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How Does Focal Firms' Dual Embeddedness in Symbiotic Networks Influence Value Co-creation in Innovation Ecosystems?

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Abstract

Under the current complex and competitive economic environment, more and more firms are embedding themselves into symbiotic networks for value co-creation, since this has become a good strategy to obtain competitive advantages. Thus, it is important to examine the impacts of firms' embeddedness in symbiotic networks on value co-creation in innovation ecosystems. This study analyzes the mechanisms and contextual factors of firms' dual embeddedness (i.e., relational and knowledge embeddedness) in symbiotic networks and how each influences value co-creation within innovation ecosystems. Using a sample of 1,972 observations, our findings show, firstly, that firms' dual embeddedness in symbiotic networks positively impacts on value co-creation in innovation ecosystems; secondly, that firms' dual embeddedness in symbiotic networks positively impacts on innovation ecosystem resilience; thirdly, that innovation ecosystem resilience mediates the relationships between firms' dual embeddedness in symbiotic networks and value co-creation in innovation ecosystems; and, fourthly, that innovative ecological environments positively moderate the relationship between firms' dual embeddedness and value co-creation in innovation ecosystems. These results not only enrich the theoretical framework concerning value co-creation within innovation ecosystems but also provide managerial suggestions for firms to efficiently enhance the degree of embeddedness in symbiotic networks and build highly resilient innovation ecosystems, thus promoting value co-creation among innovation ecosystem populations.

Keywords

symbiotic network; network dual embeddedness; value co-creation; innovation ecosystem resilience; innovative ecological environments

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1. Introduction

In recent years, the increasing complexity of the business market and the openness of innovation have challenged the capabilities of individual enterprises and the traditionally innovation mode to innovate and cope with growing environmental uncertainties and complexities, as well as with customers' diverse needs (Adner and Kapoor, 2010). In this context, an ever-greater number of firms are actively establishing close symbiotic relationships with external organizations, thus participating in or building collaborative innovation ecosystems with fellow organizations to pursue co-innovation and create value together. Such symbiotic ecosystems are a relatively new strategy for enterprises to develop or enhance their competitive advantages (Adner and Kapoor, 2010; Jacobides *et al*., 2018). An innovation ecosystem is defined as a complex, dynamic network constructed through various innovation activities; it centers on a focal firm cooperating with other firms to make full use of innovation resources and their respective strengths to carry out innovation activities jointly and create focal value propositions (Adner, 2017; Ding and Wu, 2018). In the evolutionary process of an innovation ecosystem, cooperation among different innovation populations results in symbiotic networks, in which the cooperative, symbiotic relationships and knowledge flow between the focal and other firms help all access heterogeneous resources and knowledge within the ecosystem (Bacon *et al*., 2020; Xie and Wang, 2021). Additionally, such ecosystems help their members to jointly carry out technological innovations and other activities more efficiently, thus boosting value co-creation among the members (Adner, 2006; Granstrand and Holgersson, 2020). For this reason, an increasing number of enterprises are forming or joining innovation ecosystems to collaborate with other entities to promote value co-creation. Examining how focal firms embedded in symbiotic networks impact on value co-creation in innovation ecosystems is thus of great practical significance.

Existing research on innovation ecosystems mainly focuses on its definitions (Ding and Wu, 2018), constituent elements (Xie and Wang, 2020), theoretical frameworks (Adner, 2017), symbiotic evolutionary mechanisms (Zhang *et al*., 2019), interdependence (Adner and Kapoor, 2010), knowledge flow (Brunswicker and Chesbrough, 2018), and value co-creation (Ritala *et al*., 2013) among different members within innovation ecosystems. Moreover, the extant literature on value co-creation within innovation ecosystems primarily concentrates on its modes and mechanisms (Xie and Wang, 2020), its impacts in terms of competitive advantages (Sun *et al*., 2022), and its antecedents based on case studies (Ketonen-Oksi and Valkokari, 2019) or evolutionary game models (Xu *et al*., 2023). However, the existing literature has three limitations that need to be explored further. First, the lack of empirical studies on possible drivers to improve the level of value co-creation within innovation ecosystems limits our understanding of how value co-creation is realized. Although Zhao *et al*. (2023) empirically explore the impact of interorganizational proximity on value co-creation, they only focused on the perspective of interorganizational relationships. Multidimensional research on the impact of cooperative relationships and knowledge flow among members of innovation ecosystems for the sake of value co-creation is lacking. Interactions among the members of symbiotic networks, which are composed of distinct populations within a given innovation ecosystem, involve different aspects, such as symbiotic cooperation, knowledge sharing, and knowledge transfer (Ketonen-Oksi and Valkokari, 2019). It is thus necessary to systematically explore the impacts of different dimensions of symbiotic networks on value co-creation within innovation ecosystems.

Furthermore, although a focal firm's primary goal in constructing a symbiotic network is value co-creation (Adner, 2017), the literature on symbiotic networks mainly focuses on the impacts of network size (Zhang *et al*., 2021), network relationship strength (Sun *et al*., 2021), and network proximity (Gao, 2022)

on innovation, while little research explores the impact of symbiotic networks on value co-creation. This research gap limits our understanding of how symbiotic networks impact on value co-creation within innovation ecosystems. Understanding that the relationships and knowledge flow among participants in an innovation ecosystem form the cooperative relationship network and the knowledge network, respectively, which result in distinct embedding modes (Guan and Liu, 2016), this study divides symbiotic network embeddedness into two dimensions—relational embeddedness and knowledge embeddedness—and systematically examines each one's influence on value co-creation. The first research question we ask is: How do focal firms' relational embeddedness and knowledge embeddedness in symbiotic networks respectively affect value co-creation in innovation ecosystems?

Second, "innovation ecosystem resilience" is an important variable that describes an ecosystem's ability to resist, adapt to, and automatically recover from external shocks (Chen and Cai, 2023). While such resilience is closely related to a focal firm's multilateral embeddedness in a symbiotic network, there is still a lack of research on the antecedents of innovation ecosystem resilience from the perspective of symbiotic network embeddedness. Dual embeddedness (i.e., relational embeddedness and knowledge embeddedness) in a symbiotic network is an important antecedent for promoting the flow of resources, information, and knowledge within an innovation ecosystem, thereby enhancing the ability and efficiency of the participants in the ecosystem to cope jointly with external shocks, thus increasing innovation ecosystem resilience (de Oliveira *et al*., 2023; Yan *et al*., 2020; Zhao *et al*., 2021). However, the existing literature on innovation ecosystem resilience mainly focuses on evaluating the influencing mechanism of regional innovation ecosystem resilience (Liang and Li, 2023). The literature on how to improve enterprise innovation ecosystem resilience (Falcke *et al*., 2023) and theoretically investigate the importance of this resilience (de Oliveira *et al*., 2023) lacks studies that quantify enterprise innovation ecosystem resilience and empirically explore its antecedents. Such research gaps lead to our second research question: Does focal firms' dual embeddedness (i.e., relational and knowledge embeddedness) in symbiotic networks affect innovation ecosystem resilience?

Third, in view of the importance of dual embeddedness in symbiotic networks for innovation ecosystem resilience, as well as the key role of innovation ecosystem resilience in promoting value co-creation among populations (Bednar *et al*., 2023; Yan *et al*., 2020), our next research question centers on whether a focal firm's dual embeddedness in symbiotic networks affects value co-creation via the mediating effect of innovation ecosystem resilience. On the one hand, a focal firm's relational and knowledge embeddedness in a symbiotic network can help participants in the innovation ecosystem better respond to external shocks and interference, thereby promoting innovation ecosystem resilience (Bednar *et al*., 2023; Falcke *et al*., 2023). On the other hand, high-level innovation ecosystem resilience is conducive to maintaining the stability of the innovation ecosystem, thereby providing favorable conditions for the development of value co-creation activities within the ecosystem (de Oliveira *et al*., 2023; Liang and Li, 2023). Hence, innovation ecosystem resilience can bridge the gap between relational and knowledge embeddedness in symbiotic networks and increase value co-creation among innovation ecosystem populations. Nonetheless, existing studies on innovation ecosystem resilience mainly focus on the regional innovation ecosystem perspective (Liang and Li, 2023). Studies that quantify enterprise innovation ecosystem resilience and empirically explore its antecedents, mechanisms, and consequences are lacking. In particular, few researchers examine the possible mediating effect of innovation ecosystem resilience on the relationship between focal firms' symbiotic network embeddedness and value co-creation among populations within innovation ecosystems. Therefore, this study explores how the underlying mechanism of a focal firm's relational and knowledge

embeddedness in a symbiotic network affects value co-creation within an innovation ecosystem from the perspective of innovation ecosystem resilience.

Fourth, since the impact of a focal firm's dual embeddedness in a symbiotic network on value co-creation is contextually dependent, this study also explores the boundary conditions of relational and knowledge embeddedness in symbiotic networks for promoting value co-creation within innovation ecosystems. Innovative ecological environments—as environmental conditions supporting the development of various innovation populations within an innovation ecosystem impact on the interactions that take place among various innovation populations, and thus they can affect participant cooperation in the ecosystem and the sharing and exchange of resources, information, and knowledge; therefore, they can ultimately exert significant influence on value co-creation within an innovation ecosystem (Li and Garnsey, 2014; Xie and Wang, 2021). A favorable innovative ecological environment can provide vital support, such as resources and policies for collaborative innovation. It can also promote symbiotic evolution among ecosystem members by accelerating cooperative research and development (Rong *et al*., 2021; Shu *et al*., 2015). These factors enable focal firms' relational and knowledge embeddedness in symbiotic networks to improve value co-creation among innovation ecosystem populations more effectively. Therefore, this study also explores the moderating effect of innovative ecological environments on the relationship between focal firms' relational and knowledge embeddedness in symbiotic networks and value co-creation within innovation ecosystems.

