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Analysis of collaborative innovation behaviour and its influencing factors in scientific research crowdsourcing platforms: based on the fsQCA method

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Abstract

Introduction. This study aims to explore the influencing factors and their combined effects on the benefits of knowledge innovation, and to explore the impact of factors on the effects of knowledge innovation from a configuration perspective.

Method. This study constructed a knowledge innovation ecosystem for scientific research crowdsourcing platforms, as well as a configuration model that affects the knowledge innovation benefits of scientific research crowdsourcing. Based on this, we collected data through a survey questionnaire. Then, we used the method of fuzzy set qualitative comparative analysis to identify the configuration effects of influencing factors and analyse the core configuration.

Analysis. Five core configurations were constructed, which are shown as internal and external linkage based on environmental dynamics, individual and environment interlocking based on team maintenance, individual initiative to supplement weaknesses, external drive driven, and individual led based on team and platform support.

Results. The configurations have different focuses, but all highlight the core conditions for individual innovation investment as the configuration.

Conclusion. The results indicate that individual driving factors are worth considering. Meanwhile, by referring to the core components of the five configurations, researchers can combine various factors to better form knowledge innovation.

Introduction

Scientific research cooperation is a crucial means of supporting scientific communication and technological innovation. With the drive of innovation development strategy and big data, the data-intensive scientific research paradigm is in the ascendant. It puts forward new requirements and challenges for computational scientific research and data-based scientific research, and promotes scientific research cooperation to gradually show the development trend of networking, digitisation and intelligence (Gui et al., 2019; Tekdal, 2021). Under the new paradigm, the sharp increase of interdisciplinary scientific research has triggered the eager expectation of researchers for more extensive and in-depth scientific research cooperation. At the same time, the increasingly interdisciplinary and complex nature of scientific research issues has given birth to the urgent need for scientific research cooperation and its support to break through the limitations of institutions, time and space and even disciplines (Matthews et al., 2020). Therefore, the introduction of new thinking and the use of information technology tools to explore a new scientific research cooperation model that breaks the original constraints has become a hot topic in the field of knowledge services supporting scientific and technological innovation.

The service targets of research crowdsourcing platforms are research innovation teams jointly formed by innovation driven researchers who rely on scientific research projects for implementation (Zhang et al., 2022). Researchers usually have experience in innovative research and services (Rea et al., 2021). The crowdsourcing model for scientific research fully mobilises the enthusiasm and initiative of researchers during the project operation process, weakens the boundary between project participants, and highlights the collaborative interaction process for knowledge innovation in scientific research, leveraging the complementary advantages of project participants (Uhlmann et al., 2019). The contracting party and the contracting party jointly participate in the scientific research project through collaborative innovation under the task orientation, and carry out a systematic process chain of project operation around the formation of requirements and project interaction (Franzoni and Sauermann, 2013). Throughout the entire process chain, participants jointly form an innovative service feedback system under the influence of various factors and their interrelationships.

Knowledge innovation is a dynamic process (Robertson et al, 2023), and the process of individual knowledge innovation in an organisation involves collaboration among innovative individuals. Collaboration refers to the coordinated operation and resource sharing of multiple individuals under established organisational goals, working together to achieve the goals. The overall creation generated by synergy is greater than the direct sum of parts (Minglun and Hemant, 2018). Collaboration can essentially refer to the coordination and coordination of elements, as well as the cooperation and full assistance of participating entities (Zhou, 2012). Emphasis is placed on the whole formed by individuals, which is composed of different subsystems and has structural effects on the relationships between individuals.

Existing research has analysed the influencing factors of knowledge innovation benefits from different levels (Xiao et al., 2022; Adner and Kapoor, 2010), but few studies further explore the combined effects of these factors. How are the elements combined? Which elements occupy a dominant position in the process of joint action? These issues cannot be solved through traditional linear research methods. Given this, this article mainly focuses on the research issues arising from the knowledge innovation benefits of scientific research crowdsourcing platforms. Our research considers how to optimise the configuration in the scientific research crowdsourcing process to stimulate the innovation output of the platform, and explores the collaborative improvement path of multi-level and multi factor on the innovation benefits of scientific research crowdsourcing.

The method of configuration effect analysis is used to construct the core condition configuration that affects the knowledge innovation benefits, and specific configuration configurations are analysed. Firstly, based on the analysis results of the influencing factors mentioned above, develop the names of driving factors and variables. On this basis, scale data for each variable was collected through the design and distribution of survey questionnaires, mainly focusing on the importance of variables in the dynamic mechanism layer and element layer. Subsequently, explore the correlation and impact of various driving factors on the benefits of knowledge innovation, construct core condition configurations, and conduct detailed analysis for each configuration. To summarise, the main contributions of our work are as follows:

1） This study mainly analyses various elements and interrelationships in the process of scientific research crowdsourcing projects, summarises the influencing factors of platform knowledge innovation, and analyses the specific path of the influence of knowledge innovation motivation through configuration analysis.

2） This study explores the application and expansion of crowdsourcing theory in organised scientific research, proposes the particularity of crowdsourcing based organised scientific research cooperation models, and contributes to the theoretical research of crowdsourcing and scientific research cooperation models.

3） This study combines the laws of scientific research operation to analyse the ideas of organisational innovation process. We have considered the static elements and dynamic interactive processes of scientific research cooperation models and constructed a crowdsourcing based system for the composition of scientific research cooperation models. The research has enlightening significance for constructing corresponding pattern composition systems.

The rest of this paper is organised as follows. Section 2 provides a comprehensive literature review on knowledge transfer models and influencing factors at different levels, constructing a dynamic ecosystem that integrates influencing factors at different levels. Section 3 introduces the research methods and experimental steps chosen in this study. Section 4 describes the main influencing factors and coding, and constructs a knowledge innovation benefit configuration model. Section 5 introduces the design of the survey questionnaire and the process of implementing the survey. Section 6 conducts data analysis and discussion, and based on this, determines the appropriate configuration. Finally, Section 7 concludes the paper.

