Vulnerability assessment of Chinese traditional manufacturing enterprises based on PSR model

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Abstract. The more vulnerable an enterprise is, the more likely it is to face a development crisis. This paper, using the PSR framework, designs a "pressure-state-response" vulnerability assessment index system for traditional manufacturing enterprises and analyzes data from 2016 to 2023. Key findings include: (1) Supply chain operation management, particularly customer concentration and accounts receivable turnover, significantly influence enterprise vulnerability. (2) From 2016 to 2021, vulnerability declined, but rebounded from 2021 to 2023, reflecting the delayed and persistent impact of crises like the pandemic. (3) Regionally, enterprises in Heilongjiang, Jilin, and Qinghai are more vulnerable. Highlighting the need for targeted measures by governments and businesses to reduce vulnerability.

Keywords: Traditional manufacturing enterprises, Vulnerability, PSR Model.

1 Introduction

In today's rapidly changing, complex and uncertain environment, businesses are facing increasing challenges. With the frequent occurrence of "black swan" events (unpredictable but potentially high-impact contingencies) [1] and "gray rhino" events (high-probability and high-impact crises) [2], global economic and social uncertainty has increased significantly. VUCA (Volatility, Uncertainty, Complexity, Ambiguity) has become the norm in today's global economic, social, and political spheres. In this environment, while VUCA status provides businesses with opportunities to innovate, it also exacerbates the risks and vulnerabilities they face [3].

In recent years, while China's traditional manufacturing enterprises has made remarkable achievements, it has also experienced many major shocks. Especially during the COVID-19 pandemic, the global economy contracted sharply, and many companies did not survive the worst of the crisis. A number of major U.S. companies have also gone bankrupt this year. 3B Group, a large North American furniture chain with a history of more than 50 years, and Yellow Company, which was ranked the first in the global transportation industry by Fortune magazine, are facing closure. These cases show that the economic fluctuations under the background of globalization have posed

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a severe test to the manufacturing industry of various countries, and the vulnerability of China's traditional manufacturing enterprises under these shocks has been exposed.

As the pillar industry of the national economy, the traditional manufacturing enterprises is not only the cornerstone of sustainable economic development, but also the embodiment of the country's comprehensive national strength. However, once an emergency occurs, the operation of manufacturing enterprises is vulnerable to significant impact. Different firms show different vulnerabilities to the same shocks. Therefore, identifying and assessing the vulnerability of enterprises is the key for enterprises to cope with sudden shocks and maintain normal operation. Based on the vulnerability theory, this paper establishes the vulnerability assessment system of manufacturing enterprises by constructing the "pressure-state-response" (PSR) model. This paper takes A-share listed traditional manufacturing enterprises from 2016 to 2023 as the research object, analyzes the time change trend and regional differences of their vulnerability, and puts forward corresponding policy recommendations through empirical analysis results.

2 Research Review

Vulnerability refers to the susceptibility of a system or individual to external interference or attack. It was originally introduced by geographer P. Timmerman in the study of natural disasters as an indicator of the extent of adverse reactions when disasters occur [4]. The resilience of a system determines its response to crises, while differences in shock absorption and resilience affect the degree of vulnerability. With the deepening of the understanding of vulnerability of social ecosystem, resilience factors such as shock absorption, self-organization and adaptability to change form vulnerability [5]. Geographers in the former Soviet Union linked ecosystem vulnerability to dynamic function, stability, and reversibility thresholds, showing that a system is stable if it can recover its function after being disturbed, but vulnerability increases if the disturbance causes irreversible changes [6]. As the study of vulnerability expands, it extends beyond the natural and social sciences to become relevant in fields such as finance, computer networks, and social risk management. In the context of enterprises, scholars often regard high debt and weak solvency as indicators of vulnerability, while Chinese scholars, Wen Hua define it as the ability to manage crises, control the scope of crises, and quickly recover operations [7].

