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System Dynamics Modeling and Simulation of Influencing Factors for Collaborative Knowledge Innovation in Enterprise Value Chains: Postprint

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Abstract

[Objective] To conduct causal relationship analysis and modeling simulation of the collaborative knowledge innovation process in the enterprise value chain, thereby improving its efficiency. [Method] This study proposes a system dynamics model for the influencing factors of enterprise value chain collaborative knowledge innovation. Based on identifying the influencing factors of this process, a corresponding system dynamics model is constructed according to its causal relationship analysis. [Results] The system dynamics model for influencing factors of enterprise value chain collaborative knowledge innovation is simulated using Vensim PLE software to further validate its validity and sensitivity. Experimental results demonstrate that the model can appropriately fit the real-world situation of this process. [Limitations] Simulated data was employed during system simulation; further validation using actual data from the enterprise value chain is required. Conclusion Based on the simulation results, an optimization scheme for collaborative knowledge innovation is proposed to improve the efficiency of enterprise value chain collaborative knowledge innovation.

Full Text

Preamble

System Dynamics Modeling and Simulation of Influencing Factors in Collaborative Knowledge Innovation in Enterprise Value Chains

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Abstract

[**Objective**] This research aims to conduct causal relationship analysis and modeling simulation of the collaborative knowledge innovation process in enterprise value chains to improve its efficiency. [**Methods**] We propose a system dynamics model for the influencing factors of collaborative knowledge innovation in enterprise value chains. Based on identifying the influencing factors of this process, we construct a corresponding system dynamics model according to their causal relationships. [**Results**] Using Vensim PLE software, we performed system simulation on the system dynamics model of influencing factors for collaborative knowledge innovation in enterprise value chains to further verify its validity and sensitivity. Experimental results demonstrate that the model can closely fit the actual situation of this process. [**Limitations**] The system simulation employs simulated data, which requires further validation using actual data from enterprise value chains. [**Conclusions**] Based on the simulation results, we propose optimization solutions for collaborative knowledge innovation to enhance the efficiency of collaborative knowledge innovation in enterprise value chains.

Keywords: Enterprise value chain; Collaborative knowledge innovation; Influencing factors; System dynamics
Classification Numbers: F270.7; G250.2

Introduction

In the era of knowledge economy, sustainable innovation and development of enterprises depend on knowledge innovation, yet relying solely on their own capabilities for knowledge innovation can no longer meet the demands of innovative development. Therefore, enterprises urgently need to achieve sharing and complementary advantages of knowledge resources in their value chains through collaborative knowledge innovation activities to attain sustainable innovation development goals. However, collaborative knowledge innovation activities in enterprise value chains are characterized by multiple participating entities and complex interest relationships [1]. Although Chinese enterprises have made some beneficial attempts in collaborative knowledge innovation at the current stage, many prominent issues such as low knowledge innovation efficiency still persist.

While domestic and international scholars have conducted numerous studies in the field of knowledge management, research on collaborative knowledge innovation remains insufficient. The study of knowledge creation theoretical models began with Nonaka's [2] SECI model, which encompasses the processes of knowledge "Socialization,""Externalization,""Combination,"and "Internalization."This model takes tacit knowledge as its starting point and covers the mutual transformation process between tacit and explicit knowledge. However, the model is a closed system that confines knowledge innovation within organizations and neglects the critical role of external knowledge. Ding Zhihui et al. [3] proposed an

enterprise knowledge innovation value chain model that can better demonstrate the processes of knowledge innovation and knowledge sharing, but it focuses primarily on analyzing the internal mechanisms of internal knowledge growth and transformation without proposing detailed operational mechanisms.

Currently, most research on collaborative knowledge innovation by scholars at home and abroad concentrates on the internal mechanisms of sharing, transfer, and integration processes in knowledge innovation, as well as collaborative innovation models. However, this paper argues that to achieve expected goals in collaborative knowledge innovation, it is essential to clarify the causal relationships in enterprise value chain collaborative knowledge innovation and incorporate the dynamic changes of various influencing factors into the model. Therefore, this study adopts a system dynamics perspective to improve the efficiency of collaborative knowledge innovation in enterprise value chains and provide references for domestic enterprises.

