

Identifying and Analyzing Key Factors Influencing Corporate Supply Chain Resilience: A PTOE Framework

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Abstract: This study examines the principal factors associated with corporate supply chain resilience. Using the Management Discussion and Analysis (MD&A) sections of annual reports issued by Chinese A-share listed firms, it extends the technology-organization-environment (TOE) framework by incorporating firms' internal policies and institutional mechanisms, thereby developing a PTOE analytical framework. Terms are first extracted from academic studies, policy documents, industry standards, and professional reports. After contextual validation, they are compiled into a supply chain resilience keyword list. A large language model is then used to identify relevant short sentences in the annual reports and support a two-dimensional analysis. The results show that resilience-related disclosures are concentrated in technological adjustment, responses to external risks, and supply network arrangements. Technological conditions are more often associated with adaptive capacity, whereas the market and supply chain environment is more often associated with resistance capacity; references to recovery capacity are comparatively rare. The study provides a supply chain resilience keyword list and organizes specific determinants into cross-classified cells defined by PTOE factors and the three resilience capacities, producing a structured set of tables for subsequent large-sample text identification and structural analysis.

Keywords: supply chain resilience; PTOE framework; annual report text analysis; large language models

1. Introduction

The global configuration of industrial and supply chains is being reshaped at an accelerating pace. The combined effects of geopolitical conflict, trade controls, unexpected disruptions, and fluctuations in demand have made traditional supply chain management models centered primarily on efficiency increasingly ill-suited to frequent external uncertainty. China has built one of the world's largest supply chain and logistics systems, yet the overall shock resistance of its industrial chains remains under pressure. According to the 14th Five-Year Plan for Modern Logistics Development (General Office of the State Council Document No. 17 [2022]), China's total value of social logistics exceeded RMB 300 trillion in 2020, while the ratio of total social logistics costs to gross domestic product fell to 14.7%. This advantage of scale, however, has not yet been fully converted into an advantage in security and resilience.

In recent years, Chinese firms have faced frequent supply chain risk events involving upstream supply, downstream demand, external shocks, and financial credit. Taken together, these events have further exposed the vulnerability of supply chain networks and the complexity with which risks propagate across them.

On the upstream side, an interruption in the supply of critical materials can directly undermine production continuity. In December 2024, the Bureau of Industry and Security (BIS) of the U.S. Department of Commerce added Wingtech Technology to the Entity List, imposing licensing requirements on its access to items subject to the U.S. Export Administration Regulations. On October 26, 2025, Netherlands-based Nexperia announced that it would stop supplying wafers to its assembly and testing facility in Dongguan, China (ATGD). As the facility is a major part of Nexperia's global

assembly and testing capacity, the suspension increased uncertainty surrounding both the relevant production capacity and downstream deliveries.

On the downstream side, fluctuations in customers' operations can travel backward through the supply chain and create financial pressure for upstream suppliers. Neta Auto, whose parent company is Hozon New Energy Automobile, was reported to owe suppliers more than RMB 6 billion. As of March 2025, the company held approximately RMB 320 million in cash against more than RMB 2 billion in short-term debt. Its suppliers consequently faced the combined strain of difficulty collecting receivables and tightening liquidity.

With respect to external shocks, the transmission of sudden events and regulatory restrictions across supply chain links has become increasingly visible. In October 2024, a fire at the plant of one of Zeekr's tier-two suppliers temporarily affected the supply of components for the Zeekr 7X. Qingdao Topscomm Communication was blacklisted by the State Grid Corporation of China for procurement tenders in all product categories from February 23, 2024, to February 22, 2026. Beginning on July 29, 2024, China Southern Power Grid also imposed a 15-month market-entry ban, limiting the company's ability to obtain new business within the two major power-grid systems. In another example, LONGi Green Energy recorded a net inventory impairment provision of RMB 5.171 billion in 2023, reflecting falling product prices, technological change, and the prolonged detention of certain components at ports as a result of U.S. policies.

At the level of financial credit, liquidity risks at focal firms show a tendency to spread along the chain. As of December 24, 2025, the combined overdue borrowings from financial institutions and overdue commercial acceptance bills of CCS Supply Chain Management and its subsidiaries totaled approximately RMB 2.001 billion. On February 23, 2025, Eternal Asia announced that Shanwei Investment Holding Co., Ltd. had filed a lawsuit against it over a contractual dispute involving approximately RMB 882 million. A case in which Wuxi Weifu International Trade, a wholly owned subsidiary of Weifu High-Technology Group, allegedly fell victim to contract fraud was formally accepted for investigation by the Xinwu Branch of the Wuxi Public Security Bureau on April 12, 2023.

