ISSN 2616-5902 Vol. 6, Issue 7: 68-76, DOI: 10.25236/AJBM.2024.060710

Research on Measuring the Resilience of China's Manufacturing Industry Chain and Regional Differences

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Abstract: *Industry chain resilience is an important content to improve the modernization level of industry chain and build a modernized industrial system. The article constructs a comprehensive indicator system from four dimensions: resistance, recovery, integration, and transformation capabilities of the manufacturing industry chain, adopts entropy value method to measure the manufacturing industry chain resilience level of China's 29 provinces from 2012 to 2022, and analyzes China's regional difference characteristics by using Dagum Gini coefficient method. The results of the study show that: overall resilience of China's manufacturing industry chain is steadily increasing, but the resilience level of the manufacturing industry chain in various regions is not high; there is a non-equilibrium in the development of the industry chain in the three regions, and the industry chain resilience level as a whole shows the spatial pattern of "east high and west low"; According to the contribution rate results, inter-regional differences are the main source of the gap in the resilience level of the manufacturing industry chain, and the regional differences have a tendency to expand slowly. This paper enriches the research on the empirical level of industry chain resilience and provides reference for the modernization of China's industry chain and the safe and stable development of the industry chain.*

Keywords: *manufacturing industry chain resilience; industry chain security; regional differences*

1. Introduction

As the world's largest manufacturing power, China has a complete industrial system, and its achievements in the development of manufacturing industry are beyond doubt, but the development of "quality" is an important guarantee to ensure the safety and sustainability of the manufacturing industry chain. Many events have exposed China's shortcomings in the construction of industrial chain for a long time, such as weak basic manufacturing capacity, key technologies are controlled by others, and low industrial added value restrict the operation of China's industrial chain. At present, the world is undergoing profound changes unseen in a century, the global division of labor mode has been deeply adjusted, and the manufacturing industry chain has presented a development trend of localization and short chain.In the 20th report, higher requirements have been put forward for the security and stable development of China's industrial chain and supply chain, which provides a guiding direction for the in-depth research on the resilience of China's manufacturing industry chain.

The idea of industrial chain originated in foreign countries, which can be traced back to Adam Smith's statement that "industrial production is a series of circuitous chains based on division of labor", and Hirschman (1991) discussed the industrial chain formed by division of labor and collaboration in economic activities from the perspective of industrial association in his book Economic Development Strategy, but no clear definition of the term "industrial chain" was given at this time. In the 1980s, domestic scholars put forward the concept of "industry chain" for the first time, and it is generally believed that industry chain is a kind of complex chain relationship between various industrial sectors, which reflects the relationship between industries and is the most important factor in the development of the industry chain. It is an important part of the construction of modernized industrial system.

The word "resilience" originates from the Latin word "Resilire", which began as a basic concept in physics, meaning the speed with which a system recovers to its pre-disturbance state, and was later introduced into the realm of economics. In the field of economics, resilience is used to portray the ability of an economic system to withstand external shocks, adapt to new changes, and rapidly adjust

ISSN 2616-5902 Vol. 6, Issue 7: 68-76, DOI: 10.25236/AJBM.2024.060710

and realize the state change[1]-[3].Most of the literature on industry chain resilience draws on the research content of economic resilience, which is considered to be an extension and refinement of economic resilience, and is also regarded as an important characterization of industry chain modernization. Martin, after systematically summarizing the relevant literature, defines the connotation of economic resilience as the four research dimensions of resilience to shocks, resilience to recover after shocks, adaptive capacity to reintegrate resources, and the creative capacity to open new paths[4]. Based on the description of resilience characteristics in Martin and other related studies, Tao[5]believes that industry chain resilience is the ability of the industry chain to adjust and recover to the normal state or even reach a more desirable state of the affiliation of its market entities after suffering from the impact of potential risks and uncertainties in the market.Based on relevant literature research and in connection with the main tasks and actual development of the safe and stable development of the industrial chain and supply chain, this paper defines the resilience of the industrial chain as the ability of the upstream and downstream of the industrial chain to maintain their own stability, prevent the chain from breaking, quickly integrate resources to restore the original equilibrium, and realize the chain strengthening and upgrading through internal renewal. The enhancement of industry chain resilience can be specifically manifested in four aspects: (1) the ability to "stabilize the chain" when subjected to internal and external disturbances,that is,the ability to resist and stabilize;(2) The ability to make up for the "broken chain" and incomplete chain after the impact, and restore the industry chain to a balanced state; (3) The ability to break the "path dependence" and quickly integrate resources to achieve the "extended chain", vertical extension to enhance the added value of the industrial chain, horizontal extension to achieve the diversification of supply and demand, and promote the in-depth expansion of the industrial chain; (4) The "strong chain" ability to discover new paths and realize dynamic evolution, which is manifested in the enhancement of innovation capacity and the transformation and upgrading of the industrial chain. On this basis, a comprehensive indicator system for the resilience of the manufacturing industry chain is established.