In summary, this study investigates how and under what circumstances focal firms' relational and knowledge embeddedness in symbiotic networks can promote value co-creation within innovation ecosystems. By doing so, it provides several important contributions to the literature on innovation ecosystems. First, this study broadens the theoretical scope of value co-creation within innovation ecosystems and responds to Walrave *et al*.'s (2018) appeal for more empirical research on innovation ecosystems. Second, given the lack of empirical studies on innovation ecosystem resilience at the enterprise level (Falcke *et al*., 2023; Liang and Li, 2023), this work also adds to the literature by evaluating the impact of focal firms' relational and knowledge embeddedness in symbiotic networks on innovation ecosystem resilience. Third, although some previous studies emphasize the important impact of innovation ecosystem resilience on the interactions and value co-creation among innovation ecosystem participants (Bednar *et al*., 2023; Yan *et al*., 2020), they do not elaborate on how innovation ecosystem resilience impacts on the relationship between symbiotic network embeddedness and value co-creation. Therefore, our paper contributes to the literature by identifying the mediating effect of innovation ecosystem resilience in the process of focal firms' relational and knowledge embeddedness in symbiotic networks promoting value co-creation within innovation ecosystems. Fourth, this study extends the findings of other researchers who emphasize the significant influence of the innovative ecological environments on the symbiotic interdependence and value co-creation among innovation ecosystem members (Feng *et al*., 2021; Gu *et al*., 2023) by showing that the innovative ecological environment is an important boundary condition in the relationship between a focal firm's relational and knowledge embeddedness in symbiotic networks and value co-creation.

In sum, this study intends to deepen innovation ecosystem theory from the perspectives of symbiotic network embeddedness, innovation ecosystem resilience, and value co-creation while expanding our understanding of the paths that promote value co-creation within innovation ecosystems. Furthermore, our conclusions provide theoretical references for enterprises to promote value co-creation in innovation ecosystems and enhancing innovation ecosystem resilience.

2. Theory and Hypotheses

2.1. Theoretical framework

Adner (2017) uses two key concepts to elaborate on the "ecosystem" construction process: "ecosystem-as-affiliation" and "ecosystem-as-structure." He states that "the ecosystem-as-affiliation view, which sees ecosystems as communities of associated actors defined by their networks and platform affiliations, highlights measures such as number of partners, network density, and actors' centrality in larger networks, begins with the actors (usually defined by their ties to a focal actor), considers the links among them, and ends with the possible value propositions and enhancements that the ecosystem can generate. In contrast, the ecosystem-as-structure approach begins with the value proposition, considers the activities required for its materialization, and ends with actors that must be aligned" (Adner, 2017, pp.40–41, 44). Given that an innovation ecosystem can be seen as a symbiotic network in which various affiliated innovation partners interact and mutually benefit from achieving value co-creation together (Adner, 2017; Xu *et al*., 2018), we use the ecosystem-as-affiliation perspective to examine the influence of focal firms' symbiotic network embeddedness on value co-creation among populations.

2.2. Symbiotic network embeddedness and value co-creation

An innovation ecosystem's symbiotic network can be regarded as a loosely interconnected network comprising a core innovation subject and the subject's stakeholders interacting and coevolving around a shared set of technologies, knowledge or skills, and working cooperatively and competitively for value co-creation (Nambisan and Baron, 2013; Zhang *et al*., 2019). Understanding that "an innovation ecosystem emphasizes the importance of pluralism among a broad range of interconnected innovation networks and knowledge clusters" (Tang *et al*., 2023), we focus on the cooperative relationships and knowledge flows among innovation ecosystem participants and explore the effect of relational and knowledge embeddedness in symbiotic networks on value co-creation among populations within innovation ecosystems. Specifically, "relational embeddedness" refers to the relationships formed by coupling symbiosis cooperation between a focal firm and other participants in an innovation ecosystem; higher levels of relational embeddedness and closer cooperative relationships can promote value co-creation and symbiotic evolution among populations (Guan and Liu, 2016; Yang *et al*., 2022). For its part, "knowledge embeddedness" refers to knowledge connections formed by knowledge sharing, exchange, and transfer between the focal firm and other innovation ecosystem participants; the higher the level of knowledge embeddedness, the more frequent and deeper the knowledge flow between focal firms and other participants, and thus more conducive to jointly creating new knowledge among the ecosystem members (Guan and Liu, 2016; Yoon *et al*., 2023).

A focal firm's dual embeddedness in a symbiotic network can affect the way ecosystem actors obtain resources and information, share knowledge, and undertake co-creation within an innovation ecosystem (Belso-Martinez and Diez-Vial, 2018; Yang *et al*., 2022), thus exerting an impact on the co-creation of value. In terms of focal firms' relational embeddedness in symbiotic networks, first, focal firms with higher levels of relational embeddedness tend to collaborate more with other participants in innovation ecosystems, allowing them to share and exchange innovative resources with multilateral sets of partners, thus improving the efficiency with which ecosystem members generate innovations jointly (Pomegbe *et al*., 2020; Yang *et al*., 2022). Second, a higher level of relational embeddedness represents higher-quality network interactions, which is helpful for generating trust (Pomegbe *et al*., 2020). In

turn, trust mechanisms help focal firms establish deep cooperative relationships with other ecosystem members, thereby promoting value co-creation among populations within innovation ecosystems (Cong *et al*., 2017; Steinbruch *et al*., 2022). Third, given that relational embeddedness can enrich the focal enterprise's information sharing channels, increasing the level of relational embeddedness can mitigate the information asymmetries among ecosystem members, thus reducing opportunistic behavior and other risks and uncertainties in the cooperating process and promoting value co-creation among innovation ecosystem populations (Kale *et al*., 2000; Yan *et al*., 2020).

In terms of knowledge embeddedness in a symbiotic network, first, a focal firm with a higher level of knowledge embeddedness usually has more knowledge ties with other organizations, which is helpful for enriching its knowledge base and improving its ability to recombine internal and external knowledge to create more innovative knowledge; thus, knowledge co-creation and sharing promote value co-creation (Belso-Martinez and Diez-Vial, 2018; Shi *et al*., 2019). Second, a higher level of knowledge embeddedness represents a wider range of knowledge connections between a focal enterprise and other ecosystem members; these knowledge connections can enhance the ecosystem members' heterogeneous knowledge and provide diverse knowledge sources to undertake innovation, thereby increasing the probability of successful and novel innovation among the innovation ecosystem actors (Cummings, 2004; Zhao *et al*., 2021). Third, knowledge embeddedness could establish channels for mutual learning and knowledge transfer, enabling ecosystem members to learn and absorb explicit and tacit knowledge from other participants, thus enhancing their innovation abilities, increasing the efficiency of collaborative innovations, and, finally, promoting value co-creation (Bacon *et al*., 2019; Zhao *et al*., 2021). Thus, we propose the following hypotheses:

Hypothesis 1a (H1a): A focal firm's relational embeddedness in a symbiotic network positively affects value co-creation among populations in an innovation ecosystem.

Hypothesis 1b (H1b): A focal firm's knowledge embeddedness in a symbiotic network positively affects value co-creation among populations in an innovation ecosystem.

2.3. Symbiotic network embeddedness and innovation ecosystem resilience

Innovation ecosystem resilience refers to an ecosystem's capability to maintain stability in the face of external shocks and to self-learn, adapt, recover, and eventually achieve equilibrium under the external shocks (Chen and Cai, 2023; Liang and Li, 2023). Relational and knowledge embeddedness in symbiotic networks can influence innovation ecosystem resilience by affecting symbiotic collaborations and knowledge interactions among participants. Therefore, we suggest that focal firms' relational and knowledge embeddedness in symbiotic networks positively impact on innovation ecosystem resilience.

On the one hand, regarding relational embeddedness in a symbiotic network, first, the higher the level of a focal enterprise's relational embeddedness, the stronger its ability to solve problems jointly with other participants, formulate appropriate coping strategies, and respond to external shocks more quickly, thus enhancing innovation ecosystem resilience (Pomegbe *et al*., 2020; Sulastri *et al*., 2023). Second, a higher level of relational embeddedness enables the focal enterprise to predict and prevent risks more efficiently by utilizing shared information, as well as respond better to external shocks by integrating shared resources within the ecosystem, thereby increasing its innovation ecosystem resilience (de Oliveira *et al*., 2023; Yang *et al*., 2022). Third, high levels of relational embeddedness tend to produce rich and closely interconnected symbiotic behaviors among innovation ecosystem populations, which helps them realize risk sharing and symbiotic coevolution and strengthen the entire ecosystem's ability to adapt to

and recover from external shocks, thus ultimately contributing to high-level resilience (Bednar *et al*., 2023; Yan *et al*., 2020).

On the other hand, regarding knowledge embeddedness in a symbiotic network, first, a focal enterprise's high level of knowledge embeddedness in a symbiotic network means that the knowledge flow of the whole innovation ecosystem is dynamic and active, enabling quick and flexible responses to external shocks, which ultimately enhances innovation ecosystem resilience (Bacon *et al*., 2019; Yu *et al*., 2022). Second, given that focal enterprises are the hubs connecting other ecosystem members, a focal firm's knowledge embeddedness in a symbiotic network can enhance the entire innovation ecosystem's resilience by expanding the focal firm's knowledge bases, strengthening its innovation capabilities, and increasing its organizational resilience (Mirghaderi *et al*., 2023; Sulastri *et al*., 2023). Third, knowledge embeddedness forms mutual learning and knowledge sharing channels, which help to promote the sharing and diffusion of tacit knowledge among innovation ecosystem participants about how best to cope with external shocks, thus enhancing their ability to maintain stability under external shocks, which enhances the resilience of the entire ecosystem (Bednar *et al*., 2023; Zhao *et al*., 2021). Thus, we propose the following hypotheses:

Hypothesis 2a (H2a): A focal firm's relational embeddedness in a symbiotic network positively affects the innovation ecosystem resilience.

Hypothesis 2b (H2b): A focal firm's knowledge embeddedness in a symbiotic network positively affects the innovation ecosystem resilience.

2.4. The mediating role of innovation ecosystem resilience

A focal firm's dual embeddedness in a symbiotic network is important for enhancing innovation ecosystem resilience (Pomegbe *et al*., 2020; Sulastri *et al*., 2023), and high-level resilience contributes to guaranteeing the continuous, stable, and orderly development of value co-creation activities among populations (Adner and Kapoor, 2010; Chen and Cai, 2023). As such, we argue that innovation ecosystem resilience could play a mediating role in the relationship between a focal firm's relational and knowledge embeddedness in a symbiotic network and the value co-creation among the ecosystem's populations. On the one hand, the two dimensions of a focal firm's symbiotic network embeddedness (i.e., relational and knowledge) can enhance innovation ecosystem resilience by strengthening the ability of ecosystem members to jointly solve problems, stabilizing the symbiotic interdependence among the different actors, accelerating knowledge flow within the ecosystem, and boosting organizational resilience (Bednar *et al*., 2023; de Oliveira *et al*., 2023; Yang *et al*., 2022; Zhao *et al*., 2021).

