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EXPLORING THE INFLUENTIAL FACTORS ON INNOVATION PERFORMANCE OF HIGH-TECH ENTERPRISES IN UNIVERSITY-INDUSTRY COOPERATION

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Abstract: University-industry cooperation (UIC) is a key mechanism for businesses in the era of open innovation, providing access to essential complementary resources for the genesis of novel knowledge and the development of breakthrough technologies. This collaboration significantly augments their technological innovation capacity, catalyzing regional economic growth. During his visit to Tsinghua University in April 2021, President Xi Jinping emphasized the need to "boldly overcome the formidable hardles in key core technologies, deepen the synergistic fusion of industry, academia, and research, and promote the transaction of scientific and technological advances into tangible results." The study explores how inter-organizational trust and knowledge management affect the innovation performance (IP) of high-tech firms in UIC. Partial Least Squares Structural Equation Modeling (PLS-SEM) is used for empirical research. Ultimately, a conceptual model is proposed to investigate how different dimensions of trust influence the IP of enterprises in UIC through the mediating role of knowledge management capabilities.
Keywords: University-industry cooperation (UIC); Trust; Knowledge management; Partial Least Squares Structural Equation Modeling (PLS-SEM)

1 INTRODUCTION

Cooperation between academia and industry is a complex social behavior. Only in the state of sincere cooperation can the cooperating parties achieve a high degree of fit, which limits transaction costs to a lower level and the innovation of college-industry cooperation reaches a certain level. In an environment of lack of trust, transaction costs cannot be effectively controlled before and after the contract is signed, which inevitably weakens the competitiveness of college-industry cooperation projects. Lack of trust drives up pre-signing search costs, negotiation costs, communication costs, identification costs and contract signing costs, which limits the improvement of the innovation level of college-industry collaboration. Similarly, due to a lack of trust, post-contract performance costs, monitoring costs, contract implementation costs, arbitration costs and professional investment costs increase, which in turn limits the improvement of the level of innovation in college-industry collaboration. Only by vigorously optimizing the trust environment of University-industry cooperation (UIC), so that the awareness and behavior of honesty are effectively strengthened, can we continuously reduce transaction costs and increase the efficiency of cooperation and innovation. The study of trust in organizations continues to be a focus in knowledge management and faces theoretical and practical challenges. First, although the existing literature confirms various aspects of trust and its role in fostering collaborative relationships, there is still a need for research on the origins and development of trust in collaborative innovation. Surveys have shown that different forms of trust emerge at different stages of the development of collaborative innovation relationships [1]. Second, more systematic research is needed on how the different dimensions of trust affect enterprises' IP in collaborative innovation.
The objectives of this study is “To construct a PLS-SEM model of the factors influencing the innovative performance of enterprises in the context of UIC.” This study focuses on enterprises involved in UIC innovation and focuses on the crucial question: "How do the dimensions of trust affect the IP of enterprises in UIC?" The study explores how enterprises can realize and improve their collaborative IP by building and enhancing knowledge management capabilities. The focus of the study is on defining the relevant theories and critical issues of trust, knowledge management capabilities and collaborative innovation based on a comprehensive review of relevant literature at home and abroad. Based on a comprehensive and detailed literature review, the definitions and dimensions of trust, knowledge management capabilities and corporate IP in this context are comprehensively analyzed in terms of the characteristics of collaborative innovation between industry, academia, and research.

2 CONCEPTS

2.1 Dimensions of Trust

In this study, the trust of companies towards universities in the context of cooperation between academia and industry is divided into three dimensions: institutional trust (IT), cognitive trust (CT), and affective trust (AT) IT is defined as the trustor's belief that the trustee will exhibit trustworthy behavior within the norms of institutional factors, thereby justifying his or her trust [2]. The sources of IT can be divided into two categories: formal legal rules and informal organizational cultures that include deterrent or punitive mechanisms. These mechanisms assure the trustor that the trustee will act in a trustworthy manner to avoid sanctions.

CT is defined as the trustor's willingness to trust based on the perception of evidence of the trustee's personal trustworthiness [3]. This evidence includes the trustor's personality traits, cultural background, intentions, competence, consistency of words and actions, and predictability. The trust giver carries out a cognitive process of collecting, processing, calculating and interpreting this information in order to assess his trustworthiness. This cognitive process plays a recurring role in the initial development and in the stable phase of the trust relationship to verify its sustainability. CT arises primarily from shared interests, abilities, social similarity and predictability.

