Intelligent Agents and Generative Artificial Intelligence in Enterprise Supply Chains: Mechanisms for Enhancing System Resilience in the Digital Economy

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Abstract: With the rapid development of the digital economy, enterprise supply chains are facing increasing complexity and uncertainty, creating an urgent need to enhance system resilience through intelligent technologies. This study aims to explore the application and underlying mechanisms of intelligent agents and generative artificial intelligence in enterprise supply chains. The research adopts a theoretical analysis approach, integrating resilience theory, dynamic capability theory, and complex network theory to examine how intelligent technologies enhance supply chain resilience through four mechanisms: information processing, collaborative optimization, risk response, and learning and evolution. The findings indicate that intelligent agents and generative artificial intelligence, through multidimensional synergy, not only strengthen supply chain information visualization, decision-making agility, and risk response capacity, but also achieve long-term adaptability through continuous learning and system optimization. The proposed integrative analytical framework reveals the logical relationships among these mechanisms, providing theoretical support for understanding the systemic role of intelligent technologies in improving supply chain resilience. The study concludes that the synergistic application of intelligent technologies can offer practical guidance for enterprises to build efficient, robust, and adaptive supply chain systems in the digital economy, while also providing a theoretical foundation for future empirical research and cross-industry technological applications.

Keywords: Intelligent Agents; Generative Artificial Intelligence; Supply Chain Resilience; Information Processing; Collaborative Optimization; Risk Response; Learning and Evolution

1. Introduction

With the rapid development of the digital economy, enterprise supply chains are facing increasing complexity and uncertainty. Accelerated market fluctuations, extended industrial chains, and the high interdependence among supply chain nodes have made traditional management models inadequate for coping with rapidly changing environments [1]. Conventional strategies such as inventory redundancy, multi-supplier arrangements, and linear optimization methods have limitations in enhancing supply chain resilience, with high costs and low efficiency becoming key constraints. Against this backdrop, enterprises urgently need to leverage emerging intelligent technologies to strengthen the adaptability and disturbance resistance of their supply chains.

As critical technologies in digital transformation, intelligent agents and generative artificial intelligence are becoming key tools for enterprises to build resilient supply chains [2]. Intelligent agents can enable autonomous perception, dynamic decision-making, and real-time collaboration among multiple actors in the supply chain, improving information processing and task allocation efficiency. Generative artificial intelligence excels at data pattern recognition, scenario simulation, and knowledge generation, providing firms with accurate demand forecasts, disturbance scenario analyses, and strategic decision support. Existing studies often examine applications from the perspective of a single technology, but lack systematic analysis of the synergies between the two and their joint mechanisms in enhancing supply chain resilience.

Addressing this research gap, this study aims to

explore the applications of intelligent agents and generative artificial intelligence in enterprise supply chains, with a focus on how they enhance system resilience through four mechanisms: information processing, collaborative optimization, risk response, and continuous learning. The remainder of the paper is structured as follows: Section 2 reviews the literature on supply chain resilience and the applications of intelligent technologies; Section 3 develops the theoretical analysis framework and highlights the key mechanisms; Section 4 summarizes the research contributions, practical implications, and directions for future research.

2. Literature Review

2.1 Research Progress on Supply Chain Resilience

Supply chain resilience, as a research topic, originates from the intersection of complex systems theory and risk management. It is generally defined as the ability of a supply chain to maintain stability when facing external shocks and to recover rapidly after disturbances [3]. Existing studies have summarized its core dimensions as redundancy, flexibility, agility, and recovery capacity. Redundancy emphasizes resource reserves and backup pathways; flexibility focuses on process adjustments and diversification; agility is reflected in responsiveness and dynamic adaptation; while recovery capacity highlights rebuilding and optimization after disruptions.

Traditional strategies for enhancing supply chain resilience mainly rely on inventory redundancy, diversified supplier layouts, and contingency planning [4]. While these approaches reduce the risk of disruption to some extent, they are often associated with high costs and reduced efficiency. In the context of the digital economy, supply chains are becoming increasingly complex and real-time, making static defense strategies insufficient to meet new requirements. Consequently, a growing body of research has shifted toward intelligent and digital approaches to enhance resilience at lower costs.