These incidents collectively reveal significant weaknesses in the supply chains of Chinese firms. Under mounting risk pressure, some firms have begun to move away from a singular emphasis on cost efficiency and toward a balance between efficiency and security. Overall, however, corporate supply chain resilience in China remains at an early stage of development and still lacks both systematic theoretical guidance and practical experience that can be replicated across firms.

Viewed through the evolution of public policy, China's support for supply chains can be divided roughly into three stages. During the first stage (2016-2017), policy focused on reducing logistics costs and improving efficiency to strengthen the operational foundation. In 2017, State Council General Office Document No. 84 provided the first systematic national arrangements for supply chain innovation and application. The second stage (2018-2020) saw the launch of national pilot programs for supply chain innovation and application, covering 55 pilot cities and 266 pilot firms; after the onset of the COVID-19 pandemic, policy placed still greater emphasis on supply chain security. The third stage (2021-present) has involved a strategic upgrading. The report to the 20th National Congress of the Communist Party of China explicitly called for efforts to "improve the resilience and security of industrial and supply chains," while the Third Plenary Session of the 20th Central Committee made further arrangements to strengthen the relevant institutions. Building supply chain resilience at the firm level has therefore become an important micro-level expression of this national strategy.

In academic research, the theoretical development of corporate supply chain resilience has drawn mainly on the resource-based view, dynamic capabilities theory, social network theory, and resource orchestration theory. These perspectives explain resilience in terms of resource endowments, the capacity for dynamic adjustment, network structure, and the efficiency of resource allocation, respectively. Existing empirical studies have also made progress on several fronts. Proposed measurement approaches include proxy variables, two-dimensional composite indicators, and multidimensional entropy-weighted indices. Research on determinants has examined the application of technology, financial support, supply chain structure, and policy effects, and has discussed the possible roles of information transparency, financing constraints, structural diversification, and the allocation of policy resources.

Several limitations nevertheless remain. First, no consensus has emerged on a unified measurement system for resilience, and a single indicator cannot readily capture its multiple dimensions, including resistance, recovery, and adaptation. Second, most studies concentrate on the independent effect of one factor and offer limited integration of multiple determinants. Third, few studies examine separately

how resistance, recovery, and adaptive capacities are formed, making it difficult to provide firms with phased and appropriately prioritized recommendations. Fourth, empirical evidence grounded in China's institutional environment and domestic risk events remains insufficient.

To address these limitations, this study identifies supply chain resilience content in firms' annual reports, places multiple categories of determinants within a unified analytical framework, and examines resistance, recovery, and adaptive capacities separately. It makes two principal contributions. First, it develops a supply chain resilience keyword list suitable for searching annual-report text. Second, it organizes specific determinants within cross-classified cells that combine PTOE factors with the three resilience capacities, laying a foundation for subsequent large-sample text identification and structural analysis.

2. Literature Review and Theoretical Basis

Research on supply chain resilience emerged largely in response to the widespread adoption of global sourcing and lean production, together with the systemic risk of disruption created by growing interdependence among supply chain nodes. Early studies approached the concept primarily from the perspective of engineering resilience. They focused on how a supply chain could limit performance losses after a shock and return to its original operating state, producing an early shock-loss-recovery view of resilience [1-2]. As the field developed, scholars increasingly recognized that supply chains operate in continuously changing environments and that resilience cannot be reduced to restoring the status quo after a disruption. The systematic review by Tukamuhabwa et al. reflects this shift in understanding, while Wieland and Durach further emphasize the dynamic nature of supply chain resilience [3-4]. Later research therefore considered not only recovery but also immediate responses to shocks and continuing adjustment. On this basis, the present study distinguishes three dimensions of resilience: resistance capacity, which concerns maintaining operations and limiting performance losses when a shock occurs; recovery capacity, which concerns the speed and extent to which impaired functions are restored; and adaptive capacity, which refers to a firm's ability to respond to a new environment through learning, resource adjustment, and changes in its mode of operation.

