ISSN 2616-5902 Vol. 8, Issue 1: 49-53, DOI: 10.25236/AJBM.2026.080107

Supply Chain Risk Identification and Strategic Responses in Large Listed Manufacturing Firms under Extreme Weather Shocks

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Abstract: *With the intensification of global climate change, both the frequency and severity of extreme weather events have continued to increase over the past decade, causing increasingly complex disruptions to manufacturing supply chains. These disruptions are marked by long transmission chains, rapid propagation, and broad impact, making extreme weather a major source of systemic risk for manufacturing firms. This study selects manufacturing firms included in the S&P 500 Index from 2011 to 2025 as the research sample. A total of 584 news articles were collected through combined searches of firm names and supply chain–related keywords, along with 155 corresponding Corporate Earnings Call transcripts. Using the Latent Dirichlet Allocation (LDA) model, semantic topics are extracted to uncover the specific mechanisms through which extreme weather affects supply chains. The results identify six major risk patterns: energy supply disruption risk, core component shortage risk, raw material supply and price volatility risk, concentration risk in global manufacturing networks, regional energy hub failure risk, and production capacity disruption risk in vehicle and large-scale manufacturing. From a systemic perspective, the study illustrates the transmission structure of climate-related supply chain risks in manufacturing and provides theoretical insights and empirical evidence for enhancing manufacturing resilience, optimizing regional supply strategies, and informing policy design.*

Keywords: *Manufacturing Enterprises; Supply Chain Risk; Latent Dirichlet Allocation*

1. Introduction

In recent years, the frequency and intensity of extreme weather events have increased significantly, posing profound and growing challenges to global supply chains. According to the World Meteorological Organization, the occurrence of extreme weather events has increased fivefold over the past 50 years, resulting in estimated global economic losses of USD 20.2 billion per day. A 2024 McKinsey survey further reports that nearly 90% of supply chain executives experienced disruption in the past year, indicating that climate events have become a persistent source of volatility. For manufacturing firms in particular, the risks brought by climate shocks have emerged as a critical constraint on operations, resource allocation, and long-term planning.

Supply chain risks are not isolated but interconnected, contagious, and subject to amplification. Structured as tightly interlinked systems of upstream suppliers, intermediate manufacturers, and downstream distributors, supply chains often exhibit asymmetrical and non-linear transmission of risk[1]. In highly specialized production networks, disruptions at one node can rapidly cascade across tiers, transforming localized shocks into system-wide crises. Prior studies have shown that natural disasters can trigger port closures, disrupt regional logistics hubs, and, through global trade networks, reduce capacity across continents [2-3]. In such networks, the persistence or concentration of shocks can give rise to second-order effects, such as upstream liquidity crises triggered by downstream production halts[4].

Despite growing attention, existing research on climate-induced supply chain risks remains limited in both methodological depth and empirical granularity. First, much of the literature relies on structured indicators, such as inventory delays[5] or trade volumes[6], capturing only the outcomes rather than the mechanisms of risk formation. Second, most studies focus on industries or regions[7-8], lacking firm-level behavioral evidence to explain how and why companies are affected. Third, prior work often draws from a single external data source[9], overlooking internal managerial perceptions and responses. As a result, current research tends to describe disruptions rather than uncover strategic dynamics.

This paper aims to address these limitations by proposing a text-mining framework that integrates

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external narratives with internal cognition. Specifically, we analyze both news articles, which reflect the observable impact of extreme weather on operations, and earnings call transcripts, which reveal how firms perceive, interpret, and respond to such risks. The two sources correspond to the event layer and behavioral layer of supply chain risk, respectively. By jointly examining them, we capture the full trajectory of risk, from external shock to internal strategy, offering a more comprehensive understanding of climate-related supply chain disruptions in the manufacturing sector.