2 Causal Relationship Analysis of Influencing Factors in Collaborative Knowledge Innovation in Enterprise Value Chains

Collaborative knowledge innovation in enterprise value chains refers to value chain members fully utilizing each other' s knowledge resources to achieve complementary advantages. Enterprises on the value chain create new knowledge through mutual collaboration, expand their respective knowledge reserves, and thereby enhance the core competitiveness of each member and the overall competitive strength of the value chain. The collaborative knowledge innovation system in enterprise value chains studies knowledge flow, including knowledge absorption, creation, and transfer among enterprises on the value chain. It has clear boundaries, and the collaborative knowledge innovation process conforms to the basic laws of knowledge absorption, creation, and transfer in practice, exhibiting obvious interactive and feedback relationships. Such feedback and system operation trends are difficult to judge based solely on experience. However, system dynamics enables the construction of feedback models based on the causal relationships of collaborative knowledge innovation systems and utilizes computer simulation to conduct in-depth analysis of the feedback structure and dynamic relationships in the enterprise value chain collaborative knowledge innovation process.

2.1 Influencing Factors Analysis

(1) Influencing Factors Identification

Enterprise value chain collaborative knowledge innovation is a complex process involving multiple influencing factors that interact and form very complex hierarchical factor chains. Warfield [4] pointed out that the Interpretive Structural Modeling (ISM) method can identify multi-level influencing factors for complex socio-economic system structural problems from numerous factors. We applied

the ISM model to identify influencing factors of collaborative knowledge innovation in enterprise value chains and summarized their direct and deep influencing factors. Based on a comprehensive review of existing research on influencing factors of collaborative knowledge innovation [5-7], this paper categorizes nine factors affecting collaborative knowledge innovation in enterprise value chains into two levels: direct influencing factors, including knowledge sharing willingness and knowledge innovation capability; and deep influencing factors, including enterprise value chain relationship strength, benefit distribution mechanism, enterprise collaborative knowledge innovation capital investment, enterprise leadership behavior, innovation team structure, information technology support, and collaborative knowledge innovation incentive strategies, as shown in [Figure 1: see original paper].

Among the nine influencing factors mentioned above, knowledge sharing willingness refers to the willingness of enterprises to share innovative knowledge on the collaborative knowledge innovation platform of the value chain. Knowledge innovation capability refers to the ability of enterprises to create new knowledge by absorbing knowledge from other enterprises. Enterprise value chain relationship strength refers to the closeness of relationships between leading enterprises and other collaborative enterprises [8]. Benefit distribution mechanism refers to the methods and proportions of benefit distribution among enterprises after the value chain obtains collaborative knowledge innovation returns. Enterprise collaborative knowledge innovation capital investment refers to the amount of capital invested by external sources into collaborative knowledge innovation activities. Enterprise leadership behavior refers to the degree of attention paid by the leadership of each enterprise in the value chain to collaborative knowledge innovation issues. Innovation team structure refers to the team composition responsible for collaborative knowledge innovation in each enterprise. Information technology support refers to the technical support provided by information network technology in collaborative knowledge innovation activities. Collaborative knowledge innovation incentive strategies refer to incentive strategies designed by the enterprise value chain and collaborative innovation teams to stimulate the innovative potential of knowledge workers.

(2) Influencing Factors Analysis

At the level of direct influencing factors, the stronger an enterprise' s willingness for collaborative knowledge sharing, the more efficient its knowledge sharing process with other enterprises in the value chain. Similarly, the stronger an enterprise' s knowledge innovation capability, the more likely it is to create knowledge that does not exist in the enterprise value chain by absorbing new knowledge [9]. Knowledge sharing willingness and knowledge innovation capability complement each other and substantially improve knowledge innovation efficiency. At the level of deep influencing factors, stronger enterprise value chain relationships, more reasonable benefit distribution mechanisms, and greater enterprise collaborative knowledge innovation capital investment will all enhance knowledge sharing willingness [10]. Meanwhile, greater enterprise collaborative

knowledge innovation capital investment, more attention from enterprise leadership to collaborative knowledge innovation, more reasonable innovation team structure, stronger information technology support, and more complete collaborative knowledge innovation incentive strategies will all provide guarantees for improving knowledge innovation capability.

