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Research Article

Evaluation of Product Innovation Practice of Chinese Internet Companies Based on DANP Model

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Purpose. Internet companies have played an important supporting role in China's economic growth and social resource allocation in the advent of an exogenous shock: the coronavirus disease (COVID-19) pandemic. This is owing to their digital, networked, and platform-based characteristics amidst an environment of intensified competition and stagnation of innovation activities due to the pandemic shock. Thus, based on the social network theory and resource-based theory, this study combines the DANP model with corporate innovation to build a product innovation performance evaluation framework for Chinese Internet companies. From a value network perspective, this study considers the different performance aspects of network embeddedness, knowledge management, environmental triggering, and organizational effectiveness. *Methodology*. The performance of Internet enterprise product innovation may be considered a complex multicriteria decision-making problem. This study used the decision-making trial and evaluation laboratory-based analytic network algorithms to analyze the complex influencing relationship among the factors and calculate their weights. Preference ranking organization method for enrichment evaluation was used for selecting the final solution of multiobjective optimization. Three representative and influential Internet companies in China were selected for empirical analysis and practical evaluation, to find the gap between product innovation performance and expectations and present development suggestions. *Findings*. The study results reveal that relational embeddedness, knowledge sharing degree, cognitive embeddedness, structural embeddedness, knowledge absorptive capacity, and corporate strategic orientation are important to Chinese Internet enterprise product innovation performance. *Practical Implications*. This Internet enterprise product innovation performance evaluation framework can be used by Internet business operators to assess product innovation performance and identify areas of improvement. This study provides new product innovation ideas for Chinese Internet companies during an epidemic situation. *Originality/Value*. This study contributes to the present body of knowledge by using the DANP model to conduct empirical analysis, considering value network-related performance aspects to evaluate the product innovation performance of Internet enterprise in China.

1. Introduction

A new economic entity, Internet enterprise, and a new economic development model platform were born in the environment of rapid development of big data, cloud computing, artificial intelligence, and other network technologies. The COVID-19 pandemic broke out in 2019. To stop the spread of pathogens resolutely, the Chinese government adopted measures including "closing the city" and restricting the flow of people to control the pandemic. While the pandemic situation in most areas has been effectively controlled in China, economic development has been significantly negatively affected. In this context, Internet companies, with their networked, digitized, and convenient features, have played an important positive role in Chinese economic growth and national security. With the rapid development of the Internet industry, the competition of the Internet e-commerce industry intensifies, putting forward higher requirements for innovation ability and resource allocation of various Internet subjects.

Product innovation is an important way for enterprises to obtain profit and enhance competitiveness [1]. Under the policy call of "innovation-driven development," improving an enterprise's innovation capability, emphasizing user

experience, and enhancing product innovation have become the top priorities of Internet enterprise development. In an increasingly open and complex market environment, value is no longer created solely by an enterprise entity but is created jointly by enterprises, consumers, and partners in different fields. The method of value transfer has also changed from the traditional chain structure to the value network radiation transfer [2]. All participants in the network are connected and influence each other. They achieve coordinated survival, forming a "business ecosystem" service model, which is also the core competitive strategy of Internet companies. How to evaluate the product innovation behaviour of Internet companies from the value network perspective to enhance enterprise competitiveness has become a leading issue in the field of innovation management.

Innovation research for Internet companies mainly focus on business models, entrepreneurial strategies, and sustainable development. Innovation value chain and knowledge management are the main perspectives of Internet enterprise innovation research. Aarikka-Stenroos et al. put forward the concept of innovation value chain and constructed a three-stage balanced advantage model of the innovation value chain [3]. They believe that enterprises should promote the product innovation process from the three stages of creative generation, creative transformation, and creative communication. Thus, enterprises should realize the balanced distribution of resources in the three stages, and ultimately improve their innovation performance [4]. Raymundo et al. believe that Internet news product innovation should be implemented with a view to meet the needs of customers and enhance the ease of use and usability of network products, with clear innovation concepts to guide practical innovation [5]. In addition, the timing, methods, and contents of enterprises participating in knowledge management creation will have an impact on innovation performance. Decision-making behaviours adopted by organizations with differentiated innovation content will have an impact on product innovation effectiveness [6].

Product innovation has been of great interest to scholars; however, few studies focus on product innovation evaluation from the perspective of the value network. Most existing studies are conducted from the perspective of green product innovation and sustainable development. Yang et al.'s research on 14 manufacturing enterprises proposed that learning, comprehensive, and hedonic income have a positive impact on user participation [7]. Product ease of use enhances the positive relationship between comprehensive revenue and customer participation, and perceptual control enhances the positive relationship between hedonic revenue and customer participation. Yin et al. proposed that the integration of green suppliers and green consumers has a significant positive impact on the speed of green product development, quality of green product development, and knowledge spiral [8]. Compared with green consumer integration, supplier integration has a greater impact on the knowledge spiral, product development speed, and product development quality. Discussions in the literature revolve around product innovation content and quality management; thus, there is a need to evaluate the product innovation performance of Internet enterprises, which is a crucial antecedent for customer satisfaction. However, many Internet enterprises are unable to achieve product innovation because of the pandemic shock. To resolve this plaguing challenge, Internet business operators need to assess their performance on a regular basis to identify their vulnerable areas.

To enrich the existing literature, based on the value network perspective, this study combines the decision-making trial and evaluation laboratory- (DEMATEL-) based analytic network process (DANP) and preference ranking organization method for enrichment evaluation (PROMETHEE) methods in mixed multicriteria decision-making to provide a product innovation performance evaluation framework based on social network and resource-based theories. The study analyzes the interaction between the factors and gets the corresponding weight. Three representative Internet companies in China were selected for empirical analysis, and development suggestions were put forward. This study provides new product innovation ideas for Internet companies in China under the influence of the pandemic and suggestions for the improvement of the operating efficiency and competitive strategy of Internet companies. Based on the above discussion, we focused on the following research questions:

(i) RQ1. What type, aspects, and weights of performance are appropriate for evaluating the product innovation performance for an Internet enterprise operator?

(ii) RQ2. What is a suitable product innovation performance evaluation model for the pandemic era?

The rest of the paper is structured as follows: Section 2 provides the literature review pertaining to the product innovation performance evaluation model and issues; the product innovation performance evaluation framework is presented in Section 3; this is followed by a solution methodology in Section 4; Section 5 reports the results and discussion, and Sections 6 and 7 extend key conclusions with managerial implications and future scope.

