant negative impact on a country's economic growth. When we consider the reality, we find that developed countries such as the United States, the United Kingdom, and France have highly developed producer service industries, with their share exceeding 40% of GDP, but they have a negative effect on their own economic growth. What is the reason that attracts developed countries such as the United States, the United Kingdom, and France to spare no effort in developing producer service industries? With this question in mind, we further investigate the impact of manufacturing and producer service industries on the positioning of global value chains.

4.2.2 Empirical results of smart manufacturing on enhancing global value chain positioning

According to the World Bank's "World Development Report 2020" titled "Trade for Development in the Age of Global Value Chains", global value chains (GVCs) are an important means of increasing income, creating jobs, and reducing poverty. Therefore, GVCs are an important way for countries to participate in global governance. Based on the Hausman test for endogeneity, this paper further conducts a DWH heteroskedasticity robustness test and treatment. System GMM is selected to deal with endogeneity. Due to space limitations, the fixed-effects results of the robustness checks conducted in this paper are not listed here and can be provided upon request. The paper has verified that there are no weak instrumental variables or collinearity, and robustness tests are conducted using fixed effects of year, country, and year-country, with robust results.

Table 6. Empirical results of the impact effect of smart manufacturing on enhancing global value chain positioning

Explained variable		Global value chain				
		Model 1	Model 2	Model 3	Model 4	Model 5
		2SLS	System GMM	Fixed effect	Mixed OLS	Mixed OLS
Explanatory variable	Intelligent manufacturing rate	14.9516***	2.3431**	2.2860***		
		(3.8944)	(0.4493)	(0.4054)		
	Proportion of manufacturing industry				-0.0260*	
					(0.0117)	
	Proportion of producer service industry					0.0317**
						(0.0121)
Control variable	Whether to control	yes	yes	yes	yes	yes
	Constant term	-0.0757	0.1185***	-0.0130**	-0.0065	-0.0242**
		(0.0487)	(0.0271)	(0.0053)	(0.0089)	(0.0093)
	R-squared			0.0531	0.035	0.038
	Observed value	521	463	630	630	630

Note: ( ) indicates robust standard error; ***, **, * represent significance at the 1%, 5%, and 10% levels, respectively.

From models (1), (2), and (3) in Table 6, it is found that smart manufacturing has a significant and robust enhancing effect on improving global value chain positioning, with no lag effect. That is to say, if we can successfully achieve the transformation from traditional manufacturing to smart manufacturing, it will not only facilitate the multiplier effect on economic growth in the next period after the current infrastructure construction of smart manufacturing, but also positively enhance China's manufacturing industry's global value chain positioning. This effectively avoids the existing problem that pure manufacturing or producer service industries cannot simultaneously achieve economic growth and global value chain improvement. It is very beneficial for China's manufacturing industry to achieve the goal of climbing to the mid-to-high end of the global value chain during the "14th Five-Year Plan" period in the process of economic catch-up.

This article aims to better compare the impact effects of smart manufacturing on enhancing global value chain positioning with those of traditional manufacturing and producer service industries. Meanwhile, models (4) and (5) in Table 6 empirically analyze the impact effects of manufacturing and producer service industries on global value chain positioning, respectively. The results reveal that the mere development of manufacturing exhibits a significant negative effect on global value chain positioning, whereas producer service industries have a significant positive effect. In other words, if a country solely focuses on developing manufacturing or producer service industries, it is difficult to achieve both economic growth and the goal of enhancing global value chain positioning. This finding provides a clearer understanding of one of the reasons why the proportion of producer service industries in the United States, the United Kingdom, and France is higher than 40%, namely, their position at the high end of the global value chain. However, China's proportion of producer service industries is currently low, and its position in the global value chain remains at the low end. Therefore, solely developing manufacturing or producer service industries poses a "dilemma" of being unable to simultaneously achieve economic growth and climb to the mid-to-high end of the global value chain: currently, the United States, the United Kingdom, and France have a high proportion of producer service industries, occupying the high end of the global value chain, but they face "industrial hollowing out" due to "de-industrialization," which is not conducive to rapid economic growth. However, major countries in economic catch-up, represented by China, have relied on the advantage of a high proportion of manufacturing to achieve rapid economic growth over the past four decades of reform and opening up. Since 2010, China has become the world's second largest economy, and its GDP per capita exceeded $10,000 in 2020, entering the ranks of middle-income countries. However, due to the low proportion of producer service industries, there exists a "paradox of producer service industry development," with manufacturing only ranking at the low end of the global value chain, and the industrial and supply chains still being controlled by others, resulting in weak autonomy.

