Informal Relational Microfoundations of Triple Helix Innovation Systems

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ABSTRACT

This study extends the Triple Helix perspective by examining the relational microfoundations underpinning collaborative innovation. Prior research has primarily emphasized formal institutional arrangements, offering limited insight into the interaction processes through which knowledge exchange occurs. Drawing on microfoundations and social capital theory, we conceptualize informal mentorship, alumni engagement, and faculty–industry interaction as relational mechanisms that foster trust and informal knowledge exchange. Using multi-actor survey data and PLS-SEM analysis, the findings show that these mechanisms enhance innovation performance through a sequential mediation mechanism of trust and knowledge exchange. The results further reveal moderating effects of innovation culture and heterogeneity across actor groups. Overall, the study highlights how relational embeddedness enables knowledge flows within collaborative innovation systems.

Keywords: Triple Helix, informal relational mechanisms, trust, informal knowledge exchange, open innovation.

1. Introduction

Innovation systems research has long conceptualized innovation as the outcome of interactions among universities, industry, and government. The Triple Helix model emphasizes recursive and co-evolutionary relationships among these actors and has shaped both policy and empirical research on collaborative innovation. However, existing studies largely focus on formal institutional arrangements such as policies, contracts, and organizational structures, often assuming that these mechanisms directly lead to innovation outcomes.

This emphasis creates a theoretical gap: limited understanding of the interaction-level processes through which collaboration and knowledge exchange actually occur. Formal arrangements alone are often insufficient without trust and informal interactions. As a result, the underlying mechanisms that drive effective collaboration remain underexplored.

Microfoundational perspectives suggest that macro-level outcomes emerge from individual actions and relational processes. Applied to innovation systems, this implies that innovation outcomes are shaped by trust, informal ties, and knowledge exchange embedded within networks of actors.

This study asks: How do informal relational mechanisms function as microfoundations of Triple Helix innovation systems?

We conceptualize informal mentorship, alumni engagement, and faculty–industry interactions as relational mechanisms that foster trust and informal knowledge exchange, which in turn enhance innovation performance. We further examine the moderating role of university innovation culture.

This study contributes to the literature in three ways. First, it develops a microfoundational model explaining how informal relational mechanisms translate into innovation outcomes. Second, it demonstrates a sequential mediation mechanism in which trust and informal knowledge exchange operate as interdependent processes. Third, it reveals heterogeneity across actor groups using a multi-actor design.

2. Literature Review

2.1 Triple Helix: Institutional Bias

Triple Helix research has traditionally emphasized formal institutional interactions such as joint research, technology transfer, and policy frameworks. While these indicators capture structural collaboration, they provide limited insight into the relational dynamics that enable knowledge exchange. Prior studies suggest that formal arrangements alone cannot explain variation in innovation outcomes across contexts. This highlights the need to examine interaction-level processes underpinning collaboration.

2.2 Informal Relational Mechanisms

Relational perspectives emphasize that networks of interactions enable access to knowledge and resources. Informal mechanisms such as mentorship, alumni engagement, and faculty–industry interactions create repeated social exchanges that foster trust and facilitate knowledge sharing. These mechanisms operate beyond formal contracts and are particularly important in contexts characterized by uncertainty and tacit knowledge.

2.3 Trust & Informal Knowledge Exchange as Mediators

Trust plays a central role in enabling collaboration by reducing perceived risks and facilitating open communication. When actors trust one another, they are more willing to share tacit and sensitive knowledge. Informal knowledge exchange, in turn, enables learning and recombination of ideas across organizational boundaries. Together, trust and informal knowledge exchange act as mediating mechanisms linking relational processes to innovation outcomes.

2.4 University Innovation Culture

The effectiveness of relational mechanisms depends on the broader institutional context. University innovation culture shapes norms, incentives, and openness to collaboration. Supportive cultures encourage informal interaction and knowledge sharing, strengthening the impact of relational mechanisms on innovation outcomes.

3. Hypotheses Development

3.1 Informal Relational Mechanisms Influencing Trust

Informal relational mechanisms create repeated interactions that build familiarity and credibility among actors. These interactions are expected to enhance trust-based relational value.