On the other hand, innovation ecosystem resilience is closely tied to an ecosystem's overall operating conditions, and thus it has an impact on the advancement of value co-creation activities among the ecosystem's populations. First, a high level of innovation ecosystem resilience means that the ecosystem has a strong ability to resist external shocks and maintain stability. This ensures that value co-creation activities can be carried out in an orderly and stable manner despite external shocks and disturbances, thus exerting a positive effect on the level of value co-creation among the populations (Adner and Kapoor, 2010; Liang and Li, 2023). Second, innovation ecosystem resilience also means the competence to self-learn, adapt, recover, and eventually achieve equilibrium under external shocks; therefore, high-level resilience enables an ecosystem to restore the orderly development of cooperative innovation and value co-creation activities in a relatively short period after being negatively affected by external shocks, thus guaranteeing the successful realization of value co-creation (Chen and Cai, 2023). Third, with high-

level resilience, the innovation ecosystem can more easily withstand crises and maintain steady evolution, which, in turn, boosts stable interactions and the flow of elements in the ecosystem; hence, high-level innovation resilience helps form stable resource exchange relationships among participants in the ecosystem, facilitates the rational allocation of innovation resources, and maintains the interdependent state of mutual trust and benefits among the ecosystem members, thereby promoting value co-creation within the innovation ecosystem (Adner, 2017; Huggins and Thompson, 2022). Thus, we propose the following hypotheses:

Hypothesis 3a (H3a): Innovation ecosystem resilience mediates the relationship between a focal firm's relational embeddedness in a symbiotic network and the value co-creation among populations within the innovation ecosystem.

Hypothesis 3b (H3b): Innovation ecosystem resilience mediates the relationship between a focal firm's knowledge embeddedness in a symbiotic network and the value co-creation among populations within the innovation ecosystem.

2.5. The moderating role of innovative ecological environment

Following prior work, this study defines an innovative ecological environment as "the institutional environment created by the government that provides support for innovation actors and can affect the co-creation of value by the participants in the innovation ecosystem" (Xie and Wang, 2021). A favorable innovative ecological environment can promote mutual cooperation and knowledge interactions among ecosystem members, provide strong support for value co-creation among ecosystem actors, and reduce collaboration risks (Xu *et al*., 2018; Xie and Wang, 2021). Given this understanding, we propose that a favorable innovative ecological environment can strengthen the positive impact of a focal firm's dual embeddedness in a symbiotic network on value co-creation among innovation ecosystem populations. Concerning relational embeddedness in a symbiotic network, on the one hand, a favorable innovative ecological environment can provide talent, funds, policies, and other types of support for collaborative innovation and coevolution among the different members in an innovation ecosystem, reduce the risks and costs of cooperative innovation, and boost the establishment of stable, cooperative symbiotic relationships among the participants (Li and Garnsey, 2014; Song, 2023), thus strengthening the positive impact of relational embeddedness on value co-creation. On the other hand, the government tends to build an open and transparent market environment under a sound innovative ecological environment, which can effectively mitigate information asymmetries and increase the level of trust among innovation ecosystem members (Wan *et al*., 2022), thus strengthening the positive effect of relational embeddedness on value co-creation. Therefore, focal firms' relational embeddedness in symbiotic networks can promote value co-creation among populations more effectively under favorable innovative ecological environments.

Regarding knowledge embeddedness in a symbiotic network, on the one hand, a favorable innovative ecological environment usually has a well-developed intellectual property protection system. This can reduce potential concerns about the leakage of intellectual property information and thus enhance the willingness of the ecosystem members to share knowledge, thereby strengthening their knowledge interactions and eventually promoting more efficient value co-creation (Bai *et al*., 2020; Tang *et al*., 2023). On the other hand, a sound innovative ecological environment provides a rich source of heterogeneous knowledge for innovation ecosystem actors. This positively impacts the creation of new knowledge by the focal enterprise and the other ecosystem participants (Pattinson *et al*., 2022; Yoon *et al*., 2023), thereby enhancing the positive effect of a focal firm's knowledge embeddedness in a symbiotic network on value co-creation among populations. Therefore, we suggest a focal firm's level of knowledge embeddedness

can more significantly improve value co-creation among populations when the innovative ecological environment is more favorable. Thus, we propose the following hypotheses:

Hypothesis 4a (H4a): The innovative ecological environment positively moderates the effect of a focal firm's relational embeddedness in a symbiotic network on value co-creation among populations in an innovation ecosystem such that the effect will be stronger when the innovative ecological environment is more favorable.

Hypothesis 4b (H4b): The innovative ecological environment positively moderates the effect of a focal firm's knowledge embeddedness in a symbiotic network on value co-creation among populations in an innovation ecosystem such that the effect will be stronger when the innovative ecological environment is more favorable.

Based on the various ideas discussed in this section, we develop a conceptual model that posits focal firms' relational and knowledge embeddedness in symbiotic networks as antecedents of value co-creation among innovation ecosystem populations via innovation ecosystem resilience. Further, we propose that the innovative ecological environment positively moderates the effects of a focal firm's relational and knowledge embeddedness in a symbiotic network on the value co-creation among populations (see Figure 1).

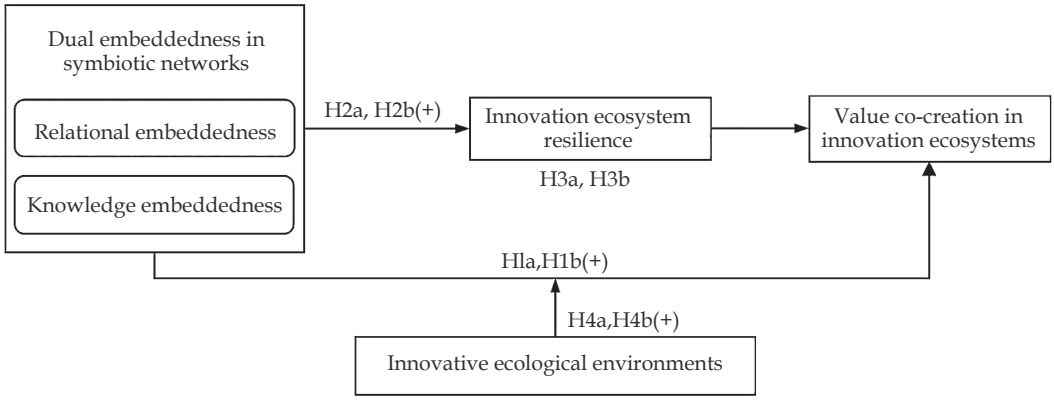

Fig. 1. Conceptual model.

3. Method

3.1. Data collection

For this study, we use a sample from the software and information technology services (SITS) industry in China. This key Chinese industry has strong innovation capabilities and plays an important role in the country's economic, social, and technological development. Moreover, given the SITS industry's rapid iterative technological innovation speed, firms in this industry often interact and collaborate with each other to construct symbiotic networks and innovation ecosystems. Thus, these firms provide a good sample for this research.

We collect data using the following steps: First, we collect the names of listed Chinese companies in the SITS industry from the China Stock Market & Accounting Research Database (CSMAR) and eliminat the ST or *ST firms. Second, for variables, we include the number of forward citations of focal firms' patents; the number of patents that focal firms applied for jointly with other organizations; the focal firms' related enterprises; collected from the Chinese Research Data Services Platform (CNRDS), the CSMAR database, the IncoPat patent information retrieval database, and China's Wind database. Finally, we delete samples without patent applications or those missing significant data between the years 2010

and 2020. Our final research sample contains 215 Chinese firms in the SITS industry, for which we have unbalanced panel data comprising 1,972 observations between 2010 and 2020.

3.2. Measures

3.2.1. Dependent variable

Value co-creation signifies the behavior of the focal enterprise and other participants in an innovation ecosystem, specifically, how they interact and pursue innovation jointly to create value for end-users (Xu *et al*., 2023; Xie and Wang, 2020). Cooperative innovation is an important form of value co-creation (Ketonen-Oksi and Valkokari, 2019; Xie and Wang, 2020), and scholars widely recognize patents as good indicators of innovation levels (Hsu *et al*., 2015). The number of patents firms apply for in collaboration with other organizations reflects public achievements and value co-creation levels among populations within the innovation ecosystems. Therefore, following Stek and Van Geenhuizen (2016) and De Silva *et al*. (2018), this study uses the number of patents applied for by focal firms together with other members in an ecosystem to measure value co-creation among innovation ecosystem populations.

3.2.2. Independent variables

We construct the symbiotic networks from our research sample based on interest-associated and patent-citation relationships between the focal firms and the other participants in innovation ecosystems, focusing on two dimensions of focal firms' embeddedness in symbiotic networks: relational embeddedness, and knowledge embeddedness. First, relational embeddedness emphasizes having symbiotic cooperation among innovation ecosystem members; thus, this study uses the number of direct ties between focal firms and non-focal organizations in their respective association networks to measure relational embeddedness in the firms' symbiotic networks (Shi *et al*., 2021; Yang *et al*., 2022). Second, knowledge embeddedness highlights knowledge flow among innovation ecosystem populations, and patent citations can reflect the cross-organizational flow of knowledge; therefore, this study uses patent-citation data to discern the knowledge flow between focal firms and other ecosystem members, measuring a focal firm's knowledge embeddedness level in a symbiotic network by the number of the firms' patent forward citations (Shi *et al*., 2019; Giura and Kumar, 2021).