This study demonstrates that smart manufacturing can integrate manufacturing with producer service industries, promoting economic growth and enhancing the positioning of the manufacturing industry in the global value chain. It represents a novel manufacturing paradigm that warrants significant promotion. China has clearly outlined the development goal of deeply implementing smart manufacturing projects in the "14th Five-Year Plan and the Outline of Long-term Vision for 2035". Smart manufacturing has become the core of this round of technological revolution and industrial transformation in China, and we must spare no effort to accelerate its transition and development from infrastructure to application.

4.2.3 Empirical results of smart manufacturing on improving GDP per capita

Table 7. Empirical results of the impact effect of smart manufacturing on increasing GDP per capita

Explained variable		GDP per capita				
		2SLS	System GMM	Fixed Effect	Mixed OLS	Mixed OLS
Explanatory variable	Intelligent manufacturing rate	-24.2764***	-62.9132*	-31.2244***		
		(9.0477)	(35.7864)	(5.6373)		
	First-order lag of intelligent manufacturing rate			25.6538***		
				(6.0782)		
	Manufacturing industry share				-3.0550***	
					(0.4960)	
	Proportion of producer service industry					4.3370***
						(0.4760)
Control variable	Whether to control	yes	yes	yes	yes	yes
	R-squared		-0.5177	0.1088	5.5720***	3.9920***
	Constant term	0.4705***	0.7573	1.4724	-0.464	-0.419
		(0.1377)	(1.8412)	-0.3444	0.436	0.472
	Observed value	492	432	231	630	630

Note: ( ) indicates robust standard error; ***, **, * represent significance at the 1%, 5%, and 10% levels, respectively.

GDP per capita, as an important indicator describing a country's economic development level, is also a key issue that China needs to focus on in order to successfully overcome the "middle-income trap". This paper also employs the system GMM to deal with endogeneity. Due to space limitations, the fixed-effects results of the robustness tests conducted in this paper are not listed here and can be provided upon request. Different empirical methods are used in the paper for robustness testing, following the same approach as above. There are no weak instrumental variables or collinearity issues in the paper.

The empirical research results of models (1), (2), and (3) in Table 7 indicate that smart manufacturing has a lag effect on improving GDP per capita. Although this effect has not yet manifested in the current period, the first-order lag shows a very significant and robust multiplier effect, meaning that smart manufacturing fully exerts its positive effect of significantly increasing GDP per capita growth in the next period after the completion of infrastructure in the current period. Considering China's goal of building a modernized powerful country on its new journey towards the second centenary goal, whether it can successfully overcome the "middle-income trap" and increase GDP per capita is crucial. After the completion of infrastructure in the current period, smart manufacturing will exert a significant multiplier effect on GDP per capita in the next period, which is very beneficial for China to maintain the catch-up effect of manufacturing on economic growth, successfully climb to the high-end of the global value chain during the "14th Five-Year Plan" period, and increase GDP per capita, providing a feasible path to overcome the "middle-income trap". The coupling of smart manufacturing with manufacturing and producer service industries can achieve high-quality development of China's manufacturing industry, increase the proportion of manufacturing, and successfully cope with "de-industrialization" in the new era of technological revolution and technological transformation. This is a solution for successfully embarking on a new journey towards becoming a modernized powerful country that is different from the industrial hollowing out experienced by European and American countries.

To compare with the empirical results of smart manufacturing on improving GDP per capita, this paper verifies the impact effects of manufacturing and producer services on the increase of GDP per capita in models (4) and (5), respectively. The results show that a high proportion of manufacturing has a significant negative effect on increasing GDP per capita; however, a high proportion of producer services significantly benefits the increase of GDP per capita. This result verifies that the practice of continuously increasing the proportion of producer services in developed countries such as the United States, Britain, and France is beneficial to the increase of their GDP per capita.