AT is the willingness of the trust giver to trust due to an emotional bond with the trust receiver [4] It is characterized by the fact that it develops in the course of the interaction and does not just arise at the beginning of the exchange relationship. As the trustor becomes aware of the good will and trustworthiness of the trustee through frequent interactions, he develops a willingness to rely on the trustee and build an emotional bond with him. AT is created primarily through a shared emotional foundation built through long-term interactions.

2.2 Dimensions of Knowledge Management

In this study, the knowledge management (KM) capabilities of companies in UIC are categorized into knowledge acquisition (KA) and knowledge transfer (KT).

KA is the fundamental process in knowledge management. Organizational KA enables the development of new knowledge or the substitution of existing knowledge, building on the organization's current tacit and explicit knowledge base [5]. In collaborative innovation between universities and industry, universities and companies jointly create a knowledge ecosystem. Given the dynamic nature of knowledge, which is constantly evolving and overtaking previous knowledge, a gap in knowledge potential between universities and industry is inevitable. When companies realize the gap in knowledge potential compared to universities and the need for technological innovation to improve their competitiveness, they inherently develop a need to absorb knowledge from entities with higher potential, namely universities, thus initiating the KA phase of knowledge management. An enterprise can demonstrate its ability to acquire knowledge by collaborating with universities on innovative projects. This includes the timely acquisition of relevant knowledge and information through observation, academic contributions and scientific exchange. It also includes the acquisition of knowledge about new products, services, suppliers and competitors. This also includes the ability to incorporate the experience gained from cooperation projects into new initiatives and to generate new knowledge from existing findings.

KT is the process by which knowledge is passed from its source to a recipient in a particular environment, followed by its uptake, integration and application by the recipient. Huber [6] refers to the process of KT between organizations as "knowledge refinement"," through which an organization gains access to previously unavailable knowledge, thereby increasing the organization's knowledge base. This article primarily examines KT between two major types of organizations: Companies and universities. In terms of the direction of KT, universities have a significant advantage over enterprises in terms of knowledge reserves and technological expertise. Normally, knowledge flows from institutions with academic and technological superiority to enterprises with lower technological capabilities. Consequently, this study refers to universities as senders of knowledge and enterprises as receivers to emphasize the movement of knowledge from universities and research institutions to enterprises.

2.3 Dimensions of IP

In this study, the innovation performance (IP) of enterprises in UIC is categorized into three dimensions: Knowledge innovation performance (KIP), technology innovation performance (TIP) and management innovation performance (MIP).

KIP is measured by employee learning, employee skills, employee knowledge, the enterprise's core technologies and the enterprise's competitive advantage in the market.

TIP focuses on the impact of collaborative innovation on the number of new products, the speed of new product development, the production value of new products, the number of patents a enterprise receives, the improvement of an enterprise's technological competitiveness, the design of work processes and the speed at which new technologies are adopted in production processes.

MIP assesses the impact of collaborative innovation on an enterprise's organizational structure, process management planning and business process re-engineering.

3 HYPOTHESIS

3.1 The Relationship Between Trust and IP in UIC

In collaboration between universities and industry, trust between the organizations has different effects on the IP of the companies. In the initial phase of cooperation, companies evaluate the reliability of universities primarily based on previous experience, historical cooperation and the reputation of the cooperating institutions. In this phase, the companies involved can formalize their mutual expectations through contracts or innovative partnership agreements. IT increases the efficiency of college-industry collaboration by creating a stable institutional framework. IT has two main prerequisites: formal regulations and organizational culture. Formal regulations include the management systems developed by both parties to ensure that the collaboration process runs smoothly, while organizational culture represents the informal norms within an organization.

No contract or agreement can comprehensively or exhaustively cover all matters or contingencies. It is impractical for partners to renegotiate contracts in the face of unforeseen events [7]. To protect their knowledge, companies will therefore integrate carefully into new environments and conduct prior analyzes and assessments of their knowledge assets and needs. This includes observing and monitoring the collaborative behavior of academic institutions to protect themselves from opportunistic actions. From this, the following hypothesis is formulated:

H1 IT has a significant positive effect on IP.

