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A study on the relationship between knowledge spillover, organizational learning, and corporate innovation

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Abstract: This article examines the relationship between knowledge spillovers, organizational learning, and corporate innovation, drawing on the absorptive capacity theory, the knowledge-based view, and the innovation ecosystem theory. From the perspective of absorptive capacity theory, knowledge spillover provides internal knowledge for enterprises; organizational learning is crucial for transforming this knowledge into endogenous capacity. Consequently, the resilience of the innovation chain ensures process stability. Based on the knowledge-based view, knowledge is central to innovation; knowledge spillover compensates for enterprise shortcomings, while organizational learning builds an internal knowledge base. The resilience of the innovation chain maintains knowledge supply. Under the innovation ecosystem theory, knowledge spillover enriches system resources; organizational learning enhances enterprise adaptability; innovation chain tenacity ensures system stability; and artificial intelligence regulates the relationships among various elements to promote innovation. The study reveals the dynamic mechanisms among these components and offers a theoretical reference for enterprises seeking to enhance their innovation capabilities.

Keywords: *Artificial intelligence, Enterprise innovation, Knowledge spillover, Organizational learning.*

1. Research Background

Today's global economy is developing at a high speed and the market competition is getting more and more intense, so small and medium-sized enterprises are facing unprecedented challenges. Technological innovation has become an important means for enterprises to adapt to market changes, improve product quality, and develop new markets, while knowledge, as one of the key factors of production, has an increasingly significant impact on enterprise innovation through its flow and transformation. In the current open economic environment, knowledge is no longer confined to a single organization, but spreads among different subjects through various channels such as technical cooperation, talent flow, industry chain interaction, etc. This knowledge spillover phenomenon has provided enterprises with abundant external knowledge resources, which have supported them to become an important external driving force for technological innovation, and in the meantime, as the core mechanisms for handling knowledge within the enterprise is organizational learning, the action effect can also affect the enterprise's absorption, integration and application of internal and external knowledge overflow. Part of the enterprise environment in the strong knowledge spillover effect, but due to the lack of enterprise subject to the full understanding of the organizational learning ,and attention to the external overflow of knowledge cannot be transformed into an inexhaustible source of corporate innovation, thus appearing stagnant innovation; while the other part of the enterprise in the knowledge overflow of the environment, with the help of their own organizational learning system, the perfect absorption of the knowledge spillover environment, and the integration of the enterprise's internal knowledge, so that its become the source of continuous innovation.

Therefore, it is necessary to research the relationship among knowledge spillover, organizational learning and enterprise innovation. On the one hand, how enterprise recognize the useful knowledge

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spillover for itself, avoiding enterprise flooded by the useless information which lead to the st, and still of innovation behavior; on the other hand, how enterprise through enhance organizational knowledge ,and enhance knowledge transformation ability, and the process of useful integration of external knowledge ,and internal resources is also need to further explanation

2. Theoretical Foundations

The relationship between knowledge spillover, organizational learning ,and corporate innovation is complex ,close, intertwined ,and interlocking, and it is necessary to split ,and combine them from the theoretical logic. The three core theories selected in this paper: absorptive capacity theory, knowledge base view ,and innovation ecosystem theory. those three core theories point to the key nodes in the chain respectively, so that a coherent explanation system can be formed: absorptive capacity theory focuses on the micro-process of external knowledge spillover being absorbed by enterprises through the organizational learning pathway, the knowledge base view further explains the process of organizational learning of the accumulation of its knowledge on the basis of the observation of its conversion into The innovation ecosystem theory puts the three theories into a more macroscopic context to examine the cyclic coupling arising from interactions among multiple subjects. These three theories form a complete theoretical framework for understanding the relationship between the three from micro to meso to macro, which lays a solid foundation for further analyses of the relationship in the later stage.

2.1. Absorptive Capacity Theory

Absorptive capacity theory was first proposed by Xing, Niu, and Li (2020)and the core idea is that the absorptive capacity of a firm refers to its ability to identify the value of new external knowledge, absorb this knowledge ,and apply it for business purposes (Xing et al., 2020). Within the scope of absorptive capacity, absorptive capacity can be subdivided into potential absorptive capacity ,and actual absorptive capacity (Jiang & Zhang, 2025). Potential absorptive capacity is mainly embodied in the ability of enterprises to effectively identify ,and accept external redundant knowledge resources, and correctly judge their reliability ,and adaptability to their own development. On the other hand, the ability of enterprise to digest, understand external knowledge ,and internalize external knowledge into their own knowledge categories is defined as actual absorptive capacity (Jiang & Zhang, 2025). Firms with stronger actual absorptive capacity tend to have a higher ability to tap into information resources, and thus the firm's innovation efficiency will be higher (Flor, Cooper, & Oltra, 2018).

From the perspective of academic mainstream, this capability is included in the framework of dynamic capability theory, i.e. it is the dynamic ability of firms to draw resources from the environment ,and internalise them to apply them to practical activities such as innovation ,and production (Makhloufi, Laghouag, Ali Sahli, & Belaid, 2021). Absorptive capacity theory provides the central link between knowledge spillovers, organizational learning ,and firm innovation: it reveals that knowledge spillovers need to be transformed into innovation momentum through a firm's ability to identify, digest ,and transform them,and that organizational learning is the key to enhancing this absorptive capacity.