Previous studies have taken several approaches to measuring supply chain resilience. Pettit et al. developed an assessment framework based on the alignment between supply chain vulnerabilities and capabilities. Ambulkar et al. developed a firm-level scale for resilience to supply chain disruptions, while Chowdhury and Quaddus incorporated capabilities such as preparedness, response, and recovery into their measurement of resilience [5-7]. Jüttner and Maklan examined supply chain resilience during the global financial crisis, a real-world shock, and likewise showed that the concept must be understood in relation to how firms respond to actual disruptions. Each measurement approach has an appropriate scope of application. For the large, cross-industry sample examined here, it is especially important to distinguish resilience outcomes from factors that may contribute to them. If antecedents such as the degree of digitalization or supplier concentration are incorporated directly into a resilience index and later used again as explanatory variables, construct overlap and mechanical correlation may result. This study therefore treats resistance, recovery, and adaptive capacities as outcomes to be explained and identifies their potentially associated factors separately.

A related body of research asks why firms differ in their level of supply chain resilience. This work covers internal resources and capabilities, technological conditions, and the external environment. The technology-organization-environment (TOE) framework offers an established approach for analyzing these factors. Tornatzky and Fleischer divided the context of technological innovation into technological, organizational, and environmental components. Baker subsequently noted that TOE is an adaptable analytical framework rather than a fixed list of variables [8-9]. It has since been applied to explain the adoption and assimilation of electronic data interchange, e-commerce, cloud computing, and business analytics [10-11]. These studies primarily explain why firms adopt technologies and how they put them into use. Research on supply chain resilience must go further by examining how technology, organization, and external conditions relate to a firm's capacity to withstand supply chain shocks.

For the analysis of supply chain resilience, this study refines the TOE framework by treating internal policies and institutional mechanisms as a separate dimension. The resulting PTOE framework comprises internal policies and institutional mechanisms (P), technological conditions (T), organizational conditions (O), and the market and supply chain environment (E). Here, internal policies and institutional mechanisms refer to formalized governance rules and arrangements within the firm,

including internal controls, supplier management systems, contractual constraints, contingency plans, and mechanisms for delegation, evaluation, and incentives. External industrial policies, regulatory requirements, government procurement, and financial support are not assigned directly to P. They are classified as internal policies and institutional mechanisms only after a firm has absorbed them and translated them into internal governance rules. E mainly covers market structure, industry conditions, infrastructure, supply chain networks, uncertainty in supply and demand, and external policy conditions that have not been transformed into internal rules. Recent studies have examined how intellectual property protection, artificial intelligence pilot programs, government procurement, and financial policies relate to firms' resource allocation, incentive arrangements, and financing conditions [12]. These studies are used here only to explain how external policies may prompt firms to adjust their internal institutions; the external policies themselves are not treated as P. The systematic review by Hughes et al. likewise indicates that public policy may participate in the formation of supply chain resilience [13].

The four categories in PTOE are interrelated. Technology can improve information acquisition, risk identification, and forecasting, but technology alone does not automatically produce resilience. Its effects also depend on whether the firm possesses the necessary organizational capabilities and whether the external environment provides adequate support [14]. A firm's innovative capacity, supply chain collaboration, and cross-organizational governance may likewise influence resilience, yet these effects are constrained by factors such as supply uncertainty and network dependence [15-17]. The supply chain network is itself an important external condition: its structure and degree of concentration influence both the reach of shock transmission and the risk of cascading failures [18]. Internal institutions, technology, organization, and the environment may therefore interact in the formation of supply chain resilience.

The same factor may also affect the three resilience capacities differently. A technology that helps a firm identify risk in advance will not necessarily improve the speed of recovery after a shock. Likewise, resources and organizational capabilities that support short-term recovery may not create long-term adaptability. Combining resistance, recovery, and adaptability into a single composite indicator may therefore conceal differences in both the direction and magnitude of particular effects. Industry variation can further shape these relationships. Industries differ in their technological base, mode of organization, market structure, and supply chain networks, so the same factor may not have consistent effects across settings. A substantial share of existing evidence comes from manufacturing or other specific industry contexts, and the findings still need to be tested in a broader cross-industry sample.

Existing studies provide substantial theoretical and empirical evidence for understanding supply chain resilience, but several issues remain unresolved. TOE research has long focused on technology adoption and innovation, leaving the independent role of firms' internal institutions in supply chain resilience underexamined. Although resilience research has considered institutional, technological, organizational, and environmental factors, it commonly examines them in isolation rather than within a unified framework. Differences among resistance, recovery, and adaptability have also received insufficient attention, and evidence from firms across multiple industries remains limited. In response, this study adopts a PTOE-based framework of relevant factors, separates supply chain resilience into resistance, recovery, and adaptability, and examines how internal policies and institutional mechanisms, technological conditions, organizational conditions, and the market and supply chain environment correspond to each of the three capacities.

