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Measurement and improvement path analysis of China's manufacturing industry chain resilience

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Abstract: *The resilience of the manufacturing industry chain is the key for the manufacturing industry to resist absorption risks and restore and update to maintain long-term stable development. This paper uses the entropy weight method to measure the industrial chain toughness of industrial enterprises above scale in 31 provinces, autonomous regions and municipalities directly under the Central Government from 2009 to 2021, and analyzes the measurement results of the industrial chain toughness in each province from the perspective of time, space and quality of industrial development. In order to narrow the development gap of China's regional manufacturing industry chain toughness, we should pay attention to the research conclusions of manufacturing product quality improvement, and provide stable guarantee for the long-term development of China's manufacturing industry.*

Keywords: *Manufacturing industry; Industrial chain toughness; Entropy weight method*

1. Introduction

After the keyword "industry chain resilience" was put forward in the "14th Five-Year Plan" and "2035 vision goal", the measurement of industry chain resilience has become the focus of many scholars. Different scholars and experts from domestic authoritative institutions interpret from different perspectives such as development results, development principles or key measures. The manufacturing industry is a pillar industry of the national economy, so enhancing the toughness of the manufacturing industry chain can effectively improve the ability of the manufacturing industry to resist, resolve and absorb risks, ensure the continuous chain of the manufacturing industry chain, and promote the sustained and stable growth of the manufacturing output value. The Party's 14th Five-Year Plan to "stable chain strong chain solid chain reinforcement chain" in an important strategic position, the Minister of Industry and Information Technology Miao Wei also mentioned that must strengthen the resilience of the manufacturing industry chain, which shows the country's importance to the resilience of the industry chain.

With the severe impact of the COVID-19 epidemic on China's economy, the manufacturing industry has been irreversibly damaged in the process. The upstream enterprises of the manufacturing industry chain cannot provide effective product supply, so the manufacturing industry chain is facing the risk of chain break, at this time to improve the toughness of the manufacturing industry chain to ensure that the manufacturing industry chain stability and strong chain solid chain policy implementation, is of great significance for the long-term stable development of the manufacturing industry. First of all, the improvement of the resilience of the manufacturing industry chain not only means that the manufacturing industry can resist risks and return to its original health when facing risks, but also means that the manufacturing industry can take the crisis faced as an opportunity to move towards the global high-end industrial chain value chain after its resilience is improved. Secondly, improving the toughness of the manufacturing industry chain can promote the prosperity and development of the manufacturing industry itself, and can also inject a steady stream of impetus into the prosperity and development of China's economy. Finally, the traditional index of manufacturing output value to measure the development level of manufacturing industry has strong limitations, which only focuses on the accumulation of manufacturing quantity, and does not pay attention to the improvement of manufacturing quality. The "industry chain resilience" of the manufacturing industry used in this paper comprehensively measures the "industry chain resilience" of the manufacturing industry from the four dimensions of coping resistance, adaptive resilience, autonomous control and leading competitiveness, so as to provide reference suggestions for China to formulate policies to improve the industry chain resilience of the manufacturing industry. Only the industry chain resilience of the manufacturing

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industry has been effectively improved. The ability of the manufacturing industry to prevent, defuse and resist crises and risks can be enhanced, and the development of the national economy can be guaranteed. Therefore, choosing to study the "manufacturing industry chain resilience" has far-reaching practical significance, which can provide a guarantee for the long-term and stable development of China's manufacturing industry.

2. Literature review and research hypothesis

As an emerging concept, industry chain toughness is extremely important to the long-term stable development of manufacturing industry. At present, China is facing the fierce impact of the epidemic, domestic demand and the international market are in a depressed state, how to achieve a steady recovery of the domestic economy, so as to promote economic growth to maintain the original trend is a common problem we face. The resilience of the industrial chain refers to the ability of the industrial chain to absorb the fluctuations caused by the shocks when it is subjected to internal and external shocks, and maintain its ability to recover to the original initial stable state, which is an ability to resist and absorb external risks and maintain its own stable development.