2. Data and Methods

2.1 Data and Sample Construction

This study focuses on manufacturing firms listed in the S&P 500 Index as the primary research sample. Compared to general manufacturing firms, these companies are more representative in terms of supply chain structure, industrial layout, and transparency in information disclosure. The sample period spans from 2011 to 2025, covering a range of climate events and corporate responses.

To capture supply chain risk from both external shock and internal perception perspectives, a dual-source text corpus was constructed. The external texts consist of 584 news articles sourced from major international business outlets, including *The Wall Street Journal*, *The Washington Post*, *Chicago Tribune*, *The New York Times*, Associated Press, and PR Newswire. These texts document how extreme weather events affect firm operations from an outside-in perspective. The internal texts comprise 155 earnings call transcripts, primarily drawn from quarterly investor communications. These transcripts reflect how firm executives interpret extreme weather, respond to supply chain disruptions, and adjust strategies related to production planning, supplier management, ESG priorities, and capital allocation. Together, the dual-source text corpus provides a comprehensive foundation for analyzing supply chain risks in a climate context.

2.2 Text Processing

To ensure the semantic consistency and economic interpretability of the topic modeling results, the dual-source corpus underwent a structured preprocessing and enhancement procedure.

Standard natural language processing (NLP) techniques were applied to clean the texts. This included removing HTML tags, metadata, time stamps, advertisements, irrelevant numerical values, tables, and formatting symbols. All texts were lowercased and sentence-segmented to ensure modeling consistency. Lemmatization was conducted to reduce word forms to their base terms. For example, both “manufacturers” and “manufacturing” were normalized to “manufacture”. This step reduced semantic redundancy and improved the model’s capacity to detect contextually relevant patterns.

For stopword handling, a custom stopword list was developed in addition to the standard English set. Industry-generic but semantically weak terms such as “company,” “manager,” and “corporate,” as well as boilerplate phrases from earnings calls (e.g., “in this quarter”), were removed to prevent noise in topic extraction. Given that supply chain semantics often involve compound expressions, such as “chip shortage,” “supply disruption,” “port congestion,” “production halt,” and “energy outage,” the corpus was enhanced using n-gram techniques to construct bigrams and trigrams. These multi-word expressions carry more precise meanings in industrial contexts than single tokens, enabling the model to better capture the structural characteristics of complex supply chain events.

Finally, a term frequency–inverse document frequency (TF-IDF) matrix was constructed to weigh the importance of terms across the corpus. This approach strengthens the representation of rare but meaningful terms, improving the model’s ability to distinguish among diverse risk-related topics.

2.3 Topic Modeling Methodology

Following text preprocessing, this study applies the Latent Dirichlet Allocation (LDA) model to identify latent topics embedded in the dual-source text corpus. LDA assumes that each document is a probabilistic mixture of multiple topics, and each topic is characterized by a distribution over terms. Its probabilistic mechanism allows for the discovery of underlying semantic structures through observed word co-occurrence patterns.

Unlike keyword-based or clustering approaches, LDA is particularly well suited for identifying overlapping and multi-dimensional risks, typical in extreme weather contexts, where a single narrative

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may involve multiple concurrent issues such as supply disruptions, energy shortages, and logistics delays[10]. Each news text and earnings call transcript is treated as an independent semantic unit. The model captures recurring term patterns across documents that correspond to real-world operational scenarios, such as refinery shutdowns, semiconductor shortages, or production halts.

The extracted topics emerge organically from the data rather than being predefined, aligning with the probabilistic and network-driven nature of supply chain risk propagation. To ensure interpretability, the topic outputs are evaluated against industry context and mapped to specific climate events, supply chain disruptions, and management responses. This interpretive step transforms statistical clusters into economically meaningful categories of supply chain risk in the manufacturing sector.

3. Results

The Latent Dirichlet Allocation (LDA) model was applied to the dual-source text corpus to identify the main risk themes associated with extreme weather events in the manufacturing sector. As shown in Table 1, six distinct topics emerged from the data, each representing a specific pattern of disruption in supply chains. In the following sections, we discuss each topic in detail to uncover the mechanisms of risk propagation and the implications for supply chain resilience.