3. Research Design

3.1. Theoretical and Analytical Framework

3.1.1. Dimensions of Corporate Supply Chain Resilience

This study defines corporate supply chain resilience as a firm's combined capacity to maintain critical functions, restore normal operations, and adjust when confronted with a supply chain shock. Resistance capacity refers to the ability to reduce risk exposure, buffer losses, and keep the supply chain operating before and during a shock. Recovery capacity is the ability to repair supply chain relationships and restore production and delivery after functions have been impaired. Adaptive capacity, or adaptability, is the ability to respond to environmental change by reconfiguring technology, processes, or networks. The three capacities correspond, respectively, to maintaining, repairing, and adjusting during the response to a shock.

3.1.2. The PTOE Framework

To identify factors related to supply chain resilience in annual reports, this study adds internal policies and institutional mechanisms to the technology-organization-environment framework, thereby forming the PTOE framework. Internal policies and institutional mechanisms (P) comprise formal rules, standards, procedures, and constraints that have been institutionalized within the firm, including internal control, supplier management, contractual constraints, contingency plans, and rules for delegation, evaluation, and incentives. Technological conditions (T) include digitalization, research and development (R&D) innovation, and production technology. Organizational conditions (O) include organizational structure, personnel, resource allocation, and implementation arrangements. The market and supply chain environment (E) encompasses changes in supply and demand, upstream and downstream relationships, logistics conditions, the external policy environment, and other external risks. In the coding process, an external policy is assigned to E unless and until it is converted into a formal internal rule, at which point it is assigned to P.

3.2. Data Processing

3.2.1. Sample and Data Sources

The sample consists of Chinese A-share listed firms and is screened according to data availability and textual completeness during the study period. Financial firms, firms under special treatment or other risk-warning designations, and observations with missing core fields are removed in sequence. The unit of observation is the firm-year. Textual data are taken from the Management Discussion and Analysis sections of listed firms' annual reports. These sections bring together management's discussion of the operating environment, major risks, operating arrangements, and future plans, making them well suited to identifying statements about supply chain shocks and the actions taken in response. Semantically complete short sentences are used as the units of identification and coding.

3.2.2. Text Processing and the Candidate Corpus

The raw annual-report text is first cleaned, standardized, and segmented into sentences. Initial terms are then extracted from academic studies, policy documents, industry standards, and professional reports concerning supply chain resilience. Synonymous expressions are consolidated, ambiguous terms are screened, and usage is checked against the context of annual reports to create a standardized keyword list. The list is then used to retrieve short sentences from the reports. Retrieved passages are segmented again to ensure that each retained unit is semantically complete. Table fragments, uninterrupted strings of numbers, formulaic language, duplicate records, and incomplete fragments are removed. This process produces the candidate sentence corpus used in the subsequent classification.

3.3. Measurement Methods

3.3.1. Keyword List

To establish the conceptual boundaries of corporate supply chain resilience, academic studies from China and elsewhere, policy documents, industry standards, and professional reports are reviewed systematically. Terms capable of representing risk exposure, response actions, and changes in capability are extracted from these sources. Synonyms, near-synonyms, and inflected forms are then consolidated. Terms that are overly broad or prone to ambiguity are checked in context, and their forms are revised to reflect common usage in listed firms' annual reports. The result is a standardized keyword list for text retrieval.

3.3.2. Candidate Sentence Corpus

Keyword matching is applied to the cleaned and segmented annual-report text, and each short sentence containing at least one keyword is included in the initial corpus. The screening process simultaneously removes table-of-contents headings, table fragments, uninterrupted strings of numbers, formulaic statements, and semantically incomplete text. Source fields, including the firm code, reporting year, location in the original document, and matched term, are recorded for every retained sentence, producing a traceable candidate corpus. Inclusion at this stage indicates only a literal keyword match and is not treated in advance as evidence that the sentence contains valid information about supply chain resilience.

3.3.3. Small-Sample Classification Examples

A small sample is drawn from the candidate corpus by simple random sampling. Using a unified set of criteria, the researchers assess each sentence to determine whether it substantively concerns supply chain resilience and record the basis for each decision. Disputed cases are reviewed, after which classification rules are summarized for positive examples, negative examples, and boundary cases. The verified samples, labels, and explanations are jointly incorporated into the prompt context as examples that help the selected large language model understand the classification task. This procedure constitutes in-context learning and does not involve fine-tuning the model's parameters.