2. Literature Review

2.1. Background and Related Works. Product innovation is an effective means to improve the competitiveness of Internet companies. Companies coordinate their resources effectively to strengthen innovation capabilities and competitive advantage in the global market, thus suppressing and turning resource-related disadvantages into advantages conducive to the development of the enterprise and ultimately improving competitiveness [9]. The principal aspects of Internet enterprises are identified in five domains: commerce, collaboration, communication, connection, and computation. These aspects lead to specific innovational opportunities that can be exploited to organize and address marketplaces and offer innovative products. In the operation process of Internet enterprises, product innovation is realized through knowledge transfer, and different Internet

application scenarios have different degrees of influence on the forward and reverse knowledge transfer of Internet enterprises [10]. Cantó et al. believe that formulating appropriate innovation strategies and accurately identifying user needs, while actively interacting with users, can effectively improve product innovation capabilities [11]. Cooper conducted empirical research on the new product development industry and proposed that the three influencing factors that affect product innovation are innovation strategy decision-making, customer demand capture, and leadership capabilities. In addition, the degree of cooperation and interaction between entities has an impact on the product innovation effect of an enterprise [1].

Changes in value propositions facilitate the transformation of product innovations into digital service innovations [12], the concept of innovation ecosystems, and value cocreation emerged. Sjodin et al. believe that value cocreation in digital servitization is best managed through an agile microservice innovation approach [13]. The innovations in value proposition, value creation processes, and value delivery processes of business models are the successful strategies proposed in the Internet industry [14]. Partnership and R&D intensity have a positive effect on product innovation performance. Manufacturing companies that implement services benefit from the strategic partnership established with knowledge-intensive business services (KIBS) companies. Knowledge-intensive enterprises reduce the scale by establishing cooperation networks, externalizing risks, and sharing knowledge with other enterprise entities, thereby effectively improving product innovation performance [15]. They believe that cocreation of enterprise value, innovation strategy, enterprise values, internal organization coordination, tolerance, and trust are important reasons for enterprise innovation performance. On the basis of considering the level of innovation and industry category, R. Lee et al. studied the synergy of product, process, marketing, and organizational innovation [16].

In addition, technological means play a key role in promoting product innovation. In recent years, strategies focused on data-driven innovation (DDI) have led to the emergence and development of new products and business models in the digital market [17]. In the era of digitalization, there are many emerging technologies, such as the Internet of Things (IoT), digital twin (DT) [18], cloud computing, and artificial intelligence (AI), which are quickly developed and used in product design and development [19]. Industry 4.0 (I4.0) technologies have been highlighted in recent literature as enablers of servitization. Simultaneously, businesses are advised to implement a circular economy (CE) to bring new opportunities. Atif et al. find that the use of Industry 4.0 technologies in a service-oriented business model is beneficial for companies to create value [20].

Many scholars believe that the classification and rating of Internet enterprise products is conducive to promoting product innovation [21], but the existing literature lacks evaluation and quantitative evaluation of product innovation.

2.2. Criteria for Product Innovation of Internet Enterprises. In the existing research, domestic and foreign scholars have studied the impact of diverse factors on product innovation performance from different perspectives. The resource-based theory and social network theory provide support for the research in this article. The resource-based theory proposed by Penrose is one of the representative research frameworks in the field of strategic management. The theory believes that an enterprise is a main body with a limited boundary, in which different types of resources are aggregated. The driving force behind the growth of the limited main body comes from its internal resources. Organizations rely on internal resources to provide a basis for organizational strategies, which are the source of corporate competitive advantage. The resource-based theory emphasizes that an organization can gain a competitive advantage by obtaining resources (capabilities and knowledge) different from other organizations. Dubey et al. believe that resources are all things controlled by the organization that can effectively improve the organization's operating efficiency and adjust development strategies. This includes physical resources, human resources, and organizational resources [22]. The boundary of an organization that integrates knowledge is determined by the difference of knowledge and the efficiency of absorbing knowledge [23]. Compared with most tangible resources, intangible resources are more difficult to be imitated by competitors.

In summary, knowledge and social networks are important strategic resources for enterprises. Enterprises obtain heterogeneous resources by embedding in social networks and form their own sustainable resource advantages in the process of knowledge sharing and transfer. Product innovation is the process of creative creation, application, diffusion, and formation of heterogeneous resources. Internet companies constructing external social networks increase the organization's heterogeneous resources and enhance their core capabilities through knowledge transfer and sharing behaviours. Through the management and use of shared knowledge, companies are conducive to product innovation and competitive advantage.

The concept of social network was first applied to the study of the relatively stable relationship between people and organizations in the field of sociology. Zhang et al. proposed that human-to-human interaction can be presented in the form of a network, and the nature of social networks is a unique, lasting, and stable social communication relationship [24]. Social network is a relatively stable relationship composed of some intersubject interactions. The synergy between intersubjects directly affects the flow and efficiency of resources. The main aspect of social network can be individuals, groups, organizations, and other collective units. As scholars continue to deepen their research, social network theory gradually absorbs the contents of anthropology, psychology, sociology, and other theories to form a complete and systematic theoretical system. It provides an important research framework for the research of organizational management, internetwork interaction, and resource flow. The three core theories of social network theory are the theory of social network strength and weakness, social capital theory, and structural hole theory.

Social network theory pays attention to the influence of the relationship between companies and other business entities and the embedded structure in the acquisition of competitive advantage and business behaviour in the social network. Cooperative network is the social capital of an enterprise, emphasizing the importance of network relationships. Companies embedded in social networks carry out innovative activities by acquiring heterogeneous resources and information to gain competitive advantages. However, in the process of literature review, it was found that the embedded behaviour of the organization plays an important role in product innovation. The development of Internet companies requires higher innovation, and heterogeneous resources are scarce. They often strengthen cooperation between enterprises to form complementary resources. By building an external cooperative network to realize information exchange and resource sorting, the organization's own profitability is better than others' is. Social network theory has gradually penetrated into the management field from anthropology and sociology and has become a powerful theoretical tool for explaining the structural relationship between the subjects and their impact on business behaviour in the process of enterprise cooperation. The strong-weak relationship theory and structural hole theory in the social network theory provide theoretical support for the establishment of an Internet enterprise product innovation framework from the perspective of structural and relational embeddedness.

3. Evaluation Framework of Internet Enterprises Product Innovation

Based on the literature review, this study defines 14 quality criteria of Internet enterprise product innovation, which are grouped into four dimensions (Figure 1).

Table 1 provides a detailed description of all dimensions and criteria. The performance aspects are qualitative in nature. Based on resource-based theory, technology, resources, opportunities, and network relationships are all elements that promote product innovation. Network embeddedness is a heterogeneous strategic resource and an important tool for enterprises to obtain new information, ideas, and opportunities. It plays a bridge role in the innovation of the organization and is the fundamental way for the organization to gain competitiveness [25]. In the existing literature, scholars have analyzed the mechanism of network embeddedness affecting product innovation from the perspectives of partner innovation, the role of repeated contact, and knowledge absorption. It is concluded that the direct, indirect, and overlapping relationship between an enterprise and its cooperation subject has an impact on the product innovation of the enterprise. In addition, the establishment of a cooperative network is conducive to the reduction of product development costs and the increase of business opportunities. The embedding behaviour of network entities is more conducive to the acquisition of key resources such as technology, information, and channels [26–30]. Structural, relationship, and cognitive embeddedness all have an impact on product innovation.