2.2 Research on the Application of Intelligent Agents in Supply Chains

Intelligent agents are computational entities capable of autonomous perception, decision-making, and task execution in dynamic environments [5]. With the advancement of distributed artificial intelligence and multi-agent systems, the application of intelligent agents in supply chain management has gained increasing attention. Their advantages are reflected in distributed information processing, dynamic collaboration and task allocation, as well as risk monitoring and anomaly response [6].

Through distributed information processing, intelligent agents can overcome the information bottlenecks caused by centralized management, enabling different nodes to autonomously process data and share results, thereby improving overall decision-making efficiency [7]. In dynamic collaboration, intelligent agents establish real-time cooperative mechanisms across different supply chain nodes, optimizing task allocation and resource configuration. In terms of risk monitoring, intelligent agents continuously perceive environmental changes, identify potential risks in advance, and reduce disruption impacts through automated response mechanisms. Existing research shows that supply chain systems based on intelligent agents are more self-organizing and robust—meaning they can maintain stable operations under uncertain environments—than traditional centralized management models, thereby providing strong support for resilience enhancement [6].

2.3 Research on the Application of Generative Artificial Intelligence

Generative artificial intelligence (GAI), powered by deep learning and generative models, is capable of pattern recognition, content generation, and scenario simulation based on large-scale data [8]. Increasingly, this technology is being introduced into the supply chain domain to address the shortcomings of traditional methods in dealing with complexity and uncertainty.

In demand forecasting, GAI improves prediction accuracy by integrating historical sales data, market trends, and consumer behavior data, enabling enterprises to better plan production and inventory [9]. In scenario simulation, GAI can construct potential disruption scenarios and generate alternative response strategies, providing multidimensional decision-making support [10]. In knowledge generation and decision support, GAI

transforms complex multi-source data into interpretable knowledge, delivering insights through natural language or visualization to assist managers in strategic planning [11]. Existing research demonstrates that GAI can significantly improve the transparency and flexibility of supply chains.

2.4 Research Gaps and Development Trends

Although studies on intelligent agents and generative artificial intelligence have yielded certain achievements, most of the literature tends to analyze them separately. For example, research on intelligent agents mainly focuses on distributed collaboration and information processing, while research on generative artificial intelligence emphasizes forecasting and simulation. In the context of the digital economy, systematic studies on the integration of the two and how they collaboratively enhance supply chain resilience remain limited.

Future research trends are expected to focus on three directions:

First, integrating intelligent agents with generative artificial intelligence to build multidimensional frameworks for resilience enhancement.

Second, validating the practical effects of technology integration through empirical studies or industry cases.

Third, comparing applications across different industrial environments to summarize more universal theoretical and practical insights.

3. Theoretical Analysis

3.1 Theoretical Foundations and Analytical Perspectives

The supply chain system is a typical complex adaptive system characterized by multiple actors, multiple layers, and dynamic evolution. Resilience theory emphasizes that when confronted with disturbances or uncertainties, a system can maintain its core functions, achieve rapid recovery, and optimize performance during the recovery process. Supply chain resilience depends not only on the resources and capabilities of individual firms but also on the overall collaborative structure and efficiency of information exchange within the supply chain. In the context of the digital economy, the dynamic nature of supply chains is further intensified, making data-driven decision-making and cross-enterprise collaboration essential for resilience building.

Dynamic capability theory provides theoretical support for analyzing how enterprises can enhance supply chain resilience. This theory posits that firms must possess environmental sensing, resource integration, and capability reconfiguration in order to remain competitive in complex and volatile environments. Intelligent agents and generative artificial intelligence are core technological tools for achieving these dynamic capabilities. Intelligent agents enhance enterprises' responsiveness to environmental changes through autonomous perception and distributed decision-making; generative artificial intelligence strengthens prediction and optimization in uncertain environments through deep data learning and scenario simulation.