Literature review

Based on the dynamic knowledge innovation model (Nonaka et al., 2000), this article believes that knowledge innovation cannot be separated from factors such as knowledge resources, knowledge innovation subjects, knowledge innovation environment, as well as required technologies and tools, and the definition of knowledge theory. At the same time, the knowledge transfer between two or more participants is represented as the process in which one participant's knowledge is acquired by another participant, and knowledge transfer is a process that operates between different participants (Argote et al., 2022). Similarly, the knowledge innovation process in platforms is the result of the combined action of multiple factors, and the knowledge innovation process in platforms involves knowledge transfer between different users. Therefore, this study analyses the knowledge innovation incentive elements in platforms from four main components based on the KTA framework (Albino et al., 1998). The following text mainly analyses the knowledge innovation incentive elements, and constructs a dynamic ecosystem of scientific research crowdsourcing platforms.

Knowledge innovation incentive elements of research crowdsourcing platform

The knowledge transfer analysis framework mainly emphasises the process of knowledge transfer between both parties. This process comprises some main components related to the actors involved (sources, recipients and intermediaries), the relationship between them, the object of the transfer, the channels and mechanisms and the reference context (Battistella et al., 2016). In summary, it is composed of four parts: subject, medium, content, and environment, which are respectively represented as participants, transmission medium, transmitted content, and environment in which interaction occurs.

Subject elements

The main element of knowledge innovation in the process of scientific research crowdsourcing is the platform's users, namely the participants of the platform project, including the project's initiator and contractor. As a direct carrier of knowledge, individual users are the most fundamental unit of knowledge innovation and behavioural operations. From the perspective of individual users, the knowledge innovation incentive elements of platforms are driven by individual user innovation, including three aspects: individual user's internal needs (Choo et al., 2007), personal traits (Smith et al., 2005), and personal abilities (Akbar, 2003). Innovation largely depends on whether users actively participate and whether they are willing to make efforts for perception tasks (Lu et al., 2020). Existing research has emphasised individuals' willingness to innovate tasks in crowdsourcing activities (Shi et al., 2020).

The project team composed of individuals in scientific crowdsourcing is also a consideration of innovation factors in the platform. The same team level also includes the needs of the team, the overall characteristics and abilities of the personnel in the team, and so on. The influencing factors of the overall effectiveness of a team involve various aspects such as team composition, internal and external composition, group norms, group experiences, and external environment (Zhang, 2018). Users become one of the team members of scientific crowdsourcing projects by participating in the project. The specific focus of project team level factors is still on individual level elements.

Media elements

The research crowdsourcing platform is an online system built on the basis of networks and information technology, and the differences in system level characteristics have an impact on the knowledge innovation of projects in the platform. The elements at the platform level mainly include basic functions, website design, communication and interaction, operation management, and promotion (Li, 2017). The performance of the platform enables users to have a certain degree of experience when using the platform, thereby generating the effect of knowledge innovation (Lu et al., 2018). The interactions generated on the platform can drive and stimulate innovative activities, activate individual knowledge, and generate new knowledge. However, due to the interaction between individuals during this process, individual user privacy data will inevitably be generated during the use of the platform, increasing the risk of user privacy exposure. The individual's perception of system risk can have an impact on their subsequent use of the platform for innovative activities (Huang and Sundar, 2022). This involves the issue of the platform management system.

The platform is a virtual carrier of knowledge innovation and also a party involved in behavioural operations during the process of scientific research crowdsourcing projects. This study suggests that the performance impact of the platform enables users to participate in the project process online and engage in knowledge innovation, while the management and service of the platform also influence participants in knowledge innovation activities.

Content elements

The object refers to the knowledge generated during the use of the platform, namely content elements, which are reflected in information content, including user-generated content, platform-published content, quoted content, and other sources. Knowledge is a key input in the process of scientific research innovation (Singh and Fleming, 2010; Gruber et al., 2013). In terms of expression, it also includes forms such as text, images, videos, links, and other forms provided by platforms that can effectively share information.

Crowdsourcing tasks are the initial knowledge carrier of the innovation process and the primary problem to be solved in crowdsourcing activities. The differences in task types can affect the innovative behaviour of participants. When participants believe that the complexity of the task is low and they are capable of performing the task, the greater the probability of their participation in innovation (Shah and Higgins, 1997). It can be considered that the complexity of tasks negatively affects the willingness to participate in innovation (Zhu et al., 2016). At the same time, changes in the reward given to a task result in different moderating effects of task complexity on internal and external motivation. The increase in task bonuses helps to improve innovation performance (Mei and Sun, 2018). The output of innovation performance varies for tasks with different attributes, and the complexity, rewards, and cycles of tasks can all have varying degrees of impact on innovation performance.

Environmental elements

The environmental factors of knowledge innovation in platforms are reflected as a situational factor of scientific research crowdsourcing, including internal and external environments. Researchers have analysed the organisational atmosphere in the internal environment as a core element, proposing that innovation atmosphere has an impact on individual innovation behaviour, and confirming that innovation atmosphere can promote individual innovation performance (Amabile and Gryskiewicz, 1989). On the one hand, the innovative organisational atmosphere positively affects individual innovation awareness, thereby affecting their innovation motivation and behaviour (Scott and Bruce, 1994). On the other hand, an innovative atmosphere can stimulate innovation ability and provide support for innovative behaviour, making it easier to promote innovative behaviour (Oldham, 1997). In addition, the combination of individual attribute characteristics and organisational atmosphere can be psychologically regulated (Luthans et al., 2008). It can be considered that an innovative atmosphere has a positive impact on an individual's innovative behaviour (Du and Qiu, 2019).

In existing research on the relationship between innovation atmosphere and performance, there is a significant correlation between innovation atmosphere and performance. Through active self-management and self-motivation guided by an innovative atmosphere, individuals are encouraged to continuously improve themselves, constantly propose new ideas and concepts through external stimuli in interaction, and thus maximise their innovative abilities.

Research crowdsourcing platform power ecosystem and its element role

Dynamic ecosystem

Based on the four levels of elements, this study believes that research crowdsourcing platforms transform innovation elements from dispersed and different states into an overall system. This study divides the driving force of knowledge innovation into three levels, including the micro power layer, meso power layer, and macro power layer. As a whole, a power ecosystem for knowledge innovation in scientific research crowdsourcing platforms is constructed, as shown in Figure 1.