3.2.3. Mediating variable

Given that innovation ecosystem resilience signifies an ecosystem's ability to maintain stability in the face of external shocks and that stable relationships among actors within an ecosystem are critical to maintaining overall stability (Chen and Cai, 2023; Kumar and Zaheer, 2019), we draw on the work of Zheng and Yang (2015) to measure innovation ecosystem resilience by evaluating the stability of each focal firm's cooperation network. Specifically, we identify the symbiotic partners of focal firms based on interest-associated network and define the partners who maintain cooperative relationships with the focal firm for at least two consecutive years as repeated partners and use the proportion of the number of repeated partners to the total number of each focal firm's partners as a proxy for innovation ecosystem resilience. This work is shown in equation (1), where k is the focal firm's repeated partners in a given year, and t is the total number of the focal firm's partners in that year.

$$\textit{Innovation ecosystem resilience} = k / t \tag{1}$$

3.2.4. Moderating variable

In this study, the innovative ecological environment refers to the government-created institutional environment that can affect value co-creation activities in innovation ecosystems (Xie and Wang, 2021), and the government's financial support for innovation activities is the most implicit indicator of the degree to which the government supports such activities. Therefore, we use government financial support as a proxy for the innovative ecological environment, and we measure the innovative ecological environment by the logarithm of government subsidies received by the focal enterprises each year under review (Li, 2014; Song, 2023).

3.2.5. Control variables

Prior research has identified several possible confounding variables as potential influences on a firm's innovation and network embeddedness, including firm size, assets-liability ratio, turnover of total assets, ownership, and growth (Bianchi *et al*., 2019; Li *et al*., 2017; Yang *et al*., 2022). We thus use these variables as control variables to support our study's initial findings. Specifically, first, we control for total assets, measured by the logarithm of a focal firm's total assets, as it may influence the firm's slack resource for innovation (Li *et al*., 2017). Second, we control for firm size, measured by the logarithm of the focal firm's number of employees, as this could influence an organization's ability to pursue growth initiatives for innovation activities (Yang *et al*., 2022). Third, we control for the assets-liability ratio and turnover of total assets, as it can affect a firm's ability to coordinate internal resources to carry out innovation (Bianchi *et al*., 2019; Li *et al*., 2017). Fourth, we control for ownership concentration, which represents the ability of major shareholders to control the company, measuring it by the proportion of shares held by the largest shareholder to the total issued share capital of the company (Yang *et al*., 2022). Fifth, we control for the focal firms' financial growth to eliminate its impact on innovation, measuring this by the gross revenue growth rate (Li *et al*., 2017). Finally, we control for the fixed effects of both firms and years to mitigate the influence of unchanging individual firm characteristics and temporal innovation trends.

4. Analyses and Results

4.1. Descriptive analysis

Table 1 presents the means, standard deviations, maximums, minimums, and medians of all study variables. The results show that the mean and standard deviation of value co-creation are 6.61 and 58.18, respectively, revealing that the value co-creation level of the innovation ecosystem in China's SITS industry is high, and thus provides a good study sample to explore this subject. Additionally, the results show that the mean and standard deviation of relational embeddedness are 9.65 and 58.19, respectively, and the mean and standard deviation of knowledge embeddedness are 4.28 and 34.85, respectively, which demonstrate that the connections between participants in the innovation ecosystem of focal enterprises in China's SITS industry are mainly formed by relational embeddedness. Furthermore, the mean value and standard deviation of the innovation ecosystem resilience are 0.16 and 0.47, respectively, indicating that the resilience of the innovation ecosystem of the focal enterprises in China's SITS industry is low. Finally, the mean value and standard deviation of the innovative ecological environment are 3.93 and 2.33, respectively, revealing that the Chinese government tends to provide favorable support for the development of the innovation ecosystem in China's SITS industry.

Table 1
Descriptive statistics.

Variables	N	Mean	SD	Max	Min	Median
Value co-creation	1,972	6.61	58.18	1,414.00	0.00	0.00
Relational embeddedness	1,972	9.65	58.19	1,416.00	0.00	3.00
Knowledge embeddedness	1,972	4.28	34.85	848.00	0.00	0.00
Innovation ecosystem resilience	1,972	0.16	0.47	11.56	0.00	0.13
Innovative ecological environments	1,972	3.93	2.33	11.81	0.04	3.63
Firm size	1,972	7.03	1.18	10.02	2.08	7.04
Total assets	1,972	20.98	1.18	24.91	16.45	21.05
Assets-liability ratio	1,972	0.33	0.29	8.26	0.02	0.30
Turnover of total assets	1,972	0.01	0.00	0.03	0.00	0.01
Ownership concentration	1,972	0.3	0.14	0.91	0.06	0.28
Growth	1,972	0.23	0.49	16.43	-0.68	0.18

4.2. Regression results

At first, the results of the multicollinearity test show that the variance inflation factors (VIFs) of our explanatory variables are less than the value of 10, indicating that the potential multicollinearity of this study is not serious. Then, we use fixed effect models to test our hypotheses, and present the results based on robust standard errors clustered at the firm level. The findings are presented in Tables 2–5. Table 2 shows the regression results of the effects of focal firms' relational and knowledge embeddedness on value co-creation among innovation ecosystem populations. The Model 4 results reveal that focal firms' high relational embeddedness ($\beta = 0.695$, $p < 0.01$) and high knowledge embeddedness ($\beta = 0.513$, $p < 0.01$) in symbiotic networks both promote value co-creation among populations within innovation ecosystems, thus supporting H1a and H1b. These findings demonstrate that the high level of relational embeddedness established by focal enterprises in their symbiotic networks can promote the flow of resources and information within innovation ecosystems and enhance trust among ecosystem members, thus boosting value co-creation among the populations within the innovation ecosystems (Cong *et al*., 2017; Yang *et al*., 2022). Furthermore, the findings demonstrate that focal enterprises' high knowledge embeddedness in symbiotic networks can promote knowledge co-creation and exchange within innovation ecosystems and improve the efficiency of collaborative innovation, thus increasing the value co-creation level among innovation ecosystem populations (Belso-Martinez and Diez-Vial, 2018; Zhao *et al*., 2021).

Table 3 presents the regression results of the effects of focal firms' relational and knowledge embeddedness on innovation ecosystem resilience. The Model 4 results show that focal firms' high relational embeddedness ($\beta = 0.007$, $p < 0.01$) and high knowledge embeddedness ($\beta = 0.001$, $p < 0.05$) in symbiotic networks both enhance innovation ecosystem resilience. Thus, H2a and H2b are proven. The findings indicate, firstly, that focal firms' high relational embeddedness in symbiotic networks can promote the efficiency of participants in innovation ecosystems to respond jointly to external shocks, thus increasing innovation ecosystem resilience (de Oliveira *et al*., 2023; Yan *et al*., 2020); and, secondly, that focal firms' high knowledge embeddedness in symbiotic networks can improve the flexibility of an ecosystem and enhance its members' organizational resilience, thereby promoting the resilience of the entire innovation ecosystem (Yu *et al*., 2022; Zhao *et al*., 2021).

Table 2
Regression results of the impact of a focal firm's relational and knowledge embeddedness on value co-creation.

Variables	Value co-creation			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Independent variables				
Relational embeddedness		1.000*** (445.088)		0.695*** (7.744)
Knowledge embeddedness			1.665*** (300.341)	0.513*** (3.432)
Control variables				
Firm size	-0.665 (-0.512)	0.479 (1.391)	0.002 (0.012)	0.336 (1.471)
Total assets	6.970 (1.065)	-0.517* (-1.824)	0.014 (0.053)	-0.376* (-1.943)
Assets-liability ratio	3.651 (0.791)	2.712*** (4.171)	-0.118 (-0.414)	1.837*** (4.009)
Turnover of total assets	137.280 (0.673)	-106.962*** (-2.687)	-23.360 (-0.319)	-81.959** (-2.580)
Ownership concentration	69.457 (1.015)	-1.246 (-0.972)	-0.367 (-0.294)	-1.192 (-1.234)
Growth	0.775 (0.837)	0.530** (2.210)	-0.052 (-0.298)	0.350* (1.946)
Firm fixed effects	Controlled	Controlled	Controlled	Controlled
Year fixed effects	Controlled	Controlled	Controlled	Controlled
Constant	-164.501 (-1.065)	6.253 (1.364)	0.089 (0.016)	4.877 (1.421)
R^2	0.045	0.996	0.990	0.997
F	3.881***	13,246.156***	5,695.095***	243,868.374***

*Note: N=1,972; *** p <0.01, ** p < 0.05, * p < 0.10 (two-tailed test); t statistics in parentheses.*

Table 3
Regression results of the effects of a focal firm's relational and knowledge embeddedness on innovation ecosystem resilience.

Variables	Innovation ecosystem resilience			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Independent variables				
Relational embeddedness		0.008*** (152.957)		0.007*** (20.698)
Knowledge embeddedness			0.014*** (94.843)	0.001** (2.312)
Control variables				
Firm size	-0.015 (-1.366)	-0.005 (-1.467)	-0.009* (-1.963)	-0.006 (-1.565)
Total assets	0.059 (1.098)	-0.002 (-0.569)	0.002 (0.498)	-0.002 (-0.467)
Assets-liability ratio	0.005 (0.122)	-0.003 (-0.308)	-0.026*** (-3.879)	-0.005 (-0.582)
Turnover of total assets	0.413 (0.235)	-1.578* (-1.656)	-0.892 (-0.788)	-1.511 (-1.587)
Ownership concentration	0.590 (1.056)	0.014 (0.675)	0.023 (0.940)	0.014 (0.684)
Growth	0.003 (0.440)	0.001 (0.298)	-0.004 (-0.804)	0.000 (0.137)
Firm fixed effects	Controlled	Controlled	Controlled	Controlled
Year fixed effects	Controlled	Controlled	Controlled	Controlled
Constant	-1.135 (-0.897)	0.256*** (3.311)	0.202** (2.193)	0.252*** (3.266)
R^2	0.045	0.961	0.951	0.961
F	23.256***	1,676.671***	680.067***	2,070.673***

*Note: N=1,972; *** p <0.01, ** p < 0.05, * p < 0.10 (two-tailed test); t statistics in parentheses.*

Table 4 shows the results of the mediating effect of innovation ecosystem resilience. The Model 2 results indicate that focal firms' high relational embeddedness (β = 0.695, p < 0.01) and high knowledge embeddedness (β = 0.513, p < 0.01) in symbiotic networks both promote value co-creation among innovation ecosystem populations. Additionally, the Model 4 results demonstrate that focal firms' high relational embeddedness (β = 0.007, p < 0.01) and high knowledge embeddedness (β = 0.001, p < 0.05) in symbiotic networks both enhance their innovation ecosystem resilience. Moreover, the Model 3 results show that when the "innovation ecosystem resilience" variable is added to Model 2, the regression coefficients of relational and knowledge embeddedness are statistically significant but become somewhat smaller than those of Model 2 (β = 0.683 < 0.695, p < 0.01; β = 0.511 < 0.513, p < 0.01). Hence, the findings indicate that innovation ecosystem resilience partially mediates the relationships between focal firms' relational and knowledge embeddedness in symbiotic networks and value co-creation among populations. Therefore, H3a and H3b are supported. These findings reveal that focal firms' relational and knowledge embeddedness in symbiotic networks promotes ecosystem members' ability and efficiency to respond jointly to external shocks, thereby raising the level of innovation ecosystem resilience, which eventually increases the level of value co-creation among innovation ecosystem actors (Chen and Cai, 2023; de Oliveira *et al*., 2023; Zhao *et al*., 2021).