2.2. Knowledge-Based View

Knowledge-based view is a kind of enterprise theory which rose in the 1990s. Its core view is that the enterprise is a collection of knowledge, and the competitive advantage of the enterprise comes from its unique knowledge ,and knowledge management capabilities. Grant ,and other scholars believe that, knowledge is the most important strategic recourse, it is difficult to imitate, different to replace ,and scarce (Guan & Zhao, 2025). The knowledge-based view of enterprise included explicit knowledge ,and tacit knowledge.Explicit knowledge refers to those Knowledge clearly expressed ,and conveyed in the form of words, icons, formulas, etc;while tacit knowledge refers to the knowledge that is difficult to be clearly expressed in words ,and mainly exists in the experience, skills, intuition ,and thinking patterns of employees,and has the characteristics of being highly personalize ,and context-dependent.

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In the corporate knowledge base view, organizations are seen as creators ,and integrators of knowledge.Enterprise through the absorption ,and transformation of explicit knowledge ,and tacit knowledge,in order to achieve the goal of establishing sustainable competitive advantage (Wu, 2022). The knowledge base view provides the core logic for the relationship between knowledge spillovers, organizational learning ,and corporate innovation: in the knowledge base view, knowledge is regarded as a key resource for corporate innovation,and the theory emphasises that the external knowledge which bring from knowledge spillover need to be combined to enterprise internal knowledge basic,only in this way can innovation momentum be formed.

2.3. Innovation Ecosystem Theory

The theory of innovation ecology was put forward by Moore (1993) refers to an ecosystem that is based on innovation elements, aims at the empowerment of the innovation environment,and takes the innovation subject as the implementer,so that the economic activities of the participants in various fields can form a benign interaction ,and co-operation relationship (Guan & Zhao, 2025). The theory further proposes that these subjects do not exist in isolation, but form a complex network relationship of interaction ,and interdependence through frequent interactions (Guan & Zhao, 2025).

From the perspective of this theory, knowledge overflow, organizational learning ,and enterprise innovation play an important role in the system ,and are closely related: knowledge overflow is like a link connecting different subjects in the system, which provides rich external knowledge materials for the enterprise's organizational learning; through organizational learning, the enterprise can effectively absorb ,and digest these knowledge overflows ,and transform them into its own knowledge ,and ability to better adapt to the competition within the system. competition within the system. At the same time, the new cognition ,and experience generated by enterprises in the process of organizational learning will also form new knowledge overflow to feed the whole system; enterprise innovation is precisely the result of the joint action of knowledge overflow ,and organizational learning,and the new products, services or technologies brought about by the innovation will promote the innovation of other enterprises in the system through knowledge overflow, thus forming a continuous cycle of benign ecology.

2.4. Comprehensive Review

The absorptive capacity theory, the knowledge base view ,and the innovation ecosystem theory have constructed an analytical framework for enterprise innovation from different levels,and they are progressive ,and mutually supportive.

The knowledge base view is the foundation of absorptive capacity theory,and the accumulation of internal knowledge assets of an enterprise determines the boundary of its ability to identify ,and digest external knowledge; absorptive capacity theory is the link between the first two,and the external knowledge provided by the innovation ecosystem needs to be transformed through the absorptive capacity of the enterprise in order to enrich the internal knowledge base; the innovation ecosystem theory provides the scenario ,and constraints for the first two,and the accumulation of knowledge base is not isolated, but needs to be iterated through cooperation in R&D, talent flow ,and other interactions in the ecosystem,and the openness of the system determines the speed of knowledge updating.

The ecosystem provides knowledge overflow,and the absorption capacity converts it into internal knowledge, while the expansion of knowledge base enhances the ecological collaboration ,and absorption capacity, which jointly promote enterprise innovation.

3. Literature Review

Enterprise innovation is the core driving force of economic development ,and enterprise competitiveness, but the process of its realisation does not exist in isolation, but needs to rely on the flow of knowledge, organizational learning capacity, the resilience of the innovation system,and the support of technological tools. In the following, we will start from enterprise innovation itself, gradually

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expand to the key factors ,and interaction mechanisms affecting it,and then construct a complete theoretical analysis framework.

3.1. Enterprise Innovation

Enterprise innovation refers to the process of purposeful, organized ,and value-creating changes in products, processes, organizations, marketing ,and other aspects of enterprises through the integration of internal ,and external resources, including maintenance innovation, disruptive innovation ,and other types, which is the core driving force to enhance enterprise competitiveness ,and promote economic development.

3.1.1. Concept Definition and Dimension

Enterprise innovation is the key factor of enterprise maintain advantage ,and achieve development in force market competition.Different scholars have defined enterprise innovation from different perspectives,and these definitions help us understand the connotation ,and influencing factors of enterprise innovation in a comprehensive ,and in-depth way.

Table 1.
Definition of enterprise innovation.

