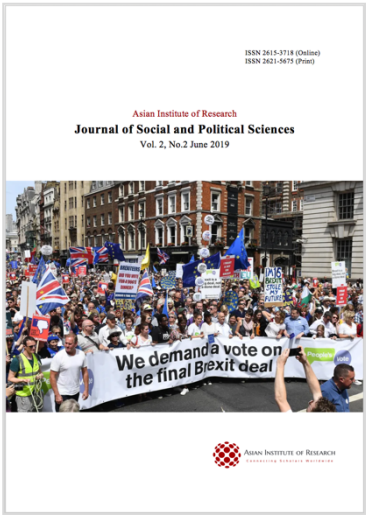

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Ties Strength and Knowledge Transfer: Investigation of Innovation Diffusion in Co-Authorship Networks

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Abstract
This study investigates the factors affecting the output of authors' cooperation. This cooperation can have a crucial role in the development of economics and technology in different fields. The investigated factors can create outputs that are more innovative and lead to better performance of intra-alliance and inter-alliance networks. The focus of this study is on transferring or exchanging intra information resources at the ego (small groups embedded in a network) and dyad levels of cooperation (individuals embedded in a group) shaped as an egocentric network using social network theory. The theory explains the effect that the strength of interpersonal ties at the dyad level has on knowledge exchange by considering how redundant information can be when it is received by an ego in networks. The authors of this paper demonstrate differences of information diffusion depending on the strength of interpersonal ties created by first authors. This study considered results of 206 studies in two areas of social science (economics and tourism) through an examination of quantitative data extracted from the Web of Science using the Histcite software. Amos was used for testing mediation effects, and SPSS version 23 was used to analyze the data via Hierarchal Learner Modeling (HLM) methodology.

Keywords: Knowledge Transfer, Intra-Network Learning, Ties Strength, Bibliography Network, Diffusion of Innovation

1. Introduction

Innovation and progress are made by inventors and scholars who might never meet each other face to face but still can collaborate in the form of a network in creative ways in order to advance the development of industries, economies, and so on. Generally, innovation is becoming a crucial element of society, economies, and the policymaking process. Innovation can be achieved by exploring something new or optimizing existing products or services and utilizing a new method to resolve problems and produce better outcomes. Innovative performance cannot occur spontaneously. There are countless factors or variables which lead products or services to be more novel and give them better performance in different regions such as infrastructure, professional labor availability, labor mobility, the availability of venture capital for innovative risk-taking, R&D stock, and copyright policies. The impact of these factors has been tested through diverse perspectives, and the conducted research works have

contributed to theories in various fields (Davila, Foster, & Gupta, 2003; Lee, Florida, & Acs, 2004; Mowery, Sampat, & Ziedonis, 2002). Scholars have initiated multiple investigations on what impacts the cooperation of these small-world networks (Fleming, King, & Juda, 2006; Uzzi, Guimera, Spiro, & Amaral, 2006).

Arguably, better, more innovative performance in co-authorship networks is happening because of diversity in dyad level relationships. Inventors are less willing to read textbooks or scientific literature reviews and more likely to approach their colleagues and collaborators who know or have read about related research topics and have more experience (Borgatti & Cross, 2003). In this study, we considered networks of papers in two research areas written by authors in China and USA. We focus on the relationship between articles' bibliography in two research areas (economics and tourism) extracted from the novel data using the Web of Science database. First, we argue for the redundant information exchanged among papers by looking at their numbers of local references and impact of that information on total citations of papers. Second, we test the papers' local citation number as a mediator between local references and the total number of papers' citations. Third, we demonstrate which approach would be the most beneficial in the conflict of repeated ties and unrepeated ties between papers' authors to help new information spread out of the network, and fourth, we test the assumption that the relationship between local citations and the number of global citations is going to be different for the authors in China and in the United States based on ties strength. The construction of an actor's set of direct ties (i.e., the actor's "egocentric network structure") was selected as a network of co-authors rather than triadic closure (i.e., whether an actor's partners are partners). The networks are diagrammed in Figure 1. In this study, all relational analyses and measurements are calculated, assuming egocentric networks.