Knowledge management is the process by which an enterprise acquires, digests, and absorbs external information; it is the ability to internalize external knowledge. Knowledge management is an important source for companies to gain competitive advantage and is an important factor in studying corporate innovation performance and knowledge management [31]. Learning and problem-solving abilities of an enterprise are important dimensions for measuring the effectiveness of enterprise knowledge management. Roldán et al. have followed the views of Cohen and Levinthal to understand the knowledge management of enterprises from three levels: the ability to recognize external knowledge, the ability to digest knowledge, and the ability to transform applied knowledge. It is believed that knowledge management has an impact on innovation [32]. Effectively improving knowledge management capabilities is conducive to the formation of a stable internal knowledge structure and system, thereby improving corporate innovation performance. Knowledge absorption capacity, knowledge characteristics, and knowledge sharing in the knowledge management dimension have an important impact on enterprise product innovation. Xie et al. divided knowledge absorptive capacity into potential absorptive capacity and realistic absorptive capacity [33]. The ability to acquire and transform knowledge and the ability to utilize knowledge both have an impact on the innovation activities and competitive advantages of an enterprise.

During the development process, Internet companies are affected by the external environment such as policy systems, which affect product innovation. Government financial subsidies, intellectual property protection, technological innovation, and other related policy support have a positive impact on Internet enterprise product innovation [34]. With the continuous improvement of consumers' status, the upgrading of user demands has put forward new requirements for Internet enterprise product innovation, prompting enterprises to upgrade their products or services. This has enhanced user stickiness, increased the number of potential users, expanded the scale of enterprise users, and enhanced the competitiveness of enterprises. De Stefano et al. proposed that market factors and regulatory factors play a positive role in regulating the relationship between product innovation and economic performance [35]. Market factors are expressed in the degree of market competition and the state of competition and cooperation among enterprises. Regulatory factors are expressed in government support and financial subsidies. In addition, the financing environment has a positive effect on product innovation of Internet companies.

The microenvironment within the organization has a positive effect on improving product innovation performance. Internet companies are information revolutions developed based on network technology, and technology is the basis of product innovation whenever possible. As users' service requirements for Internet companies continue to increase, the underlying supporting factor that meets user needs and the importance of technology is gradually highlighted. Yan et al. proposed that technology demand and competition among enterprises are important factors

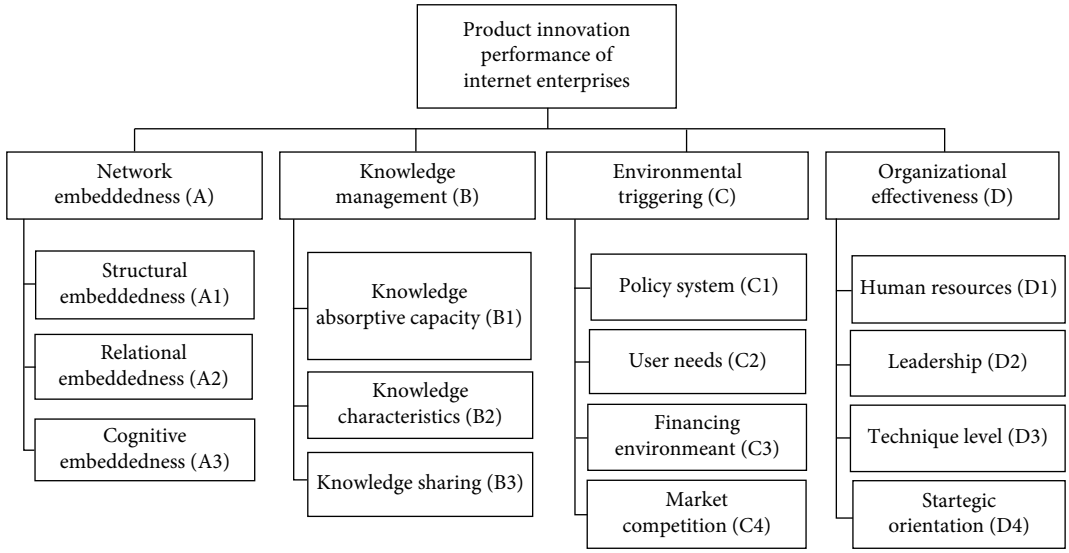

Figure 1: Internet enterprises product innovation performance evaluation framework (source: author).

influencing product innovation [34]. They believe that internal driving factors such as the company's internal operations, management methods, and human resource management have an important impact on enterprise product innovation [36, 37]. Nontechnical factors have an important impact on corporate innovation activities, and the degree of synergy between strategy, organization, and culture can largely determine the operation of the innovation ecosystem [15, 38, 39].

4. Solution Methodology

This paper uses the DEMATEL, DANP, and PROMETHEE methods in hybrid multicriteria decision-making to evaluate the product innovation practices of Chinese Internet companies. The influence value $(d_i + r_i)$ in the DEMATEL method measures the influence relationship and root degree between factors, and the relation value $(d_i - r_i)$ effectively measures the importance of different factors. Combined with the DANP method, it effectively solves the problems of influencing factor identification and product innovation evaluation weight acquisition. The PROMETHEE is a multiattribute decision-making method, based on priority preferences and attribute weights to determine the priority relationship to evaluate performance [62]. Figure 2 represents the complete solution procedure of Internet enterprise product innovation performance evaluation.

4.1. Identification and Relationship Analysis of Influencing Factors by DEMATEL Method. According to the product innovation performance evaluation framework constructed above, a questionnaire is distributed to experts and scholars in the field and senior managers with rich experience in the operation of Internet companies. Aggregate all opinions from experts and calculate the average direct-influence matrix for criteria $A = [a_{ij}]_{n\times n}$. Calculate the normalized average direct-influence matrix for criteria $G = kA$, where $k = \min\{1/\max_i \sum_{j=1}^{n} a_{ij}, 1/\max_i \sum_{i=1}^{n} a_{ij}\}$. Get the comprehensive influence relationship of dimension and criteria. Draw the influential relation map (IRM) of the dimensions and criteria in each dimension by mapping all coordinate sets of $(d_i + r_i, d_i - r_i)$.

4.2. Weighting of Each Criterion by Combining DEMATEL with ANP Methods (DANP Technique). Normalize T_C into T_C^{α}, and normalize T_D into T_D^{α}. Transpose T_C^{α} into $W = (T_C^{\alpha})$, and compute weighted super-matrix W^{α}. Compute the influential weights of the DANP with the limit super matrix $\lim_{h\longrightarrow\infty}(W^{\alpha})^h$, and get a convergent and stable limit hyper matrix W^*. Finally, the weight of each factor is obtained.