As time progresses, under the influence of factors such as enterprise leadership behavior, innovation team structure, collaborative knowledge innovation incentive strategies, and information technology support, the knowledge innovation capabilities of leading and collaborative enterprises continuously strengthen, knowledge innovation volume keeps increasing, and enterprise knowledge stock also continues to grow, leading to corresponding increases in both knowledge sharing volume and enterprise knowledge elimination volume [11]. Simultaneously, knowledge sharing willingness continuously improves under the influence of enterprise value chain relationship strength and benefit distribution mechanisms, which also increases knowledge sharing volume. The increase in knowledge stock of leading and collaborative enterprises will bring about increased knowledge integration volume, indirectly enhancing knowledge transformation capability and commercialization degree, thereby improving enterprise profitability and knowledge innovation returns, and ultimately leading to increased enterprise collaborative knowledge innovation capital investment [12]. Conversely, increased enterprise collaborative knowledge innovation capital investment brings about improved knowledge sharing willingness and enterprise knowledge innovation capability, which indirectly increases knowledge sharing volume. In this way, the enterprise value chain collaborative knowledge innovation system forms a dynamic and orderly cyclic structure.

In this cyclic structure, knowledge stock refers to the total amount of knowledge stored within an enterprise, including the enterprise' s own knowledge reserves, knowledge obtained through its own innovation, and knowledge resources from internalizing externally shared knowledge [13]. Knowledge innovation volume refers to the knowledge innovation resources obtained by enterprises through their own knowledge innovation investment and utilization of knowledge innovation capabilities, whose growth is reflected in the improvement of enterprise knowledge stock [14]. Knowledge sharing volume refers to the amount of knowledge resources that leading and collaborative enterprises share to the enterprise value chain from their own knowledge stock to achieve collaborative knowledge innovation goals [15]. Knowledge elimination volume refers to the amount of knowledge eliminated from their own knowledge stock by enterprises to better adapt to market environment changes.

2.2 Causal Loop Diagram Analysis

To make the analysis process clearer, this paper examines how a leading enterprise implements collaborative knowledge innovation with a certain collaborative enterprise on the value chain. The leading enterprise refers to a core enterprise with control and leadership rights on the value chain, while the collaborative

enterprise refers to other auxiliary enterprises that conduct division of labor around the leading enterprise on the value chain [16]. Based on the previous identification and analysis of influencing factors for collaborative knowledge innovation, this paper constructs a causal relationship diagram of influencing factors for collaborative knowledge innovation in enterprise value chains, as shown in [Figure 2: see original paper].

[Figure 2: see original paper] mainly includes the following loops: 1. Leading enterprise knowledge stock → Leading enterprise knowledge innovation volume → Leading enterprise knowledge innovation capability → Leading enterprise knowledge innovation volume → Leading enterprise knowledge stock 2. Leading enterprise knowledge stock → Leading enterprise knowledge elimination volume → Leading enterprise knowledge elimination rate → Leading enterprise knowledge elimination volume → Leading enterprise knowledge stock 3. Leading enterprise knowledge stock → Knowledge sharing threshold → Knowledge sharing volume → Collaborative enterprise knowledge stock 4. Collaborative enterprise knowledge stock → Collaborative enterprise knowledge innovation volume → Collaborative enterprise knowledge innovation capability → Collaborative enterprise knowledge innovation volume → Collaborative enterprise knowledge stock 5. Collaborative enterprise knowledge stock → Collaborative enterprise knowledge elimination volume → Collaborative enterprise knowledge elimination rate → Collaborative enterprise knowledge elimination volume → Collaborative enterprise knowledge stock 6. Collaborative enterprise knowledge stock → Knowledge sharing threshold → Knowledge sharing volume → Leading enterprise knowledge stock

All six feedback loops above are positive feedback loops, reflecting the causal relationships of influencing factors in collaborative knowledge innovation. Among them, knowledge sharing volume is influenced by four factors: knowledge sharing willingness, leading enterprise knowledge stock, collaborative enterprise knowledge stock, and knowledge sharing threshold. All four factors have a positive influence relationship with knowledge sharing volume. The stronger the knowledge sharing willingness, the greater the knowledge sharing volume. This factor is influenced by enterprise value chain collaborative knowledge innovation platform investment, relationship strength, and benefit distribution, ultimately reflected in enterprise value chain collaborative knowledge innovation capital investment.