Figure 1: Different types of ties structure within a group. The egocentric structure type (on the left) and the triadic closure structure type (on the right).

2. Theory and hypotheses

The social network literature is vast and diverse, implemented in different fields such as organizational sociology, political science, and organization theory at various levels of analysis: individual or interpersonal (dyad), impersonal (ego), and whole network in different groups, firms, organizations, and countries. Social network theory has been used widely because it not only gives researchers an opportunity to investigate the individual impact of a node but also explains how the social relationships among actors can be calculated (Galaskiewicz & Wasserman, 1994). Social network research follows an empirical approach that demonstrates the patterns of interactions among actors.

2.1 Inter, Intra-Network Knowledge Transfer and Diffusion of Innovation

Because of the complexity and various levels of application in the social network theory, the results are quite dependent on factors that are based on the construction of networks used by the researchers. Presenting an appropriate analysis of why a network or node acts as observed by the researchers is a key point that leads to the better adoption of any network study (Zaheer, Gözübüyük, & Milanov, 2010). Experiential knowledge extracted from intra-organizational learning or exploitative learning processes can be exchanged between organizations as they are learning within the network or collaborating with an inter-organizations alliance (Powell, Koput, & Smith-Doerr, 1996). Intra- and inter-network learning are related (e.g., (Baum & Rowley, 2002). This relationship is vital because technological novelty arises from a mixture of current technologies (Schumpeter, 1939) and the innovation process that includes inventors producing novelty by recombining existing information (Fleming & Sorenson, 2001; Kogut & Zander, 1992). In this paper, homogeneity or intra-network learning is defined by the numbers of

local references of the papers included in the sample. For better understanding, consider Figure 2. In that Figure, we know all the connections among nodes defined as groups of authors embedded in the network (each group represents a paper) within a research alliance network of Tourism (homogenous connections) which includes and transfers redundant information among groups which causes a decrease of information novelty. However, we do not know the details of other connections between the nodes and alliance networks in other research fields (for example, Art and Humanities), which are considered as heterogeneous or inter-organizational ties or connections.

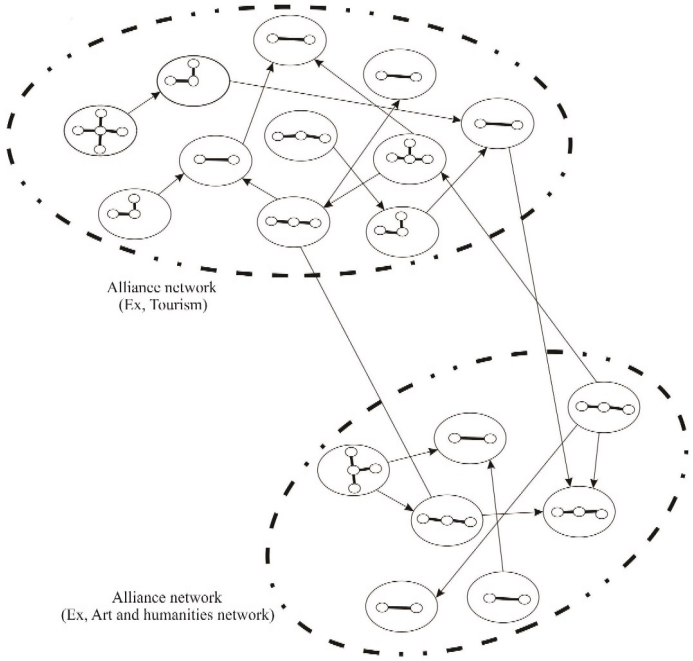

Figure 2. An example of connections among individuals embedded into groups, and groups embedded into alliance networks.