Table 4
Regression results of the mediating effect of innovation ecosystem resilience.

Variables	Value co-creation			Innovation ecosystem resilience	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Independent variables					
Relational embeddedness		0.695*** (7.744)	0.683*** (7.745)		0.007*** (20.698)
Knowledge embeddedness		0.513*** (3.432)	0.511*** (3.417)		0.001** (2.312)
Mediating variable					
Innovation ecosystem resilience			1.585** (2.027)		
Control variables					
Firm size	-0.665 (-0.512)	0.336 (1.471)	0.345 (1.510)	-0.015 (-1.366)	-0.006 (-1.565)
Total assets	6.970 (1.065)	-0.376* (-1.943)	-0.373* (-1.924)	0.059 (1.098)	-0.002 (-0.467)
Assets-liability ratio	3.651 (0.791)	1.837*** (4.009)	1.845*** (4.111)	0.005 (0.122)	-0.005 (-0.582)
Turnover of total assets	137.280 (0.673)	-81.959** (-2.580)	-79.563** (-2.471)	0.413 (0.235)	-1.511 (-1.587)
Ownership concentration	69.457 (1.015)	-1.192 (-1.234)	-1.214 (-1.256)	0.590 (1.056)	0.014 (0.684)
Growth	0.775 (0.837)	0.350* (1.946)	0.349* (1.914)	0.003 (0.440)	0.000 (0.137)
Firm fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled
Year fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled
Constant	-164.501 (-1.065)	4.877 (1.421)	4.477 (1.288)	-1.135 (-0.897)	0.252*** (3.266)
R^2	0.045	0.997	0.997	0.045	0.961
F	3.881***	243,868.374***	182,634.418***	23.256***	2,070.673***

*Note: N=1,972; *** p <0.01, ** p < 0.05, * p < 0.10 (two-tailed test); t statistics in parentheses.*

As shown in Table 5, the Model 2 results reveal that the interaction of relational embeddedness and innovative ecological environment is positively correlated with value co-creation among innovation ecosystem populations (β = 0.005, p < 0.1), demonstrating that innovative ecological environments positively

moderate the relationship between relational embeddedness in symbiotic networks and value co-creation within innovation ecosystems, providing support for H4a. The Model 4 results in Table 5 show that the interaction of knowledge embeddedness and innovative ecological environment is positively correlated with value co-creation among innovation ecosystem populations (β = 0.016, p < 0.1), indicating that the innovative ecological environment positively moderates the relationship between knowledge embeddedness in symbiotic networks and value co-creation within innovation ecosystems, thus supporting H4b. Furthermore, Models 2 and 4 in Table 5 show the moderating effect of innovative ecological environments on the relationship between relational and knowledge embeddedness in symbiotic networks and value co-creation among populations (as shown in Figures 2a and 2b). Figure 2a demonstrates that the marginal effect of relational embeddedness in a symbiotic network on value co-creation increases with the value of the innovative ecological environment. Furthermore, Figure 2b shows that the marginal effect of knowledge embeddedness in a symbiotic network on value co-creation increases with the value of the innovative ecological environment. These findings reveal that a sound innovative ecological environment can provide strong support and create favorable conditions for collaborative symbiosis and knowledge interactions among innovation ecosystem populations (Song, 2023; Xie and Wang, 2021), thus strengthening the positive impact of relational and knowledge embeddedness on value co-creation.

Table 5
Regression results of the moderating effect of innovative ecological environments.

Variables	Value co-creation			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Independent variables				
Relational embeddedness	1.000*** (449.793)	0.975*** (60.439)		
Knowledge embeddedness			1.665*** (302.375)	1.588*** (35.309)
Moderator				
Innovative ecological environments	-0.172 (-0.455)	-0.152 (-0.402)	0.655** (2.186)	0.636** (2.238)
Interactions				
Relational embeddedness × Innovative ecological environments		0.005* (1.659)		
Knowledge embeddedness × Innovative ecological environments				0.016* (1.814)
Control variables				
Firm size	0.484 (1.422)	0.479 (1.423)	-0.015 (-0.080)	-0.010 (-0.055)
Total assets	-0.503* (-1.686)	-0.471 (-1.606)	-0.037 (-0.138)	0.004 (0.015)
Assets-liability ratio	2.728*** (4.189)	2.687*** (4.223)	-0.178 (-0.645)	-0.112 (-0.404)
Turnover of total assets	-106.461*** (-2.665)	-102.547*** (-2.609)	-25.270 (-0.347)	-20.608 (-0.287)
Ownership concentration	-1.175 (-0.973)	-1.201 (-1.004)	-0.643 (-0.508)	-0.643 (-0.509)
Growth	0.538** (2.252)	0.519** (2.180)	-0.084 (-0.492)	-0.105(-0.610)
Firm fixed effects	Controlled	Controlled	Controlled	Controlled
Year fixed effects	Controlled	Controlled	Controlled	Controlled
Constant	6.133 (1.320)	5.421 (1.182)	0.561 (0.100)	-0.507 (-0.092)
R^2	0.996	0.996	0.991	0.991
F	12,764.649***	21,0850.468***	5,631.228***	61,663.343***

*Note: N=1,972; *** p <0.01, ** p < 0.05, * p < 0.10 (two-tailed test); t statistics in parentheses.*

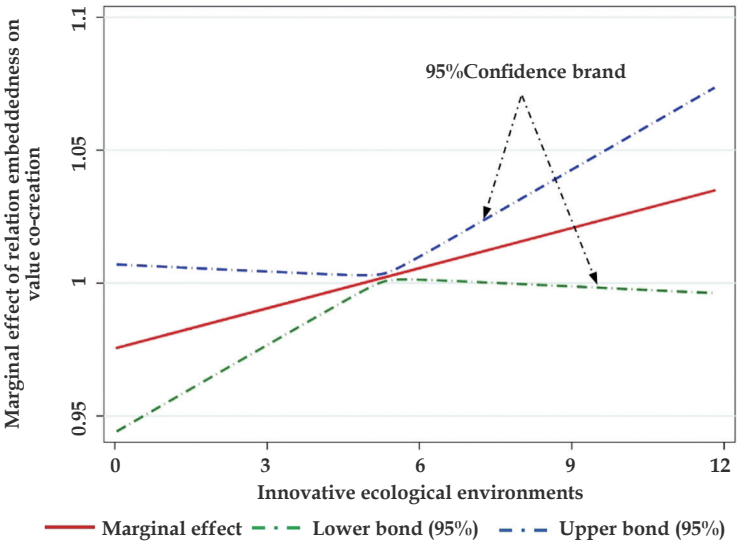

Fig. 2a. The moderating effect of innovative ecological environments on the relationship between the relational embeddedness in symbiotic networks and value co-creation.

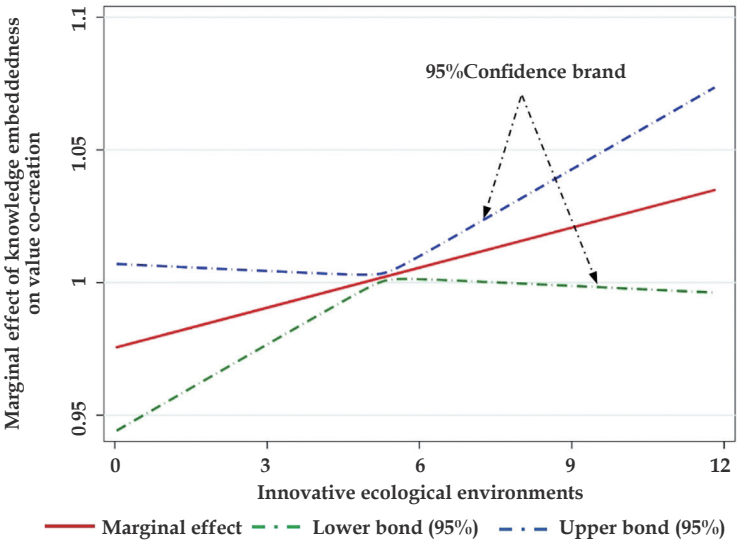

Fig. 2b. The moderating effect of innovative ecological environments on the relationship between the knowledge embeddedness in symbiotic networks and value co-creation.

4.3 Endogeneity tests

Given that the benchmark regression results might be affected by problems of endogeneity due to reverse causality and omitted variables, we conduct endogeneity tests to check whether the endogeneity problems affect the robustness of our results. First, to alleviate the potential reverse causality problem, this study uses the one-period lagged values of relational and knowledge embeddedness in symbiotic networks as independent variables and re-examines whether the main effect and mediating effect are robust to exclude the possibility that the dependent variable affects the independent variables. The results shown in Table 6 indicate that the impacts of relational and knowledge embeddedness in symbiotic networks on the

innovation ecosystem resilience and value co-creation are still significant, and the mediating effect of the innovation ecosystem resilience is confirmed again, which further supports our findings.