4.3. Internet Enterprise Product Innovation Practice Evaluation by PROMETHEE Method. PROMETHEE (preference ranking organization method for enrichment evaluation) is a multicriteria decision-making method; according to the score of the decision-maker or according to the research needs, each attribute is selected or defined as a preference function that forms a specific criterion value. Based on these attributes, the target practices are compared to obtain the selection order, outflow, and inflow of each evaluation target, and then, the net inflow of each practice is calculated, and the selection order is used to determine the order of the programs. Based on the weights obtained by the DANP method, combined with the PROMETHEE method, the target practices are ranked, and the product innovations of three Internet companies in China are evaluated and compared.

After obtaining the initial expert scoring matrix, the mutual preference function (X_i, X_k) of the three innovation practices can be derived. That is, the preference of innovation practice X_i is better than innovation practice X_k, which mainly follows two research steps:

Table 1: Literature pertains to performance aspects and performance class.

Dimension	Criteria	Description	Literature sources
Network embeddedness (A)	Structural embeddedness (A1)	Structural embeddedness refers to the manner in which the location of the Internet enterprise's main body embedded in the industrial value network, the degree of openness of the network, and the density of the network determine the degree of enterprise resource acquisition.	[40, 41]
	Relational embeddedness (A2)	Relationship embeddedness refers to the degree to which the interaction, trust, and communication among enterprise entities in the value network node determine the quality of the enterprise entity. The enterprise and partners conduct knowledge sharing and organizational cooperation across enterprise and industry boundaries to achieve value cocreation.	[42]
	Cognitive embeddedness (A3)	The cognitive nature of the network emphasizes the cognitive paradigm between the enterprise and the partner. Under the common cognitive paradigm, the efficient exchange and combination of resources by the enterprise is conducive to improving the innovation performance of the enterprise.	[43–45]
Knowledge management (B)	Knowledge absorptive capacity (B1)	Knowledge absorptive capacity refers to the ability of an enterprise to receive, analyze, and transform information in the external environment into its own controllable resources. It is an indispensable ability for an enterprise to enhance its own competitiveness in business development.	[46, 47]
	Knowledge characteristics (B2)	Knowledge characteristics refer to the nature of knowledge, which is mainly nonexclusive (knowledge subjects can pass on the knowledge they possess to other subjects), dynamic growth, transferability, increasing returns, and accumulation (the creation or integration of any new knowledge is realized on the basis of absorbing the original relevant knowledge).	[48, 49]
	Knowledge sharing (B3)	The degree of knowledge sharing refers to the flow of technology or skills between different organizational departments or different business entities.	[50, 51]
Environmental triggering (C)	Policy system (C1)	Regulations and guidelines implemented by the state or relevant departments to promote the development of social subjects.	[52]
	User needs (C2)	User demand refers to the goal that the user and the enterprise need to achieve in the communication of buying and selling activities, which is often one of the contents that the enterprise must achieve for it.	[53]
	Financing environment (C3)	Financing environment refers to the impact of the environment on the behaviour and process of corporate fund raising.	[54, 55]
	Market competition (C4)	Market competition refers to a series of benefits and behaviours that companies acquire to ensure their own profits and compete for customers under the conditions of market economy.	[56]
Organizational effectiveness (D)	Human resources (D1)	Human resources refer to the general term of education, ability, skill, experience, physical strength, and other attributes owned by the people in the organization that can be used by enterprises and contribute to value creation in a certain period of time.	[57, 58]
	Leadership (D2)	Leadership refers to the ability of enterprise managers to engage in leadership activities, including market insight, product imagination, and agile thinking ability.	[59]
	Technique level (D3)	Enterprise technical capability refers to the technical resources possessed by an enterprise to achieve its business objectives, which are reflected in personnel, knowledge, and hardware conditions.	[60]
	Strategic orientation(D4)	The strategic orientation of an enterprise refers to the strategies and development methods formulated by the enterprise to achieve certain development goals.	[61]

(i) Step 1: Calculate the preference function of each indicator according to the desired level

(ii) Step 2: Calculate the multistandard preference index based on the expected level. According to PROMETHEE I method, calculate the outflow $\phi^+(X_i)$ and inflow $\phi^-(X_i)$ of each product innovation practice. The outflow indicates the extent to which this sample is better than other practice samples, and the inflow indicates the extent to which this sample performs worse than other practice samples. For samples whose order cannot be determined, the PROMETHEE II method needs to be used to

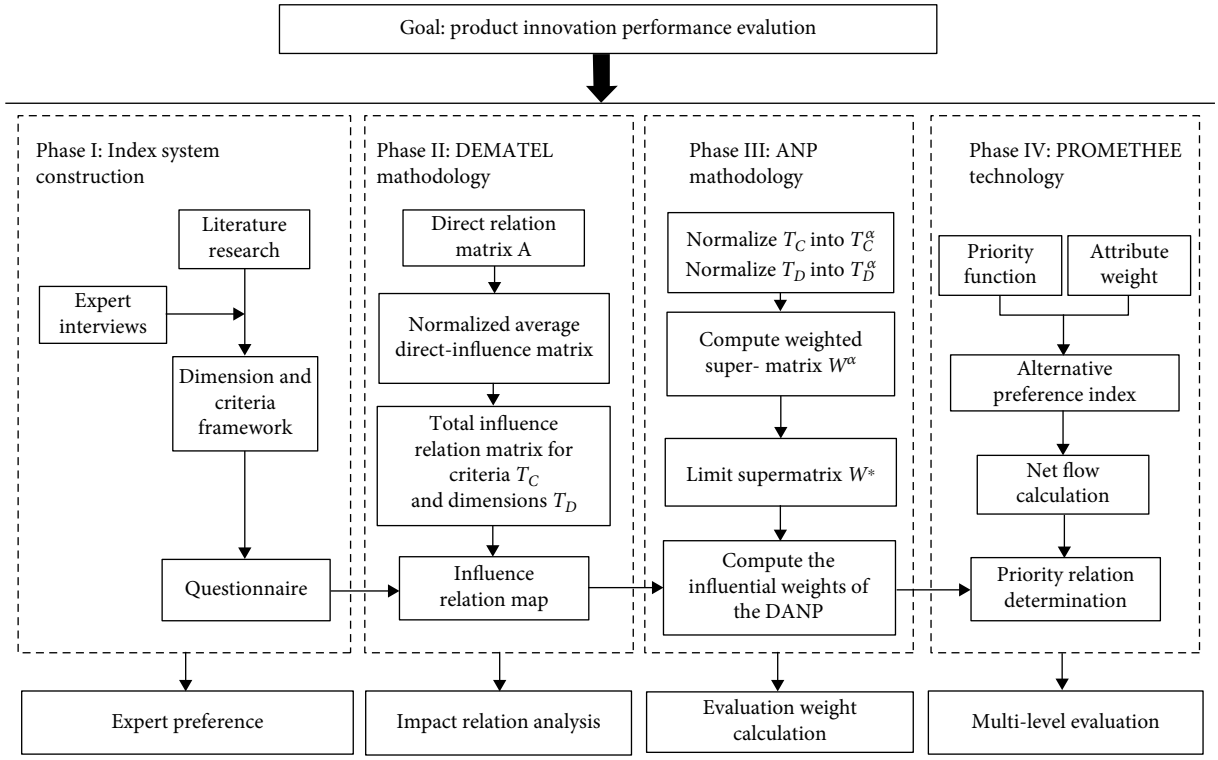

Figure 2: Solution procedure of Internet enterprise product innovation performance evaluation (source: author).

calculate the net flow $\phi^{net}(X)$ of the product innovation practice sample scheme and then sorted.