H1: A paper's learning through internal information resources (local references) in an alliance network is negatively related to its inter-alliance diffusion of innovation (number of citations outside the network).
(Asheim & Isaksen, 2002) Demonstrated that an innovative network is important for receiving the optimal allocation of resources and promoting knowledge transfer performance. New and novel information can involve more groups of scholars in an alliance network and furthermore more authors in that particular research area. Another benefit is that increasing novel knowledge can enhance opportunities for experts in other research areas to be a part of research work; this cross-pollination leads to better performance in each area's alliance network and allows networks of social sciences to be more closely related.

H2: Intra-alliance knowledge transfer capability (the number of papers' citations) mediates the relationship between intra-alliance network learning and inter-alliance diffusion of innovation.

2.2 Intra-Network Knowledge Transfer x Repeated and Unrepeated Ties

At the dyad level, we consider the moderating effects of repeated and unrepeated ties on intra-network knowledge transfer capability and diffusion performance of papers. Weak personal ties cause non-redundant knowledge and bring about innovation. (Granovetter, 1973) discussed the "strength of weak ties" and stated the critical role of weak ties, which is to spread information and provide access to non-redundant knowledge. For example, studies of small-world networks have shown that people in a large network are more interested in relying on people they do not know well; these relationships are considered to be weak ties (Dodds, Muhamad, & Watts, 2003). Many papers such as (Guimera, Uzzi, Spiro, & Amaral, 2005) have demonstrated that groups with more weak ties are more productive, probably because they have more novel information transferred through the weak ties. In contrast, (Bian, 1997) argued that more job opportunities came from the strong ties that exist among family or

relatives and that weak ties result in a lower level of new knowledge in recruiting networks (Aral & Van Alstyne, 2011). It is also known that weak ties do not spread novel information about healthcare (Christakis & Fowler, 2007).

H3: A higher number of repeated ties negatively moderates the relationship between knowledge transfer capability and diffusion of innovation. A paper with a higher number of repeated ties in an egocentric group is less likely to spread or share information with the inter-alliance network.

2.3 Commonalities Between Authors and Diffusion of Innovation

Attitudinal composition of networks refers to the composition in which the individuals embedded into a network share common viewpoints and believes (Visser & Mirabile, 2004). It has been argued that believes that is shared among people who are the part of a particular network along with common views on certain questions and problems, might have an important part in the formation of those groups and might also determine ties strength (Levitan & Visser, 2009). Chinese people have strong ties based on culture, origin, kinship, and family, and distinct attitudes exist, separating insiders from outsiders (Fan, 2002; Tong & Mitra, 2009). In egocentric networks, we suppose that all partners are chosen by leaders. For example, the first author of an article selects other members. Since all first authors in our data sample are Chinese living in China and the US and based on the assumption that there are more Chinese scholars in China than in the US, we tested if there was any difference in information diffusion based on the first authors' location.

H4: Higher diffusion of innovation occurs more among Chinese scholars with the first authorship who live in China compared to Chinese scholars with the first authorship who live in the US.

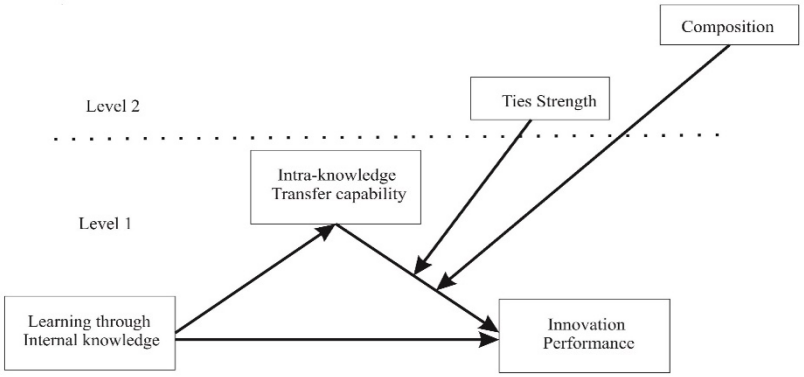

Figure 3: Hypothesized Model, the impacts of internal knowledge exchange, knowledge transfer capability, ties strength, and network composition on groups' diffusion of innovation.