3.3.4. Independent Test Set

After excluding the example sample, simple random sampling is performed again on the remaining candidate sentences to construct an independent test set that is completely separate from the examples. The researchers label the test set independently without consulting model outputs, and inconsistent labels are reviewed and adjudicated to create the human reference labels used in the comparison. Each test observation retains a unique identifier and complete source information so that the absence of overlap can be verified and the original context can be traced.

3.3.5. Comparative Evaluation of Human and Model Classifications

Human and model classifications are stored separately and then aligned observation by observation using the sample identifiers. A separate list is created for sentences on which the two classifications disagree. Accuracy, precision, recall, and the F1 score, which is the harmonic mean of precision and recall, are calculated from this comparison to evaluate the accuracy of the model's classifications.

3.3.6. Full-Corpus Classification

Once the comparative evaluation on the independent test set is complete, the model version, prompt, classification rules, and inference parameters are fixed. Batch binary classification is then applied to the candidate sentence corpus. Sentences classified as valid enter the valid-sentence corpus, while those classified as invalid enter an exclusion corpus. Both sets of records retain the model label, the basis for the decision, and the source fields. Duplicate, missing, and anomalous outputs are checked during batch processing to keep the classification criteria consistent across the full corpus.

3.3.7. Two-Dimensional Cross-Classification

Each sentence in the valid corpus is coded along two dimensions: the relevant PTOE factor and the supply chain resilience capacity. For the first dimension, the sentence's principal object and core action are used to identify the dominant category among internal policies and institutional mechanisms, technological conditions, organizational conditions, and the market and supply chain environment. For the second, the stage of response and capability outcome expressed by the sentence are used to determine whether it concerns resistance, recovery, or adaptive capacity.

4. Data Analysis

4.1. Sample Selection Results

Following the specified screening procedure, the final sample contains 38,637 firm-year observations for Chinese A-share listed firms from 2016 to 2024, covering 5,625 stock codes. All study text comes from the Management Discussion and Analysis sections in a database of listed firms' annual reports. Semantically complete short sentences serve as the units for subsequent identification and coding. Together, these observations constitute the final sample used in the analysis.

4.2. Text Identification and Model Validation Results

Terms were extracted, consolidated, and contextually checked using 51 core materials on corporate supply chain resilience drawn from multiple types of sources. This process initially produced a collection of 100 relevant terms, of which 65 were retained as the core keywords used in the analysis (Table 1).

Table 1. Sixty-Five Keywords

65 Keywords					
Supply chain resilience	Supply chain innovation and application pilot program	Digital infrastructure	Data security	Enterprise risk management	Integration of digital and real-economy technologies
Artificial intelligence	Emergency management	Inventory management	Response capacity	Demand fluctuations	Recovery capacity
Technological innovation	Corporate governance	Supply chain stability	Business continuity	Customer concentration	Dynamic capabilities
Supply chain collaboration	R&D investment	Smart manufacturing	Technology finance	Procurement management	Supplier concentration
Information sharing	Supply chain digitalization	Operational efficiency	Working capital	Logistics efficiency	Supplier management
Risk early warning	Risk prevention and control	Demand forecasting	Supply chain concentration	Resource orchestration	Capacity flexibility
Supply chain innovation	Resource allocation efficiency	Financing constraints	Information system integration	Resistance capacity	Resource redundancy
Supply chain finance	Risk identification	Supply chain flexibility	Green innovation	Environmental uncertainty	Supplier risk management
Digital transformation	Supply disruption	Supply chain integration	Innovative capacity	External shocks	Adaptive capacity
Policy support	Cash flow	Supply chain visibility	Partnership stability	Supply chain agility	Organizational resilience
Supply chain security	Green supply chain	Internal control	Data intelligence	Supplier diversification	

Keyword matching yielded 526,266 candidate short sentences. At this stage, the corpus indicates only a literal keyword match and therefore still contains noisy sentences that lack a supply chain context or do not convey information about resilience.

A simple random sample of 50 short sentences was drawn from the candidate corpus. Human classification and review identified 13 positive and 37 negative cases, for a positive-to-negative ratio of approximately 1:2.8. These observations were used to construct a small set of examples containing positive cases, negative cases, boundary cases, and the corresponding grounds for classification, thereby giving the model a clear contextual reference for the identification task.