5. Results and Discussion

Expert opinions were collected using a survey questionnaire for a pairwise comparison among the performance dimension and performance criteria in terms of influence and direction. In this study, 25 experts who were Internet company managers with rich experience answered the questionnaire. We explained to them the purpose of the study and asked questions for a pairwise comparison of performance criteria. We asked the participants to rate statements on a five-point rating scale which ranges from "0" (no influence) to "4" (very high influence). Subsequently, we analyzed the raw data of the questionnaire.

5.1. Measuring Relationships among Dimensions/Criteria Using DEMATEL. According to the questionnaire results, construct the direct impact matrix A and the normalized matrix G, calculate the comprehensive impact matrix of dimensions and criteria, and obtain the comprehensive impact relationship of each criterion. The results are shown in Tables 2 and 3.

Tables 4 and 5 show the degree of importance $(C_i = d_i + r_i)$ and the degree of relation $(h_i = d_i - r_i)$ for the above-mentioned dimensions and the related criteria. $d_i - r_i > 0$ indicates that t_i affects other factors. $d_i - r_i < 0$ indicates that t_i is affected by other factors. The top three criteria for the degree of importance are relationship embeddedness, knowledge sharing, and cognitive embeddedness. The top three criteria for the degree of relation are the policy system, leadership, and market competition.

Figure 3 illustrates the influential relation map (IRM) of the respective dimensions and the IRMs of the related criteria for each dimension, $d_i + r_i$ and $d_i - r_i$ are used as the horizontal and vertical coordinates, and the arrow indicates the degree of influence of other indicators.

The improvement of product innovation performance of Internet companies is the result of the joint action of the aspects of network embeddedness, knowledge management, environmental triggering, and organizational performance. These four aspects are closely related to each other. From the perspective of the degree of importance, the rank of the dimension is environmental triggering>knowledge management>organizational performance>network embeddedness. Among them, environmental triggering and knowledge management are the cause factors, which have a greater impact on organizational performance and network embedding. They are the most fundamental driving factors for the improvement of product innovation performance of Internet companies. Organizational effectiveness and network embeddedness are the result factors and are the most direct factors and important media that affect enterprise product innovation. From the criteria, the causal factors $(d_i - r_i > 0)$ are knowledge characteristics, policy systems, user needs, financing environment, market competition, and leadership skills, and the others are outcome factors $(d_i - r_i < 0)$. The main body of emerging Internet companies is different from traditional ones in all aspects. The results of the research on

Table 2: The comprehensive influence matrix T_C for the criteria presented above.

	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4	D1	D2	D3	D4
A1	0.037	0.115	0.093	0.078	0.026	0.120	0.003	0.012	0.003	0.007	0.010	0.003	0.021	0.011
A2	0.106	0.074	0.178	0.124	0.018	0.178	0.002	0.023	0.005	0.008	0.010	0.002	0.030	0.015
A3	0.118	0.197	0.064	0.151	0.025	0.143	0.003	0.021	0.003	0.007	0.008	0.002	0.031	0.014
B1	0.136	0.156	0.128	0.053	0.014	0.080	0.002	0.023	0.004	0.011	0.010	0.002	0.122	0.017
B2	0.104	0.161	0.126	0.172	0.009	0.171	0.004	0.036	0.004	0.010	0.010	0.001	0.070	0.018
B3	0.141	0.190	0.162	0.122	0.018	0.063	0.005	0.028	0.004	0.010	0.011	0.001	0.078	0.016
C1	0.207	0.211	0.122	0.092	0.030	0.159	0.004	0.119	0.137	0.117	0.127	0.003	0.074	0.175
C2	0.157	0.123	0.106	0.086	0.019	0.108	0.006	0.033	0.015	0.115	0.104	0.003	0.180	0.173
C3	0.177	0.159	0.114	0.085	0.022	0.112	0.008	0.032	0.009	0.075	0.101	0.002	0.090	0.117
C4	0.168	0.157	0.118	0.091	0.021	0.115	0.007	0.108	0.088	0.030	0.128	0.002	0.173	0.159
D1	0.068	0.073	0.068	0.064	0.019	0.059	0.002	0.019	0.006	0.029	0.013	0.004	0.082	0.057
D2	0.162	0.102	0.101	0.091	0.017	0.091	0.004	0.021	0.007	0.025	0.111	0.002	0.082	0.151
D3	0.057	0.060	0.061	0.131	0.010	0.059	0.002	0.087	0.007	0.051	0.022	0.002	0.040	0.061
D4	0.150	0.118	0.132	0.089	0.020	0.100	0.003	0.037	0.005	0.025	0.129	0.003	0.082	0.021

Table 3: The total influence matrix T_D for the dimensions presented above.

	A	B	C	D
A	0.322	0.345	0.239	0.410
B	0.701	0.273	0.268	0.461
C	0.800	0.481	0.210	0.688
D	0.599	0.493	0.233	0.291

Table 4: The sum of influences given and received on criteria.

Criteria	$d_i + r_i$	Rank	$d_i - r_i$	Rank
Structural embeddedness (A1)	2.326	4	-1.250	14
Relational embeddedness (A2)	2.668	1	-1.122	13
Cognitive embeddedness (A3)	2.361	3	-0.789	12
Knowledge absorptive capacity (B1)	2.184	5	-0.669	10
Knowledge characteristics (B2)	1.163	13	0.627	6
Knowledge sharing (B3)	2.408	2	-0.710	11
Policy system (C1)	1.628	10	1.525	1
User needs (C2)	1.828	8	0.631	5
Financing environment (C3)	1.398	11	0.805	4
Market competition (C4)	1.883	7	0.846	3
Human resources (D1)	1.354	12	-0.232	8
Leadership (D2)	0.997	14	0.934	2
Technique level (D3)	1.803	9	-0.506	9
Strategic orientation (D4)	1.916	6	-0.090	7

Table 5: The sum of influences given and received on dimensions.