3. Sample and data collection

Quantitative data was collected about collaborations of authors between universities in the United States of America and China in the Social Science field from 1974 to October 2017 through the usage of the advanced search option in the Web of Science database. Then the software "Histcite" was used to analyze the data. From 1716 articles in total, a sample of 211 articles was extracted in two different research areas (Tourism and Economics)*1 which was the number of papers linked to each other by citations and references out of the initial sample. The networks were created by linking the references and citations of the papers; Ucinet was used to

[1] *Tourism journals: (Journal of Travel and Tourism Marketing, Current Issues in Tourism, Asia Pacific Journal of Tourism Research, Journal of Vacation Marketing, Journal of Travel Research, Annals of Tourism Research, Journal of Hospitality and Tourism Research, Journal of Sustainable Tourism, Journal of Destination Marketing and Management, International Journal of Contemporary Hospitality Management, Current Issues in Tourism, Tourism Economics, Tourism Geographies, Tourism Management, International Journal of Hospitality Management, Journal of Destination Marketing and Management).
*Economics journals: (Econometrics Journal, Econometric Reviews, Journal of Business and Economic Statistics, Journal of Econometrics, Journal of Business and Economic Statistics, Review of Economics and Statistics, Econometrica, Oxford Bulletin of Economics and Statistics, Empirical Economics, Econometric Theory).

illustrate the network of the papers' bibliography in two study areas: two groups in economics and one in Tourism. At the first stage of analysis, it was discovered that the majority of first authors working in US universities were actually Chinese by ethnicity, but they worked with partners or coauthors in China, the USA, and a small number of other countries such as South Korea and Spain.

To reflect this fact, this study omitted all papers whose first author was not ethnically Chinese (we used Google Scholar profiles to confirm the ethnicity), so all sample papers had a Chinese first author who was working in a Chinese or American (USA) university. Five single-author papers were deleted from the economics area (no cooperation), and 125 and 81 articles on Tourism and Economics research areas respectively were selected. The network architectures created by Ucinet are shown below.