Summarizing the heterogeneous impact effects of manufacturing and producer service industries, we have verified that a high proportion of manufacturing is conductive to economic growth; however, empirical research results indicate that a high proportion of producer service industries is beneficial for climbing to the high end of the global value chain and increasing GDP per capita. Currently, developed countries such as the United States, Britain, and France are focusing on developing producer service industries, effectively leveraging their positive role in climbing to the high end of the global value chain and increasing GDP per capita. As a major developing country, China has achieved the practical effect of using manufacturing to promote economic catch-up in the four decades since its reform and opening-up. However, considering the phenomenon of "premature deindustrialization" that has emerged in China, Chinese manufacturing also faces the practical demands of climbing to the mid-to-high end of the global value chain and successfully overcoming the middle-income trap to increase GDP per capita. Therefore, from a comprehensive perspective, smart manufacturing not only helps promote economic growth but also facilitates climbing to the mid-to-high end of the global value chain and promotes the increase of GDP per capita. This strategy is very suitable for China.

In the face of the smart manufacturing transformation currently being implemented in China, we suggest that relevant governments continue to provide various support in terms of capital and supporting policies, increase the special promotion funds for smart manufacturing, and assist in the early successful completion of the intelligent infrastructure construction for China's manufacturing industry. Although smart manufacturing may lead to the displacement of workers and a reduction in the number of manufacturing employees, it can achieve economies of scale on a broader scale. Once established, it can significantly promote economic growth and prevent the occurrence of industrial hollowing out. At the same time, smart manufacturing can fully leverage the producer service roles of communication computer software and information services, climb up the global value chain to the mid-to-high end, enhance China's autonomy in industrial and supply chains, and leverage the high added value characteristics of producer services to further increase China's GDP per capita and successfully leap over the "middle-income trap" as soon as possible. Therefore, this paper suggests that China should learn from the experience of developed countries such as the United States and Japan, where excessive relocation of manufacturing industries has led to domestic industrial hollowing out. China's labor dividend is gradually diminishing, and the aging problem is becoming increasingly prominent. Therefore, it is necessary to achieve high-quality development from traditional manufacturing to smart manufacturing as soon as possible, retain key and core manufacturing production lines within China as much as possible, replace labor-intensive factors with digital, technological, and capital factors, and promote the new production paradigm of better integrating smart manufacturing with producer services and traditional manufacturing to a broader region under the condition of reversing factor intensity. This will truly pave the way for China to become a modernized, powerful country, completely different from the industrial hollowing out experienced by Europe and the United States.

5. Expansive Research

At the 2021 "Leaders' Climate Summit", President Xi solemnly pledged that China will strive to achieve the development goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. We must adhere to President Xi's concept that "green water and clear mountains are invaluable assets", effectively addressing the issue of "de-industrialization" in the process of developing smart manufacturing and increasing the proportion of manufacturing. Can we also simultaneously prioritize the concept of ecological development that protects the environment and our homeland? The Industrial Revolution fundamentally changed human production and lifestyle, but it also caused ecological damage [39]. Considering the potential negative impacts of traditional industries on the ecology, this paper conducts an extended study, using carbon emissions (the carbon emission indicators used in this article are sourced from the OECD, specifically the amount of carbon dioxide emitted by 42 countries in the World Input-Output Database (WIOD) during the period from 2000 to 2014) as the core indicator to measure environmental pollution, and analyzes the impact of smart manufacturing on carbon emissions. To better compare the impacts of traditional indicator to measure environmental pollution, and analyzes the impact of smart manufacturing on carbon emissions. To better compare the impacts of traditional manufacturing and producer service industries on carbon emissions, this paper also includes manufacturing and producer service industries as explanatory variables in empirical research, and compares their impacts with that of smart manufacturing on carbon emissions. The empirical results are as the Table 8. The system GMM is still used for endogeneity treatment. Additionally, fixed effects of year, country, and year-country are employed for robustness checks, and the results are robust. This paper verifies the absence of weak instrumental variables and collinearity issues.