Author	Time	Definition	Dimension
Shen and Sun (2009)	2009	Intense market competition will promote the R&D productivity of enterprises	Process innovation, market mechanism, enterprise, innovation quality
Wang, Li, and Liu (2025)	2016	Industrial policy significantly increases firms' innovation activities, but only in terms of the quantity rather than the quality of innovation.	Business model innovation, policy intervention, intra-firm
Deng, He, and Wang (2020)	2020.	Tax reduction, and fee reduction has a significant role in promoting enterprise innovation.	Business model innovation, policy intervention, intra-firm
Lv, Ma, Tang, and Hao (2024)	2024	Government subsidies, and tax incentives can play complementary roles in incentivising firms' green technological innovation .	Product innovation, policy + planning, intra-firm
Zheng and Liu (2024)	2024	The degree of regional digital economy development has a certain promotion effect on enterprise innovation.	organizational innovation, technological opportunities, regional
Xie, Duan, and Wang (2024)	2024	Local government regulation can play a role in influencing firms' green technology innovation.	Process innovation, environmental regulation, enterprise

As shown in Table 1, by sorting out scholars' concepts of enterprise innovation, it is not difficult to conclude that enterprise innovation is affected by multiple factors, which promote enterprise innovation in process, business model, product, organization ,and process from different dimensions, reflecting the multifaceted ,and complexity of the concept of enterprise innovation.

3.1.2. Influencing Factors of Enterprise Innovation

The realisation of enterprise innovation relies on the joint action of internal ,and external factors, which are intertwined ,and interact with each other,and together constitute the ecosystem of enterprise innovation.

Internal resource input is the basic condition for enterprise innovation,and innovation guarantee not only refers to the scale of invested R&D funds, but also points to the efficiency of the use of funds ,and the professional skills of R&D personnel. Professional skills include the professional knowledge ,and skills possessed by R&D personnel, as well as their own innovative way of thinking ,and innovative ability ,and team coordination ability, which more or less affect the breadth ,and depth of innovation

research and have obvious impact on the progress of technological innovation breakthroughs ,and product replacement.

The external environment also provides the direction ,and power for innovation, which guides and promotes the innovation behaviour of enterprises through a variety of mechanisms. The external environment can be divided into market demand ,and policy support. Market demand mainly guides enterprises to adjust their innovation focus through signalling: consumers' demand ,and feedback on products will be transmitted to enterprises in the form of market feedback, prompting them to focus their innovation resources on areas that satisfy these demands; policy support motivates innovation investment by reducing costs and guaranteeing returns; government R&D subsidies can alleviate the pressure on enterprises' innovation funds,and tax incentives can raise the expectation of innovation. The perfect intellectual property protection system provides legal protection for enterprises' innovation achievements, which makes enterprises more confident to invest in high-risk ,and high-return innovation activities.

3.1.3. Comprehensive Review

Comprehensively, enterprise innovation as a dynamic process driven by multi-dimensional and multi-factors, its conceptual connotation ,and influencing mechanism present significant systemic characteristics. From the combing of existing studies, it can be seen that the dimensional division of enterprise innovation has expanded from a single technology or product level to multiple fields such as process, business model, organizations,and process,and the different dimensions of innovation are affected by external factors such as market competition ,and policy intervention, as well as relying on the enterprise's internal resource allocation ,and capacity accumulation, forming the basic framework of "synergy between internal ,and external factors".

Further analysis shows that knowledge spillover ,and organizational learning play a central role in the multi-dimensional realization of corporate innovation. From the perspective of external knowledge input, knowledge overflow provides rich external knowledge resources for enterprise innovation in various dimensions through different subjects, spatial scales ,and content types,and whether such overflow knowledge can be effectively transformed into actual innovation results depends on the identification ,and absorption ability of enterprises of external knowledge,and also relies on the guarantee of the stability of knowledge transfer by the toughness of the innovation chain.

From the perspective of internal capability transformation, organizational learning builds an internal capability foundation for enterprise innovation in various dimensions through multi-level ,and multi-flow knowledge accumulation ,and integration. In this process, innovation chain resilience further amplifies the driving effect of internal capabilities on innovation by providing a stable environment for organizational learning ,and facilitating the diffusion of learning outcomes across innovation dimensions.

3.2. Knowledge Spillover

Knowledge spillover manifests itself as the positive impact of one firm on another (Yang, Wu, Liu, & Li, 2025). The traditional innovation model forms a linear closed innovation system with demand-driven as the main factor (Moweryd, 1979) and its innovation activities tend to be far away from competitors ,and external players to ensure that the knowledge is held within the innovation body (Wu & Mi, 2011). However, in an open ,and competitive innovation environment, the complexity ,and uncertainty of innovation is increasing,and it is difficult to achieve high-quality, breakthrough innovation by relying only on the organization's internal R&D. The use of external knowledge spillovers ,and the sharing of information resources is an important way for firms to gain a competitive advantage (Zheng & Liu, 2024).

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3.2.1. Concept Definition and Dimension

Knowledge spillover is of great significance in the era of knowledge economy, and many scholars have studied, and defined it from different perspectives.