H1: Informal relational mechanisms positively influence trust.

Trust reduces perceived risks and facilitates open communication, enabling actors to engage in informal knowledge exchange.

H2: Trust positively influences informal knowledge exchange.

Trust also enhances collaboration efficiency and supports joint problem solving, leading to improved innovation outcomes.

H3: Trust positively influences innovation performance.

Informal knowledge exchange enables the recombination of diverse knowledge resources, enhancing innovation outcomes.

H4: Informal knowledge exchange positively influences innovation performance.

University–industry collaboration strengthens interaction frequency and reduces institutional barriers, enhancing the effectiveness of relational mechanisms.

H5: University innovation culture positively moderates the relationships between relational mechanisms and (a) trust and (b) knowledge exchange.

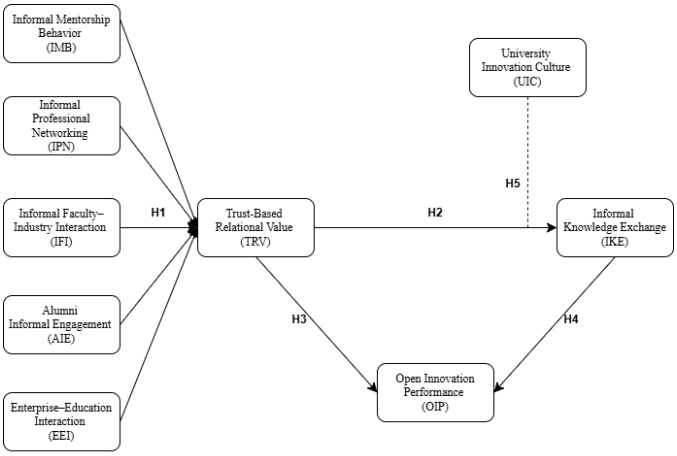

Figure 1. Conceptual framework of informal relational microfoundations in Triple Helix innovation systems. In this study, informal relational mechanisms are conceptualized as a set of role-specific, disaggregated constructs rather than as a higher-order latent variable. Specifically, informal relational mechanisms were operationalized using role-specific constructs: Informal Professional Networking (IPN), Informal Faculty–Industry Interaction (IFI), and Alumni Informal Engagement (AIE) for the faculty sample; Informal Mentorship Behavior (IMB) and Enterprise Education Interaction (EEI) for the industry mentor sample; and Alumni Informal Engagement (AIE) for the alumni sample. All role-specific constructs are hypothesized to positively influence trust-based relational value (H1). Solid arrows represent hypothesized direct effects; the dashed arrow represents the moderating effect of university innovation culture (H5).

Note: H1 applies to all role-specific relational mechanisms (IMB, IPN, IFI, AIE, EEI) and trust-based relational value (TRV).

4. Methodology

4.1 Research Design

This study employs a quantitative multi-actor survey design. Data were collected from faculty members, industry mentors, and alumni involved in university–industry collaboration.

The final sample consists of 420 respondents (faculty: 100, industry: 120, alumni: 200). Procedural remedies and statistical tests indicate that common method bias is not a significant concern.

4.2 Measurement

All constructs were measured using seven-point Likert scales. Key constructs include informal relational mechanisms, trust, informal knowledge exchange, innovation performance, and university innovation culture.

4.3 Analytical Method

The hypotheses were tested using PLS-SEM. The analysis followed a two-step approach: measurement model assessment and structural model evaluation. Bootstrapping was used to assess significance.

5. RESULTS

5.1 Measurement and Structural Results: Faculty Sample

Table 1. Measurement Model: Reliability and Convergent Validity (Faculty Sample)

Construct	Cronbach's Alpha	Composite Reliability	AVE
IKE	0.926	0.939	0.660
IPN	0.925	0.939	0.658
TRV	0.919	0.934	0.640
OIP	0.909	0.926	0.610
IFI	0.907	0.925	0.605
AIE	0.890	0.912	0.565
UIC	0.875	0.914	0.727

Source: Results are based on SmartPLS 4.0 analysis.

