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RESEARCH ARTICLE

Research on the Impact of Implicit Contracts on User Knowledge Contribution in Open Innovation Communities

XINYUAN LU[1,2], HUA MENG[1], AND XUELIN WANG[1]
[1]School of Information Management, Central China Normal University, Wuhan 430079, China
[2]Hubei E-Commerce Research Center, Central China Normal University, Wuhan 430079, China

Corresponding author: Hua Meng (menghua818@outlook.com)

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ABSTRACT Open innovation communities (OICs) have been expanding the scope of enterprises' innovation activities, and their effective functioning hinges on the ongoing knowledge contributions from users. However, the research on the impact of contractual governance mechanisms on users' knowledge-contribution behaviors has yet to be further explored. In this study, we provide a comprehensive definition of implicit contracts in OICs, clarify their dimensions, investigate their impact on users' knowledge contribution, and explore how users' network positions moderate these effects. Subsequently, we employ a questionnaire survey combined with web crawling to collect user data and empirically test the theoretical hypotheses. The results demonstrate that both user-user implicit contracts (i.e., user reciprocity, user trust, and user recognition) and user-community implicit contracts (i.e., community incentives, community trust, and community support) significantly and positively affect user knowledge contribution. Furthermore, users' structural holes exert a significant positive moderating effect on these relationships. Notably, the moderating effect of network centrality is only significant in the influence of user-community implicit contracts, and not significant in the relationship between user-user implicit contracts and user knowledge contribution. The insights derived from this study offer valuable practical guidance for effectively operating and managing OICs.

INDEX TERMS Open innovation community (OIC), implicit contract, knowledge contribution, user behavior, network position, structural holes, network centrality.

I. INTRODUCTION

Nowadays, the traditional logic of internal-oriented, centralized, and closed innovation has become outdated across numerous industries, giving way to the flourishing open innovation model. Open innovation thrives on a consistent inflow of valuable ideas from external sources, seamlessly integrating external knowledge with internal R&D endeavors [1], [2]. At its essence, open innovation is centered on the deliberate exchange of knowledge beyond organizational confines [3], [4], thereby driving innovation through the acquisition, leveraging, and assimilation of knowledge streams across these boundaries. Enterprises effectively blend internal and external knowledge to fuel internal innovation while seeking external avenues to bring their product ideas to commercial fruition [5]. Open innovation facilitates corporate innovation activities that extend beyond organizational boundaries, substantially broadening the scope for value creation [1]. Modern information technology has played a pivotal role in enabling a growing number of enterprises to establish online communities geared towards open innovation, known as Open Innovation Communities (OICs) [6]. These OICs provide an interactive platform for external users to collaboratively share, evaluate, and contribute knowledge and ideas, thus attracting active participation in innovation-related endeavors [7]. OICs have invigorated the innovation landscape

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within enterprises, as exemplified by successful platforms such as Dell's IdeaStrom, LEGO's LEGO Ideas, and Haier's HOPE platform, all of which have yielded numerous innovative outcomes. Users have transitioned from passive service recipients to proactive value co-creators, actively engaging in and influencing the design and development of products or services by submitting ideas, expressing opinions, or specifying requirements [8]. Functioning as virtual social platforms initiated by enterprises to drive product and service innovation, OICs generate a substantial volume of valuable and creative knowledge resources through the curation of extensive user-generated content [9]. The pivotal objective of OICs is to harness users' insights to enhance innovation performance, constituting the core value of these communities. Consequently, user knowledge contribution stands as the fundamental assurance for realizing their strategic value [10]. Hence, the persistent motivation of users to contribute knowledge remains a critical concern in the operational practices of OICs.

Previous studies have investigated the mechanisms that drive user knowledge contributions, considering both internal and external motivations [4], [11], [12], individual factors of users [8], [13], [14], [15], interaction elements among users [16], and environmental factors within the community [17], [18]. However, relatively little attention has been given by researchers to the influence of community governance mechanisms, particularly contractual governance mechanisms, on users' knowledge contributions. While some studies have actively explored the role of psychological contracts in shaping user knowledge behaviors like knowledge collaboration [19] and transfer [20], they often situate the issue of user knowledge contribution within the analytical framework of organizational behavior and management, treating users as quasi-employees [21] due to the origin of psychological contracts in the employment relationship between organizations and employees. Notably, scholarly literature has examined the impact of formal institutional governance mechanisms on users' knowledge contributions, addressing a research gap in this aspect [22]. However, these studies have not delved into the influence of informal institutional spillover, characterized by implicit contracts, on users' knowledge contributions. In reality, users form unspoken contracts outlining mutual expectations among themselves and with the community, and these implicit contracts may significantly affect user knowledge-contribution behaviors.

Therefore, this paper aims to investigate the impact of implicit contracts in OICs on users' knowledge contribution and examines the moderating effect of users' network positions on this relationship. An empirical test is conducted using the Xiaomi community as a case study. This study makes three main contributions. Firstly, it analyzes the mechanism of user knowledge-contribution behavior in OICs from an implicit contract perspective, thereby enhancing the theoretical understanding of user knowledge contribution in online communities. Secondly, it introduces two dimensions of implicit contracts in OICs, including the user-user implicit contracts and the user-community implicit contracts, expanding the framework for studying contractual governance mechanisms within online communities. Thirdly, social network analysis is applied by incorporating network centrality and structural holes to explore how users' network positions influence their knowledge-contribution behaviors, thus complementing existing research on online users' knowledge behaviors. Overall, this study advances our understanding of governance theories related to user knowledge-contribution behaviors in OICs while providing practical guidance for motivating continuous knowledge contribution within these communities.

II. REVIEW OF LITERATURE

A. OPEN INNOVATION COMMUNITY (OIC)

OICs are derived from the concept of open innovation, which refers to a distributed innovation process involving purposeful knowledge flow across organizational boundaries [23]. By effectively managing the inflow and outflow of knowledge across these boundaries, open innovation has emerged as a successful approach for new product development [24]. Enterprises embrace open innovation by opening up their innovation activities, resulting in reduced costs and shorter development times for new products, as well as shared risks with partners [3]. The advent of online knowledge communities has transformed the role of users from information recipients to active knowledge providers [25]. User-generated content continues to proliferate, offering enterprises abundant resources for innovative endeavors. Consequently, users actively participate in three stages of idea generation, idea transformation, and idea diffusion – encompassing the entire enterprise innovation process that encompasses six key activities: idea collection, screening, absorption, transformation, implementation and commercialization [6].