3 System Dynamics Model Construction for Influencing Factors in Collaborative Knowledge Innovation in Enterprise Value Chains

3.1 Model Boundaries and Assumptions

The first step in model construction is to consider the system boundaries. Within the boundaries refers to the system itself, i.e., the parts that need attention in modeling, while outside the boundaries refers to the external

environment of the system. This paper selects the collaborative knowledge innovation process of enterprise value chains and its influencing factors as the model boundaries.

To clarify the prerequisites for the operation of the enterprise value chain collaborative knowledge innovation system, this paper analyzes basic assumptions from three perspectives.

1. After collaborative knowledge innovation in the enterprise value chain begins, leading enterprises and collaborative enterprises are constantly carrying out collaborative knowledge innovation, and these activities alternate with each other. Therefore, Assumption 1 is proposed.

Assumption 1: Collaborative knowledge innovation between leading enterprises and other collaborative enterprises is a continuous and gradual process.

2. The number of collaborative enterprises on the enterprise value chain is large, so their knowledge stock and knowledge innovation volume both exceed those of leading enterprises in absolute terms. Moreover, leading enterprises are closer to the market and have faster knowledge update speeds. Therefore, Assumption 2 is proposed.

Assumption 2: Collaborative enterprises have large knowledge stock, and their knowledge innovation volume is higher than that of leading enterprises; leading enterprises have higher knowledge elimination rates than collaborative enterprises.

3. As the core enterprise of the enterprise value chain, the leading enterprise has higher knowledge innovation efficiency and possesses the initiative to distribute final benefits on the value chain, resulting in higher knowledge innovation willingness. Therefore, Assumption 3 is proposed.

Assumption 3: Both knowledge innovation efficiency and knowledge innovation willingness of leading enterprises are higher than those of collaborative enterprises.

3.2 System Flow Diagram

By analyzing data calculability and considering data reality, this paper generalizes the causal relationship diagram of influencing factors for collaborative knowledge innovation in enterprise value chains and further derives the system flow diagram of influencing factors for collaborative knowledge innovation in enterprise value chains. This system includes 2 level variables (L), 5 rate variables (R), 21 auxiliary variables (A), and 15 constants (C), totaling 43 variables, as shown in [Figure 3: see original paper].

3.3 Equation Design and Variables

L Leading enterprise knowledge stock = INTEG(Leading enterprise knowledge innovation volume + Knowledge sharing volume - Leading enterprise knowledge

elimination volume, 20) (1)

R Leading enterprise knowledge elimination volume = Leading enterprise knowledge stock × Leading enterprise knowledge elimination rate

A Leading enterprise knowledge innovation volume = Leading enterprise knowledge stock × Leading enterprise knowledge innovation capability

C Leading enterprise knowledge elimination rate = 0.04

L Collaborative enterprise knowledge stock = INTEG(Collaborative enterprise innovation knowledge volume + Knowledge sharing volume - Collaborative enterprise knowledge elimination volume, 100) (5)

R Collaborative enterprise knowledge elimination volume = Collaborative enterprise knowledge stock × Collaborative enterprise knowledge elimination rate

A Collaborative enterprise knowledge innovation volume = Collaborative enterprise knowledge stock × Collaborative enterprise knowledge innovation capability

C Collaborative enterprise knowledge elimination rate = 0.02

A Knowledge sharing threshold = IF THEN ELSE(Leading enterprise knowledge stock / Collaborative enterprise knowledge stock < 0.9, Leading enterprise knowledge stock / Collaborative knowledge stock, 0.9)

Knowledge sharing threshold reflects the protection of intellectual property rights or technical secrets by collaborative knowledge innovators in the enterprise value chain, where this portion of knowledge is no longer shared.