From the existing literature, foreign scholars have discussed economic resilience from various perspectives. In the field of economics, foreign scholars have conducted a more in-depth and comprehensive discussion on the concept of resilience. For example, Rose(2007) used the concept of resilience to describe the ability of a system to successfully get rid of disturbances and restore vitality. In the field of sociology, Wood, Burton and Cutter(2010) used the concept of resilience to describe the ability of a system to save itself in the event of disasters. [1]In the field of industrial ecology, Zhu and Ruth(2013) used the concept of resilience to describe the ability of a system to maintain its original ecological efficiency and energy flow after disruption. In the field of industrial engineering, Ouyang(2014) used the concept of resilience to describe the ability of a system to avoid disasters and recover to normal state after absorbing and digesting original damage.[2] The resilience of China's manufacturing industry chain is an important factor affecting the development of China's manufacturing industry, which mainly refers to the ability of China's manufacturing industry to maintain and promote its long-term development when dealing with shocks and disruptions such as cyclical economic crises, the emergence of competitors, unexpected company closures and technological changes. The existing research topics on the toughness evaluation of regional manufacturing industry chain mainly include two aspects: one is the study on the influencing factors of regional manufacturing industry chain toughness, and the other is the study on how to measure the toughness of regional manufacturing industry chain. In terms of influencing factors, Chapple(2010) investigated the ability of regional industries to restore the regional labor market by increasing wages, and applied discriminant analysis to try to find out the main influencing factors for the improvement of regional industrial chain resilience. Pendall et al.(2012) analyzed the micro-data of 84 cities in the United States and found that potential individual or family vulnerability, potentially unstable housing conditions and regional per capita disposable income have an impact on the resilience of regional industrial chain. Holm and Stergaard(2013) analyzed the regional differences in the development and growth patterns of Denmark's ICT industry around 2000, and identified the main influencing factors of regional industry resilience. [3]Capelloet al.(2015) found that industrial scale and added value of new industrial products are important evaluation indicators for the measurement of regional industrial toughness, and the improvement of the quality of production factors carried by regional industries, the quality of infrastructure and the density of external connections can all make the development potential and risk coping ability of industries have greater room for improvement.

Domestic studies on the concept of resilience mainly start from regional economic resilience and organizational resilience. The conclusion of regional economic resilience summarized by Martin is that a region can resist and absorb shocks and recover quickly after shocks. Before recovering itself, the regional economic system can adjust its internal structure and integrate resources in the process of resisting risks, so as to carry out regional economic path innovation. Organizational resilience can be understood as an organization's ability to recover from adversity or bounce back from failure. On this basis, Luo Liping (2018) considered resilience as the ability of a system to resist absorbing risks and carry out recovery and renewal from the perspectives of impact resistance, impact adaptation and recovery and renewal. Huang Hanquan (2019), director of the Institute of Industrial Economics of the Chinese Academy of Macroeconomics, believes that the manufacturing industry should have the following characteristics with high resilience: From the perspective of quality, the supply system and the demand structure can effectively match; From the efficiency point of view, the maximum economic benefit is obtained with the least resource consumption; From the perspective of power, the

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development power of manufacturing industry depends on innovation; From the regional perspective, it is necessary to form a regional pattern of coordinated development; From the ecological point of view, we should pay attention to green production; From the perspective of opening up, it is necessary to lead the manufacturing industry to the middle and high-end level of the global value chain; From the perspective of sharing, the industrial chain and small and medium-sized enterprises should be closely coordinated and integrated. In addition, the improvement of the resilience of the manufacturing industry chain has enhanced the level of the manufacturing industry to resist risks, support research and development innovation, intelligent transformation, and reduce the cost of the real economy. The improvement of the toughness of the manufacturing industry chain is the key to promoting the high-quality development of the manufacturing industry.

By reviewing the previous literature, we found that scholars made more qualitative analysis of economic resilience, while few studies focused on quantitative analysis of economic resilience. Therefore, by measuring the resilience of the manufacturing industry chain and analyzing the core factors affecting the resilience of the manufacturing industry chain, this paper filled the gaps in related research fields, and proposed the following hypotheses: From 2009-2021, what is the trend of the resilience of the manufacturing industry chain in each province over time? What are the core factors affecting the resilience of the manufacturing industry chain? From the regional point of view of the eastern region, the central region and the western region of the manufacturing industry chain toughness gap, we can find how to measure this gap.from the point of view of manufacturing industry year by year development trend, we can know the manufacturing industry chain toughness development quality and to ensure that the manufacturing industry chain can develop steadily in the process of quantity accumulation of output value. The above are three research hypotheses proposed in this paper from the time dimension, space dimension and industrial development quality dimension.