OICs are progressively emerging as crucial platforms for enterprises to access innovation resources, serving as a secondary source of innovation alongside originality. As online knowledge-sharing platforms, OICs also possess social attributes in the form of informal networks formed by individuals with shared consensus [8]. In essence, OICs are virtual spaces that facilitate interactive knowledge exchange between enterprises and end users who contribute valuable insights [26]. Consequently, OICs exhibit fundamental characteristics such as virtuality, goal-orientedness, voluntariness, interactivity, and networking [3], [6], [8], [14], [21].

B. IMPLICIT CONTRACTS IN OIC

Implicit contracts, also referred to as default contracts, are distinguished from explicit contracts based on explicit rules. Implicit contracts establish consistent expectations based on the rational behavior of all participants [27]. Due to their non-written and non-agreement characteristics, implicit contracts are considered non-contractual agreements [28]. They can be defined as Self-Enforcing Agreements since they are self-executing due to the reciprocal nature of the

contracting parties [29]. Implicit contracts essentially serve as dynamic agreements that derive value from the incompleteness of formal (explicit) contracts [30]. As certain crucial indicators cannot be explicitly stated in formal contracts, only self-enforcing implicit contracts can effectively motivate individuals [28], [29]. Parties adjust their behavioral expectations through discussions or social conventions rather than relying on external enforcement. Therefore, implicit contracts emphasize the internalization of behavioral constraints and safeguards within organizations, institutions, and cultures over extended periods of interaction, ultimately shaping universally shared values based on individual preferences [31].

Previous studies have focused on the issue of contracts in online communities, mainly exploring the psychological contracts of online users [19], [32]. The concept of psychological contracts in these studies originated from the field of organizational management, specifically referring to the psychological contracts between employees and employers [31]. Psychological contracts are defined as individuals' understanding and belief in mutual obligations formed within an employment relationship based on promises, trust, and perceptions. At its core, psychological contracts entail implicit unwritten mutual responsibilities between employers and employees [33]. While some marketing studies have replaced the term ''psychological contracts'' with ''customer-company relationships'' [20], it is still emphasized that psychological contracts encompass not only expectations but also a commitment to responsibilities and obligations [31], [33]. The concept of implicit contracts in OICs differs fundamentally from psychological contracts. Implicit contracts in OICs emphasize self-enforcement based on values that incorporate individual preferences, highlighting individual initiative derived from an objectively observable reciprocal pattern [33]. This weakens the mutual obligations-based psychological contracts that bind individuals to their responsibilities. In OICs, implicit contracts promote ongoing positive interactions through shared values and social norms among users. These are supported by tacit understanding and mutual trust between individuals and expressed as unconscious behavioral norms accepted by users [34], [35]. Therefore, this study defines implicit contracts in OICs as stable commitments to self-implementation by users who gradually develop certain expectations of behavioral outcomes based on personal preferences and their understanding and beliefs about long-term participatory interactions' behavioral constraints and guarantees.

Implicit contracts serve as contractual arrangements aimed at reducing transaction costs and enhancing transaction efficiency within the trading process [27], [35]. OICs provide a conducive environment for users to contribute their knowledge, fostering a harmonious and friendly atmosphere. Users actively engage in knowledge sharing, which not only brings them pleasure and a sense of accomplishment but also exhibits characteristics akin to transactions. When users receive feedback in the form of comments, likes, retweets from other users or recognition by the platform itself, they experience psychological benefits such as mental satisfaction and pleasure [4]. Implicit contracts within OICs fulfill four essential conditions necessary for coordinating transactions. The first is mutual benefit [29], which entails the establishment of win-win or multi-win relationships among users. The second is mutual trust [36], involving the development of enduring cooperative relationships between users. The third is complementarity [28], [37], referring to the reciprocal supplementation of resources and capabilities among users. The fourth is coordination [28], [38], encompassing the comprehensive exchange of information and knowledge among users. Therefore, implicit contracts in OICs should incorporate reciprocity [13], [18], [29], [33], trust [31], [33], [36], recognition (or identification) [12], [18], [39], incentives (or rewards for effort) [6], [11], [40], and support (e.g., feedback, system design, etc.) [9], [25], [40]. User behavior in OICs is closely intertwined with both inter-individual interactions and individual-environment interactions. Consequently, this study categorizes implicit contracts in OICs into two dimensions: user-user implicit contracts and user-community implicit contracts.

C. USER KNOWLEDGE CONTRIBUTION IN OIC

Knowledge contribution refers to the process and behavior of knowledge owners in providing and creating knowledge [12], [13], [26], [41]. In OICs, user knowledge contribution is achieved through interactions between users, both within the user community and with other users [2], [16]. This contribution is manifested such as posting, commenting, and replying to posts. Consequently, users assume dual roles as both providers and recipients of knowledge. User knowledge contribution encompasses proactive sharing and reactive engagement [42]. Proactive contribution entails active sharing of experiences, creativity, ideas, opinions, solutions, and other valuable information by users through posting. Reactive contribution involves users offering answers and opinions based on information shared by others; this includes commenting on and replying to posts. It should be noted that not all OIC users contribute knowledge; a majority are primarily viewers or searchers for information – referred to as ''diving'' users [16]. Simultaneously, knowledge contribution underscores the value of information shared by users [18]. When ideas or thoughts are innovative and potentially commercially viable, and their implementation costs are reasonable, they tend to be adopted and implemented [8]. OICs offer users support for knowledge sharing [2], [4]. The community records and stores the knowledge shared by users, resulting in an exponential growth of diverse knowledge through user-generated content accumulation [24]. Consequently, as users submit more ideas in OICs, the diversity of knowledge increases, enhancing the likelihood of realizing more valuable ideas [2], [24].

The driving force behind behavior lies in individuals' willingness. However, the willingness to contribute knowledge remains a latent variable that cannot be directly observed [15].