The dynamic character of industry chain resilience is its important inherent attribute: that is, the formation and enhancement of industry chain resilience is a dynamic evolutionary process. The "dynamic capability" of the industry chain promotes enterprises to continuously establish and update resources through the ability to perceive opportunities, control opportunities and reconfigure changes, so as to quickly respond to changes in the external environment[6-7],The dynamic character of industry chain resilience determines the significance of industry chain resilience tracking and assessment. In terms of the measurement of the industrial chain, there are two main methods for measuring the resilience of the industrial chain, namely, single-indicator measurement and multi-indicator measurement. The single-indicator analysis method mainly examines the degree of response of the industrial chain by analyzing the gap between the actual value and the trend value of a core variable, using the input-output model[8-9]or the industrial diversification index[10-11]and other related indexes to refer to it.Briguglio[12]pioneered the idea that multiple economic indicators can be selected to construct an evaluation system to measure adaptive resilience. On this basis, Martin et al.[13]comprehensively analyzed economic resilience from four aspects: resistance, resilience, adaptability and renewal. In addition to the above two methods, there are also scholars who measure industry chain resilience by calculating the value added of the industry chain in each region through theoretical models[14].

Throughout the existing relevant research of domestic and foreign scholars, they mainly focuses on the theoretical research of the definition of the connotation, the analysis of the internal characteristics and the improvement path of the resilience of the industrial chain, but lacks the tracking evaluation of the resilience of the industrial chain, and the empirical research is relatively scarce. Under the background of urgently improving the resilience and safety level of China's industrial chain, it is necessary to have a comprehensive understanding of the resilience level of China's manufacturing industry chain in all regions.Based on this, the marginal contribution of this paper lies in: firstly, fully considering the "dynamic capacity" of the industrial chain, interpreting the connotation and attributes of industrial chain resilience based on the economic resilience theory and the essential requirements of industrial chain modernization, and constructing the industrial chain resilience evaluation index system from the four dimensions of resisting, recovering, integrating and transforming ability. Secondly, most of the manufacturing industry chain resilience still remains at the level of theoretical inquiry, and there are fewer empirical studies that can be drawn on, and this paper's measurement of the level of manufacturing industry chain resilience makes up for the lack of industry chain resilience at the empirical level; thirdly, it examines the regional differences in the characteristics of the resilience of the manufacturing industry chain, and it provides realistic guidance for the local government to grasp the new opportunities in the digital economy, and to safeguard the industrial chain's security and sustainable development.

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2. Research design

2.1. Research methodology

2.1.1. Entropy method

The entropy method is an objective assignment method, which determines the weights of the indicators based on the amount of information reflected in the degree of dispersion between the indicators, and can reduce the measurement error caused by subjective factors. Therefore, this paper uses the entropy method to measure the weights of the indicators to further measure the resilience level of the manufacturing industry chain.

2.1.2. Dagum Gini coefficient

In this paper, the Dagum Gini coefficient and its decomposition by subgroups are used to further examine the extent and sources of spatial differences in the resilience level of China's manufacturing industry chain. The overall Gini coefficient is calculated as follows:

$$G = \frac{\sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_k}|MIR_{ji} - MIR_{hr}|}{2n^2\overline{MIR}} \tag{1}$$

where G denotes the Gini coefficient, n denotes the number of provinces, k denotes the number of subregions, n_j and n_k denote the number of provinces in region j and region h, respectively, and MIR_{ji} and MIR_{hr} denote the resilience level of the manufacturing industry chain for province i in region j and province r in region h, $\overline{M}IR$ represents the average value of the resilience level of China's manufacturing industry chain. The overall Gini coefficient G can also be decomposed into three parts according to the region, namely, the intra-regional Gini coefficient (G_w), the inter-regional Gini coefficient (G_{nb}) and the hypervariable density (G_t), to measure the influence of intra-regional difference, inter-regional difference and inter-regional overlap respectively. The specific decomposition process is as follows:

$$G_{jj} = \frac{\sum_{i=1}^{j}\sum_{r=1}^{j}|MIR_{ji} - MIR_{jr}|}{2n_j^2\overline{MIR_j}} \tag{2}$$

$$G_w = \sum_{j=1}^{k} G_{jj} p_j s_j \tag{3}$$

$$G_{jh} = \frac{\sum_{i=1}^{n_j}\sum_{r=1}^{n_k}|MIR_{ji} - MIR_{hr}|}{n_j n_h (MIR_j = MIR_h)} \tag{4}$$

$$d_{jh} = \int_0^{\infty} dF_j(MIR)\int_0^{MIR}(MIR - x)dF_h(x) \tag{5}$$

$$p_{jh} = \int_0^{\infty} dF_h(MIR)\int_0^{MIR}(MIR - x)dF_j(x) \tag{6}$$

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \tag{7}$$

$$G_{nb} = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j) D_{jh} \tag{8}$$

$$Gt = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j)(1 - D_{jh}) \tag{9}$$

Where $p_j=n_j/n$ represents the proportion of the number of provinces in region j, n_j in the total sample n, and $s_j=(n_j MIR_j/nMIR)$ represents the proportion of the resilience level of the manufacturing industry chain in region j in the comprehensive level of all provinces in the sample. F_j is the cumulative probability density function of the resilience level of the industrial chain in region j, d_{jh} represents the

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difference in the resilience level of the industrial chain between regions, and p_{jh} represents the first moment of hypervariation.

2.2. Construction of the indicator system

In constructing the index system for measuring the resilience of the manufacturing industry chain, this paper mainly follows the principles of comprehensiveness, systemicity and comparability, and constructs a comprehensive evaluation system for the resilience of the manufacturing industry chain from the four dimensions of the industry chain's ability to resist, recover, integrate and transform Table 1.

Industry chain resistance(MIR_Def).The resistance of the industry chain mainly refers to the resistance ability of the industry chain to cope with disturbances, and the resistance ability to cope with shocks is mainly affected by the development of the industry chain itself, such as the completeness of the chain, the industrial structure, the capacity of the industrial base, the scale of the industry and the ability to allocate resources[15].This paper selects the industry chain size and industry chain structure to measure the industry chain resistance ability, the larger the manufacturing industry chain size, the smaller the impact of the impact, and industrial structure upgrading is the inevitable requirement of industrial high-quality development.

Industry chain recuperative capacity(MIR_Rec).The recovery capacity of the industrial chain mainly refers to the ability of the industrial chain to adapt to changes and maintain the stable operation of the industrial chain in response to the impact of shocks and disturbances. The integration of innovative elements is an important factor influencing the "chain mending" of the industrial chain, and technological innovation helps to realize the breakthrough of core technology and the weakening of external dependence, so as to guarantee the safety of the industrial chain. This paper examines industrial chain innovation from two dimensions of innovation input and and innovation output, and the efficiency of industrial chain development is chosen to be measured by the growth rate of total profit in manufacturing industry and labor productivity in manufacturing industry, which indicates the speed and efficiency of the industrial chain in the recovery process.

Industry Chain Integration Capability(MIR_Int).The re-adaptation of the industrial chain to the new external environment after the impact needs to rely on the reconfiguration of resources in the economic system, to improve the control of core technologies and the control of resources, and the stronger the autonomy and control of the industrial chain, the more it will have the right of international discourse in the industrial chain as well as the role of leadership, and the higher the resilience level of the industrial chain.In this paper, three secondary indicators of industry chain digital application, industry chain resource allocation and industry chain autonomy and controllability are selected to portray the industry chain integration ability.

Industry chain transformation capability(MIR_Tra).By updating the operation mode and reconstructing its internal structure and functions, the industrial chain can realize the transformation and upgrading of the industrial chain, get rid of the "path lock" and open up the "strong chain" ability of new development paths. The industrial chain has the characteristics of digitalization, intelligence and green in the direction of transformation and upgrading. Strengthening the chain is to improve the leading power of the industrial chain and vigorously improve the leading of digitalization and high-end industries[16].On the other hand, and the service-oriented transformation of the manufacturing industry can, to a certain extent, enhance the position of the value chain[17]. This paper indicates the transformation capability of the industry chain from four dimensions: greening, high-end, intelligent and service-oriented transformation.