Table 1: Extracted Topics and Representative Keywords from LDA Model.

Topic Name	Topic Words
Energy Supply Disruption	production, prices, oil, energy, operations, shut, demand, texas, shortages, facilities
Core Component Shortage	vehicles, toyota, ford, parts, gm, honda, earthquake, shortage, factories, chips
Raw Material Price Volatility	demand, cocoa, food, flavors, chocolate, prices, consumer, natural, disaster
Geographic Concentration in Global Networks	manufacturing, china, europe, puerto, africa, asiapacific, latin, island, facility, damage
Regional Energy Hub Failure	oil, refinery, louisiana, gulf, texas, houston, storm, platforms, operations
Production Capacity Disruption	ford, production, manufacturing, shortage, water, weather, texas, damage, factories, parts

3.1 Energy Supply Disruption

The first topic exhibits a highly concentrated semantic structure centered on energy systems, with representative keywords including “production,” “oil,” “energy,” “shut,” “shortages,” “facilities,” and “Texas.” This pattern indicates that extreme weather events tend to exert their initial impact on energy production and transmission, creating a point of failure at the most upstream segment of the supply chain. Energy supply is not an isolated input but is deeply connected with electricity grids, refining capacity, and port infrastructure. When extreme weather damages these interconnected systems, manufacturing supply chains do not merely experience a gradual slowdown; instead, they are prone to synchronous failures across multiple nodes. As a fundamental input to manufacturing value chains, disruptions in energy supply typically generate spillover effects through three channels. First, they constrain the operation of production equipment and the processing of key intermediate inputs. Second, they raise transportation costs and reduce delivery efficiency. Finally, these disruptions manifest as imbalances between production and sales, accompanied by price volatility.

3.2 Core Component Shortages

The second topic centers on supply disruptions of core components and resulting production halts in manufacturing. Representative keywords include “production,” “vehicles,” “parts,” “chips,” “shortage,” “factories,” “Ford,” “GM,” “Toyota,” and “Honda.” These terms reflect how supply-demand imbalances in critical components have become a systemic risk faced by a wide range of manufacturers. In sectors such as automotive, electronics, and precision instruments, component shortages not only delay delivery schedules but can also lead to temporary shutdowns of entire production lines. Localized shocks in upstream firms are rapidly transmitted throughout supply networks, resulting in unfulfilled orders, delayed production schedules, or forced rescheduling by downstream manufacturers. In earnings call

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transcripts, firm management frequently mention “component turnover,” “chip allocations,” and “logistics bottlenecks” as key constraints on production capacity. Some firms even report proactively reducing order intake to mitigate the risk of non-fulfillment.

3.3 Raw Material Price Volatility

The third topic highlights the impact of raw material price and supply volatility on manufacturing supply chains. Keywords such as “demand,” “cocoa,” “food,” “flavors,” “natural,” and “prices” indicate that extreme weather disrupts the supply of agricultural and chemical-based inputs, leading to increased procurement costs and heightened uncertainty for manufacturers. Extreme weather events reduce crop yields, delay harvests, and disrupt the transportation of inputs such as cocoa, oils, resins, and other essential commodities used in the manufacturing of consumer goods, food products, and personal care items. As a result, manufacturers face increased input costs, procurement delays, and the need to adjust supplier contracts or sourcing regions. News texts often report reduced supply due to failed harvests or blocked ports, while earnings call transcripts reveal growing concerns over rising material costs, shrinking gross margins, and shifts in procurement strategies to manage long-term volatility. In many cases, firms also mention the difficulty of passing cost increases through to consumers, compounding the operational and financial pressure created by climate-driven raw material instability.