Table 2.
Definition of the concept of knowledge spillover.

Author	Time	Definition	Conceptual division
Xing et al. (2020)	2008	Innovation network knowledge spillovers are bidirectional, and network members can be both knowledge spillovers , and knowledge receivers.	Explicit-tacit mixing, local spillovers, and firm-individual concurrency
Kesidou and Romijn (2008)	2008	Knowledge spillovers are generally realized through enterprise derivative, personnel mobility , and information interaction.	Tacit knowledge is dominant, local + cross-regional spillovers, firms-individuals are the main actors
Zheng and Liu (2024)	2021	Knowledge spillover is one of the key concepts to explain agglomeration, innovation , and regional growth and is the main way to achieve technological progress , and innovation capacity.	Explicit knowledge, local spillovers, and region as the main player
Li, Hu, and Yu (2025)	2021	Knowledge spillovers have a significant driving effect on regional , and industrial high quality development.	Explicit knowledge, local spillovers, and region as the main body of action.
Wu, Huang, and Wang (2024)	2021	Knowledge spillover also have an impact on other economic actors, such as facilitating communication among members , and expanding external knowledge search channels.	Explicit knowledge, cross-regional spillovers, and enterprises as the main actors.

By sorting out the definitions ,and conceptual divisions of the above scholars on knowledge spillover, it can be seen that knowledge spillover has an important impact in many fields. Scholars have highlighted the undoubted importance of knowledge spillovers in corporate innovation from the perspectives of the direction of knowledge flow, the way of realization,and the impact on macroeconomic ,and regional development, etc. These research results provide an important theoretical basis for us to further study how knowledge spillovers can promote innovation, optimize the allocation of resources ,and promote economic development.

3.2.2. The Impact of Knowledge Spillover on Enterprise Innovation

The ability of organizations to absorb ,and exp,and the transformation of external knowledge is very dependent on the stability of the organizational structure, which includes flexible organizational decision-making power, institutionalized communication,and a close vertical ,and horizontal communication network (Wang et al., 2025). As a result, the usually unstable ,and highly dynamic organizational structure will be difficult to have sustainable innovation capability because it is difficult to absorb ,and utilize the innovation resources brought by external knowledge spillover; enterprises with high personnel mobility characteristics will also lead to the loss of team organizational experience ,and production technology ,and knowledge, reduce the core competitiveness of the enterprise,and negatively affect the performance of the enterprise in the market competition (Wang, Hou, & Kang, 2025).

In contrast, when enterprises have a stable organizational structure ,and low staff turnover level, they show relatively strong absorption ,and transformation ability of external knowledge spillover,and they can promote the absorption of scientific knowledge by R&D staff ,and improve market performance through stable ,and long-lasting intrinsic incentives ,and innovation decisions (Bénabou & Tirole, 2003).

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3.2.3. Impact of Knowledge Spillover on Innovation Chain Resilience

Knowledge spillovers, as a derivative of innovation activities, can generate positive economic effects through human capital ,and knowledge flows, thus enhancing the resilience of industrial innovation chains (Guangwen. Hou & Dan. Tian, 2025).

Firstly, knowledge spillovers are conducive to the aggregation of knowledge resources, promoting the diffusion of innovation resources ,and the efficient allocation of enterprises (Guangwen Hou & Dan. Tian, 2025). At the same time, knowledge spillover is also an important way of knowledge dissemination ,and diffusion, with the expansion of the scale of dissemination of knowledge, the variety of increasingly rich, the absorption capacity of the main bodies of the innovation chain ,and the ability to create knowledge is also continuously enhanced (Xing et al., 2020). Among them, the spillover of specialized knowledge ,and diversified knowledge has a particularly prominent impact on enterprise innovation: specialized knowledge spillover is very helpful to exp,and the breadth ,and depth of industrial knowledge innovation,and promote the degree of technological specialization of enterprises; Diversified knowledge spillovers help to exp,and the breadth of knowledge creation ,and accumulation (Audretsch & Belitski, 2020) and Promote the cross-integration of industrial technologies. In addition, knowledge spillover can also bring chain effect, driving effect, communication effect ,and incentive effect..Promote cross-fertilization of industrial technologies. In addition, knowledge spillover can also bring chain effect, driving effect, exchange effect ,and incentive effect (Audretsch & Belitski, 2020) these effects can also shorten the technological distance between the industries to a certain extent, strengthen the close connection between enterprises, institutions ,and government ,and other innovation subjects, form interdependent ,and mutually promoting innovation network ,and innovation ecology, improve the diversity ,and flexibility of the innovation chain from R&D to industrial isolation,and effectively prevent the risk of innovation chain breakage.

In summary,on the one hand ,knowledge spillover can use its specialization ,and diversification spillover effects to promote the aggregation and allocation optimization of knowledge resources in high-tech industries,promoting knowledge diffusion and technological innovation among different enterprises in the innovation chain, so as to enhance the stability of the innovation chain. On the other hand, knowledge spillover can reduce the cost of knowledge acquisition and innovation risk of small and medium-size enterprises in the innovation chain by improving the economy (Guangwen Hou & Dan. Tian, 2025).