Second, this study uses the instrumental variable method to alleviate the endogeneity problem due to omitted variables. Because the one-stage and two-stage lagged values of endogenous variables have occurred relative to the value in current period, they can be considered to be independent of the current error term; and endogenous variables are significantly related to their lagged values; thereby, the one-stage and two-stage lagged values of independent variables satisfy the "inclusion criteria" and "exclusion criteria" of instrumental variables. Therefore, this study takes the one-stage and two-stage lagged values of the relational and knowledge embeddedness in symbiotic networks as their instrumental variables, and uses the two-stage least squares instrumental variable method (2SLS-IV) for regression. The results of the 2SLS-IV method shown in Table 7 indicate that the *p* values of *Anderson LM statistics* of all models are less than 0.01, rejecting the null hypothesis of "insufficient identification of instrumental variables"; the *Cragg-Donald Wald F statistics* of all models are higher than the critical values at the level of 15% of *Stock-Yogo* weak instrumental variable test, rejecting the null hypothesis of "weak identification of instrumental variables"; the *p* values of *Sargan statistics* of all models are greater than 0.1, accepting the null hypothesis of "all instrumental variables are exogenous", which shows that the selection of instrumental variables is reasonable. Moreover, the regression results of the 2SLS-IV model are consistent with the benchmark regression results, thus further indicating that the regression results are robust.

Table 6
Endogeneity test results: Regression estimates for the lagged independent variables.

Variables	Innovation ecosystem resilience			Value co-creation			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Independent variables							
L. Relational embeddedness	0.009*** (174.182)		0.006*** (6.231)	1.042*** (167.463)		0.501*** (4.964)	-0.078 (-0.545)
L. Knowledge embeddedness		0.014*** (139.458)	0.004** (2.302)		1.740*** (236.698)	0.910*** (5.404)	0.551*** (4.008)
Mediating variable							
Innovation ecosystem resilience							93.105*** (5.133)
Control variables							
Firm size	-0.009*(-1.890)	-0.014**(-2.495)	-0.011**(-2.082)	0.218(0.397)	-0.405(-0.853)	-0.105(-0.215)	0.875*(1.779)
Total assets	0.011(0.922)	0.016(1.239)	0.012(0.992)	1.101(0.747)	1.607(1.090)	1.342(0.907)	0.196(0.415)
Assets-liability ratio	0.003(0.204)	-0.020*(-1.713)	-0.003(-0.272)	3.049**(2.265)	0.272(0.245)	1.594(1.435)	1.916***(3.126)
Turnover of total assets	-1.538(-1.107)	-0.720(-0.456)	-1.313(-0.925)	2.498(0.018)	103.338(0.692)	55.654(0.405)	177.866(1.458)
Ownership concentration	0.110(1.267)	0.120(1.378)	0.111	9.113(0.850)	10.061(0.949)	9.339(0.878)	-0.985(-0.410)
Growth	-0.007(-0.469)	-0.004(-0.275)	-0.006(-0.423)	-1.817(-1.038)	-1.478(-0.854)	-1.645(-0.963)	-1.051(-1.387)
Firm fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Year fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant	-0.053(-0.192)	-0.099(-0.355)	-0.062(-0.224)	-28.740(-0.880)	-33.902(-1.034)	-30.878(-0.944)	-25.143**(-2.240)
R^2	0.867	0.861	0.868	0.887	0.887	0.890	0.969
F	10,171.439***	10,069.838***	12,192.552***	23,848.078***	27,065.959***	28,739.016***	82,542.797***

*Note: N=1,728; *** p <0.01, ** p < 0.05, * p < 0.10 (two-tailed test), t statistics in parentheses.*

Table 7
Endogeneity test results: Regression estimates of two-stage least squares instrumental variable method (2SLS-IV).

Variables	Innovation ecosystem resilience		Value co-creation			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Independent variables						
Relational embeddedness	0.008*** (166.831)		1.000*** (511.054)		0.580*** (22.655)	0.519*** (13.877)
Knowledge embeddedness		0.014*** (143.769)		1.670*** (310.775)	0.705*** (16.483)	0.704*** (16.227)
Mediating variable						
Innovation ecosystem resilience						6.784*** (2.663)
Control variables						
Firm size	-0.007* (-1.712)	-0.013*** (-2.645)	0.642*** (3.890)	-0.042 (-0.155)	0.353** (2.334)	0.397*** (2.581)
Total assets	-0.003 (-0.646)	0.001 (0.199)	-0.545*** (-3.422)	-0.142 (-0.543)	-0.388*** (-2.675)	-0.369** (-2.502)
Assets-liability ratio	-0.003 (-0.340)	-0.025** (-2.385)	2.336*** (6.508)	-0.336 (-0.569)	1.207*** (3.618)	1.212*** (3.589)
Turnover of total assets	-2.499** (-2.391)	-2.553** (-2.112)	-49.105 (-1.173)	-54.670 (-0.794)	-50.928 (-1.338)	-33.987 (-0.870)
Ownership concentration	0.034 (1.485)	0.041 (1.539)	-1.674* (-1.808)	-1.167 (-0.766)	-1.632* (-1.937)	-1.868** (-2.190)
Growth	0.008 (1.185)	0.010 (1.235)	-0.318 (-1.168)	-0.119 (-0.267)	-0.237 (-0.957)	-0.291 (-1.155)
Firm fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Year fixed effects	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R^2	0.963	0.951	0.996	0.989	0.997	0.997
F	4,148.783***	3,081.898***	38,753.105***	14,330.104***	41,176.177***	39,204.298***
Anderson LM statistic	1,302.476***	1,304.675***	1,302.476***	1,304.675***	413.696***	221.703***
Cragg-Donald Wald F statistic	4,403.718 (11.59)	4,464.652 (11.59)	4,403.718 (11.59)	4,464.652 (11.59)	119.502 (9.93)	54.273 (9.93)
Sargan statistic	0.615 (0.433)	0.431 (0.512)	0.364 (0.546)	0.231 (0.630)	0.783 (0.676)	1.341 (0.511)

*Note: N=1,486; *** p <0.01, ** p < 0.05, * p < 0.10 (two-tailed test), the critical values at the level of 15% of StockYogo weak instrumental variable test in the parentheses behind Cragg-Donald Wald F statistics, p value in the parentheses behind Sargan statistics, and t statistics in other parentheses.*

5. Conclusions and Implications

5.1. Theoretical contributions

Under intensified market competition and open innovation, co-creating value with external organizations and constructing innovation ecosystems have become important strategies for firms to gain competitive advantages. Consequently, many firms co-innovate and co-create value with other organizations to seek reciprocal symbiosis and coevolution. Therefore, systematically exploring the paths to realize value co-creation among innovation ecosystem participants is important for researchers and practitioners. Hence, in this study, we construct a theoretical framework of value co-creation within innovation ecosystems from the perspective of dual embeddedness in symbiotic networks based on the "ecosystem-as-affiliation" view. Using panel data of 1,972 observations from the years between 2010 and 2020, we empirically examine the internal mechanisms and contextual factors in the relationship between relational and knowledge embeddedness in symbiotic networks and the co-creation of value among innovation ecosystem populations, thus extending the theoretical framework and discussion of value co-creation within innovation ecosystems.

First, this study identifies the effect of dual embeddedness (i.e., relational embeddedness and knowledge embeddedness) in symbiotic networks on value co-creation among populations within innovation ecosystems. Although existing studies have emphasized the importance of connections and interactions among innovation ecosystem participants for value co-creation (Agarwal and Kapoor, 2023; Dattée *et al*., 2018), there is still a lack of studies empirically examining how the connections among various innovation ecosystem participants affect value co-creation (Ketonen-Oksi and Valkokari, 2019). Therefore, based on the "ecosystem-as-affiliation" view (Adner, 2017), this study focuses on symbiotic networks formed by connections among different participants in innovation ecosystems and explores the effect of focal firms' dual embeddedness in these networks on value co-creation among innovation ecosystem populations. The results show that this dual embeddedness positively affects value co-creation within innovation ecosystems. These findings reveal that a given focal firm's high relational embeddedness in a symbiotic network can increase the symbiotic interdependence between the focal enterprise and non-focal organizations and boost the integration and utilization of shared resources and information to co-innovate within the ecosystem (Pomegbe *et al*., 2020; Yan *et al*., 2020). Additionally, the findings demonstrate that a given focal firm's high knowledge embeddedness in a symbiotic network can promote knowledge co-creation and sharing and increase the efficiency of collaborative innovation (Belso-Martinez and Diez-Vial, 2018; Shi *et al*., 2019). Therefore, both relational embeddedness and knowledge embeddedness spur value co-creation among populations within innovation ecosystems. Thus, our findings not only respond to Walrave *et al*.'s (2018) appeal for more empirical research on innovation ecosystems but also answer Pomegbe *et al*.'s (2020) call for empirically testing the mechanism of multiple network embeddedness based on longitudinal data. Additionally, our findings expand on the innovation ecosystem theoretical framework by identifying antecedent factors that can promote value co-creation in innovation ecosystems using the symbiotic network perspective.

Second, this study deepens our understanding of the effect of focal firms' relational and knowledge embeddedness in symbiotic networks on innovation ecosystem resilience. Although existing scholarship has emphasized the importance of building collaboration and knowledge networks to enhance innovation ecosystem resilience (Bednar *et al*., 2023; Boyer, 2020), existing literature mainly consists of case studies (Bednar *et al*., 2023) or theoretical discussions (Boyer, 2020). Few studies have empirically explored the idea of promoting innovation ecosystem resilience from the perspective of dual embeddedness (i.e., relational embeddedness and knowledge embeddedness) in symbiotic networks. Hence, this study fills the gap by examining how focal firms' dual embeddedness in symbiotic networks might affect innovation ecosystem resilience. The results indicate that focal firms' relational embeddedness and knowledge embeddedness in symbiotic networks both have positive effects on the innovation ecosystem resilience. The findings reveal that high levels of relational embeddedness in symbiotic networks can help ecosystem members react more quickly and efficiently to external shocks (de Oliveira *et al*., 2023; Yan *et al*., 2020). Likewise, high levels of knowledge embeddedness in symbiotic networks can promote the organizational resilience and the flexibility of such innovation ecosystems (Yu *et al*., 2022; Zhao *et al*., 2021), thus enhancing innovation ecosystem resilience. These results reveal the antecedents of innovation ecosystem resilience from the perspective of symbiotic network embeddedness, expanding on prior research emphasizing the importance of stakeholder relationships in innovation networks in responding to external shocks (de Oliveira *et al*., 2023). Additionally, our findings add to the literature on the relationship between symbiotic networks and innovation ecosystem resilience, thereby realizing the proposal by Bednar *et al*. (2023) to research synergies between various stakeholders for the sake of

improving innovation ecosystem resilience.