Dimensions	$d_i + r_i$	Rank	$d_i - r_i$	Rank
Network embeddedness (A)	3.737	1	-1.106	4
Knowledge management (B)	3.293	3	0.111	2
Environmental triggering (C)	3.128	4	1.229	1
Organizational effectiveness (D)	3.465	2	-0.234	3

the degree of relation will promote the operation of Internet companies, the enhancement of corporate competitiveness, and the improvement of product user experience details. The four factors in the environmental triggering dimension are all cause factors, indicating that the policy system, user needs, financing environment, and market competition all have an impact on a company's product innovation and on other factors affecting the company's product performance. In the environmental triggering dimension, the policy system has the highest degree of relation, indicating that although the product innovation of Internet companies only involve this part of the product, national laws and regulations, policy orientation, and tilt have a greater impact on the product innovation of Internet companies. The knowledge characteristic in the knowledge management dimension is the only reason factor. It can be seen that the explicit and implicit degree of knowledge determines the knowledge absorption capacity and knowledge sharing degree within the Internet enterprise. Leadership in the organizational performance dimension is the causal factor, which shows that within the Internet company, human resource allocation, technical level, and strategic orientation are all affected by the leader. The leader of the enterprise can lead the enterprise to achieve efficient product innovation only if they have the ideology of independent innovation.

From the perspective of dimensional importance, the degree of network embeddedness and organizational performance is higher than knowledge management and environmental triggering. The highest degree of network embeddedness is the core influencing factor for the improvement of product innovation performance of Internet companies. It plays a decisive role in the process of product innovation performance improvement. At the criterion level, the importance degree of relational embeddedness, knowledge sharing, cognitive embeddedness, and structural embeddedness of knowledge absorption capacity is all greater than two, which is significantly higher than the other influencing factors. It shows that in the process of achieving

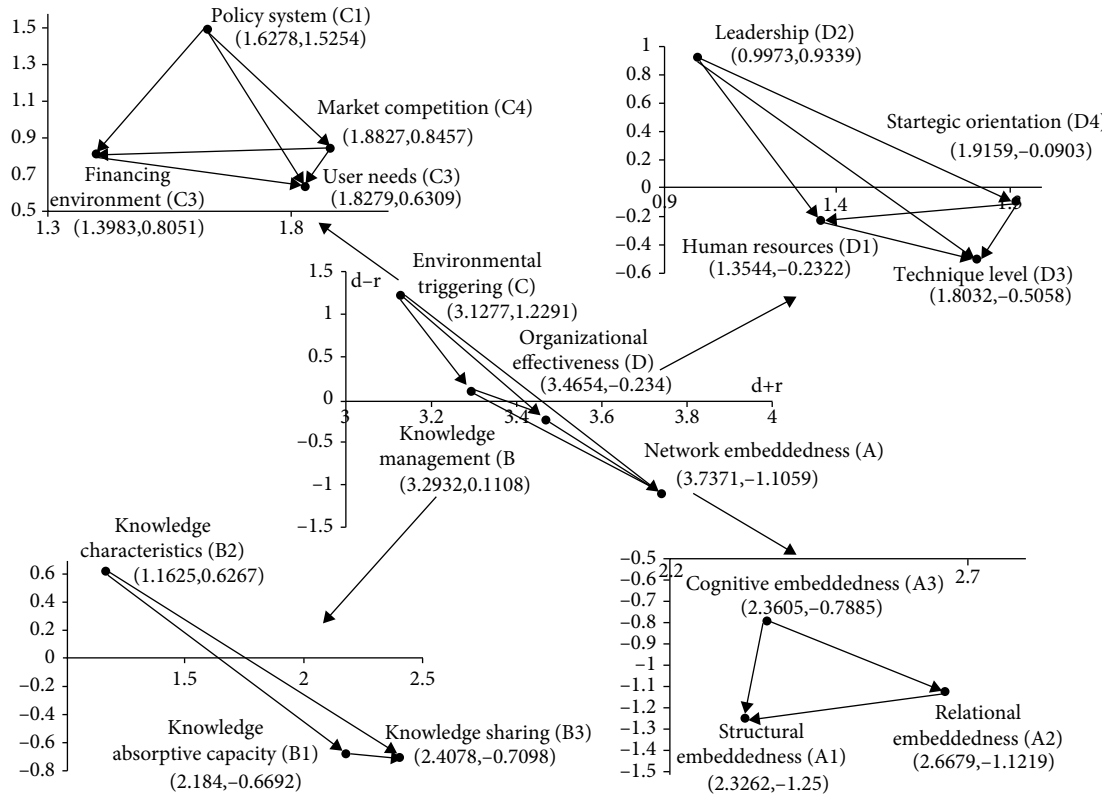

Figure 3: IRM of the dimensions and criteria (source: author).

product innovation, for Internet companies, interaction and cooperation with other network entities are the most important factors. This is followed by improving knowledge sharing ability by improving knowledge absorption capacity. In addition, Internet companies should formulate clear strategic plans and integrate them with current systems and keep an eye on market competition in a timely manner. The needs of the users are paramount; therefore, Internet companies should actively improve their technical level and optimize the allocation of human resources to promote product innovation further.

5.2. Weighting of Each Criterion by Combining DEMATEL with ANP Methods (DANP Technique). This study used DANP to compute the influential weights for the abovementioned dimensions and criteria. The matrices T_D and T_C obtained through DEMATEL were normalized as T_D^α and T_C^α. Then, matrix T_C^α was transposed to obtain an unweighted supermatrix W_{ij} and a weighted supermatrix W^α.We computed the influential weights of the DANP with the limit supermatrix $\lim_{h\longrightarrow\infty}(W^\alpha)^h$, and a convergent and stable limit hypermatrix W^* was obtained. Finally, the weights of dimensions and criteria are obtained (Table 6).

From the perspective of weighting results, the most important dimension order that affects Internet enterprise product innovation is network embeddedness, organizational performance, knowledge management, and environmental triggering. Internet enterprise product innovation activities are embedded in the internal and external social network relationships, and the interactive cooperation of the entities in the network has an important impact on enterprise product innovation. The microenvironment within the organization has a greater impact on the improvement of product innovation performance. The organizational function and operating energy within the enterprise are more important than the external environment to a certain extent. From the perspective of criteria, the technical level in the organizational performance dimension, the three factors in the network embeddedness dimension, and the knowledge absorptive capacity and knowledge sharing in the knowledge management dimension are weighted significantly higher than other factors. They are key factors influencing the product innovation of Internet companies. With the diversification and high requirements of users, the importance of technical factors to meet the needs of users is gradually highlighted, becoming the most important factor for enterprise product innovation. To achieve user portraits and precise marketing, artificial intelligence, big data, and other related technologies are developing rapidly. This puts forward new requirements for the improvement of the enterprise's human resources. Internet companies should strengthen the construction of technical teams, increase the proportion of technical personnel, and respond to and meet consumer needs in a timely manner. From the perspective of relationship embeddedness, the relationship quality and relationship strength between partners will have different effects on product innovation. A good interactive and mutually beneficial relationship can promote different types of product innovation. The relational embeddedness

Table 6: The weights of dimensions and criteria.