In recent years, vulnerability research has been increasingly applied to manufacturing. Zeng and Zhou (2013) and other scholars divided supply chain vulnerability into supply side, demand side and structural vulnerability [8]. Chen (2023) constructed a vulnerability assessment system of machinery manufacturing supply chain based on sensitivity, exposure and adaptability [9]. Wu (2022) and other studies emphasized the impact of economic policy uncertainty and corporate credit on corporate financial vulnerability [10]. Meanwhile, Wang and Huai (2022) investigated the vulnerability of capital from three aspects: physical capital, intellectual capital and social capital [11]. Despite advances in manufacturing vulnerability research, its scope remains limited. The introduction of a "pressure-state-response" (PSR) model to assess the vulnerability

of manufacturing enterprises can more comprehensively identify risks and thus improve resilience in a targeted manner, especially for Chinese manufacturing enterprises.

3 Evaluation System Construction and Measurement

The vulnerability of traditional manufacturing enterprises is rooted in various pressures (such as supply chain dependence, financial risks, operational uncertainties, etc.) they are subjected to in the process of development. What is the state of the business when it comes to meeting these challenges? Can you effectively relieve or improve these stresses? These problems are closely related to the PSR analysis framework commonly adopted by the academic community. PSR framework, or "pressure-state-response" model, was first proposed by Tony [12]. when studying the relationship between stress and response in natural environment. Subsequently, the Organization for Economic Co-operation and Development (OECD) further verified the applicability and effectiveness of this model in ecological environment assessment. Nowadays, PSR model has been widely used in many fields such as social economy due to its extensive index coverage, clear causal chain and dynamic transmission mechanism under the influence of multiple factors.

3.1 Evaluation System Construction

Based on the basic analysis idea of PSR framework, the vulnerability evaluation indicator system of traditional manufacturing enterprises is constructed from three dimensions of pressure, state and response, aiming to reveal the vulnerability of manufacturing enterprises from multiple angles. Among them, stress is the fundamental driving force of vulnerability, state is the carrier of vulnerability, and response represents the ability of enterprises to cope with and deal with vulnerability. Under the combined effect of internal and external pressures, traditional manufacturing enterprises are affected by multiple factors such as supply chain management, asset allocation, risk management and control level, organizational structure, etc., and present specific pressure states in terms of operating efficiency, financial status, innovation ability and profitability. Subsequently, enterprises adopted a series of macro and micro control measures to improve this state, as shown in **Fig. 1**.

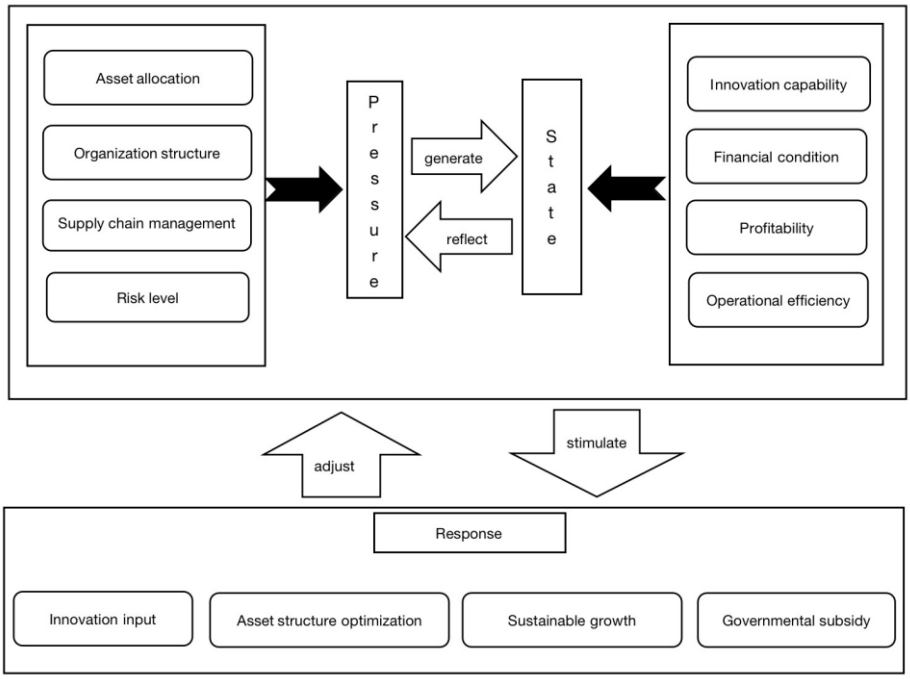

Fig. 1. PSR correlation model of vulnerability of traditional manufacturing enterprises