Table 1: Manufacturing industry chain resilience indicator system

Level1 indicators	Secondary indicators	Tertiary indicators	weights
MIR_Def	Scale of the industry chain	Gross manufacturing output	0.040
		Total manufacturing profits	0.023
	industry chain structure	Proportion of main business income of high-tech manufacturing industry in manufacturing industry	0.016
MIR_Rec	Innovative inputs	Expenditures for technology introduction/Industrial R&D expenditures	0.172
		Expenditures for technological	0.032

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		transformation/Industrial R&D expenditures	
		Industrial R&D expenditures/industrial added value	0.017
	Innovation outputs	Revenue from new product sales	0.056
		Technology market turnover	0.076
	Efficiency of industry chain development	Total profit growth rate	0.001
		labor productivity	0.038
MIR_Int	Digital Applications	Enterprise e-commerce turnover	0.013
		Proportion of enterprises with e-commerce transactions	0.058
	Resource allocation	paid-up capital	0.035
		Average number of workers in high-tech manufacturing	0.067
	Autonomous controllability	High-tech manufacturing exports/Gross manufacturing output	0.070
MIR_Tra	Greening the transition	Investment in industrial pollution control	0.033
		Number of green invention patents	0.060
	Service-oriented transformation	Employment in productive services/Average number of workers employed in manufacturing	0.028
	High-end transformation	Proportion of main business income of electronic information manufacturing industry in manufacturing industry	0.034
		Revenue from sales of new products in high-tech manufacturing	0.084
	Intelligent transformation	Number of industrial robots installed	0.046

2.3. Data sources

Relevant data come from National Bureau of Statistics, International Federation of Robotics Database (IFR), China Research Data Service Platform, China Industry Statistical Yearbook, China Electronic Information Industry Statistical Yearbook, China Science and Technology Statistical Yearbook, China Tertiary Industry Statistical Yearbook, China High-tech Industry Statistical Yearbook, China Statistical Yearbook and relevant years Statistical yearbooks issued by the provincial (municipal) Bureau of Statistics. The missing values in the process of data collection and collation were made up by the mean value method and linear interpolation method.

3. Analysis of empirical results

3.1. Analysis of the results of resilience level of manufacturing industry chain

On the basis of the index system constructed in the previous section, the entropy value method was utilized to measure the manufacturing industry chain resilience level and mean value of 29 provinces in China from 2012 to 2022(results not shown due to space constraints). From the perspective of overall regional development, the manufacturing industry chain resilience of the three major regions of China's east, center and west showed an upward trend in 2012-2022 (see Figure 1), in the eastern region from 0.115 in 2012 to 0.253 in 2022, in the central region from 0.046 in 2012 to 0.146 in 2022, and in the western region from 0.037 in 2011 to 0.088 in 2022, but at the same time, it can be seen that the manufacturing industry chain resilience level in the eastern region is significantly higher than that in the central and western regions, and the regional differences have a tendency to further expand. From the perspective of the provinces, the manufacturing industry chain resilience level is higher in Beijing, Guangdong, Jiangsu, Shandong and other provinces, most of which are concentrated in the eastern region; while distributed in the central and western regions of Heilongjiang, Qinghai, Ningxia, Gansu and other provinces of the manufacturing industry chain resilience level is lower, indicating that China's economic development is unbalanced, inadequate phenomenon in the level of resilience of the manufacturing industry chain in various parts of the country is also reflected in a very obvious.The

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reason for this result may lie in the fact that the economy of the eastern region is more developed, and the development of the manufacturing industry chain has a more solid industrial foundation, with stronger competitiveness in key industries such as high-end equipment manufacturing, new energy, new materials and information technology. And the central and western regions part of the industrial chain is in the low-end, in the process of the eastern industry transfer to undertake the lower efficiency, and thus the impact on the key links of the industrial chain effect is relatively limited.