A Knowledge sharing volume = DELAY1I(IF THEN ELSE(Knowledge sharing threshold < 0.9, Leading enterprise knowledge sharing capability × Collaborative enterprise knowledge sharing capability × Knowledge sharing willingness, 0), 2, 0)

Equation (10) indicates that when the knowledge sharing threshold reaches 0.9, knowledge sharing in the enterprise value chain temporarily stops. In reality, during the collaborative knowledge innovation process, each enterprise must select and filter the knowledge to be transmitted, followed by stages of comprehension, absorption, and re-preparation. Therefore, the first-order delay function in this formula reflects that knowledge sharing begins after a two-month delay in the model, with the initial knowledge sharing volume set to 0 here.

A Knowledge sharing willingness = Relationship strength × Benefit distribution × LN(Enterprise collaborative knowledge innovation value chain investment)

Knowledge sharing willingness is jointly determined by three factors: relationship strength, benefit distribution, and enterprise collaborative knowledge innovation value chain investment. All three are positively correlated with knowledge sharing willingness.

A Leading enterprise knowledge innovation investment = Enterprise collaborative knowledge innovation capital investment × Leading enterprise knowledge innovation investment proportion

A Collaborative enterprise knowledge innovation investment = Enterprise collaborative knowledge innovation capital investment × Collaborative enterprise knowledge innovation investment proportion

A Leading enterprise profitability = Leading enterprise profit × (1 + Leading enterprise profit growth rate)

A Collaborative enterprise profitability = Collaborative enterprise profit × (1 + Collaborative enterprise profit growth rate)

A Enterprise collaborative knowledge innovation capital investment = Leading enterprise knowledge innovation return + Collaborative enterprise knowledge innovation return

A Enterprise collaborative knowledge innovation value chain investment = Enterprise collaborative knowledge innovation capital investment - Leading enterprise knowledge innovation investment - Collaborative enterprise knowledge innovation investment

4 Simulation and Analysis

4.1 Initial Value Selection and Parameter Settings

This paper completes model simulation by constructing a Vensim PLE software environment. The simulation time is set to 60 months. According to Assumption 2, collaborative enterprises have larger knowledge stock than leading enterprises, so the initial value of leading enterprise knowledge stock is set to 20, and the initial value of collaborative enterprise knowledge stock is set to 100. The enterprise value chain conducts knowledge sharing with the leading enterprise as the core. In the enterprise value chain collaborative knowledge innovation process, collaborative enterprises will invest more knowledge resources than leading enterprises, and collaborative enterprises have stronger knowledge sharing capabilities. Therefore, the leading enterprise knowledge sharing capability is set to 0.6, and the collaborative enterprise knowledge sharing capability is set to 0.9. The profits of leading and collaborative enterprises are 600,000 yuan each month. Among them, two influencing factors of knowledge sharing willingness (relationship strength and benefit distribution) take values in the interval [0, 1].

4.2 Validity Testing

The purpose of model simulation operation is to test the validity and sensitivity of simulation results. Validity testing aims to verify whether the model reflects the characteristics and changing patterns of the actual system, enabling analysis and research on the model to determine whether it can objectively and

correctly understand the problem to be solved. Since the concept of collaborative knowledge innovation is relatively abstract, this paper adopts theoretical testing to examine the model' s validity, consistency, and adaptability. The model simulation results are shown in [Figure 4: see original paper].

[Figure 4: see original paper] System Simulation Results

(1) Figures 4(a) and 4(b) show that the knowledge gap presents a trend of first increasing and then decreasing. By analyzing its main causes, we find that in the initial stage of knowledge sharing, leading enterprises have relatively small knowledge stock and relatively weak knowledge innovation capabilities, while collaborative enterprises possess higher knowledge innovation capabilities, causing the knowledge gap between the two parties to gradually expand in the short term. As knowledge sharing progresses, leading enterprises' knowledge innovation capabilities strengthen, knowledge innovation volume increases, and knowledge stock grows, continuously narrowing the knowledge gap with collaborative enterprises. Although knowledge sharing tends to become 平缓 as leading enterprise knowledge stock increases, leading enterprises' knowledge innovation capabilities have already gained a dominant position by this time, causing the knowledge gap between the two parties to narrow rapidly.