The research crowdsourcing platform is the foundation for supporting the operation of research crowdsourcing projects, laying the foundation for the synergistic effect of innovation driving factors at the micro, meso, and macro levels. Micro level motivation mainly refers to the individual motivation of users, which is reflected at the user level, including their wishes, internal needs, personal abilities, and personal traits. Mid level motivation is the driving force for platform operation, reflected in three levels: platform, project tasks, and virtual scientific research team, including system performance, system management, and system services at the platform system layer, task requirements, task descriptions, and task types at the project task layer, as well as team requirements, team atmosphere, and team background at the virtual scientific research team layer. Macro dynamics refer to external environmental dynamics, including policy environment, social environment, scientific research environment, and network environment.

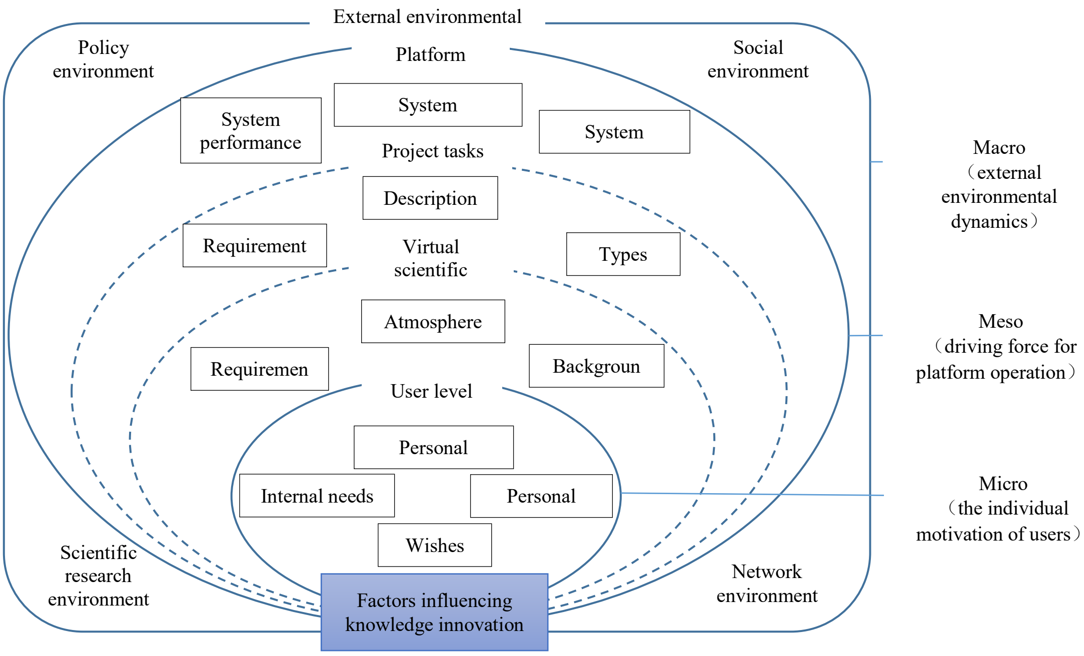

Figure 1. Knowledge Innovation Power Ecosystem

Division of dynamic mechanism layers and corresponding elements

Based on the above analysis, after confirming the main influencing factors, it can be seen that the driving factors of knowledge innovation are diverse, and the comprehensive intersection presents a complex dynamic ecosystem of multiple factors working together. Each subject is affected by factors at different levels and states. Therefore, the driving mechanism of knowledge innovation in scientific research crowdsourcing platforms involves a lot of hierarchical content. According to the division in the previous text, this study divides the knowledge innovation motivation mechanism of scientific research crowdsourcing platforms into four levels: internal motivation, team motivation, platform motivation, and external environmental motivation.

The main elements corresponding to the motivation mechanism layer are set in Table 1, and relevant definitions are made for the main elements at each level. Here, this study provides some explanations of the element hierarchy, including using the relevant elements of the contracting party as team motivation, the contracting party's willingness to innovate determines the overall atmosphere of the project team, the contracting party's innovation investment is reflected in the setting of project remuneration, and for innovative individuals, these two elements reflect the basic setting of the team at different levels.

Power mechanism layer	Main elements	Definition
Internal motivation	Demand	Individual needs for knowledge innovation
	Will	Individual's desire or intention to innovate knowledge on the platform
	Input	The cost incurred by individuals in innovation
	Ability	The comprehensive innovation quality of an individual is expressed as innovation ability, including learning ability, organisational ability, etc
	Knowledge	Individual knowledge reserves, reflecting knowledge background
Team motivation	Team interaction level	The degree of communication and interaction between individuals in the team
	Number of innovative users	Number of users innovating within the team
	Employers' willingness to innovate	The degree of intention of employers to promote project innovation
	Employers contract innovation investment	The main manifestation is the investment of funds, which is reflected in the individual rewards that the contracting party can receive
Platform motivation	Platform system usability	The comprehensive decision-making behaviour of individuals regarding the system quality, information quality, and service quality provided by the platform system
External environmental motivation	Internal environmental factors	Knowledge innovation environment in scientific research crowdsourcing platforms, reflecting the innovative atmosphere of scientific research crowdsourcing projects
	External environmental factors	Macro environmental factors, including political, economic, social, and other environmental factors

Table 1. Power mechanism layer division and corresponding elements of scientific research crowdsourcing platforms

Explanation of research methods and experimental steps

The necessity of configuration perspective

Research based on the perspective of configuration can provide a deeper understanding of the relationship between the various elements of the knowledge innovation ecosystem and the benefits of knowledge innovation. The influencing factors of knowledge innovation cover various levels. To explore the interactive relationship between elements in the knowledge innovation ecosystem, supported by research crowdsourcing platforms, and the impact of interactive effects on knowledge innovation benefits, this study further analyses the joint action relationship of influencing factors from a configuration perspective.