Empirical studies on the relationship between CT and the IP of companies show different views. Wang Xueli investigated the role of CT in the relationship between transformational leadership and knowledge sharing in organizations and found that CT hinders knowledge sharing [8]. The occurrence of free-rider behavior suggests that CT, once it reaches a certain level, can hinder knowledge sharing. Conversely, in his empirical study, Chua found a positive correlation between the CT of partners in an enterprise and cooperative IP [9]. The stronger the CT, the more likely it is that close partnership relationships will be established, which has a positive effect on cooperative IP. Within organizations, competitive relationships between individuals can lead to envy towards those perceived as more capable, resulting in a refusal to share knowledge or free-riding. In contrast, collaborative innovation between academia and industry is a cooperative endeavor in which both parties work together to research and develop technologies or products based on shared resources and complementary strengths to achieve common goals. From this, the following hypothesis is formulated:

H2 CT has a significant positive effect on IP.

Emotional trust primarily facilitates communication and collaboration among members and between members and the organization, which reduces transaction costs and thus promotes knowledge management activities. The trust mechanism has been internalized as an organizational management norm and facilitates unhindered communication between academia and business. It also enables enterprises to access and utilize the knowledge they need immediately, which increases the capacity of knowledge supply and increases the likelihood of successful collaborative innovation. From this, the following hypothesis is formulated:

H3 AT has a significant positive effect on IP.

3.2 The Relationship Between Trust and KM in UIC

In the area of IT, companies weigh up the cost-benefit ratio of trust when negotiating KT issues based onnovation cooperation with universities. In CT, enterprises infer the loyalty of Higher Education Institutions (HEIs) to the partnership by evaluating past behavior, particularly the extent to which HEIs adhere to the agreements of the collaborative relationship and provide timely, accurate, advanced explicit or tacit knowledge through various channels. Based on this, companies decide whether and to what extent they have trust, which affects the amount and extent of knowledge provided by HEIs. With emotional trust, companies are more inclined to believe that HEIs provide reliable information, which further simplifies the KA process and improves the enterprise's ability to acquire knowledge. Regardless of whether IT is based on contracts, CT on the recognition of competencies or AT on emotional and value congruence, it has a positive effect on an enterprise's ability to manage knowledge. The following hypothesis is formulated from this:

H4 IT has a significant positive effect on knowledge management.

H5 CT has a significant positive effect on knowledge management.

H6 AT has a significant positive effect on knowledge management.

3.3 The Mediating Effect of KM in UIC

Trust influences cooperative IP in college-industry collaboration by affecting an enterprise's knowledge management capabilities. Organizations can improve KA and transfer through trust-based measures that stimulate innovation enthusiasm and enhance collaborative IP.

Even if IT cannot completely prevent opportunistic behavior, it creates a favorable institutional environment for the development of cooperative innovation relationships between universities and companies. This trust spreads the risks associated with collaborative innovation and makes it easier for enterprises to acquire the technical knowledge needed to innovate in broader and deeper dimensions and to collaborate more fully with universities.

In the case of CT, companies have positive expectations of the capabilities and reliability of universities and are inclined to actively acquire knowledge from these institutions. As the collaborative relationship between companies and universities becomes more stable and mutual trust increases, acquiring knowledge from universities can significantly reduce costs compared to acquiring external resources.

After the development of AT, companies' trust in universities deepens further, enabling faster and more effective KT. This efficiency saves time and costs associated with collaborative innovation and positively increases the IP of companies.

From this, the following hypothesis is formulated:
H7 Knowledge management mediates the positive effect of IT on IP.
H8 Knowledge management mediates the positive effects of CT on IP.
H9 Knowledge management mediates the positive effect of AT on IP.

4 METHODOLOGY

4.1 Conceptual Framework

The specific features of PLS-SEM can be summarized as follows: it estimates the relationships between multivariate and inherently related dependent variables; it represents the relationships between unobservable constructs and can account for measurement error in the estimation process; it defines a model to explain all relationships. The PLS-SEM method is suitable for working with non-normal or secondary data with small samples. PLS-SEM models are also preferred when the research objective is to better understand increasing complexity by examining theoretical extensions of established theories.

This study examines the relationship between UIC, KM and IP. In the study, divides UIC is divided into institutional, cognitive and affective dimensions. The ability to manage knowledge is divided into two dimensions: KA and KT. The IP of companies is divided into three dimensions: technological innovation performance, KIP and MIP. The aim is to analyze in depth how the different dimensions of trust affect the IP of companies, as shown in Figure 1.