According to the principle of PSR model and the availability of data, this paper constructs the vulnerability assessment index system of traditional manufacturing enterprises. 24 key indicators are selected to comprehensively reflect the application direction and intensity of the current vulnerability of enterprises in various aspects, as shown in Table 1. Among them, eight pressure indicators show that the vulnerability of traditional manufacturing enterprises comes from endogenous and exogenous risk factors. Nine state indicators reveal the vulnerability of traditional manufacturing enterprises from the aspects of operation, profitability and innovation ability. The seven response indicators reflect the measures and efforts taken by enterprises to reduce vulnerability and improve resilience.

3.1.1 Pressure Indicator

The stress index reflects the internal and external challenges faced by an enterprise during environmental changes or crises. This includes both pressure to increase vulnerability and pressure to reduce it. In traditional manufacturing, supply chain efficiency is crucial. A high concentration of customers or suppliers indicates dependence, and excessive reliance on a single supplier increases vulnerability. Accounts payable turnover days reflect a company's utilization of supplier funds, and longer turnover days can lead to supply chain disruptions. Similarly, longer accounts receivable turnover days indicate slower payment recovery, tightening liquidity and increasing financial pressure.

In terms of asset allocation, the intensity of R&D investment measures the innovation intensity of a company. Insufficient R&D undermines competitiveness, while high R&D spending requires substantial funding. The asset-liability ratio reflects the overall financial stability, and the high debt ratio increases the financing cost and repayment pressure, affecting the viability. Traditional manufacturing relies heavily on fixed assets and requires a large amount of capital expenditure, which adds to the financial burden. Labor intensity is another key factor, as labor-intensive firms are more vulnerable to labor market fluctuations during a crisis.

3.1.2 Status Indicator

State indicators measure a company's current performance under stress, reflecting its health and ability to operate effectively. In manufacturing, operational efficiency is critical. High inventory turnover and current asset turnover indicate better management of assets and resources under stress, reducing vulnerability. These indicators show a company's ability to handle stress and maintain efficiency in the face of external challenges.

Innovation ability is another key factor reflecting the competitiveness of enterprises. The number of patents can be used to measure technological progress, and the higher the number of patents, the greater the innovation capacity and the lower the vulnerability. Financial health can be assessed using the Z-Score model, which measures the risk of bankruptcy. The higher the Z-Score, the better the financial position of the company and the lower the vulnerability. Other financial measures, such as the quick ratio and profitability (as measured by operating income growth and net income growth), reflect a company's liquidity and resilience under uncertain conditions.

3.1.3 Response Indicator

Response metrics assess the steps the company is taking to reduce stress and increase resilience. To enhance the ability of innovation, enterprises need to continuously increase investment in research and development. Indicators such as the number of patent applications, the proportion of R&D personnel, and the growth rate of R&D investment reflect a company's commitment to innovation, thus giving it a competitive advantage. These actions reduce vulnerability and enhance the company's ability to respond to external challenges.

A healthy asset structure is also critical to improving resilience. The growth rate of total assets and fixed assets can indicate the extent to which a company accumulates resources and prepares for long-term sustainability. The continued growth of assets indicates greater resilience and lower vulnerability to future shocks. In addition, macroeconomic interventions such as government subsidies can further support firms, reduce their vulnerability and help them better manage external pressures.

Through the comprehensive evaluation of pressure, state and response, the vulnerability performance of manufacturing enterprises under different pressure environments can be comprehensively analyzed, and the basis for formulating coping strategies can be provided.

Table 1. Vulnerability evaluation indicator system of traditional manufacturing enterprises.