By proactively anticipating users' evolving patterns of willingness and implementing effective measures, enterprises can stimulate their inclination and propensity to engage in knowledge interactions. Users' experiences, ideas, and creativity possess the characteristics of tacit knowledge, can only be transformed into explicit knowledge through development processes; this explicit knowledge then becomes valuable resources for innovation activities within enterprises. of tacit knowledge heavily relies on repeated interactions among users within a community [2]. Sustained and effective interaction not only facilitates cognitive understanding but also enhances clarity of shared knowledge, thereby fostering comprehensive synergy across different domains of expertise and enabling the creation and development of more valuable new insights [43]. Consequently, OICs exhibit consistent development and effectively support enterprise innovation through continuous knowledge exchange. The impact of knowledge resources on enterprise innovation performance is not solely determined by their quality but also closely linked to their quantity [41]. Motivating users to actively participate in interactions is a crucial approach for facilitating user knowledge contribution in OICs. Knowledge interaction within OICs possesses the characteristic of repetitive gaming [19]. Implicit contracts serve as a mechanism that encourages users to engage continuously in knowledge interactions. Within this framework, this study investigates the influence of implicit contracts on users' knowledge contribution in OICs.

III. HYPOTHESIS DEVELOPMENT

A. USER-USER IMPLICIT CONTRACTS AND USER KNOWLEDGE CONTRIBUTION

Reciprocity is a crucial factor in motivating users to contribute knowledge in OICs [13], [18]. The reciprocity theory posits that individuals tend to exhibit kind and favorable behavior towards those who assist them [31]. Drawing from the implicit contract theory, ''reciprocity'' benefits participants by ensuring the execution of the contract during transactions [36]. The principle of reciprocity serves as an ongoing assurance for maintaining repeated gaming relationships through information exchange among users in OICs [19]. With the expectation of mutual benefit, i.e., ''receiving help from others in the future,'' users actively provide answers or comments on questions or ideas they are knowledgeable about, thereby guaranteeing responses to their own posted information at a later time by others [44]. This reciprocal ''response to each other'' enables users to gain knowledge and enhance their experiences. Sustaining knowledge-contribution behavior becomes challenging if users do not receive expected responses after sharing their knowledge [19]. Consequently, by engaging in active giving based on the belief that others have reciprocal preferences, users can eventually obtain rewards from fellow community members [44]. The pattern of facilitated interaction between users, refining existing knowledge within OICs and fostering new knowledge generation. Therefore, this paper proposes the hypothesis:

Hypothesis 1a (H1a): *User reciprocity has a positive effect on user knowledge contribution in OICs.*

Within the framework of implicit contracts, trust refers to one participant's certainty regarding the other participant's intention and ability to perform, as well as the consequences of performance [36]. This expectation of certainty ensures the self-execution of transactions. Trust fosters pro-social motivation [36], positive attitudes toward others, effective and constructive assistance, accurate communication, and collaborative problem-solving [43]. In essence, trust facilitates pro-social interactions among individuals [36]. Regarding knowledge sharing, trusting others enhances the effectiveness [45]. The virtual nature of online user relationships and the public goods aspect of knowledge often result in users' reluctance to share information. Inter-user trust not only encourages users freely share their knowledge by creating a friendly and harmonious environment but also effectively reduces opportunistic and infringing behaviors [34], [36], [46]. Inter-user trust encompasses both trust in users' character and their abilities. Trust in users' abilities is reflected in their belief that they can gain inspiration from other users' ideas [46], thereby fostering continuous knowledge interaction. Thus, we hypothesize:

Hypothesis 1b (H1b): *User trust has a positive effect on user knowledge contribution in OICs.*

In implicit contract theory, recognition refers to the satisfaction of transaction participants with the performance outcome, as evaluated based on expected achievement [9], and is premised on individual rationality [31]. In OICs, inter-user recognition takes the form of simple acknowledgments or more detailed responses to knowledge-contribution behaviors [47], such as liking, supporting, retweeting posts, providing positive comments, and following posters. Social cognitive theory suggests that receiving recognition from others induces tendencies to produce behaviors leading to better outcomes [43]. Peer recognition is commonly used in motivating individuals to contribute public goods in OICs [47]. Inter-user recognition effectively motivates users' active participation in community interactions and knowledge contribution behavior [43], [47]. Recognition provides users with psychological feelings of approval, respect, and a sense of belongingness, which enhances their closeness to the community and increases their satisfaction with social interactions [4], [18]. Ultimately, this inspires them to continuously share information and exhibit more active knowledge contribution behaviors [18], [43], [44]. Therefore, we hypothesize that:

Hypothesis 1c (H1c):*User recognition has a positive effect on user knowledge contribution in OICs.*

B. USER-COMMUNITY IMPLICIT CONTRACTS AND USER KNOWLEDGE CONTRIBUTION

Incentives serve as effective tools for OICs to stimulate users' knowledge contribution, encompassing both intrinsic and

extrinsic motivations. Extrinsic incentives refer to the visible rewards for knowledge-contribution behaviors, while intrinsic incentives are associated with hidden motivation [36]. Currently, online communities primarily employ a combination of mental incentives such as reputation mechanisms (e.g., granting active users points, medals, ranks, and honors) and financial rewards like lotteries and discounts [12], [39], [40]. These incentives explicitly outline the tangible financial and non-financial benefits that users can attain through their contributions and represent explicit institutional engagements or contracts [27], [30], [37]. Community incentives ensure a continuous flow of knowledge contribution from users by sustaining their interests [6]. This study incorporates community incentives into the framework of implicit contracts, focusing on intrinsic motivations closely linked to user perceptions. These perceptions are considered as spillovers from extrinsic community motivation contained in explicit contracts [30]. Fair and reasonable incentives can effectively motivate users and encourage more active knowledge contribution [41], [48]. Intrinsic incentives based on user-formed understanding and beliefs regarding the fairness and rationality of these incentive systems play a crucial role in stimulating behavioral motivation. Hence, intrinsic incentives characterized by implicit contractual elements can significantly enhance user expectations of behavioral outcomes while motivating them to actively participate in knowledge contribution [9], [47]. Therefore, we hypothesize that:

Hypothesis 2a (H2a):*Community incentives have a positive effect on user knowledge contribution in OICs.*