(2) Figures 4(c) and 4(d) show that the growth rates of knowledge innovation volume for both leading and collaborative enterprises exhibit an accelerating trend, with leading enterprises' knowledge innovation volume growing rapidly in the later stage. After a period of knowledge sharing and accumulation, leading enterprises gradually enhance their own knowledge innovation capabilities, resulting in higher absolute numbers of knowledge innovation and faster growth rates than collaborative enterprises.

(3) Figures 4(e) and 4(f) show that in terms of absolute quantity of knowledge elimination volume, leading enterprises are higher than collaborative enterprises. This is because leading enterprises are closer to the market and have faster knowledge update speeds than collaborative enterprises.

(4) Figures 4(g) and 4(h) show that the profitability of both leading and collaborative enterprises tends to grow, yet their growth rates gradually slow down. This is because in the initial stage of knowledge sharing, both leading and collaborative enterprises have relatively small knowledge stock. As knowledge stock gradually increases, knowledge integration volume also gradually increases, knowledge transformation capability continuously strengthens, and the commercialization degree of knowledge products continuously improves, ultimately leading to gradual profit increases. When the knowledge transformation capabilities of both enterprises reach a certain level, the growth rate of knowledge product commercialization slows down, and the profit growth rate also consequently slows down.

The knowledge stock of leading and collaborative enterprises can be reflected through knowledge gap and knowledge sharing volume, so they are not discussed

separately. The simulation results of this model show that some important patterns have high consistency with reality, indicating that the model can conduct relatively realistic simulation of the dynamic process of collaborative knowledge innovation in enterprise value chains and can also provide valuable decision-making references for enterprises.

4.3 Sensitivity Analysis

Sensitivity analysis involves changing variables or structures in the model and comparing model outputs to analyze their impact levels, enabling enterprises to obtain theoretical support and effective decision-making support in practical work. This paper considers the importance of each variable when conducting sensitivity analysis by changing two variables in the model: knowledge sharing willingness and knowledge sharing threshold.

(1) Changing Knowledge Sharing Willingness

First, while keeping enterprise collaborative knowledge innovation value chain investment unchanged, we increase relationship strength and benefit distribution to obtain Improvement Plan 1. Based on Improvement Plan 1, we further increase enterprise collaborative knowledge innovation value chain investment to obtain Improvement Plan 2. The simulation results are shown in [Figure 5: see original paper].

[Figure 5: see original paper] Sensitivity Analysis of Knowledge Sharing Willingness

From the original plan to Improvement Plan 1, and then to Improvement Plan 2, the knowledge gap shows a clear narrowing trend, yet its pattern remains relatively consistent. After continuous improvement of the plans, the knowledge stock of both leading and collaborative enterprises shows an upward trend. This demonstrates that the model has high sensitivity to knowledge sharing willingness. In response to this result, we believe that enterprises should establish a collaborative knowledge innovation mechanism for the value chain, strengthen the construction of enterprise collaborative knowledge innovation value chains, clarify benefit distribution between leading and collaborative enterprises on the value chain, and promote knowledge sharing and integration among value chain members. These measures will effectively improve the trust level among collaborative knowledge innovation entities in enterprise value chains and the overall knowledge architecture.

(2) Changing Knowledge Sharing Threshold

By lowering the knowledge sharing threshold boundary in the knowledge sharing volume equation to 0.7, we obtain Improvement Plan 1; further lowering it to 0.5 yields Improvement Plan 2. The model simulation results are shown in [Figure 6: see original paper].

[Figure 6: see original paper] Sensitivity Analysis of Knowledge Sharing Threshold

[Figure 6: see original paper] shows that as the knowledge stock of leading and collaborative enterprises continuously improves and the knowledge sharing threshold reaches its critical value, both enterprises stop knowledge sharing to avoid homogenization trends in knowledge products. It is precisely due to the lack of knowledge sharing that the knowledge stock of both leading and collaborative enterprises decreases to varying degrees. This leads to the conclusion that the model has high sensitivity to knowledge sharing threshold. Therefore, we believe that continuously promoting close cooperation among all parties in the enterprise value chain collaborative knowledge innovation system and expanding the scope of collaborative innovation will facilitate knowledge absorption, transfer, and sharing in the enterprise value chain, which will bring knowledge stock increases to all enterprises in the value chain.