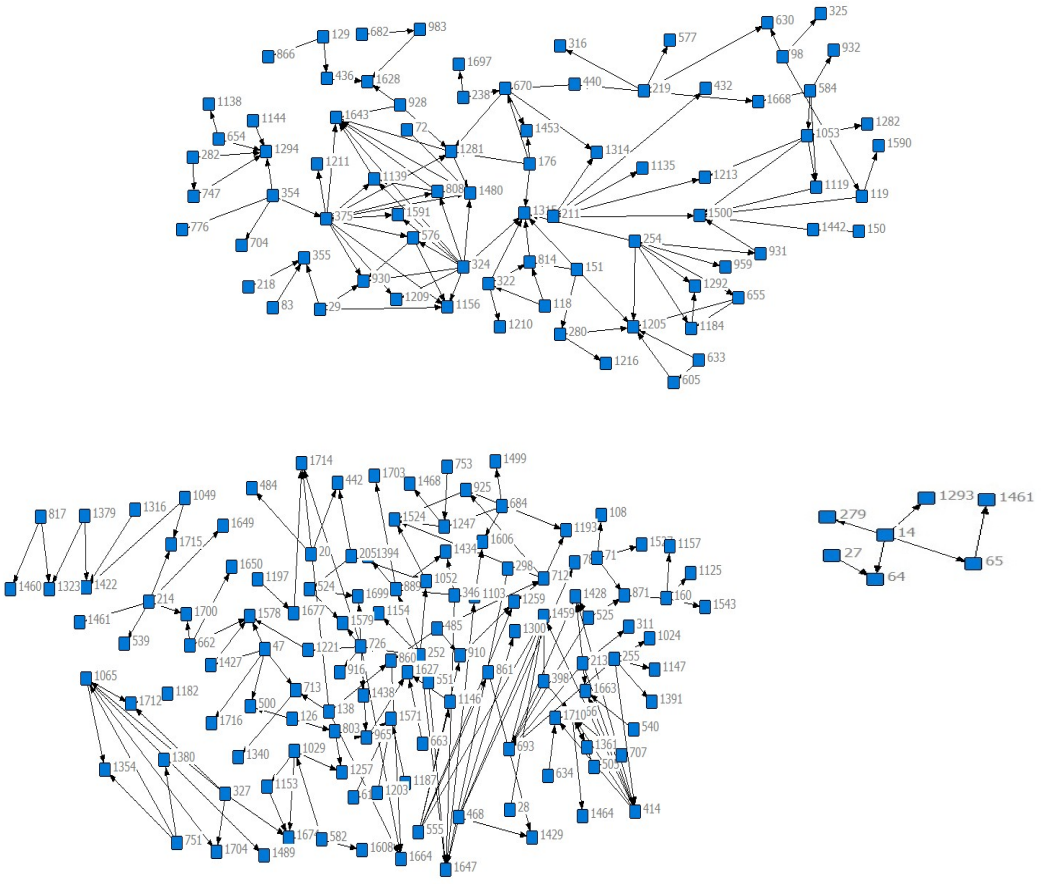

Figure 5. Structures of networks with directional ties (cited and referenced papers): two networks consist of groups published in the economics research area and one in the tourism research area

4. Method and variable measurement

The importance of highly cited patents and papers is recognized by researchers (Trajtenberg, 1990). In this study, Global citations subtracted from local citations of papers were used as a quantitative indicator of inter-network diffusion of innovation. The software "Histcite" and "Ucinet" were used to draw the networks' structure by looking at the numbers of citations (local citation score) and references (local cited references) of the papers. Next, we used local cited references as the measurement for learning from internal resources. This measurement shows the number of intra-network references for a node, and we define the local citation score as the capability of a node to spread or transfer knowledge to intra-network alliances after it processes the knowledge it has received from intra-

network databases. Many ties strength assessment methods and measurements exist, such as the measurement method using five Likert-scale items for closeness and relational trust seen in (Marsden, 1990; Marsden & Gorman, 1999). In this research, we use a new way of calculating the group's ties strength: the repeated cooperation of first authors with other coauthors. This idea is based on the fact that the question "Does familiarity breed trust?" has been answered with "Yes, as demonstrated by repeated ties" by prior researchers (Gulati, 1995; Zheng & Yang, 2015). We define weak ties as "unrepeated ties" (only one interaction and no former cooperation observed) and strong ties as "repeated ties" (the authors have cooperated once or more times previously). In the next stage, the number of repeated ties was subtracted from the number of unrepeated ties since our data included the total number of research collaborations from the year 1974 including all prior individual collaborations in these networks. For example, article number 966 had four authors: Zhang HM (Zhang, Hongmei), Fu XX (Fu, Xiaoxiao), Cai LPA (Cai, Liping A.), and Lu L (Lu, Lin) who cooperated on the paper "Destination image and tourist loyalty: A meta-analysis" published in the Tourism Management Journal in February 2014. In this case, we suppose that Zhang HM is the leader and center (see Figure 1). We found that Zhang HM had never worked with these three authors before, so in this case, the number of the group's unrepeated ties was 3 and the number of group's repeated ties was 0. Then we subtracted the number of repeated ties from unrepeated ties to get the value of (-3) in order to calculate ties strength of a group as a continuous variable. To investigate the group's network composition, we investigated where the first author was located to see if there were any differences between authors living in the US and in China (including Hong Kong). As data was not collected through questionnaires, we were not able to know the age and gender of authors, so we adopted group size which refers to the number of co-authors of papers, year of papers' publication, and SJR index of journals in the publication year using the website information (www.scimagojr.com) and prior experience (prior number of publications as the first author) of first authors as control variables. The multilevel analysis of groups in alliance networks, authors' cooperation, and country impacts were tested using hierarchical linear modeling (HLM) (Raudenbush, 2004). HLM and structural variance decomposition have been implemented in different studies (Bou & Satorra, 2007, 2010) and HLM is a suitable technique for this study because of the definition of hierarchical data (in our case, authors are nested in papers and papers nested in innovative alliance networks). HLM provides for simultaneous partitioning of the variance-covariance components, while “explicitly accounting for the independence of errors assumptions that may be violated when using other techniques such as OLS regression” (Siemsen, Roth, & Oliveira, 2010). HLM is more flexible with data since it allows estimation of random and fixed effects.