Trust serves as an implicit guideline for user-user interaction and also functions as a potential norm for user-community interaction, representing a shared consciousness encompassing reciprocal trust towards the community as a whole and its members [3]. While inter-user trust pertains to interpersonal relationships, trust between users and communities is characterized by non-interpersonal trust, commonly referred to as institutional trust or users' reliance on communities [3], [18], [46], [48]. User-community trust entails the belief in the community's reliability, fidelity, sincerity, and integrity that users perceive through OICs [21], leading to their absence of doubt regarding the communities' credibility [46] while enhancing their sense of identity, trustworthiness, and belongingness [6]. Trust between users and the community originates from users' perception and evaluation of various safeguard systems such as intellectual property rights protection, privacy security measures, secure interactions protocols, evaluation standards etc. It is based on users' preference for trustworthy environments along with their gradually formed certainty about what they can expect from the community during their interactions with OICs. Drawing upon contract theory principles; this interactive relationship between users and communities exhibits characteristics akin to repeated gaming dynamics where maintaining long-term engagement relies on high-quality norms provided by the community [4], [27], [36] which generate user's confidence in these guarantees [46]. Trust stimulates psychological commitment combined with autonomous implementation among users thereby motivating them to actively participate in knowledge contribution. Therefore, this paper proposes the hypothesis that:

Hypothesis 2b (H2b):*Community trust has a positive effect on user knowledge contribution in OICs.*

Community support in OICs refers to users' beliefs about their experience and satisfaction with the community, based on personal preferences. It represents the expectations of implicit contracts regarding recognition between users and the community [18]. OICs are characterized by fast response times, user-friendly interfaces, and reliable systems, which significantly influence users' interactive experiences. Higher quality OICs are considered to be more user-friendly, offering a high level of helpfulness and functionality [40]. System quality reflects effective community management practices that enhance cooperative norms and perceived benefits of user participation [21]. Through long-term knowledge interactions in OICs, users develop stable expectations of community support and internalize their commitment to gaining approval from the community. This psychological proximity to the community is regarded as its salience for users [16]. Such commitment leads users to form beliefs about the outcomes of their behavior, shaping their motivation to contribute and ultimately influencing behavioral intentions and actual contributions [9]. Users perceive community support services as leverage for their contribution actions [45], [48]. Therefore, community support enhances users' recognition of the community, motivates them to contribute actively [47], and ultimately promotes their continuous participation in knowledge contribution. Thus, we hypothesize that:

Hypothesis 2c (H2c): *Community support has a positive effect on user knowledge contribution in OICs.*

C. MODERATING ROLE OF THE USER NETWORK POSITIONS

Users in OICs establish associative relationships with each other through information interaction in the form of network structures, namely social networks [3], [6], [12], [19], [41]. Within these social networks, individuals acquire the ability to exert influence and control over network resources due to their unique positions within the network, subsequently shaping their behaviors and characteristics [49]. Previous research has confirmed that users gain external knowledge through network interactions in OICs, and their positions within the interactive network significantly impact sustainable knowledge contribution [26]. The attributes of individuals' network positions are typically measured by assessing both network centrality and structural holes [50], [51], [52], [53], [54]. Therefore, this study focuses on examining users' network positions in OICs from two dimensions: network centrality and structural holes.

Centrality refers to the extent to which a user is positioned at the core of the network [54], indicating their relative position and relationship with other users in the

community. It reflects how deeply embedded a user is within the network and measures their access to and control over resources [50], [55]. Users occupying central positions in a social network enjoy easier access to valuable information and resources, thereby enhancing their advantage in terms of resources and authority [49], [53], [56]. In OICs, higher network centrality for a user signifies greater attention received (more followers, retweets, and views on posts). Furthermore, active participation by this user in knowledge interactions among others increases their potential to become a core or leading figure [57], [58]. A highly central user attracts more followers due to their ability to share high-quality expertise. They possess elevated status, reputation, influence within the community [53] while also experiencing positive emotions and stronger satisfaction [55]. This helps foster understanding, beliefs of reciprocity, trust, recognition among users as well as incentives and trust from the community. Consequently, forming stable expectations and commitments towards knowledge contribution that promote such behaviors. Simultaneously, users with higher centrality can lead ordinary users towards active engagement in knowledge interaction [55], [58]. This facilitates more users developing a sense of contractual contribution behavior thus promoting overall knowledge contribution activities within OICs. Therefore, it can be hypothesized that network centrality moderates a user's knowledge contribution. The specific hypotheses are as follows:

Hypothesis 3a (H3a):*Network centrality plays a positive moderating role between user-user implicit contracts and user knowledge contribution in OICs.*

Hypothesis 3b (H3b):*Network centrality plays a positive moderating role between user-community implicit contracts and user knowledge contribution in OICs.*

Structural holes serve as pivotal nodes that regulate information flow within a network. In social networks, certain individuals lack direct connections or have sporadic relationships, resulting in the emergence of 'caves' in the network structure known as structural holes [51], [52], [54]. The individual occupying the structural hole acts as a ''middleman'' between two adjacent nodes, facilitating and bridging the flow of information [51]. The number of structural holes occupied by an individual reflects his/her ability to control the flow of information. By occupying more structural holes, individuals can connect with more diverse groups. Consequently, they not only govern information dissemination between different groups but also acquire non-redundant knowledge through cross-group comprehension and integration [43]. In OICs, users occupy these structural holes by establishing links among otherwise disconnected groups through activities such as posting and replying. Users who occupy these structural holes function as conduits for information transfer across different groups, granting them greater control over knowledge dissemination. This enhanced interactive experience fosters higher expectations and commitment towards participation while generating a strong inclination to contribute knowledge [26], [49]. Therefore, occupying more structural holes not only enables users to access superior quality knowledge resource [9] but also plays a crucial role in developing heightened expectations and commitment towards contribution behaviors, thereby promoting users' engagement in knowledge sharing activities [13], [21], [41]. Thus, it is reasonable to assume that the attribute of structural holes has a moderating effect on user knowledge contribution. This study proposes the hypothesis that:

Hypothesis 4a (H4a): *Structural holes play a positive moderating role between user-user implicit contracts and user knowledge contribution in OICs.*

Hypothesis 4b (H4b): *Structural holes play a positive moderating role between user-community implicit contracts and user knowledge contribution in OICs.*

Based on the analysis of the above, the theoretical model constructed in this study is shown in Figure 1.

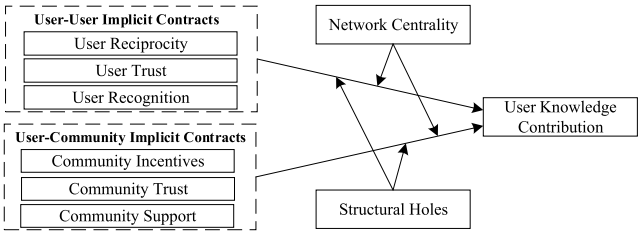

FIGURE 1. The theoretical model of this study.