After the small example sample was excluded, a separate simple random sample of 2,000 short sentences was drawn to form the independent test set. Verification using sample identifiers confirmed that it did not overlap with the examples. The human reference labels comprised 256 positive and 1,744 negative cases, with positive cases accounting for 12.80% of the test set.

On the same independent test set, the model classified 238 observations as positive and 1,762 as negative. It agreed with the human reference labels for most observations, indicating that the established prompt, classification rules, and examples can support reasonably stable binary classification.

The human labels and model classifications disagreed on 52 observations. Based on these results, the model achieved an accuracy of 97.40%, a precision of 92.86%, a recall of 86.33%, and an F1 score of 89.47%. Its performance on the independent test set was therefore sufficiently stable for the model to be applied to the full candidate corpus.

After the model classified all 526,266 candidate short sentences, 65,820 were identified as valid. These sentences form the valid corpus used for the subsequent two-dimensional coding and cross-classification analysis.

4.3. Key Factors Influencing Corporate Supply Chain Resilience within the PTOE Framework

After the 65,820 valid resilience-related sentences were identified, each sentence was assigned one primary PTOE label and one primary resilience-capacity label. The leading specific factor was then identified within each cross-classified cell. Table 2 presents the resulting 4×3 distribution, and Table 3 reports the internal composition of the 12 cells.

Table 2. Overall Cross-Distribution of PTOE Factors and the Three Corporate Supply Chain Resilience Capacities

Resilience capacity	Internal policies and institutional mechanisms (P)	Technological conditions (T)	Organizational conditions (O)	Market and supply chain environment (E)	Total
Resistance	7,361 (11.18%)	2,379 (3.61%)	4,007 (6.09%)	16,320 (24.79%)	30,067 (45.68%)
Recovery	130 (0.20%)	68 (0.10%)	57 (0.09%)	88 (0.13%)	343 (0.52%)
Adaptability	1,546 (2.35%)	23,200 (35.25%)	2,070 (3.14%)	8,594 (13.06%)	35,410 (53.80%)
Total	9,037 (13.73%)	25,647 (38.97%)	6,134 (9.32%)	25,002 (37.99%)	65,820 (100.00%)

4.3.1. Overall Characteristics of the Data

Of the 65,820 valid resilience-related sentences, those concerning technological conditions and the market and supply chain environment together account for 76.96%, while the four largest cross-classified cells account for 84.28%. The relevant disclosures center mainly on technological adjustment, protection against external risks, the reconfiguration of supply networks, and institutionalized governance. Sentences concerning recovery capacity account for only 0.52%.

Table 3. Composition of Specific Factors within Each PTOE × Resilience-Capacity Cell

PTOE dimension (overall share)	Resilience capacity	Cross-classified cell sentences (overall share)	Specific factors: sentences (share within cell)
Internal policies and institutional mechanisms (P) 9,037 (13.73%)	Resistance	7,361 (11.18%)	1. Risk identification and early-warning mechanisms: 1,241 (16.86%) 2. Internal control and end-to-end risk governance: 2,999 (40.74%) 3. Supplier admission, evaluation, and auditing: 1,710 (23.23%) 4. Procurement, contracts, and quality standards: 1,231 (16.72%) 5. Supply chain security and accountability mechanisms: 180 (2.45%)
	Recovery	130 (0.20%)	1. Contingency plans and tiered response systems: 98 (75.38%) 2. Cross-departmental emergency command mechanisms: 9 (6.92%) 3. Business continuity and work-resumption systems: 16 (12.31%) 4. Insurance, compensation, and protection arrangements: 1 (0.77%) 5. Post-event review and corrective mechanisms: 6 (4.62%)
	Adaptability	1,546 (2.35%)	1. Dynamic governance and delegation mechanisms: 638 (41.27%) 2. Rules for dynamic supplier evaluation and updating: 265 (17.14%) 3. Innovation incentives and R&D management systems: 323 (20.89%) 4. Information-sharing and collaboration rules: 108 (6.99%) 5. Mechanisms for policy response and standards alignment: 212 (13.71%)
Technological conditions (T) 25,647 (38.97%)	Resistance	2,379 (3.61%)	1. Risk monitoring and data-driven early-warning technologies: 158 (6.64%) 2. Traceability and supply chain visibility systems: 38 (1.60%) 3. Smart manufacturing and process quality control: 557 (23.41%) 4. Production, inventory, and logistics information