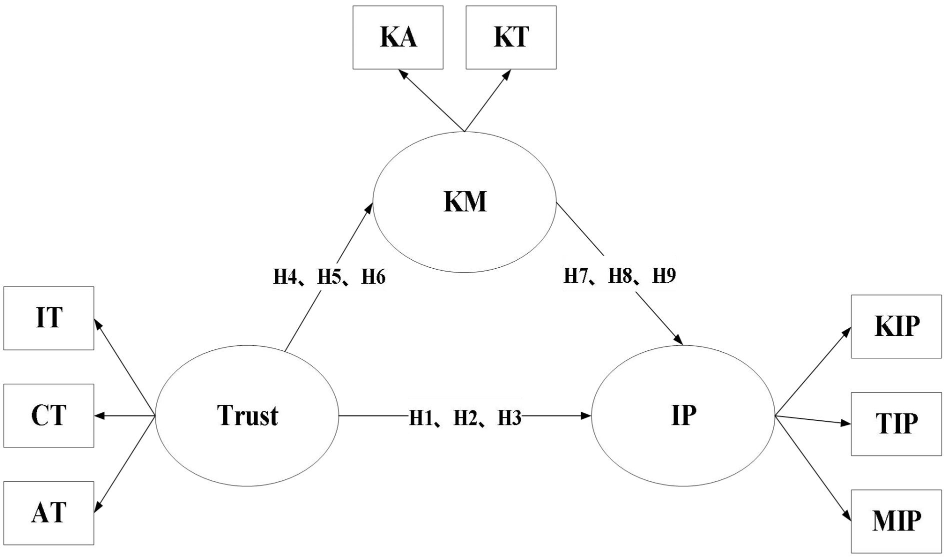

Figure 1 Conceptual Framework of PLS-SEM

To build an PLS-SEM model with IBM-SPSS and WarpPLS. IBM-SPSS is used to perform reliability and validity analysis of the data on the questionnaire results. WarpPLS is used for model construction, fitting and data analysis in empirical research.

5 EXPERIMENTAL DESIGN

5.1 Population and Sample

The population of this study consists of 978 high-tech (new engineering, new medicine, new agriculture) companies that have completed projects under the 2022 Academic Research Cooperation and Collaborative Education Program of the Ministry of Education of China (the most important cooperation project between academia and industry in China).

The sample of this study includes high-tech enterprises from the three northeastern provinces. The SEM model examined in this paper includes 8 parameters, which requires a sample size of more than 160. Therefore, it is assumed that between 250 to 300 sample surveys will be conducted to collect data from managers, technical directors and engineers in about 60 high-tech enterprises, using purposive sampling with a sample size between 200 to 250.

5.2 Technical Route of the Research

A qualitative analysis and assessment of how trust in industry-university-research cooperation affects firms' IP and the mediating role of knowledge management capabilities based on a literature review, field interviews and surveys.

The PLS-SEM method uses sample data from questionnaire distribution. Statistical analysis techniques such as factor analysis and structural equation modelling are used to test the research hypotheses using IBM-SPSS and WarpPLS software tools. The results include the parameters of the factors affecting the variables of interest, as shown in Figure2.