IV. RESEARCH DESIGN

A. DATA COLLECTION

This study adopts the Xiaomi community (https://www.xiaomi.cn) as the empirical research object, which represents a prominent OIC. In this community, users actively engage in product discussions, idea exchange, problem feedback, and knowledge sharing. By effectively integrating user-generated ideas with internal corporate resources, the Xiaomi community drives product innovation [8]. To collect behavioral data of Xiaomi community users for analysis of variables such as user knowledge contribution and network position, we used crawler software. From January 1 to December 31, 2022, we collected data from the MIUI section of the Xiaomi Community including usernames for posting and replying along with post content. A total of 94,218 posts were initially obtained. After eliminating invalid posts including those with fewer than 10 words of content, posted by official developers, uncommented and self-commented posts, we retained 173,681 valid posts. Simultaneously, we recruited participants from the MIUI community for a questionnaire study on implicit contracts and provided them with compensation. We collected a total of 400 questionnaires but excluded 109 invalid ones due to missing usernames, excessively short completion time, identical options for each question, and incorrect answers to test questions. Ultimately, we obtained 291 valid samples. Subsequently, the questionnaire data was matched with the web crawler data based on

TABLE 1. Characteristics of the sample.

Characteristics	Categories	Number	Proportion
Sex	Male	230	79.04%
	Female	61	20.96%
Age	Under 18 years	15	5.15%
	18～25 years	123	42.27%
	26～35 years	102	35.05%
	36～45 years	47	16.15%
	Over 45 years	4	1.37%
Education	High school	51	17.53%
	College	104	35.74%
	University	97	33.33%
	Master or Doctor	39	13.40%
Registration time	Less than 1 year	9	3.09%
	1～2 years	47	16.15%
	2～5 years	146	50.17%
	6 years or more	89	30.58%
Total		291	100%

usernames resulting in a network comprising 9021 posts and 289667 relationships involving a total of 46968 nodes.

The characteristics of the sample are shown in Table 1. The proportion of male users is nearly 80%, the proportion of users aged 18-35 is 77.32%, and 82.47% of users have a university education or above. These characteristics are basically consistent with the overall situation of Xiaomi community users, indicating that the study sample is representative. Additionally, over 80% of users have been registered for more than 2 years. This group of long-term community members ensures that their answers align more closely with the real situation, thereby enhancing the authenticity of the sample data.

B. VARIABLES MEASUREMENT

1) INDEPENDENT VARIABLES

This paper on the measurement of implicit contracts refers to the studies of Pirkkalainen et al. [9], Zhao et al. [11], Mustafa and Zhang [13], Liao et al. [18], Barreda et al. [40], Cai et al. [41], Pai and Tsai [44], Fang and Chiu [48], Chen and Hung [56]. Experts specializing in online user behavior research and experienced members of the Xiaomi community were invited to critically review the content of the questionnaire. The questionnaire was subsequently refined to account for the specific contextual factors within the community and align with its users' actual experiences. Additionally, a preliminary version of the questionnaire was distributed among eligible participants for pre-testing. Factor analysis was performed on 67 valid datasets obtained, leading to exclusion of certain items that did not accurately reflect measured variables, resulting in a finalized official questionnaire. All variables were assessed using a Likert 5-point scale format, with details provided in Table 2.

2) DEPENDENT VARIABLE

Previous studies have typically considered the measurement of knowledge contribution in terms of both quantity and quality [39], [47]. The quantity of knowledge contribution is often assessed based on the number of posts, while the quality is evaluated by the number of likes received. However, focusing solely on one dimension, whether it be quantity or quality, fails to provide an objective and comprehensive characterization of knowledge contribution. In reality, quantity and quality are intertwined and inseparable. Therefore, this paper employs the entropy weighting method to assign weights to both the quality and quantity aspects of knowledge contribution, enabling a more accurate assessment. The entropy weighting method determines index weights based on data variability, ensuring a more objective allocation. Considering the significant variability inherent in web crawler data, logarithmic transformation is applied in this study to reduce discreteness. As a result, using the entropy weighting method yields weights for quantity and quality as 0.317 and 0.683 respectively.

3) MODERATING VARIABLES

In this paper, we utilize relative centrality to measure the network centrality of users. If the network size is N, i.e., the number of users in the network is N, and the number of connections of user i to other users is n_i, then the network centrality of user i is calculated as

$$Centralit\ y_i = \frac{n_i}{N-1}$$

In the structural hole theory, there are several indicators proposed to measure whether one node is likely acting as a structural hole spanner in a network [51]. The indicators of structural holes mainly include four aspects: effective size, efficiency, constraint, and hierarchy. Constraint is considered the most important one which refers to the degree to which nodes in a network are constrained in their use of structural holes [50], [51]. The "constraint" of a node represents its ability to utilize the structural holes in its network, and the larger this value is, the stronger it indicates that the node is constrained by single relationships. In other words, lower restriction on a node implies a stronger role played by it through structure holes [52]. Therefore, in this article, the difference of 1 and the constraint is used to measure

TABLE 2. Items of independent variables, and reliability and validity analysis.

Variables	Items	Loading	AVE	CR	α
User Reciprocity	I believe that other users are as happy as I am to share their thoughts and ideas.	0.888	0.758	0.904	0.840
	I believe that other users will provide suggestions and answers to the questions I ask.	0.867			
	I believe that my suggestions and answers will be responded to by other users.	0.857			
User Trust	I believe that the creativity and ideas of users in the community hold value.	0.883	0.763	0.906	0.844
	I believe that users in the community share ideas and thoughts without reservation.	0.872			
	I believe that there are many creative users within the community.	0.865			
User Recognition	I believe that users are willing to like and support creative and thoughtful posts.	0.868	0.741	0.896	0.824
	I believe that users are willing to provide positive comments on creative and thoughtful posts.	0.854			
	I believe that users enjoy following creative and thoughtful posters.	0.860			
Community Incentives	I believe it is very reasonable that users who actively participate in community interactions can receive rank advancement.	0.859	0.737	0.894	0.822
	I believe it is very fair that users who actively participate in community interaction can gain honorary titles.	0.870			
	I believe it is very necessary that users who actively participate in community interaction can earn higher rewards.	0.847			
Community Trust	I believe the rules of the community are reliable and have no doubts about them.	0.868	0.745	0.898	0.829
	I believe that the protection of intellectual property rights and privacy is reliable and have no doubt about it.	0.867			
	I believe that the evaluation criteria of the community are fair and have no doubt about it.	0.855			
Community Support	I believe the system is designed to fully consider the variability of users' needs, and it is very user-friendly.	0.853	0.734	0.892	0.818
	I believe the system fully satisfies the users' need for information exchange, and it is highly interactive.	0.856			
	I believe the system has fully taken into account the users' experience, resulting in a strong sense of presence and immersion for them.	0.862			

the users' structural holes. The constraint of the user i is calculated as

$$constraint\ L_i = \sum_j (P_{ij} + \sum_{q,q\neq i,q\neq j} P_{iq} \times P_{qj})^2$$