Principle level	Indicator level	Unit	Attribute	Weight
Pressure	Top 5 Customer Concentration (P1)	%	+	0.1119
	Top 5 Supplier Concentration (P2)	%	+	0.0763
	Days of turnover of accounts payable (P3)	day	+	0.1044
	Days of turnover of accounts receivable (P4)	day	+	0.1597
	Asset-liability ratio (P5)	%	+	0.0682
	Employee density (P6)	%	+	0.1115
	R&D investment intensity (P7)	%	-	0.0061
	Capital expenditure ratio (P8)	%	+	0.1405
State	Inventory turnover ratio (S1)	-	-	0.0077
	Current assets turnover ratio (S2)	-	-	0.0102
	Z-Score(S3)	-	-	0.0070
	Quick ratio (S4)	%	-	0.0069
	Inventory ratio (S5)	%	+	0.0960
	Number of patents (S6)	number	-	0.0053
	Revenue growth rate (S7)	%	-	0.0090
	Net profit growth rate (S8)	%	-	0.0090
	Equity balance degree (S9)	-	-	0.0182
Response	Percentage of R&D personnel (P1)	%	-	0.0202
	Number of patent applications (P2)	number	-	0.0065
	R&D investment growth rate (P3)	%	-	0.0037
	Cash and cash equivalents ratio (P4)	%	-	0.0036
	Total assets growth rate (P5)	%	-	0.0082
	Fixed assets growth rate (P6)	%	-	0.0043
	Government subsidies (P7)	yuan	-	0.0054

3.2 Vulnerability Measurement

3.2.1 Make Indicators being Dimensionless.

In order to solve the problem of inconsistencies in the scale dimension of evaluation of indeterminate quantity, the range method is used to standardize the attributes of each indicator.

$$Z_{ij} = (X_{ij} - minX_{ij})/(maxX_{ij} - minX_{ij}) \quad (1)$$

(X_{ij} is a positive indicator)

$$Z_{ij} = (maxX_{ij} - X_{ij})/(maxX_{ij} - minX_{ij}) \quad (2)$$

(X_{ij} is a negative indicator)

In the formula, i is the evaluation enterprise; j is the vulnerability evaluation index of traditional manufacturing enterprises; X_{ij} is the initial value; Z_{ij} is the standardized value.

3.2.2 Determine the Indicator Entropy Weight.

$$P_{ij} = Z_{ij} / \sum_{i=1}^{n} Z_{ij} (0 \le P \le 1) \tag{3}$$

$$e_j = (-\frac{1}{\ln n}) \sum_{i=1}^{n} P_{ij} \ln(P_{ij}) \tag{4}$$

$$d_j = 1 - e \tag{5}$$

$$W_j = d_j \sum_{j=1}^{m} d_j \tag{6}$$

In the formula, P_{ij} is the standardized data ratio, e_j is the information entropy, d_j is the information entropy redundancy, and W_j is the index weight.

3.2.3 Comprehensive Vulnerability Score of Traditional Manufacturing Enterprises.

Objective weighting method is used to measure the comprehensive vulnerability index of traditional manufacturing enterprises, and the weight W_j of each index and the standardized index value VU_i are used to calculate the comprehensive index of the i th enterprise:

$$VU_i = \sum_{j=1}^{n} (W_j Z_{ij}) \tag{7}$$

In the formula, VU_i is the comprehensive vulnerability score of i traditional manufacturing enterprises. The higher the score, the higher the vulnerability.

4 Empirical Analysis

4.1 Data Sources

Considering the availability, consistency and importance of data, this paper takes the traditional manufacturing enterprises listed in A-shares from 2016 to 2023 as the research object for panel data analysis, The sample mainly includes 20 traditional manufacturing industries such as textile industry, furniture manufacturing industry, food manufacturing industry, chemical fiber manufacturing industry, metal products industry, paper and paper products industry. In order to increase the reliability of sample results, the sample data is modified. The following processes are performed: (1) ST and ST* companies are excluded; (2) Eliminate companies with serious data missing and abnormal; (3) Tail reduction of 1% for the beginning and end of continuous variables. After the above operations, a total of 6,597 samples of data from 1079 companies were obtained. The data used in this paper are mainly from the Economic and Financial Research Database CSMAR and WIND, and some missing data are supplemented by querying the annual reports of enterprises.