Applicability of qualitative comparative analysis of fuzzy sets

The main idea of configuration effect analysis is to consider interrelated structures and practical clusters, emphasising the synergistic and symbiotic relationships between elements. This idea is consistent with the concept of constructing a knowledge innovation ecosystem proposed in this study. Therefore, further analysis of the influencing factors from the perspective of configuration analysis can reveal the comprehensive causal relationship of multiple factors in the knowledge innovation benefits of scientific research crowdsourcing platforms. Among the research methods based on configuration perspective, the fuzzy set qualitative comparative analysis (fsQCA) method is representative. This method has the dual attributes of qualitative and quantitative analysis (Ragin and Strand, 2008), analysing the combination of antecedents that lead to results. It transforms fuzzy set data into truth tables, retaining the advantages of truth tables in handling qualitative data with limited diversity and simplified configurations (Lu et al., 2020). It has strong explanatory power for the analysis of multivariate interactions and can well describe the path driven by results.

Experimental steps for qualitative comparative analysis based on fuzzy sets

We adopt the qualitative comparative analysis method of fuzzy sets for the specific steps of experimental research. Firstly, it is necessary to clearly define variables as antecedent and outcome variables based on the research question. Secondly, we establish relationships between variables and construct a configuration effect model. Next, we designed a scale based on variables and collected data through a questionnaire survey. Then, we conduct reliability and validity tests on the collected sample data, set membership calibration sample data, and test the necessity of a single antecedent variable. Subsequently, construct a truth table to identify causal relationships. Finally, we organise the identified results and analyse the configuration effects of multivariate interactions.

Power factor coding and configuration effect model construction

Main influencing factors and their coding

Based on the factor analysis in Section 2, this article further codes the factors to form the specific connotations of each influencing factor, as shown in Table 2. We mainly explore four dimensions, including intrinsic motivation(I), team motivation(T), platform power(P), and environmental motivation(E). Among them, the degree of team interaction and the number of innovative users are merged into the elements of the team interaction process, and the innovation willingness of the contracting party and the availability of project funds are merged as two representation codes for the initial investment elements of the contracting party. The platform power layer consists of two main elements, namely platform system availability and system risk. Among them, platform system availability is measured by system performance level, system service effectiveness, and system management effectiveness. This study does not primarily consider the overall external environment, but focuses on the team environment supported by the platform as the main environmental factor for later discussion.

Dimension	Main elements	Secondary coding	First level coding	Encoding connotation
Intrinsic motivation (I)	Demand	The demand for individual innovation（DI）	The demand for new knowledge（DI1） The demand for knowledge transformation（DI2）	The degree to which individual users perceive a need for knowledge innovation
	Will	Individual willingness to innovate（WI）	The willingness to innovate independently（WI1） Willingness to participate in collaborative innovation（WI2）	The evaluation of the individual user's desire or intention to innovate knowledge on the platform
	Input	Investment in individual innovation（II）	Investment of time, energy, and funds（II1） Investment in knowledge and technology resources（II2）	The perceived cost of individual users in project innovation
	Personal traits	The characteristics of individual knowledge（CI）	Individual innovation ability（CI1）	Individual user evaluation of their comprehensive innovation quality
			Individual knowledge reserve（CI2）	The evaluation of individual user's knowledge reserve, reflecting their knowledge background
Team motivation (T)	Team processes	Team comunicatiion level（CT）	Frequent interaction between teams（CT1） Effectiveness of team interaction（CT2）	The degree of communication and interaction between individuals in the team
			Number of innovative users（CT3）	The scale of the innovation network constructed by the number of innovative users in the team
	Team initial motivation	Employers as the source in the team（ST）	Employers' willingness to innovate（ST1）	The degree to which users perceive the intention of project employers to promote innovation
			Project funding availability（ST2）	The degree to which users perceive the costs invested by employers in project innovation and the availability of project funds
Platform power (P)	Platform system usability	The usability of the platform system（PU）	System performance level（PU1）	User perception of platform usability
			System service effectiveness（PU2）	
			System management effectiveness（PU3）	
	System risk	System risk assessment（RP）	Personal privacy risks（RP1） intellectual property risk（RP2）	The risk perception of users towards personal information exposure, leakage, loss, and knowledge security issues on the platform
Environmental motivation (E)	Project environmental factors	Team innovation environment（TE）	Harmonious team atmosphere（TE1） Team knowledge accumulation（TE2） Shared Innovation Vision（TE3）	User perception of the overall innovation atmosphere environment of project teams in scientific research crowdsourcing platforms

	Macro environmental factors	External innovation environment (ME)	Political environment (ME1) Social environment (ME2) Research environment (ME3) Network environment (ME4)	User perception of external policy environment, social environment, scientific research environment, and network environment

Table 2: Encoding and Conceptual Connotation of Various Elements in the Power Mechanism Layer of Scientific Research Crowdsourcing Platform

Construction of knowledge innovation benefit configuration model

Therefore, this study constructs a conceptual model of the influencing factors of knowledge innovation benefits during the project operation process carried by the scientific research crowdsourcing platform, as shown in Figure 2. The knowledge innovation ecosystem of scientific research crowdsourcing platforms comprises four driving factors: internal motivation, team motivation, platform motivation, and environmental motivation. These factors are considered the antecedent variables of knowledge innovation benefits.