Dimension	Weight	Rank	Criteria	Weight	Rank
Network embeddedness (A)	0.338	1	Structural embeddedness (A1)	0.107	6
			Relational embeddedness (A2)	0.122	2
			Cognitive embeddedness (A3)	0.109	5
Knowledge management (B)	0.243	3	Knowledge absorptive capacity (B1)	0.113	3
			Knowledge characteristics (B2)	0.020	11
			Knowledge sharing (B3)	0.110	4
Environmental triggering (C)	0.153	4	Policy system (C1)	0.009	13
			User needs (C2)	0.082	7
			Financing environment (C3)	0.016	12
			Market competition (C4)	0.046	10
Organizational effectiveness (D)	0.267	2	Human resources (D1)	0.049	9
			Leadership (D2)	0.006	14
			Technique level (D3)	0.141	1
			Strategic orientation (D4)	0.071	8

of the social network enables the formation of resource sharing consciousness among network subjects, enabling in-depth communication and information exchange. Therefore, Internet companies should strengthen communication with partners, improve the degree of knowledge sharing, and improve the internal knowledge absorption capacity. They should also cultivate the common values and business philosophy of cooperative enterprises, develop heterogeneous partners, and improve their network scale and network centrality to achieve the ultimate goal of improving product innovation performance.

In addition, the weight results are consistent with the analysis results of the importance of the DEMATEL method. It shows that the technological level, the three factors in the network embeddedness dimension, the knowledge absorption capacity, and the knowledge sharing in the knowledge management dimension are significant aspects that require attention in the process of product innovation for Internet companies. Combining the results of dimensions and influential relation map between criteria, these six factors are affected by other factors. Therefore, although these six key factors play a large role in influencing Internet enterprise product innovation, to further promote the development of Internet companies, it is necessary to strengthen the management level of higher-cause factors.

5.3. Evaluating the Product Innovation Practices of Chinese Internet Companies by PROMETHEE Method. In this study, three representative Chinese Internet enterprises M, N, and Q were selected for empirical analysis. Enterprise M is the largest e-commerce company in China; the enterprise's business involves many fields such as finance, medical care, and tourism. Its product innovation follows the "two-way strategy to achieve synergy in the industrial chain of the ecosystem." Enterprise N is one of the largest integrated Internet service providers in China and is recognized as the Internet company with the most product advantages in China, providing social and content services to users. Enterprise Q is the largest search engine website and leading artificial intelligence company in the world. It was aimed at providing users with comprehensive and fast technology and searching services. Enterprise Q adheres to the business philosophy of "innovative and enterprising, leading technology," pay attention to scientific and technological innovation talents, drive product upgrading with technological innovation, and meet the needs of modern people with high technology and good sense of use. The initial evaluation of the product innovation of the above three practice samples was carried out according to the internal senior management of the company's approval and researchers of scientific research institutions guidelines. Through calculation, the results of the preference index of the three product innovation practice samples are shown in Table 7.

Using the PROMETHEE I method to calculate the outflow and inflow of each product innovation practice, the results produced are shown in Figure 4. We used the PROMETHEE II method to calculate the net flow of the product innovation practice sample plan. Taking innovation practice N as an example, the outflow of N was 0.151, indicating the extent to which N is superior to other practice sample solutions. The inflow was 0.738, indicating the degree of N worse than other practical sample programs; thus, the net flow was -0.587.

From the results of the flow value (PROMETHEE I) of the three product innovation practices, the outflow of the sample M is the largest, while the inflow is the smallest, which shows that the product innovation practice of the enterprise M is better than that of the other two enterprises. The inflow of sample N is the largest, while the outflow is the smallest, which shows that the product innovation effect of enterprise N is worse than the other two enterprises. The research conclusions drawn by the PROMETHEE I method are consistent with the net flow (PROMETHEE II) results, and the net flow of product innovation assessment for sample M is greater than sample Q and sample N. In the evaluation process, the gap rate between the three product

Table 7: Product innovation practice preference index.

	Enterprise M	Enterprise N	Enterprise Q
Enterprise M	0	0.459	0.436
Enterprise N	0.027	0	0.124
Enterprise Q	0.159	0.279	0

innovation practices and the expected level was calculated. The results are shown in Table 8.

The results of Table 8 reveal that, for longitudinal analysis within enterprise M, the gap between the product innovation performance of the network embeddedness dimension and the expected level is the largest and needs to be paid attention to. In the network embeddedness dimension, the gap rate between cognitive embeddedness and expectation level is the highest. This shows that the enterprise has independent thinking and lacks the identity of other entities in its value network in terms of management and corporate culture. The gap rate of the organizational effectiveness dimension is the lowest, which indicates that enterprise M has a better grasp on the internal management and operation of the organization. The human resource factor has the highest gap rate in the dimension. This shows that enterprise M should pay attention to the human resources setting and formulate a scientific personnel ratio and human resource management system to promote the improvement of organizational performance. For longitudinal analysis within enterprise N, the results reveal that enterprise N regards user value as the first priority of development, and enterprise leaders play an irreplaceable role in the process of enterprise operation and product innovation. This is confirmed in the results of the gap rate between product innovation practices and expectations. The difference rate of leadership of enterprise N is the lowest among all factors, which shows that enterprise N has fully exerted the role of leader ability to promote product innovation of the company. From a dimensional point of view, enterprise N has the highest network embeddedness dimension gap rate. The gap rate between structural embeddedness and cognitive embeddedness is the highest among all criteria; this shows that enterprise N neglected interaction and collaboration with partners during the development process. Enterprise N should expand its network scale in future development processes, improve its network centrality, and enhance its degree of heterogeneity with other networks to maximize the advantages of resources and product innovation. Knowledge management is another important dimension that limits the improvement of product innovation performance of enterprise N. The results show that the knowledge sharing gap rate of enterprise N is 21%; this shows that the degree of knowledge sharing of the enterprise is poor. The enterprise should actively realize knowledge sharing and promote the flow of explicit and tacit knowledge in the value network to promote the improvement of product innovation performance. In addition, market competition puts more pressure on enterprise N and improves its sensitivity to capture user needs. However, relying on technology and perfect product experience is conducive to improving enterprise N's competitiveness. Enterprise Q adheres to the business philosophy of "innovative and enterprising, leading technology" and attaches great importance to scientific and technological innovative talents. This is reflected in the results of the gap between product innovation practices and expectations. The gap rate of the technical level is 8%, indicating that the technical management and technical level of the enterprise Q are relatively high. Q's network embeddedness is still the dimension with the highest gap rate, and its structural embeddedness and cognitive embeddedness are also the highest among the factors. Enterprise Q should focus on the construction of value networks and the cultivation of partners in future development processes, to improve its degree of knowledge sharing and thus product innovation performance.