In the equation, node j is a user directly connected to the user i, while node q is an intermediary user who can establish a connection between user j and user i. P_{ij} denotes the proportion of direct connections from user i to user j out of all connections made by user i. $P_{iq} \times P_{qj}$ represents the proportion of connections from user i to user j through intermediary user q out of all connections made by user i. Therefore, the structure holes of user i are defined as $(1 - constraint\ L_i)$.

4) CONTROL VARIABLES

Drawing upon existing studies [8], the characteristics of users and posts are selected as control variables in this article. User characteristics include *User's Experience* which represents the number of posts made by the user, *User's Level* which indicates the number of medals and tags awarded to the user, and *User's Qualifications* which represent the length of time (in days) that a user has been registered as a community member. Post characteristics include the *Length of Post* which is defined as the average number of words in each post, *Number of Comments* which represents the average number of comments received on each post, and *Length of Comment* which denotes the average number of words in each comment. These variables have also been transformed into logarithmic form in the data analysis process.

V. EMPIRICAL ANALYSIS

A. RELIABILITY AND VALIDITY ANALYSIS

The results of the reliability and validity analysis are illustrated in Table 2. The minimum value of Cronbach's α for the implicit contracts is 0.818, surpassing the optimal threshold of 0.8, thereby indicating exceptional consistency among the question items within the scale. Additionally, the average variance extracted (AVE) of these variables is above 0.5 and the composite reliability (CR) exceeds 0.7, suggesting that the items are reliable. Factor loadings of 6 observed variables ranged from 0.847 to 0.888, exceeding the threshold of 0.71 (explaining more than 50% variance), demonstrating good convergent validity for these scales. Furthermore, all correlation coefficients between variables are lower than the square root of their respective AVE (as shown in Table 4), indicating strong discriminant validity among variable scales. In summary, the reliability and validity of the measurement scales in this study are favorable.

Additionally, variable names have been abbreviated in this paper to form symbols as shown in Table 3. Furthermore, Table 3 illustrates the maximum and minimum values, mean, and standard deviation of these variables.

B. CORRELATION ANALYSIS

The results of the correlation analysis among the variables are shown in Table 4. The correlation coefficients between implicit contracts and knowledge contribution exhibit a positive and statistically significant relationship ($r > 0$, $p < 0.001$), thereby providing initial empirical support for the theoretical predictions regarding implicit contracts and user knowledge contribution. However, further investigation

TABLE 3. Descriptive statistical analysis.

Variables	Symbols	Obs	Min	Max	Mean	Std.Dev
User Reciprocity	UserRecip	291	1	5	3.940	0.735
User Trust	UserTrust	291	1	5	3.885	0.805
User Recognition	UserRecog	291	1	5	3.873	0.745
Community Incentives	ComMotiv	291	1	5	3.875	0.777
Community Trust	ComTrust	291	1	5	3.829	0.775
Community Support	ComSuppo	291	1	5	3.942	0.702
Knowledge Contribution	Contribution	291	0.014	9.148	4.121	1.431
Network Centrality	NetCentr	291	0.004	0.754	0.402	0.211
Structural Holes	StrucHole	291	0.111	0.803	0.620	0.106
User's Experience	UserExper	291	0.000	3.930	3.328	1.571
User's Level	UserLevel	291	1.946	7.651	2.193	0.714
User's Qualifications	UserQual	291	2.398	9.146	6.258	0.946
Length of Post	PostLength	291	0.693	8.924	5.064	1.315
Number of Comments	NumComment	291	0.000	4.596	4.467	1.718
Length of Comment	CommentLength	291	0.693	6.690	2.076	0.999

TABLE 4. Correlations of the variables.

Variables	UserRecip	UserTrust	UserRecog	ComMotiv	ComTrust	ComSuppo	NetCentr	StrucHole	Contribution
UserRecip	0.859								
UserTrust	0.400***	0.863							
UserRecog	0.392***	0.511***	0.857						
ComMotiv	0.414***	0.388***	0.488***	0.871					
ComTrust	0.479***	0.377***	0.404***	0.395***	0.873				
ComSuppo	0.453***	0.527***	0.516***	0.487***	0.437***	0.861			
NetCentr	0.104#	0.176**	0.108#	0.098#	0.100#	0.143*	——		
StrucHole	0.127*	0.124*	0.132*	0.101#	0.073	0.102#	0.110#	——	
Contribution	0.493***	0.480***	0.487***	0.465***	0.432***	0.506***	0.190**	0.191**	——

The underlined data is the square root of AVE, *** $p<0.001$, ** $p<0.01$, * $p<0.05$, # $p<0.1$

is required to establish a causal relationship between these variables.

C. OLS REGRESSION MODEL

The hypotheses were tested using ordinary least squares (OLS) regression analysis, and the results are shown in Table 5. Model 1 examined the impact of user-user implicit contracts on knowledge contribution, revealing significantly positive regression coefficients for user reciprocity ($\beta_{UserRecip} = 0.281$, $p < 0.001$), user trust ($\beta_{UserTrust} = 0.203$, $p < 0.01$), and user recognition ($\beta_{UserRecog} = 0.233$, $p < 0.001$). These findings indicate that all three user-user implicit contracts have a significant positive effect on user knowledge contribution, supporting hypotheses H1a, H1b, and H1c. The test results of model 2 demonstrate that community incentives ($\beta_{ComMotiv} = 0.271$, $p < 0.001$), community trust ($\beta_{ComTrust} = 0.117$, $p < 0.01$), and community support ($\beta_{ComSuppo} = 0.277$, $p < 0.001$) also exhibit significantly positive regression coefficients, validating hypotheses H2a, H2b, and H2c. Thus, user-community implicit contracts exert a substantial positive influence on user knowledge contribution.