3.3. Organizational Learning

If knowledge spillover is an "external economic nutrient" to reduce innovation costs, organizational learning is an "internal transformation mechanism" to enhance the economic value of knowledge. organizational learning begins with experience,and organizations create knowledge by interpreting experience to form practices (Wu, Xiao, & Wu, 2024) the process by which organizations continuously improve their behaviours ,and performances by acquiring,digesting,transforming,and applying knowledge so as to enhance the economic efficiency of knowledge utilization is called organizational learning.

3.3.1. Conceptual Definition and Dimensions

In today's rapidly developing business environment, organizational learning is crucial to the sustainable development of enterprises. Different scholars have defined ,and studied organizational learning from different perspectives in an attempt to reveal its mechanism of action in the process of enterprise growth ,and innovation. The following is the elaboration of the concepts related to organizational learning by several scholars.

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Table 3.
Definition of organizational learning concepts.

Author	Time	Definition	Dimension
Davies and Brady (2000)	2000	The dynamic nature of organizational learning can enhance the expertise of latecomer firms ,and deepen their understanding of complex technical architectures, thereby breaking through technical bottlenecks in complex product systems.	Double-loop learning, tacit knowledge, organizations as a whole
Gu, Li, and Wang (2006)	2005	The process by which members of an organizations continuously acquire knowledge, improve their own behaviour,and optimise the organizations's system, in order to maintain sustainable survival ,and healthy ,and harmonious development in the ever-changing internal ,and external environments.	Double-loop learning, hybrid knowledge, organizational whole
Argote and Miron-Spektor (2011)	2011	Firms effectively store ,and dynamically accumulate new knowledge, which in turn drives continuous organizational innovation ,and capability.	Meta-learning, explicit knowledge, organizations as a whole

As can be seen from Table 3, organizational learning has a non-negligible impact on both technological breakthroughs, organizational knowledge management ,and development,and the enhancement of corporate knowledge storage ,and innovation capabilities,and these studies from different perspectives provide a theoretical basis for enterprises to better understand ,and apply organizational learning.

3.3.2. The Impact of Organizational Learning on Enterprise Innovation

The basic way of organizational learning can be divided into two categories: exploratory learning and exploitative learning. Exploratory learning requires companies to pay for a longer time period ,and may even come at the cost of short-term performance loss, but the benefit is that it helps organizations to seek innovative solutions; exploitative learning allows for higher certainty and faster rate of return, but it also reduces the likelihood that organizations will acquire innovative solutions, which affects the long-term competitiveness of organizations (Wu et al., 2024).

organizational innovation helps companies to break the constant business habits, companies optimise the existing processes , improve the absorption and conversion rate of external resources through self-adjustment of internal ,absorption and conversion of external resources, thus giving companies more economic base that can be used for innovation.

3.3.3. Impact of Organizational Learning on Innovation Chain Resilience

Organizational learning starts from the economic point of view of enhancing the resilience of the innovation chain , through enhancing the adaptive ability and collaborative ability of the enterprise main body, so as to achieve the purpose of reducing the risk cost of innovation chain breakage.

On the one hand, through organizational learning, enterprises can effectively absorb the experience ,and lessons learned from similar enterprises, so as to enhance their ability to perceive and respond to environmental changes,and have the ability to quickly adjust their strategies in the face of environmental shocks; on the other hand, organizational learning can help to promote the sharing of knowledge and the establishment of trust among enterprises, so that each subject can complement each other's resources in a crisis, collaborate to fight against risks and safeguard the economic stability of the innovation chain.

3.4. Innovation Chain Resilience

Innovation chain resilience is a key economic link connecting knowledge spillovers, organizational learning ,and enterprise innovation, which refers to the ability of enterprises to maintain system

stability, recover or even evolve to a higher level of innovation in the face of external shocks (Shi & Hong, 2025).

3.4.1. Concept Definition and Dimensions

In today's fast-developing business environment, innovation chain resilience is crucial to the innovative development of enterprises. Different scholars have defined ,and studied innovation chain resilience from different perspectives in an attempt to reveal the role it plays in subject innovation.

Table 4.
A compendium of definitions of the concept of innovation chain resilience.

Author	Time	Definition	Dimension
Davies and Brady (2000)	2020	In global competition, the core of innovation competition is the innovation chain game.	Technological factors, macrosystems, exogenous perturbations
Moweryd (1979)	2022	Strengthening the knowledge spillover effect ,and the synergy of innovation subjects are important ways to promote industrial innovation ,and enhance the resilience of industrial innovation chain.	Knowledge elements, mesoscopic network, endogenous perturbation
Z. Li, Nie, Liu, and He (2023)	2023	The innovation chain can reflect the evolutionary trend of knowledge ,and technology throughout the commercialisation process as well as the value realisation process.	Knowledge elements, mesoscopic networks, endogenous perturbations
Guangwen Hou and Dan. Tian (2025)	2025	Enhancing the resilience of the innovation chain is particularly important for the improvement of the innovation level ,and competitiveness of high-tech industries.	Value factor, meso-network, exogenous perturbation

Through the elaboration and dimensional division of the concept of innovation chain resilience by the above scholars, it can be seen that innovation chain resilience plays a key role in business and industrial development. Whether it is on innovation capacity, adaptive capacity or anti-disturbance capacity, innovation chain resilience has an important impact. These research results provide an important theoretical foundation for us to further study how to improve innovation chain resilience ,and provides an important theoretical basis for promoting the development of enterprises and industries in a complex environment.