The differences between this paper and previous scholars in measuring the toughness of the manufacturing industry chain are as follows: First of all, the selection of indicators to measure the toughness of the manufacturing industry chain is scientific. The first-level indicators are constructed from four aspects, namely coping resistance, adaptive resilience, autonomous control, and leading competitiveness, which contain 10 second-level indicators to comprehensively measure the toughness of the manufacturing industry chain from the perspective of impact resistance, impact adaptability, and recovery and reorganization of the industry chain. Secondly, through the measurement of the toughness of the manufacturing industry chain, it is clear which factors are the core factors affecting the toughness of the manufacturing industry chain, so as to provide reference for the subsequent improvement of the toughness of the manufacturing industry chain. Finally, the methods and research ideas for measuring the toughness of the manufacturing industry chain provided in this paper can lay a foundation for the subsequent research on the toughness of the manufacturing industry chain. The purpose of this paper is to explore the methods and paths to promote the industry chain resilience of the manufacturing industry through theoretical framework, case analysis and empirical measurement of the industry chain resilience of 31 provinces, autonomous regions and municipalities in China from 2009 to 2021, so as to enable China's manufacturing industry to maintain stable growth of its output value when suffering from economic fluctuations. Therefore, it provides scientific and reasonable opinions and policy basis for improving the toughness of China's manufacturing industry chain.

In order to achieve the goal of improving the toughness of the manufacturing industry chain, thus creating conditions for the stable development of the manufacturing industry. Some domestic scholars took the lead in studying the influencing mechanism of manufacturing industry chain resilience in some provinces and cities in China. Wang Zhongya (2018) showed that in recent years, the comprehensive strength of the manufacturing industry in Henan Province has been continuously enhanced, and the toughness of the manufacturing industry chain has been continuously improved, which is reflected in new breakthroughs in the structural adjustment, cluster development, innovation ability and open cooperation of the manufacturing industry. However, compared with the high-quality development requirements of the manufacturing industry, the development of Henan's manufacturing industry is still faced with the impact of traditional development concepts, weak competitiveness of green development, relatively lagging quality brand construction, poor industrial ecological environment and low information level. Chengwen (2019), a researcher at Tianjin Academy of Social Sciences, analyzed and found that the influencing mechanisms of the industrial chain resilience of Tianjin's advanced manufacturing industry include the low level of independent innovation, the lack of supporting producer services, the low density of industry-university-research connections, the low degree of coordination between Beijing, Tianjin and Hebei, and the shortage of middle and high-end talents, etc. These deficiencies have seriously restricted the improvement of the industrial chain resilience of Tianjin's advanced manufacturing industry. Lv Tie and Liu Dan (2019) concluded that in the past 40

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years of reform and opening up, China's manufacturing industry has developed with great scale advantages, while its labor productivity has continued to grow and technological innovation has achieved remarkable results. However, China's manufacturing industry has not yet formed a comparative advantage in technology, lack of core competitiveness in the international market, lack of innovation ability, and is at a disadvantage in the global industrial technology innovation pattern. Moreover, from the perspective of the input-output efficiency of key elements, the gap between China's manufacturing industry and global manufacturing powers such as the United States, Japan and Germany is still obvious.

Zhang Caixia (2016) analyzed and found that (1) the added value of China's manufacturing industry accounted for 30% of the regional GDP.[4] China has entered the stage of steady and slightly negative economic growth, and the manufacturing industry is gradually slowing down and is in the stage of steady rise. From the point of view of the scale of investment, the manufacturing industry is still the key factor of economic growth in China. And for the manufacturing industry investment in general and the government stage planning subsidies, it have a great close relationship for them, and from the point of view of the manufacturing industry investment scale, the investment plate does not show a concentrated situation, the manufacturing industry has participated in each industry. (3) There are some problems in the manufacturing industry chain of China, such as the total output value is below the national average level; The industrial structure of the manufacturing industry is lack of rationality, the proportion of agriculture or low-end primary processing industry is high, and the product technology content is low. In the new technology manufacturing industry, the intensity of scientific research and product development is lower than the international average. Therefore, the toughness of the manufacturing industry chain has no competitive advantage in technology, and the toughness of the China manufacturing industry chain deals with competitive disadvantages compared with other countries, so it is urgent to improve the toughness of the manufacturing industry chain. Duan Yu (2017) analyzed the internal resource allocation of the manufacturing industry in China and the development of high-tech industry, and found that the first is the single industrial structure. The top ten industries in China's manufacturing structure are all labor-intensive industries, and capital-intensive industries account for a relatively low proportion in the whole manufacturing industry, which is lower than the international average level. For example, the technology-intensive manufacturing industry represented by general equipment, special equipment, railway ships, electrical machinery and electronics accounted for only 10.6% of the added value; Second, the capacity for independent innovation needs to be strengthened. As one of the new strategic industries, the high-tech industry occupies a relatively small proportion in the manufacturing industry, which is lower than the international average level.