Models 3 to 5 were used to test the moderating effect of network positions between user-user implicit contracts and user knowledge contribution. The results indicated that the regression coefficients of the interaction terms between network centrality and user-user implicit contracts did not reach statistical significance ($\beta_{User\_\times NetCentr} > 0$, $p > 0.05$). This suggests that the moderating effect of network centrality is not significant, thereby failing to support H3a. On the other hand, the coefficients of the interaction terms between structural holes and user-user implicit contracts were found to be positive and significant ($\beta_{User\_\times StrucHole} > 0$, $p < 0.001$), indicating a significant positive moderating effect of structural holes and supporting H4a.

The moderating role of network positions in the influence of user-community implicit contracts on user knowledge contribution was validated by Models 6 to 8. The results indicate that the coefficients of the interaction terms between network centrality and user-community implicit contracts ($\beta_{Com\_\times NetCentr} > 0$, $p < 0.05$) are significantly positive, as well as the coefficients of the interaction terms between structural holes and user-community implicit contracts ($\beta_{Com\_\times StrucHole} > 0$, $p < 0.001$). These findings suggest that network positions, including network centrality and structural holes, have a significant positive impact on the relationship between user-community implicit contracts and user knowledge contribution. Therefore, hypotheses H3b and H4b are supported.

D. BOOTSTRAP TEST FOR MODERATING EFFECTS

The OLS regression analysis necessitates adherence to a normal distribution for the data. However, in this study, the data exhibits skewness, which may introduce biased estimates.

TABLE 5. Results of regression analysis.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
UserRecip	0.281***		0.495***					
UserTrust	0.203**			0.507***				
UserRecog	0.233***				0.4735***			
ComMotiv		0.271***				0.448***		
ComTrust		0.177**					0.414***	
ComSuppo		0.277***						0.507***
NetCentr			0.199***	0.055	0.2235***	0.2338***	0.189***	0.122*
StrucHole			0.249***	0.072	0.2275***	0.2858***	0.206***	0.159**
UserRecip×NetCentr			0.083					
UserRecip×StrucHole			0.329***					
UserTrust×NetCentr				0.071				
UserTrust×StrucHole				0.274***				
UserRecog×NetCentr					0.074			
UserRecog×StrucHole					0.3055***			
ComMotiv×NetCentr						0.1648**		
ComMotiv×StrucHole						0.3148***		
ComTrust×NetCentr							0.139**	
ComTrust×StrucHole							0.277***	
ComSuppo×NetCentr								0.114*
ComSuppo×StrucHole								0.255***
Control Variables	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.369	0.384	0.428	0.367	0.409	0.418	0.376	0.418
R^2 Change	0.324	0.338	0.382	0.322	0.364	0.373	0.331	0.373
F	18.243***	19.429***	18.944***	14.706***	17.543***	18.214***	15.292***	18.249***

*** p<0.001, ** p<0.01, * p<0.05, # p<0.1

TABLE 6. Bootstrap test for moderating effects.

	NetCentr		StrucHole	
	β(se)	95% CI	β(se)	95% CI
UserRecip	0.0879(0.0561)	[-0.0226, 0.1985]	0.3272(0.0547)	[0.2196, 0.4348]
UserTrust	0.0872(0.0607)	[-0.0324, 0.2067]	0.3857(0.0724)	[0.2433, 0.5282]
UserRecog	0.0747(0.0575)	[-0.0385, 0.1878]	0.2773(0.0528)	[0.1733, 0.3813]
ComMotiv	0.1522(0.0478)	[0.0581, 0.2464]	0.2897(0.0480)	[0.1953, 0.3841]
ComTrust	0.1556(0.0559)	[0.0456, 0.2655]	0.3220(0.0581)	[0.2076, 0.4365]
ComSuppo	0.1345(0.0554)	[0.0254, 0.2436]	0.2976(0.0547)	[0.1900, 0.4052]

To address this issue, we employed the Bootstrap method to supplement the validation of the moderating effect. By repeatedly sampling from the dataset and estimating the moderating effect in each resampled dataset, the Bootstrap method overcomes the limitations of OLS regression analysis without requiring conformity to a normal distribution. We conducted 5,000 bootstrap resamples to generate bias-corrected confidence intervals (Bias-Corrected CI). The moderating effect is considered significant when the 95% CI excludes zero [59]. The results are shown in Table 6.

The moderating effects of network centrality on the relationships between user-user implicit contracts and knowledge contribution fail to be tested, as indicated by the 95% CIs including zero, which does not support H3a. Conversely, the moderating effects of structural holes in these relationships are confirmed by the 95% CIs excluding zero, thus supporting H4a. Furthermore, both network centrality and structural holes have significant moderating effects on the relationships between user-community implicit contracts and knowledge contribution, as evidenced by their respective 95% CIs excluding zero, thereby supporting H3b and H4b. Consequently, the Bootstrap test results for moderating effects align with those obtained from OLS regression analysis.

VI. CONCLUSION AND DISCUSSION

A. RESEARCH CONCLUSION

This paper explores the impact of implicit contracts in OICs on the user knowledge contribution, focusing on two dimensions: user-user implicit contracts and user-community implicit contracts. Moreover, the moderating effect of users' network positions on the aforementioned relationships is analyzed in terms of network centrality and structural holes. The theoretical model is tested with the users' behavioral data of the Xiaomi community, and the following three conclusions are obtained.

First, implicit contracts in OICs significantly impact user knowledge contribution. Implicit contracts in OICs refer to users' understandings and beliefs about behavioral constraints and safeguards that are gradually formed during long-term interactions. Based on these implicit contracts, users establish expectations of behavioral outcomes and commitments to self-execution that provide implicit safeguards

and drivers for user behavior regarding knowledge contribution. The results of this study demonstrate that both user-user implicit contracts (user reciprocity, user trust, and user recognition) and user-community implicit contracts (community trust, community incentives, and community support) contribute significantly to user knowledge contribution. Furthermore, regression analysis was conducted with the quantity and quality of knowledge contribution as dependent variables. It was found that the effects of implicit contracts are stronger on the quantity rather than the quality of user knowledge contribution. Additionally, user-user implicit contracts have a greater impact compared to those between users and the community. This conclusion is consistent with actual observations within Xiaomi's community, where inter-user interaction plays a more significant role in facilitating posting, following, and commenting activities, resulting in an accumulation of quantity that can lead to qualitative change. Furthermore, this finding supports previous research indicating how generalists' ability to create popular and feasible ideas depends on their accumulation of deep knowledge [7].