Third, this study reveals the underlying mechanism by which relational embeddedness and knowledge embeddedness in symbiotic networks increase value co-creation within innovation ecosystems by identifying the mediating role of innovation ecosystem resilience. While previous studies have highlighted the impact of mutual cooperation and knowledge sharing among innovation ecosystem members on innovation ecosystem resilience and its important role in maintaining the steady advancement of value co-creation activities (Boyer, 2020; de Oliveira *et al*., 2023), the existing literature has mainly focused on case studies, theoretical discussions (Boyer, 2020; de Oliveira *et al*., 2023), or the influence of regional innovation ecosystem resilience on the development of the digital economy (Liang and Li, 2023). In contrast, our study focuses on the enterprise innovation ecosystem perspective and how innovation ecosystem resilience mediates the relationship between focal firms' dual embeddedness in symbiotic networks and value co-creation within innovation ecosystems. The results show that innovation ecosystem resilience mediates the relationships between a focal firm's relational and knowledge embeddedness in a symbiotic network and value co-creation among populations in the ecosystem, which reveals that focal firms' relational and knowledge embeddedness in symbiotic networks helps to enhance innovation ecosystem resilience and stability under external shocks, thus providing favorable circumstances for conducting value co-creation activities and ultimately increasing the level of value co-creation among innovation ecosystem members (Adner, 2017; Chen and Cai, 2023; de Oliveira *et al*., 2023; Zhao *et al*., 2021). These results thus deepen our understanding of one of the internal mechanisms at play by identifying the intermediary role of innovation ecosystem resilience, thus responding to Pomegbe *et al*.'s (2020) call to explore useful intermediary variables that could significantly influence the effect of network embeddedness on firms' innovation activities.

Fourth, our work deepens our understanding of the role of the innovative ecological environment as an important moderator in the links between focal firms' relational embeddedness and knowledge embeddedness in symbiotic networks and value co-creation among populations. Although there have been some studies indicating the important role of innovative ecological environments in the development of innovation ecosystems (Feng *et al*., 2021; Gu *et al*., 2023), most just theoretically discuss these environments' possible effects on the flow of elements and population symbiosis within innovation ecosystems (Feng *et al*., 2021) or concentrate on the impact of innovative ecological environments on the evolution and development of regional innovation ecosystems (Gu *et al*., 2023; Liu *et al*., 2023). Meanwhile, there has been little research on how an innovative ecological environment might affect the relationship between firms' embeddedness in a symbiotic network and value co-creation within an innovation ecosystem. Our findings suggest that innovative ecological environments positively moderate the effects of focal firms' relational and knowledge embeddedness in symbiotic networks on value co-creation within innovation ecosystems since a favorable innovative ecological environment can support network symbiosis and value co-creation among innovation ecosystem populations (Song, 2023; Xie and Wang, 2021). In this way, our study deepens the research on the boundary conditions under which symbiotic networks promote value co-creation within innovation ecosystems while expanding the literature that emphasizes the innovative ecological environment's important influence on symbiotic dependence and value co-creation among innovation ecosystem members (Feng *et al*., 2021; Gu *et al*., 2023).

5.2. Managerial suggestions

Our study provides some significant managerial suggestions for firms and governments in emerging

economies. First, from the embeddedness in symbiotic networks perspective, enterprises should attempt to improve their multi-level embeddedness in innovation ecosystems' symbiotic networks; form close, symbiotic relationships with other organizations based on this embeddedness; and interact and co-create value together with external organizations to achieve win-win cooperation and reciprocal symbiosis. More specifically, on the one hand, firms should actively increase their relational embeddedness in symbiotic networks within innovation ecosystems by collaborating and sharing resources with other actors in order to promote value co-creation. On the other hand, they should actively exchange knowledge and participate in sharing activities with other organizations to increase their knowledge embeddedness levels in symbiotic networks so as to promote knowledge sharing and value co-creation among ecosystem members.

Second, from the innovation ecosystem resilience perspective, high-level resilience is ideal for developing innovation ecosystems, and it is also a fundamental condition for fostering value co-creation activities within innovation ecosystems (Chen and Cai, 2023). Therefore, innovation ecosystem actors should take measures to enhance ecosystem resilience to increase value co-creation among innovation ecosystem populations. Particularly, on the one hand, firms should promote symbiotic interdependence among ecosystem members by improving their level of relational embeddedness in their symbiotic networks, thereby boosting value co-creation through enhanced innovation ecosystem resilience. On the other hand, they should actively try to absorb tacit knowledge about how to cope with external shocks to enhance their organizational resilience, thereby strengthening innovation ecosystem resilience and creating favorable conditions for value co-creation.

Third, with the understanding that an innovative ecological environment is the soil needed for an innovation ecosystem's evolution and development and that it plays an important role in boosting cooperation and value co-creation among innovation ecosystem members (Xu *et al*., 2018; Xie and Wang, 2021), the government should take measures to create an ecological environment conducive to developing innovation ecosystems. Specifically, on the one hand, measures should be taken to support cooperative innovation among different organizations, such as strong financial support, sustained strategic talent, R&D subsidies, and tax incentives, all of which could help firms carry out collaborative innovations and thus boost cooperative symbiosis and value co-creation among different innovation entities. On the other hand, the government should build a sound intellectual property protection system and an open and transparent market environment in order to reduce information asymmetries and opportunistic behaviors, thereby mitigating innovation members' concerns about possible risks from intellectual property leaks and opportunism, and promoting in-depth cooperation among innovation ecosystem participants.

5.3. Limitations and future research

This study had some limitations that should be considered in future research. First, our samples only involved firms in the Chinese SITS industry; future research could expand the sample by including different industry types to further analyze the impact of symbiotic network embeddedness on value co-creation. Second, due to the limitation of available data, this study only measured value co-creation among populations within innovation ecosystems based on patent data—specifically, patent applications filed by focal firms together with other organizations. However, in practice, value co-creation could be reflected at multiple levels, such as in terms of services, products, technologies, and processes (Xu *et al*., 2023). Therefore, future research could synthesize multiple indicators at various levels to measure value co-creation within innovation ecosystems in order to provide a more comprehensive measurement. Third,

given that the empirical data on innovation ecosystems remain scarce (Luo, 2018), this study used the stability of each focal firm's cooperation network as a proxy to measure innovation ecosystem resilience, which may not reflect the complete picture of the innovation ecosystem; future research could measure the innovation ecosystem resilience by constructing indicators from the dynamic capability perspective (Khurana *et al*., 2022) or multi-dimensional perspectives.

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References

Adner, R., & Kapoor, R., 2010. Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations, *Strategic Management Journal*, 31(3), 306-333.

Adner, R., 2017. Ecosystem as structure: An actionable construct for strategy, *Journal of Management*, 43(1), 39-58.

Agarwal, S., & Kapoor, R., 2023. Value creation tradeoff in business ecosystems: Leveraging complementarities while managing interdependencies, *Organization Science*, 34(3), 1216-124.

Bacon, E., Williams, M.D., & Davies, G., 2020. Coopetition in innovation ecosystems: A comparative analysis of knowledge transfer configurations, *Journal of Business Research*, 115, 307-316.

Bacon, E., Williams, M.D., & Davies, G.H., 2019. Recipes for success: Conditions for knowledge transfer across open innovation ecosystems, *International Journal of Information Management*, 49, 377-387.

Bai, O., Wei, J., & Yang, X., *et al*., 2020. Third-party relational governance and collaborative innovation performance: The role of IPR protection, *International Journal of Innovation Studies*, 4(1), 1-15.

Bednar, P., Danko, L., & Smekalova, L., 2023. Coworking spaces and creative communities: Making resilient coworking spaces through knowledge sharing and collective learning, European Planning Studies, 31(3), 490-507.

Belso-Martinez, J.A., & Diez-Vial, I., 2018. Firm's strategic choices and network knowledge dynamics: How do they affect innovation? *Journal of Knowledge Management*, 22(1), 1-20.

Bianchi, M., Murtinu, S., & Scalera, V.G., 2019. R&D subsidies as dual signals in technological collaborations, *Research Policy*, 48(9), 1-20.

Boyer, J., 2020. Toward an evolutionary and sustainability perspective of the innovation ecosystem: Revisiting the Panarchy model, *Sustainability*, 12(8), 1-17.

Brunswicker, S., & Chesbrough, H., 2018. The adoption of open innovation in large firms practices, measures, and risks, *Research-Technology Management*, 61(1), 35-45.

Chen, H.M., & Cai, S.L., 2023. Research on evaluation and influencing factors of regional digital innovation ecosystem resilience-empirical research based on panel data of 30 provinces and cities in China, *Sustainability*, 15(13), 1-20.

Cong, H.B., Zou, D.L., & Wu, F.X., 2017. Influence mechanism of multi-network embeddedness to enterprises innovation performance based on knowledge management perspective, *Cluster Computing-The Journal of Networks Software Tools and Applications*, 20(1), 93-108.

Cummings, J.N., 2004. Work groups, structural diversity, and knowledge sharing in a global organization, *Management Science*, 50(3), 352-364.

Dattée, B., Alexy, O., & Autio, E., 2018. Maneuvering in poor visibility: How firms play the ecosystem game when uncertainty is high, *Academy of Management Journal*, 61(2), 466-498.

De Oliveira, W.D., Guimaraes, M.R.N., & da Silva, J.E.A.R., 2023. Ecosystems, strategy, and resilience: Four empirical cases in the COVID-19 crisis, *Journal of Engineering and Technology Management*, 67, 1-15.

De Silva, M., Howells, J., & Meyer, M., 2018. Innovation intermediaries and collaboration: Knowledge-based practices and internal value creation, *Research Policy*, 47(1), 70-87.

Ding, L., & Wu, J., 2018. Innovation ecosystem of CNG vehicles: A case study of its cultivation and characteristics in Sichuan, China, *Sustainability*, 10(1), 39-55.