In addition, complex network theory and collaborative innovation theory offer supplementary perspectives for analyzing supply chain resilience. Complex network theory highlights how network structures and the strength of connections among supply chain nodes influence system stability and risk propagation. Collaborative innovation theory underscores that multi-actor resource sharing, information exchange, and joint decision-making can significantly enhance system adaptability. By integrating these theories, a multi-level and multi-perspective analytical framework can be established to examine the role of intelligent technologies in enhancing supply chain resilience.

Based on this theoretical foundation, the pathways through which intelligent agents and generative artificial intelligence function in supply chains can be identified: they enhance the efficiency and adaptability of individual nodes through technological means, while also optimizing collaboration structures, improving information flow, reducing risk diffusion, and enabling long-term evolution of the supply chain through continuous learning.

3.2 Mechanisms of Intelligent Technologies for Enhancing Supply Chain Resilience

In the digital economy, intelligent agents and generative artificial intelligence collaborate through multidimensional mechanisms to effectively enhance supply chain resilience.

First, the information processing mechanism is one of their core functions. Generative artificial intelligence integrates multi-source data from

production, logistics, markets, and customers, identifies complex patterns and potential anomalies, and provides accurate demand forecasts and risk warnings. This data-driven capability significantly improves supply chain visibility, allowing enterprises to detect potential issues in a timely manner and optimize decision-making. Intelligent agents enable real-time information sharing and distributed processing across nodes, transmitting predictive results quickly to decision-makers and execution systems, thereby forming a rapid feedback loop. The effective operation of this mechanism enhances foresight and early warning capabilities in supply chains.

Second, the collaborative optimization mechanism plays a vital role in improving supply chain resilience. Supply chains consist of multiple enterprises or departments, each facing different constraints and tasks. Intelligent agents establish automated cross-node collaboration networks, dynamically allocating tasks, optimizing production scheduling, and adjusting logistics routes to enhance overall system flexibility. The forecasts and simulation results generated by generative artificial intelligence provide a scientific foundation for collaboration, enabling firms to select optimal solutions quickly under complex conditions. Collaborative optimization not only increases supply chain agility but also strengthens responsiveness to sudden events and market fluctuations.

Third, the risk response mechanism ensures that supply chains can adjust rapidly during disturbances. Generative artificial intelligence simulates various disruption scenarios, evaluates risk impacts, and generates response strategies. Intelligent agents automatically execute adjustment measures based on simulation results, such as redistributing orders, optimizing inventory, or adjusting transportation routes. This mechanism reduces losses from disruptions and enhances adaptability under uncertainty. At the same time, the interaction between risk response and collaborative optimization mechanisms creates a resilience safeguard network for enterprises, enabling supply chains to follow a “protection–response–recovery–optimization” cycle.

Finally, the learning and evolution mechanism serves as the foundation for continuously improving supply chain resilience. Enterprises accumulate data and experience during operations; generative artificial intelligence continuously trains and refines models, while intelligent agents update strategies through execution and feedback. This forms a learning loop within the supply chain system. Through iterative improvement, the supply chain can optimize decision-making paths and collaboration models when facing new environments and risks, achieving dynamic adaptation and system evolution. This mechanism enhances not only recovery capacity but also innovation and long-term competitiveness.

The mechanisms of intelligent agents and generative artificial intelligence in supply chains exhibit strong synergies: the information processing mechanism supports collaborative optimization and risk response with data; collaborative optimization and risk response reinforce each other in practice; and the learning and evolution mechanism improves the efficiency and effectiveness of all mechanisms through continuous iteration. Collectively, these mechanisms constitute the pathways for enhancing supply chain resilience, enabling enterprises to cope with complex and dynamic environments in the digital economy.