5. Result

5.1 Preliminary Analysis

Descriptive statistics and bivariate correlations (Pearson two-tailed tests) of all the variables are presented in Table 1. The average group size was 2.94 authors, and the average prior experience for the first author was 1.76 between 2000 and 2017, according to the data. The majority of first authors, 51.5 percent (106 scholars), were located in Chinese universities and other 48.5 percent (100 scholars) were located in US universities

Table 1. Means, Standard deviation, and correlations[a]

Variables	Mean	S.D.	Min.	Max.	1	2	3	4	5	6	7	8	9	10	11	12
1 Group size	2.96	0.81	2.00	6.00												
2 Impact Factor	2.44	2.01	0.22	19.52	-0.18*											
3 Prior Experience	1.76	2.70	0	14.00	-0.06	0.06										
4 Publication Year	2012.63	3.97	2000.00	2017.00	0.31**	-0.12	0.20**									
5 Area [b]	1.60	0.48	1.00	2.00	0.24**	-0.45**	-0.06	.019**								
6 diffusion of innovation	15.64	25.14	0	209.00	-0.08	0.07	-0.10	-0.48**	0.11							
7 Intra-learning	1.25	1.69	0	10.00	-0.13	0.14*	-0.04	-0.49**	0.00	0.61**						
8 Intra-knowledge transfer	1.34	1.39	0	7.00	0.18**	-0.08	0.27**	0.47**	-0.07	-0.33**	-0.38**					
9 Composition [c]	1.48	0.50	1.00	2.00	-0.01	0.29**	0.13	-0.03	-0.31**	-0.05	0.07	0.04				
10 Repeated ties	0.54	0.76	0	5.00	0.17*	-0.02	0.27**	0.21**	0.07	-0.12	-0.13	0.26**	0.07			
11 Un-repeated Ties	1.44	1.04	0	5.00	0.69**	-0.14*	-0.23**	0.11	0.16*	0.05	0.00	-0.03	-0.07	-0.55**		
12 Ties strength	-0.90	1.60	-4.00	5.00	-0.37**	0.09	0.28**	0.02	-0.07	-0.09	-007	0.15*	0.08	0.84**	-0.92**	1

*Significant at level P<0.05

**Significant at level P<0.01

b 1=Papers published in the Economics area. 2=Papers published in the Tourism area.

c 1= First authors are located in China or Hong Kong. 2= First authors are located in the US.

a Pearson product-moment correlations based on two-tailed tests (N=206).

5.2 Main Analysis

First, Hypotheses 1 and 2 were tested without considering moderators using Amos to analyze mediation effects and we used the following control variables: group size, impact factor, year of publication, and prior experience. **Model 1** (Path a: F(5,200) =16.65, P<0.001, R2= 0.29), (Group size β=0.14, t(200) =1.04, P=0.29, Impact Factor β=0.08, t(200) =1.53, P=0.12, Year of publication β=-0.18, t(200) =-5.98, P<0.001, Prior experience β=0.06, t(200) =1.54, P=0.12, Learning through internal knowledge β=-0.26, t(200) =-3.17, P=0.001), **Model 2** (Path b and c: F(6,199) = 24.94, P<0.001, R2= 0.43), (Group size β=1.88, t(199) =1.05, P=0.29, Impact Factor β=-0.23, t(199) =-0.33, P=0.74, Year of publication β=-1.49, t(199) =-3.39, P=0.001, Prior experience β=-0.11, t(199) =-0.21, P=0.83, Learning through internal knowledge β=-0.86,t(199)=-0.75,P=0.45, knowledge transfer capability= β=7.30, t(199) =7.71, P<0.001), and **Model 3** (path c' F(5,200) = 13.92, P<0.001, R2=0.26), (Group size β=2.89, t(200) =1.43, P=0.29, Impact Factor β=0.34, t(200) =0.44, P=0.63, Year of publication β=-2.80, t(200) =-6.11, P<0.00, Prior experience β=0.33 t(200) =0.55, P=0.58, Learning through internal knowledge β=-2.81, t(200) =-2.20, P=0.03). Standardized coefficients were reported.