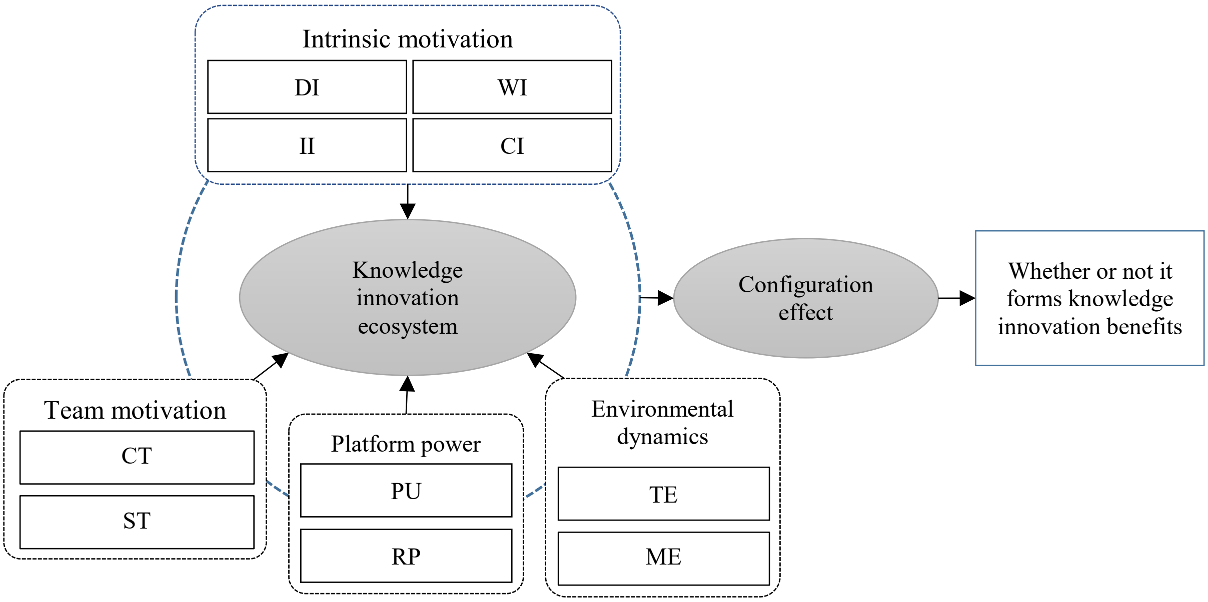

Figure 2: Configuration Effect Model of Dynamic Factors Influencing Knowledge Innovation in Scientific Research Crowdsourcing Platforms

Questionnaire design and survey implementation

Questionnaire design

The content of the research design questionnaire includes three parts: an introduction to the concept of a research crowdsourcing platform, a survey of basic information of participants, and an evaluation and measurement of the research scale. Among them, the evaluation measurement of the research scale includes the antecedent variable and the outcome variable. The scale items of the antecedent variable are measured using a 5-level scale, and the outcome variable is set to measure and evaluate the benefits of knowledge innovation in the scientific research crowdsourcing platform. To clarify the impact of the antecedent variable on the outcome variable, this study used a two-component scale to directly assess the generation of knowledge innovation benefits. To increase the validity and reliability of the survey, this study set up pre survey and formal survey. On the basis of the reference literature constructed by the variables in the previous text, combined with the design of existing research (Wu et al., 2021), the reference literature for scale design is supplemented again. The research scale labels of the survey questionnaire are set as shown in Table 3, and the scale scores are calculated using the mean method.

Tags	Question setting	References
The demand for individual innovation（DI）	The degree to which individual users perceive their need for new knowledge acquisition. The degree to which individual users perceive their need for knowledge transformation.	(Ardichvili et al., 2003)
Individual willingness to innovate（WI）	The evaluation of user's desire or intention to innovate knowledge on the platform. The evaluation of user's desire or intention for team collaboration knowledge innovation on the platform.	(Bock et al., 2005; Li et al., 2019)
Investment in individual innovation（II）	Individual users perceive the time, effort, and funding costs required for project innovation. Individual users perceive the knowledge, technology, and other resources required for project innovation.	(Huang & Cao, 2018)
The characteristics of individual knowledge（CI）	Individual user evaluation of their comprehensive innovation quality. Individual user evaluation of their own knowledge reserves, reflecting their knowledge background.	(Cohen & Bailey, 1997; Todorova & Durisin, 2007)
Team communication level（CT）	User perception of the frequency of communication and interaction between individuals in the team. User perception of the effectiveness of communication and interaction among individuals in the team. Perception of belonging among users towards participating in project teams and other participants.	(Luo et al., 2009; Eisingerich et al., 2010)
Employers as the source in the team（ST）	The degree to which users perceive the intention of the project contracting party to promote innovation. The level of importance that users place on the investment costs of the contracting party (compensation that the contracting party can receive).	(Li et al, 2018; Xu, 2018)
The usability of the platform system（PU）	Evaluation of the impact of users on the performance level of platform systems. Evaluation of the impact of users on the effectiveness of platform system services. Evaluation of the impact of users on the effectiveness of platform system management.	(Yli-Renko et al., 2001; Zhang & Zhang, 2017)
System risk assessment（RP）	User's risk perception of personal information exposure, leakage, loss, and other issues on the platform. User's risk perception of knowledge security issues on the platform.	(Harper & Kim, 2018)
Team innovation environment（TE）	User perception of the level of harmony in the innovation atmosphere of project teams in scientific research crowdsourcing platforms. User perception of knowledge accumulation level of project teams in platforms. User perception of the consistency of project team goals in platforms.	(Scott & Bruce, 1994; Liao & Chou, 2012; Nahapiet & Ghoshal, 1998)
External innovation environment（ME）	Perception of the degree of support provided by the overall policy environment. Perception of the degree of support provided by the overall social environment. Perception of the degree of support provided by the overall research environment Perception of the degree of support provided by the overall network environment	(Kim & Oh, 2018; Tohidinia et al., 2010)

Table 3. Basis for item setting of the questionnaire on the influencing factors of knowledge innovation in scientific research crowdsourcing platforms

Pre-survey

The pre-survey is established after the initial questionnaire is formed, to modify the questionnaire to ensure that participants can complete the questionnaire smoothly. Firstly, we collected the opinions of two experts in this field and improved the questionnaire based on their feedback. Subsequently, with the joint participation of members of the research group, a scenario for questionnaire design was proposed, and modifications were made to the accuracy of the problem description, as well as adjustments to the main structural order of the questionnaire. Afterwards, the questionnaire was adjusted again and 8 experts and scholars in the field were targeted for pre-testing. Among these 8 experts and scholars, 4 have a certain research foundation in research crowdsourcing, while the other 4 are familiar with but not familiar with research crowdsourcing, and their years of participation in research projects vary. Therefore, it can ensure the professionalism of the questionnaire and also ensure that participants with different levels of research experience can understand the questionnaire items. Next, a small-scale questionnaire was distributed, and a total of 67 sample data were received. The reliability and validity of the variable data were tested, and the Cronbach's Alpha coefficient value was 0.861. The reliability test passed, and the KMO value of the sample was 0.715, indicating good validity. Then proceed to set the questionnaire as a formal survey questionnaire.