3.4.2. Research on the Mediating Role of Innovation Chain Toughness between Knowledge Spillover and Enterprise Innovation

Knowledge spillover smooths the science and technology innovation chain of basic research, applied development and industrial transformation, which happen to be the main content of enterprise innovation.

Knowledge spillover reduces information asymmetry between enterprises and promotes the flow of innovation factors between different enterprises, makes information sharing between innovation subjects in the innovation chain more convenient, information transmission more fluent, operational efficiency more efficient,and prompts them to form collaborative decision-making and innovation division of labour in operation management, risk warning and emergency treatment, so that they can react faster and take timely measures in the face of shocks,and influences the response to shocks. Influence the shock response speed and risk resilience of each subject in the innovation chain (Shi & Hong, 2025).

It is also the enhancement of the resilience of the innovation chain caused by knowledge spillover. on the one hand, reduces the cost of knowledge acquisition, the increase in the way to verify the accuracy of foreign knowledge, thus reducing the uncertainty brought about by business risks, so that enterprises have more funds and capital to put more costs on enterprise innovation; on the other hand, knowledge spillover also directly leads to the innovation cost saving effect and innovation knowledge

spillover effect, thus enhance the innovation efficiency and innovation ability of each subject in the innovation chain, significantly expanding the boundaries of enterprise R&D, promoting the massification of enterprise R&D personnel,and facilitating the interaction of enterprise R&D process (Shi & Hong, 2025) which further promotes the innovation of enterprises.

3.4.3. Research on the Mediating Role of Innovation Chain Resilience between Organizational Learning and Corporate Innovation

organizational learning can be divided into two categories: internal learning and external learning. Internal learning of an enterprise can accumulate unique technical and managerial knowledge, which can be diffused to other departments in the innovation chain through personnel mobility and cooperation projects, thus enriching the knowledge reserve of the main enterprise and enhancing the stability of the innovation chain. The opposite of internal learning is external learning. The external learning of enterprises can enhance the trust among the subjects of the innovation chain, strengthen the unified formation of the collaboration norms of different enterprises in the industry,and this "learning co-operation network" makes it easier for the subjects to reach the agreement on resource complementarity in the face of crisis, which can further accelerate the recovery process of the enterprises.

Secondly, the resilience of the innovation chain can provide systemic support for enterprise innovation,and a highly resilient innovation chain can amplify the results of organizational learning. On the one hand, the innovation chain can help the main enterprises in the innovation chain to build a stable knowledge sharing platform, so that the learning results among enterprise subjects can spread rapidly in the innovation chain, driving the upstream downstream subjects to improve together,and indirectly enhance the innovation output of enterprises; on the other hand, the innovation chain with high toughness can provide a feedback mechanism for the enterprise's organizational learning - the The technical problems encountered by enterprises in the learning process can be quickly solved through intra-chain collaboration, avoiding learning stagnation and guaranteeing the continuous promotion of innovation activities.

3.5. Artificial Intelligence

Artificial intelligence is a technology that simulates human intelligence through procedures to achieve perception, reasoning, learning and decision-making.In today's era of digitalisation, AI, as an emerging technological tool, offers new possibilities for continuous innovation in many dimensions.

3.5.1. Concept Definition and Dimension

With the rapid development of science and technology, the application of artificial intelligence in enterprises is becoming more and more extensive, which has a profound impact on enterprise operations,and the following will show the elaboration of several scholars on the concepts related to artificial intelligence in enterprises.

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Table 5.
Conceptual Definition of Artificial Intelligence Sorting.

Author	Time	Definition	Dimension
Wu et al. (2024)	2024	Artificial Intelligence can increase the speed of data collection ,and processing, quickly detect innovation needs, shorten the R&D cycle,and enhance innovation capabilities.	Natural Language Processing, Data Perception ,and Processing, Intra-Enterprise, R&D
Yu, Shi, and Wan (2023)	2024	Artificial Intelligence promotes technological innovation by improving learning ,and assimilation,and also facilitates knowledge dissemination ,and sharing, reshaping corporate innovation models.	Natural Language Processing, Learning ,and Absorption, Intra-enterprise, Requirement Identification
Yang et al. (2025)	2025	Artificial Intelligence is a technology in which computers, based on big data, machine learning and deep learning, enable computer systems to perform complex tasks by simulating human systematic thinking and autonomous decision-making, thus replacing human beings to perform specific tasks more efficiently.	Robotics, task substitution, intra-enterprise, commercialisation
Xie et al. (2024)	2025.	Artificial Intelligence (AI), as an important tool for enterprises to adapt to environmental changes,and its accelerated integration with the real economy are crucial to breed enterprise innovation resilience.	Machine learning, decision making ,and optimisation, intra-enterprise + supply chain

As shown in Table 5, by sorting out the concepts related to AI in enterprises by the above scholars, it can be seen that AI has a significant impact on a number of aspects such as enterprise innovation, human and resource allocation, knowledge management, technology base and innovation resilience. These studies reveal the opportunities and challenges brought by AI to enterprises from different perspectives, providing theoretical references and practical guidance for enterprises to better apply AI technology.