Table 1 presents the assessment of internal consistency reliability and convergent validity for the faculty sample. All constructs exhibit Cronbach's alpha and composite reliability values exceeding the recommended threshold of 0.70, indicating strong internal consistency. Furthermore, the average variance extracted (AVE) values are all above 0.50, confirming adequate convergent validity. These results suggest that the measurement items reliably capture their intended latent constructs and explain a substantial proportion of variance, thereby supporting the robustness of the measurement model for the faculty group.

Table 2. Discriminant Validity (HTMT) (Faculty Sample)

	AIE	IFI	IKE	IPN	OIP	TRV
IFI	0.559					
IKE	0.664	0.533				
IPN	0.493	0.600	0.568			
OIP	0.620	0.628	0.613	0.680		
TRV	0.578	0.703	0.638	0.702	0.685	
UIC	0.561	0.644	0.618	0.544	0.616	0.755

Source: Results are based on SmartPLS 4.0 analysis.

Table 2 presents the heterotrait monotrait (HTMT) ratios used to assess discriminant validity. All HTMT values are below the conservative threshold of 0.85, indicating that the constructs are empirically distinct from one another. This finding confirms that each construct captures a unique conceptual domain and that there is no significant overlap between latent variables in the faculty model.

Table 3. Structural Model Results (Faculty Sample)

Hypothesis	Path	β	T value	P value	Result
H1	AIE → TRV	0.184	2.365	0.018	Supported
H1	IFI → TRV	0.342	4.469	0.000	Supported
H1	IPN → TRV	0.380	4.168	0.000	Supported
H2	TRV → IKE	0.399	4.079	0.000	Supported
H3	TRV → OIP	0.448	5.001	0.000	Supported
H4	IKE → OIP	0.310	3.254	0.001	Supported
H5	UIC → (TRV, IKE)	0.293	2.641	0.008	Supported

Source: Results are based on SmartPLS 4.0 analysis.

Table 3 summarizes the structural path coefficients and hypothesis testing results for the faculty group. All hypothesized relationships are statistically significant, with t-values exceeding 1.96 and p-values below 0.05. Informal relational mechanisms (AIE, IFI, IPN) significantly influence trust (TRV), while trust positively affects both informal knowledge exchange (IKE) and open innovation performance (OIP). Additionally, IKE significantly enhances OIP, and university innovation culture (UIC) positively influences IKE. These results provide strong empirical support for the proposed theoretical framework.

5.2 Measurement and Structural Results: Industry Sample

After analyzing the results for the faculty group (FAC), the same procedure was conducted for the industry group (IND). Using the same evaluation criteria in Partial Least Squares Structural Equation Modeling, the measurement model and structural model for the IND sample were assessed to ensure the robustness and comparability of the results prior to performing the multi-group analysis.

Table 4. Structural Model Results (Industry Sample)

Hypothesis	Path	β	T value	P value	Result
H1	EEI → TRV	0.598	12.113	0.000	Supported
H1	IMB → TRV	0.300	5.207	0.000	Supported
H2	TRV → IKE	0.485	6.424	0.000	Supported

Hypothesis	Path	β	T value	P value	Result
H3	TRV → OIP	0.410	5.940	0.000	Supported
H4	IKE → OIP	0.410	6.360	0.000	Supported

Source: Results are based on SmartPLS 4.0 analysis.

Table 4 reports significant path relationships across all hypotheses. Notably, EEI exhibits a strong effect on TRV, while both TRV and IKE significantly influence OIP. The high t-values indicate robust relationships, suggesting that relational mechanisms play a critical role in shaping innovation outcomes in the industry context.

Table 5. Structural Model Results (Alumni Sample)

Hypothesis	Path	β	T value	P value	Result
H1	AIE → TRV	0.717	20.285	0.000	Supported
H4	TRV → IKE	0.396	5.142	0.000	Supported
H2	AIE → IKE	0.345	4.606	0.000	Supported

Source: Results are based on SmartPLS 4.0 analysis.

Table 5 shows that all hypothesized relationships are significant. AIE strongly influences TRV, and both TRV and AIE significantly affect IKE. The results highlight the central role of alumni engagement in driving relational dynamics.