A horizontal comparison of the three product innovation practice samples, among the three enterprises, reveals that enterprise Q has the highest network embeddedness dimension gap rate. During the development process, enterprise N should focus on knowledge management and organizational performance, and enterprise M should focus on the environmental triggering dimension. Judging from the results, enterprise M's market competition pressure is the greatest. The enterprise should make full use of policy tilts, broaden financing channels, accurately capture and meet user needs, and ultimately achieve corporate competitiveness improvement.

6. Research Implications

This study provides managerial as well as theoretical implications, which are presented in this section.

6.1. Managerial Implications. This research provides new ideas and inspiration for Internet enterprises to improve product innovation management and performance. The outcomes of this work may help organizations with issues related to product innovation, by understanding the degree of importance of each criteria. The causal interrelationship of the dimensions and criteria assists management in understanding the influence of one factor over the others, which can help in the formulation of an effective strategy for successful product innovation. Using new technological means, Internet companies can effectively strengthen the relationship and cooperation between each other. They can quickly connect and integrate into external value networks, absorb resources flowing between network entities, and effectively expand financing channels, thereby promoting product innovation and enhancing competitiveness. Research shows that Internet enterprises should strengthen their network embeddedness capabilities and actively promote the symbiosis of Internet enterprises and partners. They should also continuously enhance their knowledge absorption capacity, improve their degree of knowledge sharing, and pay attention to the improvement of organizational performance.

6.2. Theoretical Implications. The fourteen product innovations clustered into four dimensions given in this study provide theoretical insinuation for scholarly discussion on the

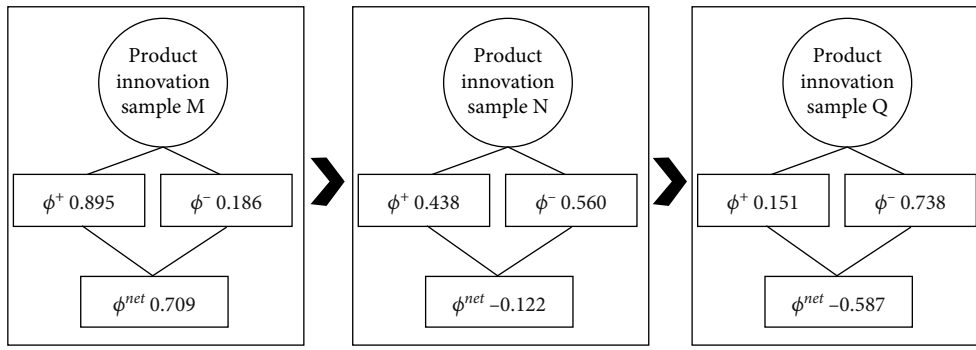

Figure 4: Results of PROMETHEE I and PROMETHEE II (source: author).

Table 8: Gap rate between the three products innovation practices and the expected levels.

Criteria	Enterprise M (%)	Enterprise N (%)	Enterprise Q (%)
Network embeddedness (A)	17.000	23.333	25.333
Structural embeddedness (A1)	14.000	26.000	28.000
Relational embeddedness (A2)	16.000	20.000	19.000
Cognitive embeddedness (A3)	21.000	24.000	29.000
Knowledge management (B)	15.333	18.000	16.671
Knowledge absorptive capacity (B1)	16.000	17.000	14.000
Knowledge characteristics (B2)	17.000	16.000	11.000
Knowledge sharing (B3)	13.000	21.000	25.000
Environmental triggering (C)	16.000	15.500	11.500
Policy system (C1)	11.000	11.000	9.000
User needs (C2)	7.000	9.000	8.000
Financing environment (C3)	17.000	18.000	13.000
Market competition (C4)	29.000	24.000	16.000
Organizational effectiveness (D)	11.250	14.000	11.251
Human resources (D1)	14.000	18.000	11.000
Leadership (D2)	11.000	8.000	14.000
Technique level (D3)	11.000	17.000	8.000
Strategic orientation (D4)	9.000	13.000	12.000

product innovation of Internet enterprises. Combining resource-based theories and social network theories, an Internet enterprise product innovation evaluation framework was proposed from the perspective of value networks, which enriches theories in related fields. The innovative combination of the DANP and PROMETHEE methods enriches the application of mixed multicriteria decision evaluation methods. The findings of this research will help academia to develop the understanding and importance of the combination of product innovation and value network.

7. Conclusion, Limitation, and Future Scope

Chinese Internet companies actively obey the national leadership and meet consumer needs accurately and in a timely manner under the COVID-19 pandemic shock. Evaluation of personal product innovation capability is an effective means to promote the development of Internet companies and improve their competitiveness. In this study, from the perspective of the value network, combined with the DEMATEL, DANP, and PROMETHEE methods in mixed multicriteria decision-making, an Internet enterprise product innovation evaluation model was constructed. It revealed that network embeddedness, knowledge management, environmental triggering, and organizational performance are important dimensional indicators of Internet enterprise product innovation assessment. The most important dimensional indicators that affect the product innovation performance of Internet companies are network embeddedness, organizational performance, knowledge management, and environmental triggers. Environmental triggering and knowledge management have a great impact on organizational performance and network embeddedness and are the most fundamental driving factors for Internet companies to improve their product innovation performance. Organizational performance and network embeddedness are the

most direct factors and important mediums that affect enterprise product innovation performance. The importance degree of network embeddedness is the highest. It is the core influencing factor for the improvement of product innovation performance of Internet companies and plays a decisive role in the process of product innovation performance improvement. The interrelationship and interaction between dimensions and criteria have an impact on the product innovation of Internet companies. The microenvironment within the organization has a great impact on the improvement of product innovation performance. The organizational function and operating energy within the enterprise are more important than the external environment to a certain extent. In addition, this study selects three influential and representative Internet companies in China to evaluate their product innovations. It not only tests the usability and scientificity of the evaluation method but also provides theoretical support for the management decision on the product innovation practice of Internet enterprises.

This study uses Chinese Internet companies as the research object and discusses the product innovation assessment method and innovation development direction of enterprises during the pandemic. For the development of Internet companies in a highly uncertain environment, future research can draw on the successful experience of Internet companies' innovative activities in developed countries. Research can be conducted from the perspective of other entities within the value network (such as suppliers, scientific research institutions, and consumers) and provides a reference for countries to use when facing such major emergencies in the future. In addition, many factors affect the product innovation of Internet enterprises, and the relationship between the factors is complex. In the future, a more comprehensive literature review can be done in order to improve the product innovation evaluation framework, provide more comprehensive and accurate guidance and suggestions for enterprises to carry out innovation activities, and determine the direction of development.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

It is declared by the authors that this article is free of conflict of interest.

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