4.2 Comprehensive Measurement Result

Using standardized data to calculate the weight coefficient of each indicator, the weight results are shown in **Table 1**.

In the dimension of vulnerability measurement of traditional manufacturing enterprises, the weight of pressure index is 0.7786, indicating that the contribution of pressure to enterprise vulnerability accounts for the vast majority. Days of turnover of accounts receivable is an important aspect of enterprise pressure, and the proportion of capital expenditure, customer concentration, asset-liability ratio and days of turnover of accounts payable are also major parts of enterprise pressure. The effect of the other three indicators is relatively weak. In the status dimension, according to the weight of the indicator, inventory is more important to the operation status of the enterprise. In the response dimension, the proportion of R & D personnel is the largest, which reflects that the continuous output of human capital is an effective means to adjust the pressure of enterprises to a certain extent.

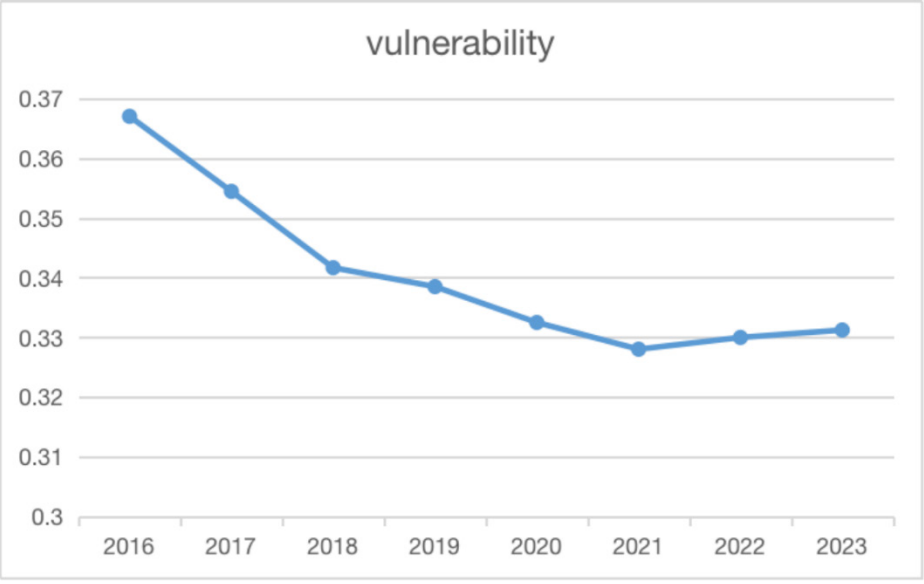

Fig. 2. Trends of vulnerability of traditional manufacturing enterprises from 2016 to 2023.

According to the vulnerability index value of traditional manufacturing enterprises, the change trend of vulnerability of traditional manufacturing enterprises during 2016-2023 (see **Fig. 2**). The analysis shows that the vulnerability of traditional manufacturing enterprises in China declined rapidly from 2016 to 2018, and the vulnerability still declined and the speed slowed down from 2028 to 2021, indicating that the traditional manufacturing industry developed rapidly and the stability of enterprises increased during this period. The increase in the 2021-2023 period is most likely due to the increased vulnerability of enterprises caused by the impact of the pandemic.