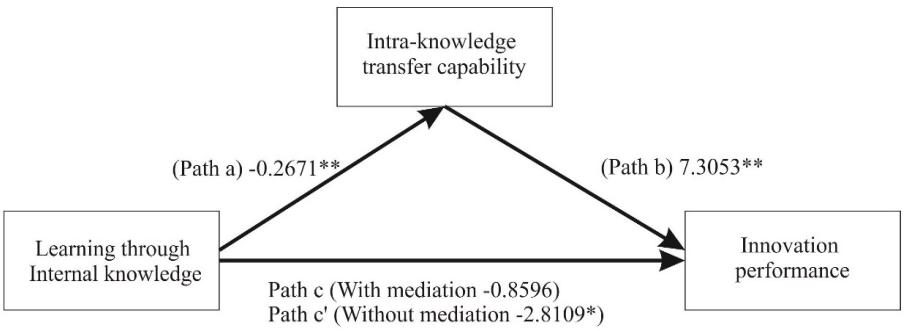

Figure 6. Mediation effect

For partial mediation effect, two methods were used, first (path a x path b) which is -1.94 (BOOTLLCI= -3.32 and BOOULCI= -0.98) (this intervals do not include zero), then the Sobel Test (normal theory test) with the result (Z= -2.90, P= 0.003). The results show that knowledge transfer capability is a partial mediator in the model. Next, we tested variables by HLM adding Level 2 (ties strength) and the comparison between universities of first authors to the model. We also added squared variance changes. The number of samples is reported in the table below.

Table 2. Results of Hierarchy Linear Regression Analysis: Effect of Ties, Strength, and Country.

variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Group Size	2.55 (2.04)	1.88 (1.79)	1.58 (1.93)	1.83 (1.93)	1.26 (1.90)	1.78 (1.87)
Impact Factor	0.26 (0.79)	-0.23 (0.69)	-0.22 (0.69)	0.14 (0.32)	0.33 (0.71)	0.50 (0.70)
Year Of Publication	-3.22*** (0.42)	-1.49*** (0.43)	-1.49*** (0.44)	-1.52** (0.44)	-1.28*** (0.44)	-1.21*** (0.43)
Prior Experience	0.05 (0.59)	-0.11 (0.53)	-0.06 (0.55)	0.04 (0.55)	0.01 (0.54)	0.07 (0.52)
Intra-Learning		-0.86 (1.15)	-0.89 (1.16)	-0.74 (1.16)	-0.87 (1.13)	-1.02 (1.11)
Intra-Transfer Capability		7.30*** (0.95)	7.28*** (0.95)	7.36** (0.95)	6.03*** (1.02)	14.15 (2.82)***
Group Ties Strength			-0.39 (0.96)	-0.31 (0.96)	1.29 (1.08)	1.22 (1.05)
Country				-5.08* (2.84)	-5.24* (2.78)	0.56 (3.31)
Intra-Transfer ×Ties Strength					-1.68** (0.59)	-1.42** (0.55)
Intra-transfer × Country						-4.89*** (1.59)
Sample	206	206	206	206	206	206
R^2	0.24	0.43	0.43	0.44	0.46	0.48
Delta R^2	024	0.19	0	0.01	0.02	0.2
Delta F	15.89**	32.93**	0.17	3.21*	9.10**	9.43**

***Significant at the level of P<0.01, Two-tailed test. Beta unstandardized coefficients (Standard Errors) are reported in this table. ** Significant at the level of P<0.05. * Significant at the level of P<0.1.