3.5.2. Research on the Regulation of Artificial Intelligence

The moderating effect of artificial intelligence runs through the interaction of knowledge overflow, organizational learning, innovation chain resilience and the whole chain of enterprise innovation, optimising the efficiency and quality of each link through technological empowerment,and then reinforcing or modifying the relationship between the original variables.

In the relationship between knowledge spillover and innovation chain resilience, AI plays a moderating role by improving knowledge identification and matching efficiency. In traditional knowledge spillovers, a large amount of mixed information may reduce the efficiency of the innovation chain in absorbing key knowledge, leading to the interference of invalid knowledge on the system resilience, while the use of artificial intelligence can make the enterprise subject efficiently and quickly lock the high-value knowledge spillovers,and thus improve the resilience of resistance and adaptability. For the correlation between organizational learning and the resilience of the innovation chain, AI achieves regulation by empowering the precision and synergy of the learning process. On the one hand, the intelligent recommendation system can push personalised learning resources based on employees' knowledge structure and learning objectives, accelerating the process of method optimisation in single-loop learning and goal reflection in double-loop learning,and make it easier for internal learning results to be transformed into collaborative capabilities of the innovation chain; on the other hand, the AI-driven collaboration platform can break the time and space constraints, promote real-time knowledge sharing and problem consultation among the subjects of the innovation chain,and strengthen the construction of trust mechanism for external learning. Strengthening the role of external learning on the construction of trust mechanism, making the promotion effect of organizational learning on resilience more significant.

3.6. Study Review

Enterprise innovation is closely related to knowledge spillovers, organizational learning, innovation chain resilience and artificial intelligence. Although existing studies have constructed a preliminary framework of association, the interaction mechanism among the elements still needs to be further deepened.

From the perspective of knowledge spillover, knowledge spillover provides a rich source of external knowledge for enterprise innovation, reduces the cost of knowledge acquisition for SMEs,and thus effectively improves the innovation capability ,and innovation chain resilience of enterprises.

From the perspective of organizational learning, organizational learning plays a crucial role in the process of enterprise innovation. organizational learning helps enterprises to further accumulate and transform knowledge through internal employee exchanges, departmental collaboration,and external industry bench marking and cooperation exchanges.

Innovation chain resilience is an important factor in guaranteeing the smooth implementation of enterprise innovation activities. For knowledge spillover, the knowledge spillover between enterprise subjects can significantly enhance the enterprise's innovation chain toughness, thus giving the enterprise subjects a better ability to cope with external interference; for organizational learning, the innovation chain can amplify the results of organizational learning and guarantee the continuous promotion of innovation activities.

Artificial intelligence plays a moderating role in the enterprise innovation ecology. For example, when assisting enterprises in screening knowledge, AI can help them eliminate irrelevant news and distill knowledge that is useful to the enterprise, which to a large extent, can ensure the comprehensiveness and accuracy of the knowledge; in promoting the process of organizational learning, AI can also be empowered by the precision and synergy of the learning process, thus avoiding an excessive impact on the enterprise's original culture and management model, significantly Promote the positive effect of organizational learning on resilience.

3.7. Mechanism of Action

This article is arrounded enterprise innovation as core issue,contributes a multi-factor interaction framework which included knowledge spillover,organizational learning,artificial intelligence and enterprise innovation,and incorporate the regulatory role of artificial intelligence.The specific action mechanism is as follows:

As for knowledge spillover,it through three dimensions of spillover content, spatial scale and main body form a multi-dimensional knowledge flow network.Knowledge in different stages, with explicit or invisible content as the carrier, in the local or cross-regional spatial scale, with the help of enterprises, colleges and universities ,and other subjects of the interaction to complete the process of knowledge transfer,and ultimately flow into the enterprise to become the enterprise innovation of the external learning resources ,and learning from the object.The toughness of the innovation chain assumes an intermediary role in this process: the innovation with better tough can maintain the stability of knowledge flow and the efficiency of knowledge absorbed,enable enterprises to avoid innovation opportunities missed due to knowledge transfer interruption or integration failure.In contrast,if the resilience of the innovation chain is insufficient, the knowledge spillover may be unable to be transformed into the actual innovation kinetic energy of the enterprise due to the channel breakage or collaboration conflict.

From the perspective of organizational learning,the internal knowledge accumulation system is constructed through two dimensions, namely, knowledge type and organizational level: different enterprise subjects rely on the division of explicit and implicit knowledge types,and carry out learning activities at each organizational level through internal and external flows, thus accumulating and forming the enterprise's internal knowledge capital.In this process,the toughness of innovation chain play a magnifying role : on the one hand ,the toughness of innovation chain provides a stable collaborative environment,ensuring the continuity of study process;on the other hand,it also promote

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the diffusion with learning achievement in innovation chain,and ultimately feeds the enterprise's own innovation capability.