Formal survey

The formal survey of this study was conducted in two forms of questionnaire distribution. Firstly, with research personnel related to the research group as the core object, questionnaires are distributed through snowball methods and limited to those who have participated in the research, continuously expanding the number of participants in the questionnaire survey. Secondly, through online social media, identify platform bloggers with scientific research foundations, such as teachers, doctoral students, technology company employees, and research related-workers, and distribute targeted questionnaires to these users. The sending and receiving period of the questionnaire is from August 21, 2022, to August 29, 2022, a total of 9 days, and 287 questionnaires were collected. Filter the sample based on the results of the control items in the first question, remove the sample data of participants whose results show that they have no knowledge of the platform, and filter out samples with a response time of less than 120 seconds. Then, remove the sample data with less than one year of scientific research work, and obtain a final sample of 247.

Data analysis and discussion

Descriptive statistical analysis

Firstly, this study used SPSS software to conduct a descriptive statistical analysis on the sample data. The basic information description statistics of the survey participants are shown in Table 4, and the sample characteristics mainly include gender, age, educational background, work unit, and nature.

From the overall sample characteristics, the sample involves users from different levels. The distribution of sample data is relatively balanced, with 54.7% being female and 45.3% being male. The sample users cover different age groups, with a large number concentrated between 26 and 35 years old, mostly young people, and a small number of samples in the age group of 41 and above. This study combines and displays them in Table 4. The educational background mainly consists of graduate students, including master's and doctoral studies, accounting for approximately 81% of the sample user group. The working units are mainly universities and enterprises, accounting for about 43.3% and 39.2% respectively, while research institutes account for about 5.7%. Other working units involve government agencies and political and legal departments. Meanwhile, the proportion of scientific researchers in the sample is close to 50%. It can be seen that the overall sample population understands the process of scientific research and has a certain research foundation. The research crowdsourcing platform set up by this research institute mainly serves the scientific research process, therefore, the participants in the survey questionnaire have a research foundation to ensure the feasibility of project implementation.

Sample characteristics		Frequency	Percentage	Cumulative percentage
Gender	Male	112	45.3%	45.3%
	Female	135	54.7%	100%
Age	<=25	46	18.6%	16.5%
	26~30	168	68.0%	86.6%
	31~35	26	10.5%	97.1%
	36~40	3	1.2%	98.3%
	>=41	4	1.7%	100%
Educational background	Bachelor's degree or below	47	19.0%	19.0%
	Postgraduate degree	124	50.2%	69.2%
	Doctoral degree	76	30.8%	100%
Work unit	Colleges and universities	107	43.3%	43.3%
	Research Institute	97	39.2%	82.5%
	Enterprise	14	5.7%	88.2%
	Other	29	11.8%	100%
Nature of work	scientific researcher	115	46.6%	46.6%
	Technical developers	69	27.9%	74.5%
	Other	63	25.5%	100%

Table 4. Sample Statistical Feature Distribution

In addition, considering the research background of the participants, in addition to their workplace and nature of work, this study investigated the professional titles or grades of the participants, as well as their disciplinary categories and research work hours. Firstly, based on the work units of the participants, this study mainly considers the research background of participants from universities, research institutes, and enterprises from two levels: job level and professional title, and does not currently consider the professional titles or professional level backgrounds of other work units. On the one hand, apart from current students, the professional titles of participants in universities and research institutes are divided into senior high, associate high, intermediate, and junior high, and others, accounting for 0.8%, 2.8%, 8.5%, 4.9%, and 1.6%, respectively. On the other hand, participants in enterprises are divided into authoritative experts, senior experts, senior, intermediate, junior, and others according to their job levels, accounting for 0.8%, 7.7%, 14.6%, 16.6%, and 2.8% respectively. Secondly, statistics on the disciplinary categories of the participants in the questionnaire survey were conducted. Considering that the participants have a multidisciplinary background and a foundation of interdisciplinary research, the disciplinary category was designed as a multi choice topic. The statistical results showed that the participants covered different disciplinary backgrounds, and were ranked according to frequency, namely 49.4% in management, 25.1% in engineering, 13.4% in science, 7.3% in law, 6.1% in economics, 4.5% in interdisciplinary studies, 2% in art, 1.6% in medicine, 1.6% in education, 1.2% in literature, 0.8% in philosophy, and 0.4% in history, agriculture, and military science. Thirdly, the survey and statistical results of the research work duration of participants show that the majority of participants have a research work duration of 1 to 5 years, accounting for approximately 58.8%. Participants who have participated in research work for 6 to 10 years account for 14%, while those who have worked for 11 years or more account for 2.4%. From the perspective of research background, the sample covers different disciplinary attributes, research experiences, and hierarchical backgrounds, which can demonstrate the diversity of users of research crowdsourcing platforms.

Data verification and processing

The data processing stage before research analysis includes reliability and validity testing, data calibration, and single variable necessity testing. This article uses SPSS software and fsQCA software to calculate various indicators, and explains these three parts separately in the following text.