For **Model 1** including only control variables, standardized and unstandardized (in table) coefficients, and partial correlations were reported: Group Size β= 0.09, t(201) =1.25 , P=0.21 , pr^2= 0.007, Impact Factor β= -0.02, t(201) = 0.33, P= 0.74, Pr^2=00, Year of publication β= -0.50, t(201) = -7.60, P<0.001, Pr^2=0.22, Prior experience β= 0.00, t(201) =0.08, P=0.93, Pr^2=00) **Model 2** was formed by adding independent variables, learning through intra-network: β= -0.05, t(199) =-0.76, P= 0.45, Pr^2= 0.000), intra-network knowledge transfer β=, t(199) =0.49, P<0.001, Pr^2= 0.23).

In **Model 3**, we added moderator variable ties strength: β=-0.2, t (198) = -0.41, P=0.68, Pr^2= 00. In **Model 4**, we included Country as the moderator: β= -0.10, t (197) =-1.79, P=0.07, Pr^2=0.07), For the next stage, **Model 5**, we added the interaction of intra-transfer capability and tie strength: β= -0.22, t(196) =-3.02, P=0.003, Pr^2=0.04), and for final stage, we added the interaction of intra-transfer capability and country, **Model 6,** β=-0.57, t (195) =-3.07, P=0.002, Pr^2=0.05 At level one (see model), Hypotheses 1 and 2 were supported; learning through internal resources was negatively related to inter-network diffusion performance, and intra-knowledge transfer capability was a partial mediator of this relationship. At level two, the analysis showed that the spreading of knowledge happened through higher numbers of a group's unrepeated ties, and Hypothesis 3 was supported. According to the model 6, higher diffusion of innovation was observed with first authors located in China compared to US. To compare ties strength between authors located in China and US, we demonstrated the differences of ties strength moderation effect between intra-network knowledge transfer and diffusion performance shown in table 3.

Table 3: The comparison between US and China, the moderation effect of ties strength between intra-network transfer and diffusion of innovation

Variable	China	US
Intra-Transfer Capability	8.92***	6.201***
Group Ties Strength	2.04	0.52
Interaction	-3.21***	-1.03*
Sample size	106	100

`*** Significant at the level of P<0.01, Two-tailed test. Beta unstandardized coefficients are reported in this table.
* Significant at the level of P<0.1.

As for the country effect, we observed that information with an article with more unrepeated ties had been transferred more through first authors in Chinese universities rather than in the case of US universities, although for both countries, resources flowed better with more unrepeated ties, hypothesis 4 was supported.

6. Conclusion and Limitations

In this study, we have demonstrated that intra-network information resources from the exploitative learning process or learning through internal knowledge transformation have a negative impact on the diffusion of innovation. However, the model used here ignores explorative or inter-network learning resources. We have shown that less use of the intra-network information would lead that ego to have better intra-performance, which is related to many variables according to different theories and frameworks, not all of which were explained in this study. In this study, we tested influences of a group's intra-knowledge transfer capability as a mediator and ties strength as a moderator of knowledge sharing through an inter-alliance network. Diffusion of innovation occurs more among Chinese authors who live in China than among Chinese authors living in the US. One of the limitations of this study is that the quantitative data used lacks information about the authors' demographic data such as age and gender. Future studies could focus more on the inter-organizational learning process and resources. In addition, further research could be focused on testing the moderation effect of diverse authors' perspectives in a group and see if the relationship between intra-network learning and intra-network knowledge transfer capability is moderated by the diversity between the authors' perspectives or research areas. Follow-up studies could consider cross-sectional data, more countries, more research areas (the macro level), and different network structures (see Figure 1).

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