In view of the current situation of the manufacturing industry chain in China and its corresponding problems, this paper puts forward some suggestions to improve the toughness of the manufacturing industry chain from the aspects of expanding industrial clusters, strengthening innovation ability, improving policy soft environment and increasing technology research and development investment. Wen Zhitao (2017) provided the following suggestions: we should expand industrial clusters to form industrial advantages. For example, strengthen scientific and technological research to form core competitiveness, and to adjust the industrial structure and promote the balanced development of the region's manufacturing industry; In this way of the digitized industry, we can achieve industrial chain coordination, and with flexible manufacturing to create new core competitiveness, so as to enhance the toughness of the manufacturing industry chain. Duan Yu (2017), based on the theory of industrial upgrading and quantitative measurement of the toughness of the manufacturing industry chain in China, built an empirical analysis model for the deep integration of double cycles to improve the toughness of the manufacturing industry chain. The paper proposes three policy suggestions to enhance the toughness of the manufacturing industry chain by increasing the intensity of manufacturing technology development, strengthening the construction of independent innovation system and improving the soft environment for manufacturing development. Lv Yongquan (2018) analyzed and found that the current manufacturing industry in China still maintains rapid growth, and the growth rate is slowing down. Growth in the added value of high-tech manufacturing and equipment manufacturing became a bright spot, and new breakthroughs were made in the research and development and production of high-tech products such as new energy vehicles. In this regard, he believes that we should expand the opening up, deepen the reform of the innovation system and mechanism, and inject vitality and impetus to accelerate the innovation and development of the manufacturing industry. We should pay attention to increasing the proportion of capital-intensive products, improve manufacturing quality and efficiency, build well-known domestic and international brands, and improve competitiveness.

In summary, there are few studies on the measurement of the toughness of the manufacturing industry chain at home and abroad, but there are more studies on the toughness of regional industries.

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The enhancement of the toughness of the industrial chain is extremely important for the modernization of the industrial chain, and the high toughness of the industrial chain can enhance the ability of the industrial chain to resist and absorb risks, which is conducive to stable economic development. Therefore, it is of great significance to measure the toughness of the manufacturing industry chain and give a reasonable improvement path for the stable growth of manufacturing output value. The existing research on the measurement of the toughness of the manufacturing industry chain mainly focuses on the study of industrial maintenance, industrial recovery, industrial integration effect, influencing factor analysis and path selection.

As China's economy began to change its development direction in 2017, the research on the measurement of industry chain resilience began to gradually enter the research field of scholars and experts, and the research heat is getting higher and higher. At present, the research on industrial chain resilience measurement has just started, and the overall number of literatures is relatively small. Moreover, the research scope of resilience measurement mostly focuses on regional economic resilience measurement, and there are more studies on urban economic resilience measurement, but few studies on manufacturing industry chain resilience measurement. In addition, the existing scholars' research on the measurement of the toughness of the manufacturing industry chain mostly stays on the discussion of the connotation of the manufacturing industry chain and the construction of the index system, and few scholars have conducted measurement research on the toughness of the manufacturing industry chain. There are few research results on the path selection for improving the toughness of the manufacturing industry chain in China, and there is a lack of action mechanism and policy recommendations on the resilience measurement of the manufacturing industry in the context of the deep integration of "domestic and international cycles". Therefore, the study on the measurement of the toughness of the manufacturing industry chain and its improvement path has important strategic significance for maintaining the steady and healthy economic growth of China.