3.4 Geographic Concentration in Global Networks

The fourth topic reflects the structural risks arising from the geographic concentration of global manufacturing networks. Keywords such as “China,” “Europe,” “Puerto,” “Africa,” “Asia-Pacific,” “Latin,” and “facility” suggest that extreme weather events，such as typhoons, floods, and hurricanes，disrupting production capacities in key regional hubs where many manufacturers have clustered operations or rely on shared upstream suppliers. The damage to these concentrated facilities, particularly in island or coastal regions vulnerable to climate shocks, often triggers simultaneous supply disruptions across multiple firms and sectors. News texts frequently report on regional infrastructure failures or industrial park shutdowns affecting a wide range of suppliers, while earnings call transcripts reveal firms' difficulties in finding immediate substitutes, managing high switching costs, and implementing regional diversification strategies. In some cases, the lack of redundancy in geographically centralized production networks exposes firms to compounding delays and increased dependence on emergency logistics, undermining supply stability and production continuity across global value chains.

3.5 Regional Energy Hub Failure

The fifth topic shows supply chain risks associated with extreme weather disruptions to regional energy hubs. Keywords such as “oil,” “refinery,” “Louisiana,” “Gulf,” “Texas,” “Houston,” and “storm” point to the vulnerability of concentrated energy infrastructure. Hurricanes, floods, and severe storms frequently cause shutdowns of offshore platforms, coastal refineries, and pipeline systems, interrupting the flow of critical energy inputs to manufacturing firms across North America and beyond. News reports highlight how weather-induced outages in this region lead to fuel shortages, input cost spikes, and logistical congestion at ports and terminals. Within earnings calls, firm executives describe the cascading effects of such disruptions on production planning, transportation reliability, and supply contracts. In many cases, firms express concerns about limited visibility into energy restoration timelines and the challenges of reallocating production or shipments under infrastructure strain. These localized disruptions often have widespread consequences, especially for energy-intensive manufacturers that rely on stable and cost-effective fuel and feedstock supply.

3.6 Production Capacity Disruption

The sixth topic focuses on how extreme weather disrupts production capacity in the vehicle manufacturing sector. Keywords such as “Ford,” “production,” “manufacturing,” “shortage,” “water,” “weather,” “Texas,” and “factories” indicate that extreme climate events frequently affect manufacturing plants located in climate-sensitive regions of the United States. These weather shocks often lead to factory shutdowns, labor shortages, and delays in parts delivery, all of which undermine the continuity of assembly line operations. News reports document cases where water damage to facilities or weather-related transportation delays result in unplanned production halts, especially in vertically integrated plants. In earnings calls, company executives discuss lost production days, cost overruns due to emergency logistics, and challenges in meeting contractual delivery targets. For example, the dependency

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of vehicle production on just-in-time inventory systems and tightly synchronized supply chains makes these operations particularly vulnerable, as even short-term disruptions can result in significant backlogs and revenue loss.

4. Conclusion

This study investigates the impact of extreme weather events on manufacturing supply chains by combining external media reports with internal corporate disclosures. Using a dual-source text corpus and applying Latent Dirichlet Allocation (LDA), we identified six key categories of risk: energy supply disruptions, core component shortages, raw material volatility, geographic concentration vulnerabilities, regional energy hub failures, and production capacity interruptions.

The research makes several contributions in several ways. Methodologically, the study introduces a framework that links unstructured textual data with supply chain risk analysis. Empirically, the integration of event-level reporting with firm-level behavioral data enables a richer understanding of how climate-related risks influenced within organizations. This approach allows for the detection of risk structures that are often missed by traditional models, and highlights the importance of organizational cognition in shaping resilience strategies.

Future research could expand this framework in multiple directions. Longitudinal analyses may help track how risk perceptions evolve over time with repeated climate events. Integrating supply network data, financial indicators, or climate risk scores could further enhance the explanatory power of text-based models. As climate risks intensify, developing interdisciplinary tools to understand their operational implications remains an urgent research agenda.

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