			systems: 1,314 (55.23%) 5. Data security, backup, and system redundancy: 312 (13.11%)
	Recovery	68 (0.10%)	1. Information-system disaster recovery and rapid switchover: 2 (2.94%) 2. Digital emergency command platforms: 13 (19.12%) 3. Intelligent scheduling and restart technologies: 33 (48.53%) 4. Technologies for finding alternative sources and routes: 0 (0.00%) 5. Equipment diagnosis, emergency repair, and restoration technologies: 20 (29.41%)
	Adaptability	23,200 (35.25%)	1. Digital transformation and platform integration: 4,180 (18.02%) 2. Intelligent, automated, and flexible manufacturing: 6,462 (27.85%) 3. R&D and product and process innovation: 11,877 (51.19%) 4. Demand forecasting and data analytics: 37 (0.16%) 5. Information-sharing and collaboration technologies: 579 (2.50%) 6. Technological transformation and equipment upgrading: 65 (0.28%)
Organizational conditions (O) 6,134 (9.32%)	Resistance	4,007 (6.09%)	1. Safety stocks and material reserves: 791 (19.74%) 2. Cash flow and financial buffers: 1,128 (28.15%) 3. Redundancy in capacity, equipment, and resources: 69 (1.72%) 4. Stable operations and business continuity management: 1,901 (47.44%) 5. Professional teams and role-specific capabilities: 106 (2.65%) 6. Cross-departmental coordination and integrated resource planning: 12 (0.30%)
	Recovery	57 (0.09%)	1. Emergency teams, training, and drills: 23 (40.35%) 2. Resource deployment and temporary organizational arrangements: 1 (1.75%) 3. Work resumption and capacity-restart capabilities: 13 (22.81%) 4. Financial support for recovery: 14 (24.56%) 5. Organizational learning and retention of experience: 6 (10.53%)
	Adaptability	2,070 (3.14%)	1. Organizational flexibility and flat structures: 116 (5.60%) 2. Talent reserves and multidisciplinary teams: 61 (2.95%) 3. Resource recombination and dynamic allocation: 218 (10.53%) 4. Process optimization and lean operations: 1,503 (72.61%) 5. Production-sales coordination and flexible capabilities: 172 (8.31%)
Market and supply chain environment (E) 25,002 (37.99%)	Resistance	16,320 (24.79%)	1. Diversification of supplier and customer structures: 3,333 (20.42%) 2. Strategic suppliers and long-term cooperation: 323 (1.98%) 3. Raw-material sourcing, pricing, and supply risk management: 6,744 (41.32%) 4. Multi-route logistics and channel networks: 666 (4.08%) 5. Upstream-downstream coordination and industrial-chain security: 2,777 (17.02%) 6. Supply chain finance and credit support: 2,477 (15.18%)
	Recovery	88 (0.13%)	1. Backup suppliers and alternative sources: 1 (1.14%) 2. Upstream-downstream mutual support and network coordination: 56 (63.64%)

			3. Emergency procurement, logistics, and channels: 13 (14.77%) 4. Customer communication and order rescheduling: 6 (6.82%) 5. External policy, financial, and public-service support: 12 (13.64%)
	Adaptability	8,594 (13.06%)	1. Demand forecasting and customer responsiveness: 2,433 (28.31%) 2. Supplier portfolio and network reconfiguration: 736 (8.56%) 3. Supply chain integration and upstream-downstream coordination: 2,907 (33.83%) 4. Market, product, and channel diversification: 1,102 (12.82%) 5. Domestic substitution and localization of supply sources: 15 (0.17%) 6. Industrial-chain extension and business-footprint adjustment: 14 (0.16%) 7. Dynamic adjustment of procurement, inventory, and logistics: 1,387 (16.14%)

4.3.2. Analysis of Internal Policies and Institutional Mechanisms

At the resistance stage, internal policies and institutional mechanisms operate mainly by embedding risk control in routine processes and supplier management. Internal controls, admission and evaluation procedures, contractual constraints, and early-warning procedures allow risk identification, the allocation of responsibility, and remedial action to begin sooner. During recovery, contingency plans, delegated authority, and a defined order of tasks can reduce the cost of ad hoc coordination. Over the course of longer-term adjustment, changes to evaluation, incentive, and delegation rules can support new approaches to procurement, production, and collaboration.

4.3.3. Analysis of Technological Conditions

Technological conditions are relevant throughout risk identification, operational restoration, and continuing adjustment. At the resistance stage, information systems, monitoring and early-warning tools, and production technologies can improve operational transparency and process reliability, reducing the spread of risk caused by delayed information. During recovery, revised production scheduling, equipment repair, and emergency dispatch provide direct support for restoring production and delivery. At the adaptation stage, R&D innovation, process improvement, and flexible manufacturing help firms change both their products and their methods of production.