The Proposal of the Central Committee of the Communist Party of China on Formulating the 14th Five-Year Plan for National Economic and Social Development and the long-term Goals of 2035 clearly points out that we should adhere to the combination of economy and security, make up the short board and forge the long board, do a good job in the supply chain strategy design and precise policies by industry, and form a more innovative, higher added value, safer and more reliable industrial chain supply chain. We will strengthen the manufacturing sector, strengthen resources, technology and equipment support, strengthen international industrial security cooperation, and diversify industrial and supply chains. We can meet the direction of future industrial change by consolidating and improving the competitiveness of the whole industrial chain in the fields of high-speed rail, electric power equipment, new energy, ships, etc, and can build a strategic overall industrial chain from the whole machine products that based on the advantages of industrial scale in some fields. We will improve the distribution of regional industrial chains, guide key links in the industrial chain to stay at home, and strengthen the capacity of the central and western regions and Northeast China to undertake industrial relocation. Subsequently, the People's Daily article "Technological innovation around the industrial chain" pointed out that in some developed countries, trade protectionism is rising and some emergencies, some supply chains may face the risk of disruption. In the face of the pressure brought by the profound and complex changes in the current international situation on the supply chain, it is not only necessary to promote China's industry to the global industrial chain and the value chain to climb to the high-end, but also to overcome the excessive dependence of key technologies in the industrial chain on foreign suppliers, and enhance the supply and supporting capacity of China's industry in the industrial chain. Therefore, it is of great significance to measure the toughness of the manufacturing industry chain and propose ways to improve it.

There are many studies on the economic resilience of cities or regions, but few on the resilience of the manufacturing industry chain. Therefore, the study on the resilience of the manufacturing industry chain can fill the gap in related research fields and has great practical significance. Only when the method of measuring the resilience of the manufacturing industry chain is reliable and effective, can accurate research conclusions be obtained. This paper measures the toughness of the manufacturing industry chain in China under the "double cycle deep integration", and proposes relevant policy suggestions to improve the self-repair ability of the manufacturing industry chain in the face of risks, aiming at the problems such as low added value of products, lack of innovation level, distortion of industrial structure, low technical content of products, and weak industrial agglomeration effect in the development process of the manufacturing industry.In order to maintain the steady growth of manufacturing output value and restore the original stable state before the impact,we can provide policy suggestions for the government to formulate industrial policies.

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From the perspective of literature review, to clarify the gap between backward manufacturing and advanced manufacturing and to promote the resilience of the manufacturing industry chain . the policy environment and practical significance of the double cycle should be provided by explaining the meaning and formation value of the "double cycle". Combined with the current industrial development status of the country, the mechanism of different dimensions of various policies under the "double cycle" to improve the toughness of the manufacturing industry chain is analyzed, and the mutual promotion relationship between the double cycle policy and the toughness of the industrial chain is clarified.

First, we should pay attention to a more coordinated and reasonable industrial structure. For example, we can strengthen the role and efficiency of industrial development, and improve the technical level of the industry, and build a perfect industrial layout system, which can enhance the ability to absorb and resist risks in order to enhance the resilience of the industrial chain. Second, a sound industrial structure system can strengthen the long-term stable development of the economy and provide adequate protection for consumer demand. Then improve the supply quality of products from the supply side to ensure that the quality of products is guaranteed. A perfect industrial layout can improve the vitality of the sector economy, enrich the types of industry sectors in the manufacturing industry, strengthen the guarantee mechanism for the supply of manufacturing talents, and then promote the toughness of the manufacturing industry chain.

3. Model construction and data explanation

3.1. Model construction

This paper uses the entropy weight method and builds an index system to measure the industry chain toughness of the manufacturing industry in 31 provinces, autonomous regions and municipalities from 2009 to 2021. The toughness of the manufacturing industry chain is measured from the dimensions of coping resistance, adaptive resilience, autonomous control and leading competitiveness. Since there are 23 three-level indicators selected to measure the toughness of the manufacturing industry chain, in order to scientifically measure the toughness of the manufacturing production chain, we use the entropy weight method to assign weights to ensure that the measurement results are accurate and reliable.

This paper constructs 10 secondary indexes respectively from economic scale, economic benefits, market players, human capital, industrial contribution, technology absorption, investment environment, scientific and technological innovation input, scientific and technological innovation output, including 23 tertiary indexes. The entropy weight method is used to give scientific and reasonable weights to the three indexes.