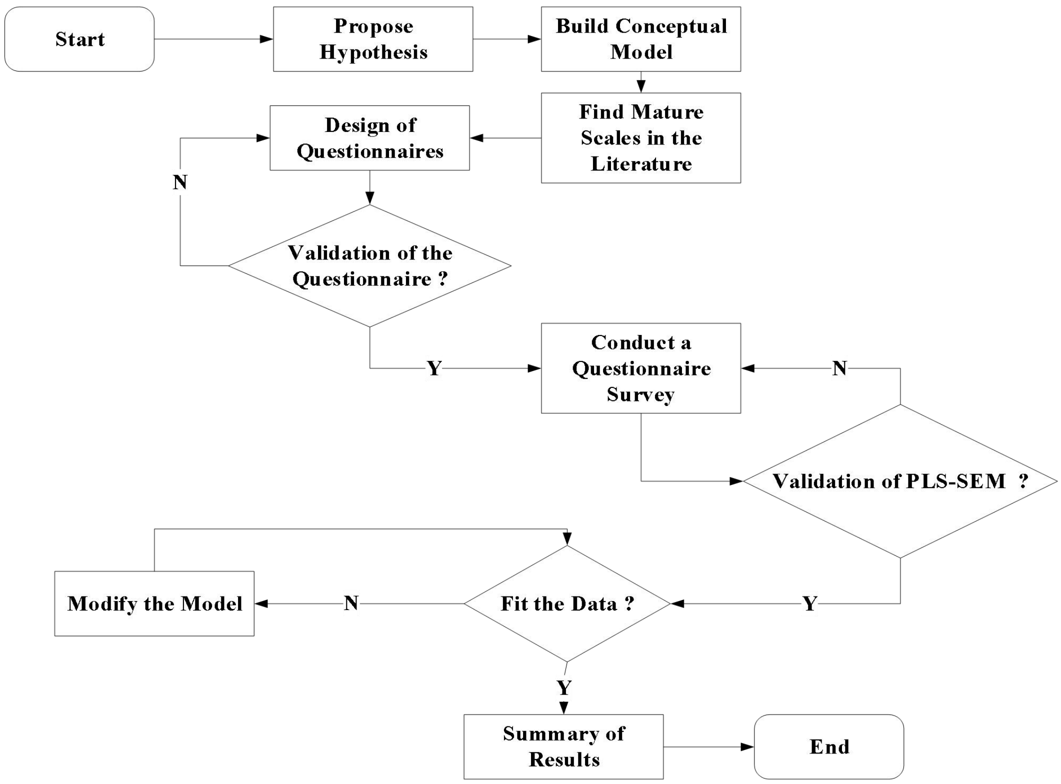

Figure 2 Technical route

5.3 Questionnaire Development

This study conducts a questionnaire survey that thoroughly reviews the literature on inter-organizational trust, corporate knowledge management capabilities, and corporate IP. It draws heavily on theoretical concepts from authoritative research and selects mature scales that are frequently cited in empirical studies both domestically and internationally. These scales, in conjunction with the theoretical framework of this study, serve as guidelines for the design of the measurement instruments.

1.The survey is divided into two main sections: The first section collects basic enterprise data, with participants selecting or giving their answers directly. In the following section, respondents are asked to indicate their agreement on a 5-point Likert scale, where 1 stands for " strongly disagree", 2 for " disagree", 3 for " neither agree nor disagree", 4 for " agree" and 5 for " strongly agree". A positive evaluation approach is used, i.e. the points are awarded directly on the Likert scale: 1 corresponds to 1 point, 2 corresponds to 2 points, 3 corresponds to 3 points, 4 corresponds to 4 points and 5 corresponds to 5 points.

2.Since the study focuses on corporate knowledge management, technological innovation, management innovation and knowledge innovation, subjects who have a clear understanding of the processes and outcomes of collaborative innovation between academia and industry are needed. Consequently, this study interviews the heads of technology and management departments of companies involved in science-industry innovation, primarily middle and senior managers.

3.The questionnaire explicitly asks respondents to reflect on their most recent experience of college-industry collaboration to avoid problems with recall.

4.To encourage open and honest responses, the introduction to the survey clarifies that no questions relate to specific management or operational procedures or confidential business information to ensure that all data collected remains confidential and is not used for commercial purposes.

5.To avoid misunderstandings, the questionnaire is developed with extensive input from experts, academics and business leaders, resulting in refinement of content and adjustments in wording and terminology.

5.4 Data Collection

The data collection process is divided into two stages: small sample and large sample.

1. Small-sample test

After finalizing the structure and items of the questionnaire, a preliminary small-scale distribution will be conducted to assess the reliability and validity of the pre-survey questions. This phase involves selecting 10 high-tech companies with a cooperative relationship with the researcher's working unit, with an estimated distribution of 70 questionnaires.

2. Large-sample test

Contact will be made with 50 high-tech companies across the three northeastern provinces. Mid-to-senior level managers within these companies will be asked to distribute the survey, with an expected distribution of 200 questionnaires.

From both phases, an estimated 200 to 250 valid questionnaires are anticipated to be collected. Descriptive statistical analysis will be performed on the sample, including handling any missing values in the questionnaire to facilitate monitoring large-sample data. The analysis will cover various indicators such as the respondents' positions, enterprise size, ownership type, years of operation, and industry sector.

5.5 Data Analysis

5.5.1 Descriptive Statistics

Descriptive statistical analysis presents the general characteristics of a population by analyzing the characteristics of a sample. This analysis usually uses metrics such as the mean and standard deviation. In this study, descriptive statistics were applied to assess the identity of respondents, enterprise size, type of enterprise ownership, industry sector, years of enterprise establishment, and the mean, standard deviation, skewness, and kurtosis of the sample data.