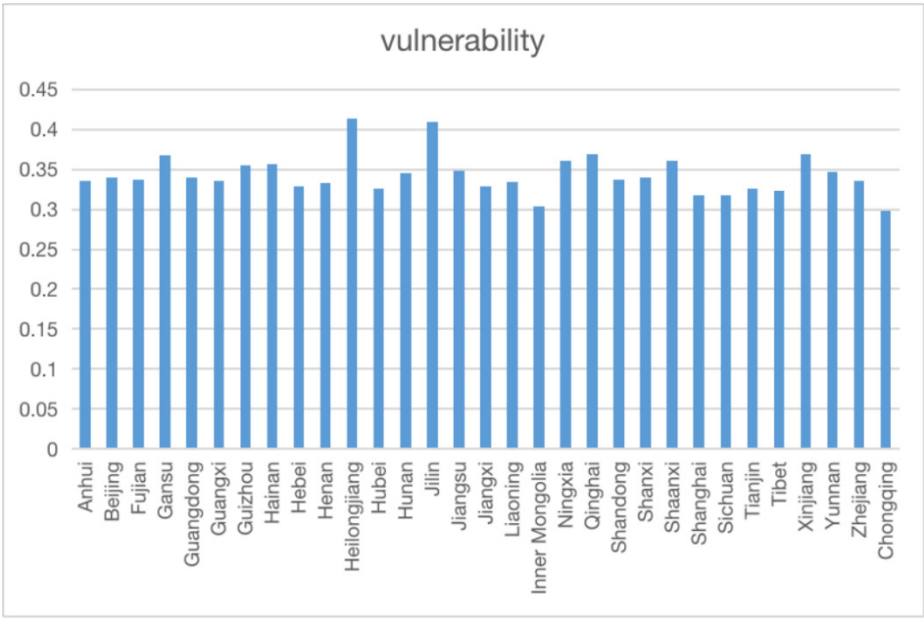

Fig. 3. Industry distribution of vulnerability of traditional manufacturing enterprises.

The vulnerability performance of traditional manufacturing enterprises is further analyzed (see **Fig. 3**). According to the results of regional enterprise vulnerability classification, the traditional manufacturing enterprises in Heilongjiang and Jilin have the highest vulnerability. According to the "protection, governance and sustainable development" strategy put forward by the National Development and Reform Commission, these areas have shortcomings in terms of construction scale and resource utilization, and at the same time, because they are located deep in the inland, they are attracting talents, attracting investment, and undertaking industrial transfer Under extreme restriction. The traditional manufacturing enterprises in Xizang and Chongqing have the lowest vulnerability. On the one hand, due to the rich science and education resources gathered in the cities where they are located, they have significant advantages in policy support, technology accumulation and talent cultivation. On the other hand, affected by location conditions, some of these parks have strong international market development, rapid transformation of innovation results and complete infrastructure, and are easy to generate agglomeration scale effect.

5 Conclusions

According to the above empirical analysis results, it can be seen that the operational efficiency of supply chain greatly affects the vulnerability of traditional manufacturing enterprises. Therefore, in order to reduce the vulnerability of traditional manufacturing enterprises, enterprises need to improve the operational efficiency of supply chain. At the same time, the performance of enterprise vulnerability varies with the change of

year. In addition, different provinces should take different measures to help enterprises improve their vulnerability.

In view of the above results, this paper puts forward the following suggestions:

(1) Improve the efficiency of supply chain management. Optimize the order processing, shipping, invoicing process, accelerate the recognition of accounts receivable, use financial instruments such as factoring to convert accounts into cash flow, shorten turnaround time. Strictly check the credit of customers when offering credit to ensure that they have the ability to repay. At the same time, expand sales channels, maintain customer relations, and reduce the dependence risk caused by customer concentration.

(2) Optimize asset structure and guarantee cash flow. Control debt levels, set reasonable debt targets, and maintain good credit ratings to reduce financing costs. The manufacturing industry needs to rationally arrange capital expenditure, reduce the pressure of one-time expenditure through phased investment or equipment leasing, and ensure the liquidity of working capital. Conduct return on investment analysis, choose projects with high return and short payback period, and avoid low-return investments.

(3) Optimize the talent introduction and training mechanism. Strengthen the construction of R & D team, cooperate with universities and scientific research institutions to attract outstanding talents, improve the salary incentive policy to stimulate innovation vitality. Improve staff skills through internal training and promotion mechanisms to ensure the continuous development of the R&D team.

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