3.2. Data description

Since China's manufacturing industry suffered little impact from the global economic crisis after 2009, the availability and integrity of data were considered. The data used in this paper are all from the National Bureau of Statistics, China Statistical Yearbook and China's Economic and Social Big Data research Platform, and select the panel data of 31 provinces, autonomous regions and municipalities in China from 2009 to 2021. Some missing values in the study were obtained from provincial statistical yearbooks or completed by linear interpolation method.

4. The measurement of China's manufacturing industry chain resilience

In the measurement of the resilience of China's manufacturing industry chain, secondary indexes of economic scale and economic benefit are constructed from the dimension of coping resistance; secondary indexes of market players, industrial capital and industrial contribution are constructed from the dimension of adaptation resilience; secondary indexes of technology absorption and investment environment are constructed from the dimension of autonomy control. The leading competitiveness dimension is selected to construct the second-level indicators of scientific research and innovation input and output. Under the 10 second-level indicators, 23 third-level indicators are included to measure the toughness of the manufacturing industry chain, among which there are 20 positive indicators and 3 negative indicators. These indicators with a weight that are more than 5% are provincial GDP (one hundred million yuan), provincial industrial added value (one hundred million

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yuan), provincial general public budget revenue (one hundred million yuan), total profits of industrial enterprises above the scale of manufacturing industry (one hundred million yuan), the number of industrial enterprises above the scale of manufacturing industry, the total assets of industrial enterprises above the scale of manufacturing industry (one hundred million yuan), the number of urban units in manufacturing industry (ten thousand people), and outside the provinces Number of commercial investment enterprises, total import and export trade of units in each province (thousands of US dollars), number of patents granted to industrial enterprises above manufacturing scale, full-time equivalent of R&D personnel of industrial enterprises above manufacturing scale, number of new product projects of industrial enterprises above manufacturing scale. The entropy weight method was used to determine the weight of each three-level index, and then the toughness level of the manufacturing industry chain in 31 provinces, autonomous regions and municipalities in China from 2009 to 2021 was measured.

Through the use of entropy weight method to measure the industrial chain toughness of the manufacturing industry in 31 provinces, autonomous regions and municipalities in China from 2009 to 2021, the following measurement results are obtained:

By comparing the manufacturing industry chain resilience of 31 provinces, autonomous regions and municipalities in China from 2009 to 2021, we found that the resilience level of the manufacturing industry chain in each province has increased over time. In addition, we found that the GDP of each province is one of the core factors affecting the resilience of the manufacturing industry chain, and the GDP of each province has a promoting effect on the resilience of the manufacturing industry chain. With the gradual growth of the GDP of the province, the resilience of the manufacturing industry chain is also enhanced, mainly because the GDP is the embodiment of economic strength. The higher the GDP, the stronger the economic strength of the province, so the province can use more funds to enhance the ability of the manufacturing industry to withstand shocks in the development process. [5]When the manufacturing industry chain is facing internal and external shocks, if there is sufficient financial support, all links of the industry chain can operate stably to ensure the continuous chain of the industry chain, thus improving the toughness of the manufacturing industry chain.[6]

From 2009 to 2021, the toughness of the manufacturing industry chain in China's provinces is constantly improving, but the toughness of the manufacturing industry chain in 2020 has declined to different degrees in all provinces. For example, represented by Beijing, the toughness of the manufacturing industry chain in Beijing in 2019 was 0.2516, and the toughness of the manufacturing industry chain in 2020 was reduced to 0.2433. The decline reached 3.3 per cent. This is because the COVID-19 epidemic has caused an irreversible impact on China's economy, and the manufacturing industry has also been affected by the unprecedented impact of the epidemic. The impact has reduced or stalled the production capacity of industrial enterprises above the scale of the manufacturing industry, and cut off the supply of manufacturing products, resulting in the disruption of the manufacturing industry chain. The impact of the COVID-19 epidemic has led to the disruption of the manufacturing industry chain, and the direct consequence of the disruption is to inhibit the improvement of the resilience of the manufacturing industry chain. This shows that the COVID-19 epidemic not only has irreversible harm to China's overall economy and even the world economy, but also has a huge impact on the manufacturing industry chain. Therefore, during this period, China has proposed policies and measures to deeply integrate domestic and international double cycles, and stimulate domestic demand to drive product supply when external demand is insufficient, so as to stabilize the basic economic market. To promote the balance between the total supply and total demand of manufacturing industry products and so as to achieve the purpose of stabilizing the economy,we should provide excellent environment for manufacturing industry.