6.2.1. Reliability and validity testing

Variable	Scale measurement items	Estimate	Cronbach's Alpha	CR	AVE
DI	1	0.649	0.750	0.760	0.616
	2	0.931			
WI	3	0.951	0.878	0.883	0.791
	4	0.822			
II	5	0.766	0.778	0.788	0.652
	6	0.839			
CI	7	0.679	0.715	0.723	0.569
	8	0.821			
CT	9	0.717	0.756	0.755	0.507
	10	0.696			
	11	0.725			
ST	12	0.771	0.701	0.704	0.544
	13	0.678			
PU	14	0.856	0.898	0.899	0.747
	15	0.872			
	16	0.864			
RP	17	0.689	0.716	0.718	0.560
	18	0.812			
TE	19	0.757	0.748	0.747	0.496
	20	0.696			
	21	0.667			
ME	22	0.633	0.756	0.757	0.441
	23	0.740			
	24	0.605			
	25	0.682			

Table 5: Reliability and validity measurement of the questionnaire on the influencing factors of knowledge innovation in scientific research crowdsourcing platforms

The reliability and validity of the sample data were analysed using SPSS software, and the results of the reliability and validity tests are shown in Table 5. Firstly, the Cronbach's Alpha factor values for each variable in this study are greater than 0.7, indicating acceptable reliability of the questionnaire and consistency among the questionnaire items. Secondly, the standard factor loadings of the measurement items representing each variable are all greater than 0.5, and the standard factor loadings of most items are greater than 0.7, with values greater than 0.9 indicating that the items have strong explanatory power for the variables.

Therefore, this study retains the set items. In addition, considering the values of CR and AVE simultaneously, when CR is greater than 0.7 or AVE is greater than 0.5, it indicates an ideal aggregation effect. However, the CR results of the variables in this study are all greater than 0.7, and the AVE results are all greater than 0.5, indicating that the aggregation effect of this study is good. In addition, the outcome variable of this study is set as a binary variable and is only formed by one item, so reliability and validity tests are not required.

Data calibration

This study used the mean of the variable set items as the result of the variable, as the raw data before data calibration. Data calibration is the calibration of result variables and condition variables, which involves calibrating the original data to a fuzzy set between 0 and 1. It involves setting three calibration anchors: complete membership, intersection, and complete nonmembership, and assigning set membership scores to cases. The scale used in this study was a five-level Likert scale. According to Jacobs et al.'s research conclusion, the five-level scale had the best calibration effect when the complete membership point was 5, the intersection point was 3.5, and the complete non membership point was 1 (Jacobs and Bart, 2019). Therefore, the calibrated variable data is calculated using the calibrate (x, 5,3.5,1) function in the fsQCA software. To avoid the influence of intermediate values, this study further processed data with a value of 0.5 to 0.499. Based on the calibration process of the above data, generate values for each variable between 0 and 1.

Truth table construction

The construction of a truth table is the process of processing numerical values into conditional combination judgments. This study utilised the truth table construction algorithm in fsQCA software, with a frequency threshold of 3 and a consistency threshold of 0.8, to obtain the truth table data. At this point, both consistency and PRI consistency are relatively high, and there is a strong subset relationship between each configuration and the results. Therefore, this study uses natural truncation to compensate for the shortcomings of the threshold value (Crilly et al., 2012). After obtaining the truth table, consistency is arranged from high to low. In order to retain more rows in the truth table, 0.923784 is used as the truncation value, and the encoding below this value is set to 0. Standardisation analysis is performed to obtain concise and intermediate solutions, and conditional configuration analysis is performed based on this.

Analysis of configuration effects

The data analysis of the configuration effect of variable influencing factors in this study includes two parts: the analysis of the necessity of a single variable and the analysis of the sufficiency of conditional configuration. Necessity analysis is mainly measured by the consistency and coverage of the antecedent variable on the outcome variable. The calculation formulas for the indicators are shown in formulas (1) and (2), respectively.

$$\text{Consistency}(X_i \ll Y_i) = \sum \min(X_i, Y_i) \,/ \sum X_i \qquad (1)$$

$$\text{Coverage}(X_i \ll Y_i) = \sum \min(X_i, Y_i) \,/ Y_i \qquad (2)$$

X_i represents the antecedent variable or antecedent variable configuration, and Y_i represents the result variable. Consistency represents the degree to which the antecedent condition explains the outcome variable, which is the proportion of their intersection to the set X_i. Coverage represents the explanatory power of antecedent conditions or antecedent condition configurations on the proportion of the outcome variable Y_i.

This study refers to existing research settings (Dan et al., 2022) and sets the consistency index of the variable to be greater than 0.9 as a necessary condition for forming the results. Based on this, a conditional configuration analysis is conducted. Subsequently, this study used fsQCA software to calculate and analyse the results of various measurement indicators.

6.3.1. Single variable necessity test and analysis

This study mainly analyses the necessity of a single variable to test whether it constitutes a necessary condition for knowledge innovation benefits, as a judgment basis for the core condition in later configuration analysis. The consistency level of each variable detected is shown in Table 6.

Antecedents	KI	
	Consistency	Coverage
DI	0.700489	0.944017
~DI	0.299511	0.915281
WI	0.715935	0.951685
~WI	0.284065	0.896153
II	0.776839	0.947591
~II	0.223160	0.894577
CI	0.617368	0.945007
~CI	0.382632	0.919855
CT	0.725541	0.949360
~CT	0.274459	0.899802
ST	0.787848	0.935827
~ST	0.212151	0.932987
PU	0.780043	0.940645
~PU	0.219957	0.916486
RP	0.653441	0.940514
~RP	0.346558	0.925406
TE	0.750822	0.946570
~TE	0.249177	0.902619
ME	0.672900	0.950378
~ME	0.327100	0.905518

Table 6. Results of Single Variable Necessity Test

The list of antecedent variables includes two types: belonging and not belonging. The variable with a "~" symbol indicates that it does not belong to the target set. The results of the consistency test show that the consistency of each variable is less than 0.9, indicating that the explanatory power of a single variable on the outcome variable is weak. Therefore, none of the ten variables proposed in this study serve as a single necessary condition for knowledge innovation benefits, and multiple antecedent conditions need to be combined for configuration analysis. Afterwards, this study will further explore the adequacy explanation of configuration for the results of knowledge innovation benefits.