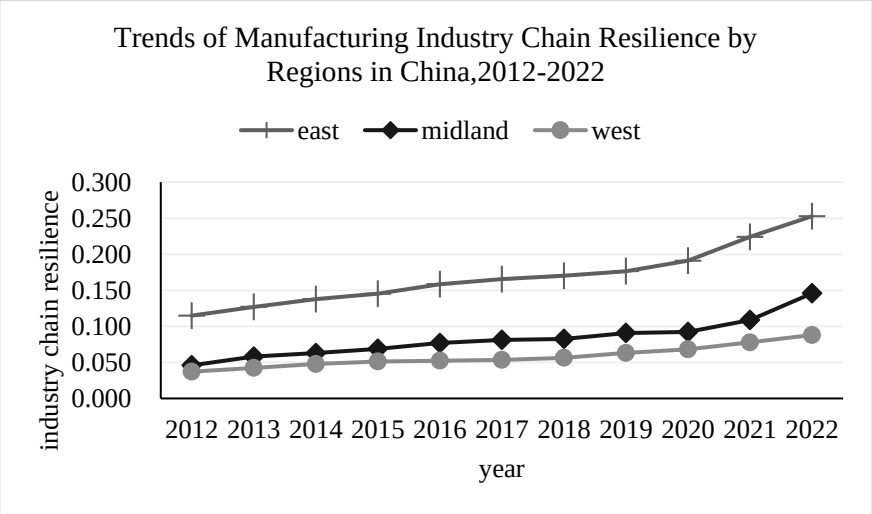

Figure 1 Trends of Manufacturing Industry Chain Resilience by Regions in China,2012-2022

3.2. Characterization of regional differences in the resilience level of the manufacturing industry chain

This paper calculates the overall Gini coefficient (G) and the intra-regional Gini coefficient (G_w), the inter-regional Gini coefficient (G_{nb}), the hypervariance density (G_t), and their respective contribution ratios (the results are shown in Table 2), discusses the characteristics of the national and intra-regional differences and inter-regional differences, and analyzes the sources of regional differences.

From the national overall Gini coefficient point of view, Figure 2 (a) shows the evolution of the overall Gini coefficient of China's manufacturing industry chain resilience level in 2012-2022, the Gini coefficient fluctuates from 0.395 in 2012 to 0.394 in 2022,and the overall gap in the resilience of China's manufacturing industry chain shows a small expansion trend. The overall Gini coefficient in 2014 was 0.378, when the overall gap in the resilience of China's manufacturing industry chain was the smallest. The reason for this change may be that the resilience of China's manufacturing industry chain is still at a low level at the present stage, and the central and western regions are in the digestion stage of undertaking the industrial transfer from the east,which makes the overall development of manufacturing industry chain resilience not stable enough.

In terms of intra-regional differences, Figure 2(b) reports the Gini coefficient differences in the resilience level of the manufacturing industry chain within the three major regions of China. The differences in the resilience level of the manufacturing industry chain in the three major regions are smaller than at the national level, and the eastern region has the largest difference in the resilience level of the manufacturing industry chain,and showing a small upward trend; the Gini coefficient of the central region has generally shown a fluctuating downward trend, which suggests that the differences in the resilience of the manufacturing industry chain among the subregions of the central region have been gradually narrowed, specifically the Gini coefficient of the central region experienced a more substantial decline in 2018-2019, from 0.242 in 2018 to 0.183 in 2019, a decline of 24.38%. The Gini coefficient in the western region shows an upward trend change, the Gini coefficient from 2012 to 2022 increased by 25.78%, and from the upward momentum, the gap in the level of resilience of the manufacturing industry chain between subregions in the western region may continue to expand.

From the perspective of regional differences, Figure 2 (c) describes the gap and evolution trend of the resilience of the manufacturing industry chain among the three regions. It can be seen that the gap between the eastern and western regions is the largest, which is consistent with the resilience results of

ISSN 2616-5902 Vol. 6, Issue 7: 68-76, DOI: 10.25236/AJBM.2024.060710

the manufacturing industry chain calculated above.The gap between the eastern and central regions decreases slightly,and the gap between the central region and the western region is the smallest, but the overall trend is on the rise, and the range of change is the largest, rising from 0.211 in 2012 to 0.334 in 2022, with an increase of 58.3%. In the future, regions will pay more attention to the coordinated development among regions in industrial cooperation, and the role of the central region as a bridge between the eastern and western regions is gradually emerging.