From the perspective of China's eastern and western regions, the industrial chain toughness of the manufacturing industry in the eastern region is the strongest, mainly represented by Guangdong, Jiangsu and Zhejiang. The industrial chain toughness of the manufacturing industry in Guangdong, Jiangsu and Zhejiang in 2021 is 0.9114, 0.6939 and 0.5716, which are higher than other domestic provinces in the same period. This is mainly because these provinces in the eastern region have geographical advantages, their export trade demand is large, and foreign investors will choose these developed provinces for investment, with the growth of foreign investment will introduce advanced technologies, these technologies can greatly improve the production efficiency of the manufacturing industry chain, so as to promote the resilience of the province's manufacturing industry chain. [7]Compared with the eastern region, there is still a big gap in the toughness level of the manufacturing industry chain in the central region. The toughness of the manufacturing industry chain in Anhui, Jiangxi and Hubei in the central region is 0.2549, 0.2148 and 0.2602, respectively. The low toughness level is mainly due to the fact that the central region does not have the convenient trade conditions of

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the eastern region, and the small number of ports restricts the export supply. In addition, the gap between the economic strength of the central region and the eastern region is obvious, so there will be insufficient financial support for the manufacturing industry, and the manufacturing industry lacks financial support will cause the chain to break, thereby reducing the toughness of the manufacturing industry chain; Compared with the eastern region and the central region, the toughness of the manufacturing industry chain in the western region is the lowest. In 2021, the provinces with the lowest toughness of the manufacturing industry chain are Tibet, Qinghai and Ningxia, and their toughness is 0.0696, 0.069 and 0.0913, respectively. Therefore, the gap between the toughness of the manufacturing industry chain in the western region and the eastern region is the largest. This is because the western region's economic foundation is weak, economic strength needs to be improved, infrastructure is not perfect, and the development of the manufacturing industry is weak. [8]The western region lacks leading industries mainly based on manufacturing, and the transaction cost in the western region is high, and the transportation cost increases the transaction cost. The lack of investment in innovation research and development in the western region leads to the shortage of talents and therefore the shortage of human capital, which will cause the lack of innovation support in the manufacturing industry, thus limiting the improvement of production efficiency in the manufacturing industry.

From the perspective of time and space, the resilience of the manufacturing industry chain in all provinces in China is increasing year by year, but the resilience of the manufacturing industry chain is decreasing under the impact of the epidemic in 2020, and the resilience of the manufacturing industry chain in China will recover to a certain extent in 2021.[9] First of all, from the perspective of influencing factors, innovation research and development investment and expenditure are the core influencing factors affecting the toughness of the manufacturing industry chain. With the improvement of innovation and research and development investment of industrial enterprises above the manufacturing scale, the toughness of the manufacturing industry chain will also be improved accordingly. Therefore, enhancing the innovation strength of the manufacturing industry and increasing the investment in innovation and research and development of the manufacturing industry are of great significance for improving the toughness of the manufacturing industry chain. Secondly, the GDP of the provinces is also the core influencing factor of the resilience of the manufacturing industry chain, the higher the GDP means that the economic strength of the province is stronger, so that more funds can be invested in the construction of the manufacturing industry, the manufacturing infrastructure is gradually improved, the financial strength is stronger, the stable operation of the industrial chain can be fully guaranteed, so as to enhance the resilience of the manufacturing industry chain. Finally, the manufacturing industry chain in the eastern region has strong resilience and great potential for improvement. The resilience of the manufacturing industry chain in the western region is insufficient, and there is still a long way to go to improve the resilience of the manufacturing industry chain. Although the toughness of the manufacturing industry chain in the central region is higher than that in the western region, it is still at a low level.