Composition and analysis of the adequacy of conditional configuration

This study uses the simplified and intermediate solutions generated from the standardised analysis of the truth table as the basis for configuration analysis. The configuration results generated by constructing knowledge innovation benefits with intermediate solutions as the core and simplified solutions as auxiliary are shown in Table 7. The existence and absence of core conditions are represented by ● and ⊗ respectively, while the existence and absence of auxiliary conditions are represented by small symbols • and ⊗. As shown in Table 7, there are a total of 5 configurations that promote the generation of knowledge innovation benefits. The consistency of each configuration is greater than 0.9, and the overall consistency is also greater than 0.9, indicating a significant configuration effect. An overall coverage rate greater than 0.5 indicates that 5 configurations can explain more than half of the cases. From the perspective of common conditions, the core existence condition is individual innovation investment(II), and the auxiliary conditions for common existence include team communication level(CT), employers as the source in the team(ST), the usability of the platform system(PU), and the team innovation environment(TE). There are five configuration configurations for the benefits of knowledge innovation in this study, which will be explained in the following sections.

Antecedents	The configuration of knowledge innovation benefits				
	1	2	3	4	5
DI			●	⊗	●
WI	•		•		•
II	●	●	●	●	●
CI		•	⊗		
CT	•	•	•	•	•
ST	•	•	•	•	•
PU	•	•	•	•	•
RP				•	•
TE	•	•	•	•	•
ME	●	●		●	
Original coverage	0.530996	0.504896	0.315264	0.249251	0.484528
Unique coverage	0.010632	0.013805	0.002809	0.001489	0.013948
Consistency	0.955035	0.954365	0.937103	0.930387	0.949870
Consistency of solutions	0.953266				
Coverage of solutions	0.578987				

Table 7. Configuration of knowledge innovation benefits generated by scientific research crowdsourcing platforms

Configuration 1 takes individual innovation investment and external innovation environment as the core existence conditions, with individual innovation willingness, team interaction, initial motivation of the contracting party, platform system usability, and team innovation environment as auxiliary existence conditions. It indicates that with good individual innovation investment and external innovation environment, individuals have a certain degree of innovation willingness, are attracted by the investment of the contracting party to a certain extent, and the platform system has good usability support and forms a good team innovation atmosphere, which can form knowledge innovation benefits. The conditional configuration of this configuration is relatively scattered, with both the internal and external environment as conditional variables, represented as an internal external linkage type relying on environmental dynamics.

The core existence conditions of Configuration 2 are the same as Configuration 1, but the auxiliary existence conditions are personal knowledge traits, team interaction level, initial motivation of the contracting party, platform system usability, and team innovation environment. The individual's internal needs and willingness, as well as the perception of system risk, are irrelevant conditions, all of which are related to the individual's perception.

It indicates that in addition to meeting the conditions of strong individual innovation investment and a good external innovation environment, individuals also need to have a certain level of knowledge traits, engage in effective communication and interaction within the project team, lead and invest funds in innovation by the contracting party, have good usability of the platform system, and provide a good innovation atmosphere by the project team. The benefits of knowledge innovation can be formed. This configuration emphasises a high level of the external environment and individual investment, as well as the support of team motivation, representing a cross relationship between individuals and the environment maintained by the team.

The core existence conditions of Configuration 3 are different from the first two configurations, with individual innovation needs and investment as the core existence conditions. The auxiliary conditions include one auxiliary non-existent condition as individual knowledge traits, and five auxiliary existence conditions as individual innovation willingness, team interaction degree, initial motivation of the contracting party, platform system usability, and team innovation environment. This configuration indicates that, under strong individual innovation needs and investments, although individuals have insufficient knowledge innovation capabilities and reserves, if they still have a high willingness to innovate and support from the team, platform, and environment, they can still form knowledge innovation benefits. This configuration emphasises its active role and is represented as an individual's active complement type.

The core existence conditions of Configuration 4 are the same as Configuration 1 and Configuration 2, with auxiliary conditions including one auxiliary non-existent condition and five auxiliary existence conditions. The condition for the absence of assistance is individual innovation needs, while the condition for the existence of assistance is all factors at the team and platform motivation levels, as well as the team innovation environment. This configuration indicates that although individuals have sufficient knowledge reserves and innovation capabilities when their innovation needs are insufficient, the overall macro innovation environment is good, and is effectively influenced by team and platform motivation, which can form knowledge innovation benefits. This configuration reflects the effective role of the platform and team supported by the environment, compensating for the shortcomings of individual needs, and represents an external driving force excluded from the individual's perspective.

The core existence conditions of Configuration 5 are the same as those of Configuration 3, with auxiliary conditions including individual innovation willingness, team motivation level factors, platform motivation level factors, and team innovation environment, while individual knowledge traits and external innovation environment are irrelevant conditions. This configuration indicates that with the support of team and platform motivation, strong individual needs and a large amount of individual innovation investment can form knowledge innovation benefits. This configuration emphasises the individual needs and investment of the receiving party, and is represented as an individual led model supported by the team and platform.

Discussion and conclusion

This study analyses the roles of factors in the knowledge innovation ecosystem at different levels, selects platform influencing factors from different frameworks and perspectives, ultimately establishes the main driving factors for the operation of research crowdsourcing platforms, and summarises the main conditions for platform operation.

This study proposes that the main influencing factors in the operation process of scientific research crowdsourcing platforms include intrinsic motivation, team motivation, platform motivation, and environmental motivation. Internal motivation is mainly influenced by individual needs, willingness, investment, ability, and knowledge. The factors of team motivation include the degree of team interaction, the number of team innovations, the innovation willingness and investment of the contracting party. The platform power factor is related to the applicability of the platform system. The environmental driving factors mainly refer to the innovative environmental factors constructed by the scientific research crowdsourcing platform. The analysis of configuration effects on influencing factors resulted in the construction of five core configurations, all highlighting the core conditions for individual innovation investment as the configuration. The five configurations have different focuses, namely the internal and external linkage type relying on environmental dynamics, the individual and environment interlocking type maintained by the team, the individual's active compensation type, the external driving type, and the individual dominant type supported by the team and platform.

This study argues that the operation of scientific research crowdsourcing platforms is a system that is interconnected, developing, and moving, containing various elements with dynamic interactions. This study focuses on the development of the platform and the three-party elements of the scientific research crowdsourcing platform. However, there was no consideration given to whether the selection of key elements would change after a certain stage of the project. If an individual's project stage on the platform changes, this study does not provide immediate strategic guidance on how to make temporary decisions. In the future, in-depth dynamic decision analysis will be conducted on this.

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