The regulating role of artificial intelligence runs through the whole chain,and artificial intelligence optimizes the efficiency of each link through technological empowerment: in the knowledge spillover link,artificial intelligence can promote the knowledge recognition and matching accuracy,and reduce the interference of the toughness of innovation made by redundant information;in the organizational learning link,it through personalized recommendation and redundant collaborative platform reinforcement learning makes the promotion effect for toughness;in the transformation of toughness of the innovation chain to enterprise innovation link, artificial intelligence accelerates system response and resource scheduling, making the supporting role of resilience more timely ,and forward-looking.

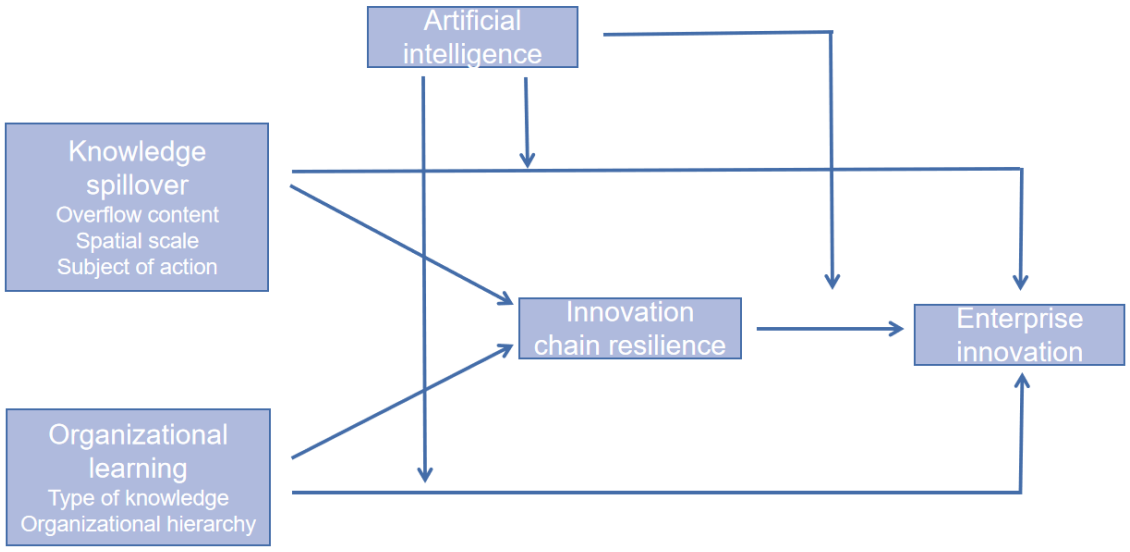

Figure 1.
Mechanism of action.

4. Conclusion

Based on absorptive capacity theory, knowledge base view and innovation ecosystem theory, this study overviews enterprise innovation and related elements.

Firstly,from the perspective of absorptive capacity theory,this study deeply analyzes the synergistic mechanism of knowledge spillover to provide external knowledge input, organizational learning to achieve knowledge internalization ,and transformation,and innovation chain resilience to ensure process stability and clarifies the dual dependence of enterprise innovation on internal resources and external knowledge absorption and transformation capacity.

Secondly,based on knowledge-based view,this paper clarifies the nature of knowledge as the core resource of enterprise innovation,and points out that knowledge spillover can make amends in the short board of knowledge of the enterprise itself efficient,organizational learning is a way for enterprises to construct the enterprise's internal knowledge base,and innovation power through continuous knowledge acquisition,digestion ,application and the innovation chain resilience plays a key role in maintaining the continuous supply of knowledge.

Thirdly, based on the innovation ecosystem theory, the study in this paper explores the dynamic interaction pattern of multiple elements, revealing how knowledge overflow enriches system resources,

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how organizational learning enhances enterprise adaptability, how innovation chain resilience safeguards system stability,and the facilitating role of AI in regulating the relationship between the various elements for enterprise innovation.

Fourthly, through the integrated analysis of cross-theoretical research, this paper clearly presents the specific relationship between each variable and enterprise innovation: knowledge spillover provides external knowledge source for enterprise innovation and is an important external driving force for enterprise innovation, while organizational learning is the key link between knowledge spillover and enterprise innovation and lays the foundation for innovation; Innovation chain toughness plays an intermediary role in the transformation process from knowledge spillover to enterprise innovation, which indirectly promotes enterprise innovation; artificial intelligence plays a moderating role in the above relationship, which strengthens the promotion effect of knowledge spillover and organizational learning on enterprise innovation.

On the whole, this paper organically integrates the logic of the role of elements from different theoretical perspectives,and although there are still limitations that some of the potential relationships in the complex interactions of the elements have not yet been fully revealed, it still clearly presents the role paths ,and intrinsic links of the elements related to enterprise innovation, which provides valuable references to the research in this field.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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