5.1 Innovation Points Analysis

Comparing this paper with previous research, the innovations are as follows:

1. Liu Yanfang et al. [17] conducted research from the perspective of knowledge innovation subjects and characteristics; Wang Yumei et al. [18] mainly analyzed the positive and negative effects of various factors on knowledge innovation; Pei Le [19] analyzed from the perspective of internal and external demands for knowledge innovation. The research objects in the above literature are direct factors of knowledge innovation, while this paper, based on analyzing direct factors of knowledge innovation, further employs the ISM model to excavate deeper influencing factors of collaborative knowledge innovation direct factors.

2. Some literature [18-20] conducted detailed analyses on influencing factors of knowledge innovation and their operational mechanisms and transmission paths, but did not employ system dynamics methods in this process. This paper, based on identifying and analyzing influencing factors of knowledge innovation, constructs a specific system dynamics model and conducts simulation research.

3. Previous literature only conducted system dynamics modeling for certain links in collaborative knowledge innovation, such as knowledge transfer [21], knowledge absorption [22], and knowledge creation [23]. In contrast, the system dynamics modeling in this paper covers the entire process of collaborative knowledge innovation, including the full knowledge lifecycle of knowledge innovation, knowledge sharing, knowledge elimination, and knowledge transformation.

4. Some literature [23-24] used system dynamics modeling to study collaborative innovation issues, but their system dynamics modeling and simulation were conducted based on analyzing various sub-processes of collaborative

innovation without involving influencing factors of collaborative innovation. This paper conducts in-depth identification and analysis of influencing factors for collaborative knowledge innovation in enterprise value chains, analyzes the internal mechanisms of the entire collaborative knowledge innovation process more thoroughly, and constructs a more specific system dynamics model based on this foundation, thereby obtaining more accurate conclusions.

Conclusion

This paper explores the process of collaborative knowledge innovation in enterprise value chains from a system dynamics perspective, analyzes the main influencing factors of the collaborative knowledge innovation process, and constructs a system dynamics model for influencing factors of collaborative knowledge innovation in enterprise value chains. System simulation is conducted in the Vensim PLE software environment, and sensitivity analysis is performed on two parameters: knowledge sharing willingness and knowledge sharing threshold. The conclusions are as follows:

1. Knowledge sharing willingness has high sensitivity to knowledge innovation volume. Enterprise value chains should establish reasonable benefit distribution mechanisms to enhance relationship strength among value chain members, thereby improving the knowledge innovation volume of both leading and collaborative enterprises. Additionally, investment in enterprise collaborative knowledge innovation value chains should be increased to further enhance the knowledge innovation capabilities of value chain enterprises.

2. Knowledge sharing threshold has high sensitivity to knowledge innovation volume. Connections among enterprises in the value chain should be continuously strengthened to enhance trust between leading and collaborative enterprises and improve collaborative innovation intensity, thereby increasing knowledge innovation volume in the enterprise value chain.

Based on these results, the model can better fit the actual process of collaborative knowledge innovation in enterprise value chains, indicating that using system dynamics methods to study collaborative knowledge innovation is feasible. Because collaborative knowledge innovation in enterprise value chains is a complex and difficult-to-materialize process, and its influencing factors are difficult to consider comprehensively, the model simplifies some variables. Therefore, more detailed model construction requires deeper research. Moreover, this paper uses simulation data in model simulation; if actual data from enterprise value chains were used in the simulation process, it would provide more valuable decision-making reference information.

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Author Contributions

Luo Zheng: Designed the research framework, wrote the paper, and revised the final version.
Li Yu' na: Proposed the model validation plan and revised the paper.

Conflict of Interest Statement

All authors declare no conflict of interest.

Supporting Data

Supporting data is available in the online version of the journal at http://www.infotech.ac.cn.

[1] Luo Zheng, Li Yu'na. Enterprise Collaborative Knowledge Innovation Causal Loop Diagram.mdl. Enterprise Collaborative Knowledge Innovation Causal Loop Diagram.
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