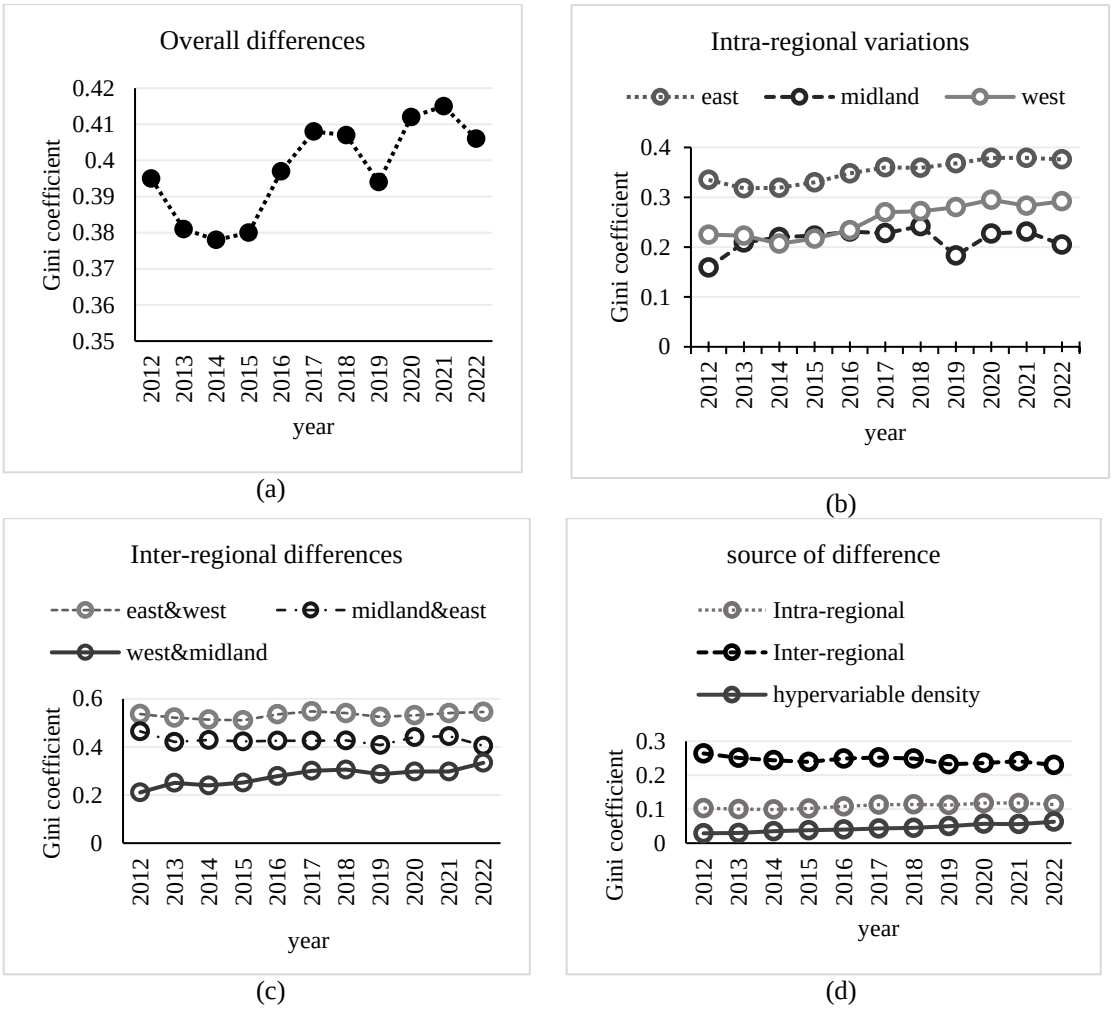

Figure 2 Dagum Gini coefficient decomposition and regional differences in China's manufacturing industry chain resilience level

To deeply analyze the source of regional differences, the intra-regional Gini coefficient (G_w) in Table 2 indicates the internal differences of each regio, the inter-regional Gini coefficient (G_{nb}) indicates the inter-regional differences of each region, and the hypervariable density (G_t) indicates the residual Gini coefficient of the cross-impact of inter-regional manufacturing industry chain resilience. As can be seen from Figure 2(d) the inter-regional Gini coefficient is always higher than the intra-regional and hypervariable density Gini coefficients in the observation period, and the proportion of inter-regional differences in the differences in the level of resilience of China's manufacturing industry chain is as high as about 65%, which shows that the inter-regional differences are the direct source of the differences in the resilience of the manufacturing industry chain in China. Promoting the synergistic improvement of the resilience level of the industrial chain between regions and narrowing the overall gap between regions is the key to improving the resilience and security of China's industrial chain.