Table 8. Empirical results of smart manufacturing on carbon dioxide emissions

Explained variable		Carbon dioxide emissions			
		TSLS	System GMM	OLS	OLS
Explanatory variable	Intelligent manufacturing rate	-163.3467*	-10.5818**		
		(89.0247)	(6.1313)		
	Proportion of manufacturing industry			2.1493**	
				(0.8829)	
	Proportion of producer service industry				-5.5527***
					(0.5993)
					yes
Control variable	Whether to control	yes	yes	yes	yes
	Constant term	9.3478***		8.9420***	11.5344***
		(0.5965)		(0.6277)	(0.5842)
	Observed value	462	199	495	495
	Hansen's P-value		0.989		

Note: ( ) indicates robust standard error; ***, **, * represent significance at the 1%, 5%, and 10% levels, respectively

It can be seen that traditional manufacturing has a significant negative effect on carbon emission reduction, indicating that the development of traditional manufacturing has a destructive effect on the ecological environment. Due to their knowledge-intensive and technology-intensive characteristics, producer service industries are conductive to environmental protection and reduce carbon emissions. Compared with traditional manufacturing and producer service industries, increasing the proportion of manufacturing can effectively cope with the "de-industrialization" of smart manufacturing, which also has a significant protective effect on the ecological environment and significantly reduces a country's carbon emissions. Therefore, in the process of accelerating the construction of a powerful manufacturing country, China has taken smart manufacturing as the main direction for the high-quality development of its manufacturing industry. This approach not only achieves positive effects on economic growth but also enhances positioning in the global value chain and improves GDP per capita. At the same time, it can well balance the ecological concept that "green water and clear mountains are invaluable assets", which is conducive to China achieving carbon peak and carbon neutrality in the process of promoting high-quality development of the manufacturing industry.

6. Conclusion and Policy Recommendations

The issue of "de-industrialization" not only arises in developed countries such as the United States, Britain, and France, but also in sub-Saharan Africa, Latin American countries, and China. This paper, after systematic theoretical and empirical research, clearly points out that a high proportion of manufacturing is conductive to a country's economic growth, but not conductive to its ascent to the high end of the global value chain and the improvement of GDP per capita. Many European and American countries have experienced further evolution of "de-industrialization" leading to industrial hollowing out, which has a significant negative impact on economic growth. However, an industrial structure with a high proportion of producer service industries is conducive to a country's stable position at the high end of the global value chain and the improvement of GDP per capita. As the largest developing country in the world, China can no longer maintain the threshold values of a manufacturing share less than 0.0865 and a producer service industry share greater than 0.5224 to couple the growth and decline of manufacturing and producer service industries. Based on theoretical and empirical research, this paper clarifies that intelligent manufacturing is an effective way to couple manufacturing and producer service industries. By increasing the proportion of manufacturing in the process of achieving high-quality development of China's manufacturing industry, we can effectively apply "de-industrialization".

Based on this, this article proposes policy recommendations: During the "15th Five-Year Plan" period, we should expedite the completion of the current infrastructure transformation for smart manufacturing, so that smart manufacturing entering the next application phase can effectively counteract the effects of "de-industrialization". This will not only ensure the positive role of manufacturing in promoting economic growth but also smoothly advance China's manufacturing industry to climb up the global value chain to the mid-to-high end and steadily increase GDP per capita, thereby helping China successfully overcome the "middle-income trap".

Therefore, this paper suggests that as China has already implemented a digital national strategy and is advancing the transformation of enterprises towards smart manufacturing, it can better integrate with the practical difficulties of enterprise intelligent upgrading. By providing low-interest, necessary, timely, and compensatory financial subsidies and related policy support to traditional manufacturing enterprises through government special funds for smart manufacturing and related supporting policies, more Chinese manufacturing can smoothly overcome the current difficulties of smart manufacturing transformation and upgrading. This will create conditions for effectively addressing the effects of "de-industrialization" during the application period after the successful completion of smart manufacturing infrastructure. At the same time, based on the empirical research findings of this paper, it is particularly recommended that Chinese manufacturing, in the process of intelligent transformation, should learn from the lessons of excessive expansion of foreign direct investment (net outflow) policies in the United States and Japan, which have led to the hollowing out of domestic industries. Efforts should be made to make good use of smart manufacturing and retain key and core production lines in the manufacturing industry through intelligent transformation, thereby better achieving the organic integration of producer services and local manufacturing. In particular, it is necessary to avoid the passive situation that emerged during the COVID-19 pandemic, where countries such as the United States, Britain, and France had to rely mainly on imports for the most basic medical supplies due to industrial hollowing out. Therefore, this paper emphasizes that as the living standards of the Chinese people gradually improve, the proportion of consumption on services and other spiritual products is increasing. This underscores the important practical significance of high-quality development of basic industries, which is related to both economic benefits and national security. It is a wise move to retain the key and core links and processes of Chinese manufacturing in the country through smart manufacturing, and every effort should be made to facilitate this.

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