Second, the relationships between implicit contracts and user knowledge contribution are moderated by network positions. The moderating role of structural holes in these relationships reveals the importance of users' control over information in knowledge contribution. However, the moderating effect of network centrality on the relationships between user-community implicit contracts and user knowledge contribution is insignificant. This may be due to the low tacitness of knowledge in the Xiaomi community and the presence of a ''peer effect'' within the community. The low tacitness reduces the difference in effects between high and low network centrality on the relationship between knowledge behavior and its performance. In other words, network centrality weakens the positive impact of knowledge behavior on performance, with its moderating effect becoming more significant only when there is high tacitness [53]. Wang et al. [58] studied how network centrality moderates peer effects in knowledge contribution based on social capital theory, finding that intimate centrality enhances peer participation in seeking knowledge but has no effect on knowledge contribution, and mediated centrality does not affect the effect of peer participation.

Third, the users' network positions have a positive impact on their knowledge contribution. In the correlation analysis, the correlation coefficients of network centrality, structural holes and knowledge contribution are significantly positive ($r_{NetCentr} = 0.190$, $p < 0.01$; $r_{StrucHole} = 0.191$, $p < 0.01$). Meanwhile, this study further reveals the impact of network positions on user knowledge contribution using OLS regression, and the results show that both network centrality ($\beta = 0.185$, $p < 0.01$) and structural holes ($\beta = 0.192$, $p < 0.001$) have a significant positive impact on user knowledge contribution as well. This finding also suggests that structural embeddedness(including network centrality and structural holes) is related to various forms of network commitment or one's psychological bonds with their personal network of contacts [55].

B. MANAGERIAL IMPLICATIONS

The following management enlightenment is obtained:

First, knowledge contribution in OICs relies on a continuous exchange among users, with implicit contracts between users serving as intrinsic motivators for interactions. Therefore, it is crucial for the community to attract users from diverse knowledge backgrounds, enabling them to acquire new knowledge and develop a belief in reciprocity through complementary expertise. Additionally, the community should actively encourage user participation by promoting active engagement through following and commenting. This will establish stable interactive relationships and foster a norm of trust. Moreover, positive affirmations during knowledge interactions should be promoted to acknowledge and validate other users' perspectives and ideas, allowing individuals to internalize a sense of recognition.

Second, the community serves as a platform for users' knowledge interaction and fosters consensus among them regarding incentives, trust, and support to cultivate a collective ''community consciousness''. It is essential to construct a comprehensive and fair incentive mechanism that instills confidence in users towards community incentives. Additionally, measures such as enhancing intellectual property rights protection and privacy security for users, strengthening supervision and punishment mechanisms against violations and opportunistic behaviors, valuing user opinions and feedback on platform development are crucial steps in improving overall user experience satisfaction levels while promoting belief in community support.

Third, leading users who have higher network centrality and occupy more structural holes possess advantages in knowledge creativity, expertise, sophistication, and social influence. These leading users not only proactively contribute knowledge to the community but also enhance the loyalty of ordinary users to the community and lead them to participate in knowledge interaction by serving as leaders and role models. In short, communities should focus on cultivating leading users while strengthening cooperation with them and encouraging ordinary users to actively contribute their knowledge.

C. LIMITATIONS AND FUTURE DIRECTIONS

This paper has some limitations. Firstly, it takes Xiaomi community as the research object, which is not only an OIC but also a virtual brand community with users who are brand enthusiasts. Due to their limited knowledge literacy and innovation ability, most users' postings, follows and replies do not strictly qualify as knowledge contributions. Future research can consider studying professional knowledge communities such as Haier's HOPE to examine the knowledge-contribution behaviors of leading users [57], while also conducting comparative studies of different types of OICs. Secondly, this paper measures implicit contracts based on users' understanding and beliefs about interaction

norms using questionnaires to measure variables. However, there may be limitations in statistical test efficacy due to insufficient sample size or questionnaire design that could affect respondents' emotions. Future research can consider extracting indicators from web crawler data to measure implicit contracts instead. Thirdly, this paper initially reveals that network positions have an impact on users' knowledge contribution. Future research should conduct an in-depth analysis of this matter and explore how other types of network positions, such as network density [57], brokerage [49], network breadth and network depth [26], influence users' knowledge contribution.

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XINYUAN LU received the Ph.D. degree in management science and engineering from the Huazhong University of Science and Technology (HUST). He is currently a Professor, a Ph.D. Supervisor, and the Vice Dean of the School of Information Management, Central China Normal University (CCNU). He is also the Director of the Hubei E-Commerce Research Center. He has published more than 50 articles in SSCI, SCI, and CSSCI journals. He has presided over more than ten scientific research projects, mainly including two projects of the National Natural Science Foundation of China, two projects of the National Social Science Foundation of China (including one key project), and five projects of the Fundamental Research Funds for the Central Universities. His current research interests include knowledge management and knowledge services, e-commerce, social media, and information systems management.

HUA MENG received the B.S. degree in e-business and the M.S. degree in business management. He is currently pursuing the Ph.D. degree in management science and engineering with the School of Information Management, Central China Normal University (CCNU). He has great academic passion and has published more than ten articles in CSSCI and other journals. He has presided over two provincial research projects and participated in several national research projects. His research interests include knowledge management and intelligent decision-making, open innovation management, digital economy, and artificial intelligence. He was awarded the National Scholarship for Graduate Students.

XUELIN WANG received the B.S. and M.S. degrees in management science from Central China Normal University (CCNU), where she is currently pursuing the Ph.D. degree with the School of Information Management. She has also been participating in several research projects and has demonstrated exceptional academic potential. She has published several articles in journals, such as *Data Analysis and Knowledge Discovery*, *Knowledge Management Forum*, and *Information Science*. Her research interests include social networks and user behavior, with a specific emphasis on user information behavior within online knowledge communities and user behavior in human-intelligence interactions.