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Table 2:Dagum Gini coefficient and contribution rate results

year	G	G_w		G_{nb}		G_t	
		coefficient	contribution	coefficient	contribution	coefficient	contribution
2012	0.395	0.103	25.968%	0.264	66.799%	0.029	7.233%
2013	0.381	0.100	26.208%	0.251	65.966%	0.030	7.826%
2014	0.378	0.099	26.243%	0.244	64.568%	0.035	9.189%
2015	0.380	0.102	26.924%	0.239	62.962%	0.038	10.114%
2016	0.397	0.108	27.216%	0.249	62.701%	0.040	10.083%
2017	0.408	0.113	27.696%	0.252	61.739%	0.043	10.565%
2018	0.407	0.114	27.870%	0.249	60.994%	0.045	11.136%
2019	0.394	0.112	28.384%	0.232	58.949%	0.050	12.666%
2020	0.412	0.118	28.753%	0.236	57.368%	0.057	13.879%
2021	0.415	0.118	28.414%	0.241	58.009%	0.056	13.577%
2022	0.406	0.114	28.099%	0.230	56.507%	0.063	15.395%

4. Conclusions and implications

This paper summarizes the existing research, defines the basic connotation of industry chain resilience andthe specific performance of resilience enhancement, constructs a comprehensive evaluation index system of manufacturing industry chain resilience from the four dimensions of industry chain resistance, recovery, integration and transformation ability, measures the manufacturing industry chain resilience level of China's 29 provinces in 2012-2022 through entropy value method, and further Using the Dagum Gini coefficient method, the study explores the regional difference characteristics and dynamic evolution of the resilience level of the manufacturing industry chain in the whole country as well as in the three major regions of east, central and west. Thestudy found that: first, the manufacturing industry chain resilience level in each region of China is not high, but the overall trend is steadily increasing, with the eastern region relatively high, followed by the central region, while the western region is low. Secondly, there is an imbalance in the development of the industry chain in the three major regions, and the industry chain resilience level in the eastern region is significantly higher than that in the central and western regions, showing an overall spatial pattern of "high in the east and lowin the west"; the differences between the eastern and western regions have a tendency to gradually expand, and the gap between the manufacturing industry chain resilience of the central region and the sub-regions has adownward momentum. Thirdly, according to the contribution rate results, the regional manufacturing industry chain resilience has been reduced. Third, according to the contribution rate results, interregional differences are the main source of the gap in the level of manufacturing industry chain resilience, of which the gap betweenthe eastern and western regions is the largest, and the gap between the regions will slowly expand during the process of transformation and upgrading of the manufacturing industry.

Based on the above conclusions, the following suggestions are made to effectively enhance the resilience of China's manufacturing industry chain: First, we should increase the construction of new digital infrastructuresuch as 5G network base stations, big data centers, industrial Internet, etc., to consolidate the development foundation of the manufacturing industry chain and the underlying support; second, we should push forward the deep integration of the industrial chain innovation chain and talent chain, focus on the cultivation of the awareness of independent innovation, accelerate scientific research of key technologies, integrate innovative forces to break through technological blockades, and enhance the independent control ability. The integration of innovation force constantly break through the technical blockade, and enhance the independent and controllable ability of the manufacturing industry chain; Thirdly, we should improve the level of digital governance, build a firm digital security barrier, and focus on improving the relevant laws and regulations in the field of digital in the era of big data, and preventing and reducing the risk of network security for the industry chain development; Fourthly, fully recognize and pay attention to the current stage of China's manufacturing industry chain resilience of the existence of non-equilibrium, focusing on the three major inter-regional

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industry chain convergence, transformation and synergistic development, and constantly reduce the level of inter-regional industry chain resilience gap, to achieve a balanced development of the manufacturing industry chain resilience.

Acknowledgements

Fund project: Guangxi Philosophy and Social Sciences Planning Research Project: "Research on the mechanism and realization path of enterprise digital transformation to help Guangxi economic resilience development"(22BJL06)

Project supported by Graduate Student Innovation Program of School of Economics, Guangxi University/China-ASEAN College of Financial Cooperation: "Research on Mechanism, path and Countermeasures of big Data Policy to enhance the Resilience of Manufacturing Industry chain: evidence from the National Big Data Comprehensive Pilot Zone"

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