5.5.2 Questionnaire Reliability and Validity Verification

The reliability and validity test ensures that the scale-type questionnaire has a high degree of reliability and validity. Assume that the reliability and validity of the questionnaire are good. In this case, this proves that the data reliability of the questionnaire is high, the internal consistency of the questionnaire data is high, and the questionnaire can be used for subsequent model analysis; on the other hand, if the reliability and validity are not high, the questionnaire needs to be redesigned and redistributed. The standard methods for testing reliability and validity are listed in Table 1.

Table 1 Questionnaire Reliability and Validity Verification

Verification	Parameter	Content	Standard
Reliability	Cronbach's alpha	Equation (1) α is the reliability coefficient. **K** is the number of test questions. **S_i** is the variance of the scores of all subjects on question i. **S_x** is the variance of the total score obtained by all subjects.	$\alpha \geq 0.9$: Excellent $0.8 \leq \alpha < 0.9$: Good $0.7 \leq \alpha < 0.8$: Acceptable $0.6 \leq \alpha < 0.7$: Questionable $0.5 \leq \alpha < 0.6$: Poor $\alpha < 0.5$: Unacceptable
Validity	Content validity	Expert judgment	Judge whether the scale is reasonable and enough.
	AVE	Equation (2) λi represents the standardized loading of the **i^th^** indicator on the latent variable, **n** is the total number of indicators of the latent variable.	AVE ≥ 0.5 Good
	HTMT	WarpPLS	HTMT< 0.90 Good HTMT< 0.85 Excellent

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum S_i^2}{S_x^2}\right) \quad (1)$$

$$\text{AVE} = \frac{\sum_{i=1}^{n} \lambda_i^2}{n} \quad (2)$$

5.5.3 Validation of PLS-SEM

Path coefficient (t): a significant path coefficient (p-value < 0.05) indicates a significant relationship between the variables.

The coefficient of determination (R^2) indicates the explanatory power of model. In general, values of 0.67, 0.33, and 0.19 are considered robust, moderate, and weak, respectively.

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \quad (3)$$

In equation (3), are the observed values, are the predicted values, is the mean of the observed values, is the number of samples.

The predictive relevance (Q^2) is determined using the blind sample method. A value greater than 0 means that the model is predictively relevant. The calculation of is similar to R^2 but is used for cross-validation.

Effect size (F^2) : 0.02, 0.15, and 0.35 stand for small, medium, and large effect sizes respectively.

$$F^2 = \frac{R_{included}^2 - R_{excluded}^2}{1 - R_{included}^2} \quad (4)$$

In equation (4), is the coefficient of determination when the specific predictor variable is included in the model, is the coefficient of determination when the predictor variable is excluded from the model.

Goodness-of-fit index (GOF) : The GOF coefficient is a value between 0 and 1 used to assess the ability of the model to explain the observed data. It combines the degree of fit of the measurement model and the structural model.

Bootstrapping: Bootstrapping is the main method for estimating the standard error in PLS-SEM.

$$S_I = \sqrt{\frac{1}{N_S}\sum_{i=1}^{N_S}(\beta_i - \bar{\beta})^2} \qquad (5)$$

S is a set of samples created from an empirical data set. Each sample within is created by randomly selecting rows from the original dataset with the possibility of repetition, ensuring that the size of each sample is equal to that of the dataset in terms of the number of rows. Denote as the number of such samples. The standard error denoted as S1, derived by bootstrapping for a given path coefficient β, is determined as described in Equation (5). Here, represents the estimate of the path coefficient for sample i, while is the average path coefficient for all samples [10].

6 CONCLUSION

This study proposes a conceptual model to explore how different dimensions of trust influence the IP of firms in UIC through the mediating role of knowledge management capabilities. The dimensions of trust, knowledge management and IP are delineated through a literature review. The conceptual model and technical route of PLS-SEM are given, and the scope, methodology, questionnaire data collection method and calibration method of the empirical study are designed. The next step is to conduct the questionnaire survey and data collation according to the technical line . Software experiments are carried out according to the conceptual model and model fitting results and conclusions are drawn. Ultimately it will provide targeted data parameters to help companies improve their IP through UIC and provide managers with insights into the development of knowledge management practices.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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