3.3 Integrative Analytical Framework

Based on the above analysis, this study proposes an integrative analytical framework linking intelligent agents, generative artificial intelligence, information processing, collaborative optimization, risk response, learning and evolution, and supply chain resilience enhancement. Within this framework, intelligent technologies strengthen adaptability, recovery, and optimization capacity systematically through multi-level and multidimensional mechanisms. Specifically, the information processing mechanism provides a data foundation and early-warning support for decision-making; the collaborative optimization mechanism enhances resource allocation efficiency and system agility; the risk response mechanism ensures rapid adjustment and maintenance of core functions during disruptions; and the learning and evolution mechanism continuously improves and adapts the system in dynamic environments.

The framework emphasizes the interconnections among these mechanisms. Enhanced information processing increases the

scientific basis of collaboration and risk management; collaborative optimization and risk response reinforce each other to ensure stability and flexibility; the learning and evolution mechanism permeates the entire process, offering pathways for improvement and performance feedback. Through the coupling and synergy of these mechanisms, enterprises can build efficient, robust, and adaptive supply chain systems.

Moreover, the framework has strong applicability and practical value. Different industries or enterprises can apply it according to their supply chain structures and operational characteristics. For example, in manufacturing, it can guide intelligent optimization of production planning, inventory management, and logistics scheduling. In retail and distribution, it can support demand forecasting, delivery route planning, and customer response management. In logistics and service supply chains, it can strengthen coordination efficiency across nodes and improve risk management capabilities. Overall, the framework not only clarifies the mechanisms through which intelligent technologies enhance supply chain resilience but also provides theoretical grounding and practical guidance for future empirical research and applications.

4. Conclusion

Based on the complexity and uncertainty of enterprise supply chains in the digital economy, this study systematically explores the applications of intelligent agents and generative artificial intelligence, as well as their mechanisms for enhancing system resilience. Through theoretical analysis, the study proposes that intelligent technologies strengthen supply chain adaptability, recovery, and optimization capacity through four mechanisms: information processing, collaborative optimization, risk response, and learning and evolution. The integrative analytical framework further reveals the logical connections and dynamic interactions among these mechanisms, offering a systematic theoretical perspective for understanding how intelligent technologies enhance supply chain resilience.

From a theoretical perspective, this study expands the boundaries of supply chain resilience research. On one hand, by integrating intelligent agents and generative artificial intelligence into the analytical framework, it enriches the theoretical system of resilience enhancement in the context of the digital economy. On the other hand, the multi-mechanism and multi-level analysis uncovers the systemic impact of technological synergies on supply chain performance, providing new cases and theoretical support for supply chain management, complex adaptive systems, and dynamic capability theory.

From a practical standpoint, the proposed integrative framework provides actionable guidance for enterprise supply chain management. In manufacturing, retail and distribution, and logistics and service supply chains, firms can leverage intelligent agents and generative artificial intelligence to optimize production planning, inventory management, logistics scheduling, demand forecasting, and risk response strategies. At the same time, the learning and evolution mechanism highlights the importance of establishing continuous data feedback and model optimization systems, enabling long-term sustainable development and resilience improvement in supply chains.

Despite its theoretical and analytical contributions, this study has several limitations. First, it primarily relies on theoretical analysis without empirical validation; future research can incorporate case studies or big data–driven empirical analysis to test the practical effects of intelligent technologies on supply chain resilience. Second, the study focuses mainly on intelligent agents and generative artificial intelligence, without examining other technological factors that may influence resilience, such as the Internet of Things, blockchain, or edge computing. Future research may broaden the analytical scope in these directions. Finally, differences across industries and firm sizes may lead to variations in the effectiveness of technology applications, suggesting the need for further research into cross-industry and cross-regional applicability.

Overall, this study systematically explains the mechanisms through which intelligent agents and generative artificial intelligence enhance supply chain resilience and proposes a practical integrative analytical framework. The findings not only enrich the theoretical foundation of supply chain resilience and enterprise management in the digital economy but also provide theoretical guidance and practical reference for enterprises seeking to build

efficient, robust, and adaptive supply chains in complex and dynamic environments. Moreover, this research establishes a theoretical basis and analytical approach for future empirical studies and cross-technology, multi-industry research, contributing to the broader application and development of intelligent technologies in supply chain management.

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