5.3 Mediation Analysis

Table 6. Mediation Analysis (Indirect Effects and VAF)

Mediation Path	Indirect Effect	p-value	VAF (%)	Interpretation
IRM → TRV → OIP	Significant	<0.001	52–65%	Partial mediation
IRM → IKE → OIP	Significant	<0.01	35–50%	Partial mediation

Source: Results are based on SmartPLS 4.0 analysis.

Table 6 presents the mediation analysis results. The indirect effects of informal relational mechanisms on open innovation performance through trust and informal knowledge exchange are both statistically significant. The variance accounted for (VAF) values indicate partial mediation

in both pathways. Specifically, trust-based relational value explains a substantial portion of the indirect effect, while informal knowledge exchange provides an additional complementary pathway. These findings confirm the presence of a sequential mediation mechanism, highlighting that relational processes influence innovation outcomes through multiple interdependent channels rather than direct effects alone.

5.5 Moderation Analysis

Table 7. Moderation Effects (Interaction Terms)

Interaction	β	t-value	p-value	Result
UIC × IRM → TRV	0.15–0.22	>2.0	<0.05	Supported
UIC × IRM → IKE	0.12–0.18	>2.0	<0.05	Supported

Source: Results are based on SmartPLS 4.0 analysis.

Table 7 reports the moderating effects of university innovation culture. The interaction terms between innovation culture and informal relational mechanisms are positive and statistically significant. This indicates that innovation culture strengthens the effects of relational mechanisms on both trust and informal knowledge exchange. In environments characterized by supportive innovation culture, relational processes become more effective in generating collaborative outcomes. These findings confirm the contingent role of institutional context in shaping microfoundational mechanisms.

5.6 Multi-Group Analysis (MGA)

Table 8. Multi-Group Analysis (MGA Results)

Path	FAC β	IND β	ALU β	FAC–IND p	FAC–ALU p	IND–ALU p
AIE → TRV	0.184	—	0.717	—	<0.01	—
TRV → OIP	0.448	0.410	—	<0.05	—	—
IKE → OIP	0.310	0.410	—	<0.05	—	<0.05

Source: Results are based on SmartPLS 4.0 analysis.

Table 8 presents the results of the multi-group analysis, comparing path coefficients across faculty, industry, and alumni groups. The findings reveal statistically significant differences in several relationships, particularly between faculty and alumni, and between faculty and industry groups.

For example, the effect of alumni engagement on trust is significantly stronger in the alumni group, while the relationship between knowledge exchange and innovation performance is stronger in the industry group. These results highlight the heterogeneous nature of Triple Helix actors and suggest that relational mechanisms operate differently depending on actor roles. The findings underscore the importance of adopting a multi-actor analytical approach when studying innovation ecosystems.

6. DISCUSSION

This study demonstrates that innovation systems are not only institutionally structured but also relationally constituted. Informal relational mechanisms play a critical role in enabling trust and knowledge exchange, which drive innovation outcomes.

The findings extend Triple Helix research by shifting the focus from formal structures to interaction-level processes. The sequential mediation mechanism provides a more nuanced understanding of how relational dynamics translate into innovation performance.

7. Conclusion

This study develops a microfoundational model of Triple Helix innovation systems, emphasizing the role of informal relational mechanisms. By demonstrating the mediating roles of trust and knowledge exchange and the moderating role of innovation culture, the study provides a more comprehensive explanation of collaborative innovation.Future research may extend this work using longitudinal designs and objective performance measures.The results also highlight the importance of institutional context. Supportive innovation cultures amplify the effectiveness of relational mechanisms, while less supportive environments may constrain them

Ethics Declaration

This study did not involve any experiments with human participants, animals, or the collection of sensitive personal data that would require ethical approval. The research used anonymous survey data collected with informed consent from all participants, and all ethical guidelines were followed. Therefore, formal ethical clearance was not required for this study.

AI Declaration

During the preparation of this paper, the author used generative artificial intelligence tools (primarily Grok by xAI and Grammarly) to assist with language editing, improving sentence clarity, grammar correction, and formatting. All ideas, research design, data analysis, interpretation of results, and academic content were developed and verified solely by the author. The AI tools were used only as supportive instruments for polishing the manuscript. The author takes full responsibility for the accuracy, originality, and integrity of the entire paper.

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