5. Conclusion and enlightenment

This paper uses the entropy weight method to measure the industrial chain resilience of the manufacturing industry in 31 provinces, autonomous regions and municipalities directly under the Central Government from 2009 to 2021, and provides policy suggestions for the development of China's manufacturing industry. It also analyzes the industrial chain resilience of the manufacturing industry in each province from the perspective of time dimension and space dimension, and draws the following conclusions: First of all, from 2009 to 2021, the resilience of the manufacturing industry chain in all provinces in China was on the rise, but the resilience of the manufacturing industry chain declined under the impact of the novel coronavirus epidemic in 2020. In 2021, the manufacturing capacity of provinces was further restored due to the adjustment of national policies. Secondly, comparing the toughness of the manufacturing industry chain in the eastern and central regions of China, it is found that the toughness of the manufacturing industry chain in the eastern region of China is the highest, followed by the central region, and the western region is the lowest. In addition, there is a big gap between the eastern region and the central and western region in the toughness of the manufacturing industry chain. The central and western region needs to learn from the experience of the eastern region in the development of manufacturing industry, so as to strengthen its own manufacturing industry development and improve the toughness of its manufacturing industry chain. Finally, the improvement of the toughness of the manufacturing industry chain for China's provinces is the embodiment of their own manufacturing strength, but the development of the manufacturing industry in addition to the accumulation of the quantity of output value, but also need to make efforts at the quality

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level to ensure that the products produced by the manufacturing industry contain more technology accumulation and capital content.

With the further implementation of the policy of stabilizing the chain and strengthening the chain in the manufacturing industry, China has become the only country in the world with the ability to produce products of all industrial categories. In the process of continuous development of manufacturing industry, ensuring the balanced development of China's overall manufacturing industry, narrowing the development gap of regional manufacturing industry, ensuring the production quality of manufacturing products has become the key to the manufacturing industry to cope with the crisis, dissolve risks and achieve restoration and renewal. The balanced development of manufacturing industry in all provinces will provide the most powerful guarantee for China's manufacturing industry to prevent and resolve the crisis, resist the risk and cope with the impact of the epidemic. Based on the above conclusions, this paper puts forward the following policy suggestions for the development of China's manufacturing industry:

5.1. Promoting the deep integration of China's double cycles

Under the impact of the novel coronavirus epidemic, China's proposed policy of deep integration of domestic and international double cycles based on the domestic cycle has become a strong guarantee for the long-term development of China's manufacturing industry. We can establish internal circulation system to stimulate the demand for domestic manufacturing products, so as to maintain the stable growth of domestic consumption level, and we can establish external circulation system to stimulate foreign demand. After ensuring that the internal demand is fully met, we can establish the external circulation system to stimulate the growth of manufacturing export trade, and to achieve the effective allocation of manufacturing commodity resources. To ensure that the deep mutual integration of the double cycle is effectively implemented, the economic growth potential of China's manufacturing industry is effectively released, so as to prepare sufficient conditions for the resilience of the manufacturing industry chain.

5.2. Narrowing the regional manufacturing industry chain resilience gap

From the inter-provincial level, the toughness of China's overall manufacturing industry chain is constantly increasing. However, in terms of regions, the toughness of the manufacturing industry chain in the eastern region of China is significantly stronger than that in the western region. The main reason for the gap lies in the lack of perfect manufacturing investment conditions in the western region and insufficient investment in R&D and innovation in the manufacturing industry. Therefore, the manufacturing industry in the western region needs to increase investment in manufacturing infrastructure and increase R&D and innovation investment in the manufacturing industry, so as to lay the foundation for the development of the manufacturing industry in the western region. On the other hand, the manufacturing industry in the western region needs to develop new product projects and encourage mass entrepreneurship and innovation. Thus, the toughness gap between the manufacturing industry chain in the eastern region and the central and western region is narrowed, and the toughness of the manufacturing industry chain is promoted by enhancing innovation strength.

5.3. Focus on improving the quality of manufacturing products

The manufacturing industry should obtain long-term development and maintain its ability to cope with crises and resist risks. Then manufacturing products in the output of the continuous growth at the same time also need to ensure the improvement of their own quality. First, the manufacturing industry needs to actively introduce foreign capital, foreign capital will bring advanced production technology and management experience, so as to help the manufacturing industry use capital to improve production technology to improve production efficiency. Second, manufacturing enterprises learn from the management experience of foreign enterprises, optimize the enterprise management organization, and reduce the cost of internal communication. Third, manufacturing enterprises need to be more independent in the production process, which helps stimulate the innovation vitality of enterprises, and then produce more high value-added products. By introducing foreign capital, optimizing management and emphasizing autonomy, the manufacturing industry can effectively improve its ability to resist risks when facing crises, and thus enhance the resilience of the manufacturing industry chain.

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