Falcke, L., Zobel, A.K., & Comello, S.D., 2023. How firms realign to tackle the grand challenge of climate change: An

innovation ecosystems perspective, *Journal of Product Innovation Management*, Early Access, 1-15. DOI: 10.1111/jpim.12687.
Feng, L.J., Lu, J.R., & Wang, J.F., 2021. A systematic review of enterprise innovation ecosystems, *Sustainability*, 13(10), 1-26.
Gao, Y., 2022. The Belt and Road Initiative and cascading innovation in China's domestic railway ecosystem, *Journal of International Business Policy*, 5(2), 236-258.
Giura, S.I., & Kumar, S., 2021. The impact of alliances on knowledge growth within firms, *IEEE Transactions on Engineering Management*, 68(4), 1155-1167.
Granstrand, O., & Holgersson, M., 2020. Innovation ecosystems: A conceptual review and a new definition, *Technovation*, 90-91, 1-12.
Gu, Y.Z., Hu, L.Y., & Hou, C.X., 2023. Leveraging diverse ecosystem partners for innovation: The roles of regional innovation environment and partnership heterogeneity, *Economic Research-Ekonomska Istrazivanja*, 36(1), 1167-1186.
Guan, J.C., & Liu, N., 2016. Exploitative and exploratory innovations in knowledge network and collaboration network: A patent analysis in the technological field of nano-energy, *Research Policy*, 45(1), 97-112.
Hsu, C.W., Lien, Y.C., & Chen, H.M., 2015. R&D internationalization and innovation performance, *International Business Review*, 24(2), 187-195.
Huggins, R., & Thompson, P., 2022. Cities, innovation and entrepreneurial ecosystems: Assessing the impact of the COVID-19 pandemic, *Cambridge Journal of Regions Economy and Society*, 15(3), 635-661.
Jacobides, M.G., Cennamo, C., & Gawer, A., 2018. Towards a theory of ecosystems, *Strategic Management Journal*, 39, 2255-2276.
Kale, P., Singh, H., & Perlmutter, H., 2000. Learning and protection of proprietary assets in strategic alliances: Building relational capital, *Strategic Management Journal*, 21(3), 217-237.
Ketonen-Oksi, S., & Valkokari, K., 2019. Innovation ecosystems as structures for value co-creation, *Technology Innovation Management Review*, 9(2), 25-35.
Khurana, I., Dutta, D.K., & Ghura, A.S., 2022. SMEs and digital transformation during a crisis: The emergence of resilience as a second-order dynamic capability in an entrepreneurial ecosystem, *Journal of Business Research*, 150, 623-641.
Kumar, P., & Zaheer, A., 2019. Ego-network stability and innovation in alliances, *Academy of Management Journal*, 62(3), 691-716.
Li, D., Zheng, M., & Cao, C., *et al*., 2017. The impact of legitimacy pressure and corporate profitability on green innovation: Evidence from China top 100, *Journal of Cleaner Production*, 141, 41-49.
Li, J.F., & Garnsey, E., 2014. Policy-driven ecosystems for new vaccine development, *Technovation*, 34(12), 762-772.
Li, Y., 2014. Environmental innovation practices and performance: Moderating effect of resource commitment, *Journal of Cleaner Production*, 66(1), 450-458.
Liang, L., & Li, Y., 2023. How does government support promote digital economy development in China? The mediating role of regional innovation ecosystem resilience, *Technological Forecasting and Social Change*, 188, 1-9.
Liu, R.J., Tang, F.C., & Wang, Y.H., *et al*., 2023. A modified NK algorithm based on BP neural network and DEMATEL for evolution path optimization of urban innovation ecosystem, *Complex & Intelligent Systems*, 9(3), 2333-2349.
Luo, J., 2018. Architecture and evolvability of innovation ecosystems, *Technological Forecasting and Social Change*, 136, 132-144.
Mirghaderi, S.A., Aboumasoudi, A.S., & Amindoust, A., 2023. Developing an open innovation model in the startup ecosystem industries based on the attitude of organizational resilience and blue ocean strategy, *Computers & Industrial Engineering*, 181, 1-17.
Nambisan, S., & Baron, R.A., 2013. Entrepreneurship in innovation ecosystems: Entrepreneurs' self-regulatory processes and their implications for new venture success, *Entrepreneurship Theory and Practice*, 37(5), 1071-1097.
Pattinson, S., Cunningham, J., & Preece, D., *et al*., 2022. Trust building in science-based SMEs in the North East of England: An ecosystem perspective, *Journal of Small Business and Enterprise Development*, 29(6), 902-919.
Pomegbe, W.W.K., Li, W.Y., & Dogbe, C.S.K., *et al*., 2020. Enhancing the innovation performance of small and medium-sized enterprises through network embeddedness, *Journal of Competitiveness*, 12(3), 156-171.
Ritala, P., Agouridas, V., & Assimakopoulos, D., *et al*., 2013. Value creation and capture mechanisms in innovation ecosystems: A comparative case study, *International Journal of Technology Management*, 63(3-4), 244-265.
Rong, K., Lin, Y., & Yu, J., *et al*., 2021. Exploring regional innovation ecosystems: An empirical study in China, *Industry and Innovation*, 28(5), 545-569.
Shi, X., Lu, L., & Zhang, W., *et al*., 2021. Managing open innovation from a knowledge flow perspective: The roles of embeddedness and network inertia in collaboration networks, *European Journal of Innovation Management*, 24(3), 1011-1034.
Shi, X.X., Zhang, Q.P., & Zheng, Z.L., 2019. The double-edged sword of external search in collaboration networks: Embeddedness in knowledge networks as moderators, *Journal of Knowledge Management*, 23(10), 2135-2160.
Shu, C., Wang, Q., & Gao, S., *et al*., 2015. Firm patenting, innovations, and government institutional support as a double-edged sword, *Journal of Product Innovation Management*, 32(2), 290-305.

Song, Y., 2023. How do Chinese SMEs enhance technological innovation capability? From the perspective of innovation ecosystem, *European Journal of Innovation Management*, 26(5), 1235-1254.

Steinbruch, F.K., Nascimento, L.D., & de Menezes, D.C., 2022. The role of trust in innovation ecosystems, *Journal of Business & Industrial Marketing*, 37(1), 195-208.

Stek, P.E., & Van Geenhuizen, M.S., 2016. The influence of international research interaction on national innovation performance: A bibliometric approach, *Technological Forecasting and Social Change*, 110(1), 61-70.

Sulastri, S., Mulyadi, H., & Disman, D., *et al*., 2023. Resilience acceleration model of small and medium enterprises through digital transformation, *Journal of Eastern European and Central Asian Research*, 10(4), 609-619.

Sun, Y., Li, L., & Chen, Y., *et al*., 2021. An empirical study on innovation ecosystem, technological trajectory transition, and innovation performance, *Journal of Global Information Management*, 29(4), 148-171.

Sun, Y., Xu, X.B., & Yu, H.Q., *et al*., 2022. Impact of value co-creation in the artificial intelligence innovation ecosystem on competitive advantage and innovation intelligibility, *Systems Research and Behavioral Science*, 39(3), 474-488.

Tang, H.X., Ma, Z.Z., & Jing, L., 2023. Interfirm network structure and innovation creation: A simulation study, *Journal of The Knowledge Economy*, Early Access, 1-25. DOI: 10.1007/s13132-023-01231-x.

Walrave, B., Talmar, M., & Podoynitsyna, K. S., *et al*., 2018. A multi-level perspective on innovation ecosystems for path-breaking innovation, *Technological Forecasting and Social Change*, 136, 103-113.

Wan, Y.L., Gao, Y.C., & Hu, Y.M., 2022. Blockchain application and collaborative innovation in the manufacturing industry: Based on the perspective of social trust, *Technological Forecasting and Social Change*, 177, 1-9.

Xie, X., & Wang, H., 2020. How can open innovation ecosystem modes push product innovation forward? An fsQCA analysis, *Journal of Business Research*, 108, 29-41.

Xie, X., & Wang, H., 2021. How to bridge the gap between innovation niches and exploratory and exploitative innovations in open innovation ecosystems, *Journal of Business Research*, 124, 299-311.

Xu, G., Wu, Y., & Minshall, T., *et al*., 2018. Exploring innovation ecosystems across science, technology, and business: A case of 3D printing in China, *Technological Forecasting and Social Change*, 136, 208-221.

Xu, Y.Y., Sun, H., & Lyu, X.C., 2023. Analysis of decision-making for value co-creation in digital innovation systems: An evolutionary game model of complex networks, *Managerial and Decision Economics*, 44(5), 2869-2884.

Yan, Y., Zhang, J.J., & Guan, J.C., 2020. Network embeddedness and innovation: Evidence from the alternative energy field, *IEEE Transactions on Engineering Management*, 67(3), 769-782.

Yang, B.X., Li, X.G., & Kou, K., 2022. Research on the influence of network embeddedness on innovation performance: Evidence from China's listed firms, *Journal of Innovation & Knowledge*, 7(3), 1-12.

Yoon, S.J., Jo, G.S., & Kang, J., 2023. Exploratory innovation through gaining knowledge from alliance portfolio: Interplay between network structure and knowledge composition, *International Journal of Innovation Management*, 26(7), 1-35.

Yu, J., Pauleen, D.J., & Taskin, N., *et al*., 2022. Building social media-based knowledge ecosystems for enhancing business resilience through mass collaboration, *International Journal of Organizational Analysis*, 30(5), 1063-1084.

Zhang, W., Liu, P.F., & Zhang, J.K., 2019. Multi-group symbiotic evolution mechanism in an innovative ecosystem: Evidence from China, *Revista de Cercetare si Interventie Sociala*, 66, 249-277.

Zhang, Y.L., Wang, D.T., & Xu, L., 2021. Knowledge search, knowledge integration and enterprise breakthrough innovation under the characteristics of innovation ecosystem network: The empirical evidence from enterprises in Beijing-Tianjin-Hebei region, *Plos One*, 16(12), 1-16.

Zhao, Y., Han, X., & Yang, X.R., *et al*., 2021. Interorganizational knowledge networks, R&D alliance networks, and innovation capability: A multilevel network perspective, *Complexity*, 8820059, 1-22.

Zhao, Y., Xiao, Y., & Lyu, J., 2023. The effect of proximity on enterprise innovation performance in the innovation ecosystem, *IEEE Access*, 11, 20923-20939.

Zheng, Y., & Yang, H., 2015. Does familiarity foster innovation? The impact of alliance partner repeatedness on breakthrough innovations, *Journal of Management Studies*, 52(2), 213-230.