4.3.4. Analysis of Organizational Conditions

Content related to organizational conditions focuses on whether resources can be mobilized and reallocated in a timely manner. At the resistance stage, buffers in finance, inventories, capacity, and personnel absorb short-term disruptions, while business continuity arrangements help keep critical links operating. During recovery, cross-departmental coordination and integrated resource planning determine whether repair measures can be implemented. At the adaptation stage, process optimization, lean operations, and organizational collaboration support changes in the way the firm operates.

4.3.5. Analysis of the Market and Supply Chain Environment

In the annual-report text, the market and supply chain environment is reflected mainly in a firm's relationships with external actors. At the resistance stage, diversified supply sources, stable cooperative relationships, risk sharing, and financial support help reduce the impact of failure at a single node. During recovery, reconnecting networks of materials, information, funding, and orders determines whether the supply chain can resume operation. At the adaptation stage, responses to demand, changes in the supply footprint, and the reconfiguration of cooperative networks lead firms to alter how they provide products and services. Firms cannot fully control their external environment. Whether environmental factors become sources of effective support also depends on the firm's cooperative arrangements and its capacity to adjust the network.

5. Conclusions

Based on the independent test, full-corpus text identification, and two-dimensional cross-

classification results, the study reaches the following principal conclusions.

First, after the initial keyword screening, a large language model can use context to filter noisy sentences. Of the 526,266 candidate short sentences, only 65,820 were identified as valid resilience information, for an overall validity rate of 12.51%. A sentence that contains a keyword does not necessarily concern supply chain risk, a response action, or a change in capability. On the independent test set, the model achieved 97.40% accuracy, 92.86% precision, 86.33% recall, and an F1 score of 89.47%. These results show that examples and unified rules can support reasonably stable binary classification, providing a feasible tool for large-scale analysis of annual-report text.

Second, among the 65,820 valid sentences, technological conditions and the market and supply chain environment account for 38.97% and 37.99%, respectively, or 76.96% in total. Internal policies and institutional mechanisms account for 13.73%, and organizational conditions for 9.32%. Relevant annual-report disclosures focus more heavily on direct operating activities, including technological upgrading, production transformation, sources of supply, and upstream and downstream relationships. Content related to internal institutions mainly concerns rule-based constraints and risk governance, while organizational content centers on resource buffers, business continuity, and process support.

Third, adaptive-capacity and resistance-capacity sentences represent 53.80% and 45.68%, respectively, of the 65,820 valid sentences, whereas recovery-capacity sentences account for only 0.52%. The annual reports devote more attention to long-term adaptation through technological innovation, process adjustment, and network reconfiguration, as well as to ex ante protection through risk warning, resource reserves, and supply diversification. Relatively few sentences address the repair of supply relationships, the restarting of production capacity, or the resumption of work and production after a disruption.

Fourth, the textual distribution of PTOE factors differs substantially across the three resilience capacities. The technological conditions-adaptability and market and supply chain environment-resistance cells account for 35.25% and 24.79%, respectively. The market and supply chain environment-adaptability and internal policies and institutional mechanisms-resistance cells account for 13.06% and 11.18%, respectively. Together, these four leading cells represent 84.28% of all valid sentences.

Fifth, the resilience content associated with each category of factors is distinct. Sentences concerning internal policies and institutional mechanisms commonly address internal control, supplier management, contingency plans, and dynamic governance. Technological-condition sentences focus on production and logistics information systems, intelligent scheduling and emergency equipment repair, R&D innovation, and flexible manufacturing. Organizational-condition sentences often concern business continuity, financial and material buffers, emergency mobilization, and process optimization. Sentences related to the market and supply chain environment cover supply risk management, structural diversification, upstream and downstream coordination, network reconnection, and responsiveness to demand.

Overall, the annual-report text shows that internal institutions, technological capabilities, organizational foundations, and supply chain networks are associated with supply chain resilience to different degrees at different stages of a shock. Firms can allocate resources according to the specific tasks required for resistance, recovery, and adaptation, linking risk prevention, emergency repair, and long-term adjustment. Measuring the resilience capacities separately and analyzing them in context can prevent a single composite indicator from obscuring these differences, thereby providing a clearer basis for corporate management and policymaking.

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