Economics and Management of Innovation – additional material chapter 8

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The importance of network to study strategic collaborations

(FRIENDSHIP OF WHOM?)

	A	B	C	D	E	F
A		1	1	1		1
B	1					
C	1					
D	1	1			1	
E				1		
F						

NXN (SYMMETRIC) THE RELATIONSHIPS EXIST (1) OR NOT EXIST (BLANK CELL)

(DEGREES OF FRIENDSHIP)

	A	B	C	D	E	F
A		3	7		2	1
B	2					
C					6	1
D		4			5	
E		8				
F						

NXN THE RELATIONSHIP ARE DIRECTED AND NOT SYMMETRIC

Some basic network measures

Density → the proportion of existing relationships among all the possible ones
g*(g-1) for directed network and [g*(g-1)]/2 for undirected network

Distance → how many steps the actor “i” should do to reach actor “j”?

-*geodesic path* is exactly the path that any actor in the network must take to reach the others (another generic network node)
-*Average distance*: Given all possible pairs of nodes in the network, what is the measure of the average distance between nodes?
-*Reachability*: Are all nodes in the network reachable in some way from each other (regardless of path length)?
-*Connectivity*: How many nodes in the network would have to be removed for the node in question to no longer be able to reach the others?

Some basic network measures II

Degree centrality measures the number of ties possessed by an actor: the more ties she/he has with other nodes, the more central it will be in a network.

It can be measured on two levels:
At the level of the whole network: how many relationships in total exist in the network? How many outgoing from nodes? How many incoming?

At the level of the individual actor: How many relationships is the actor involved in? How many outgoing and how many incoming?

Some basic network measures II

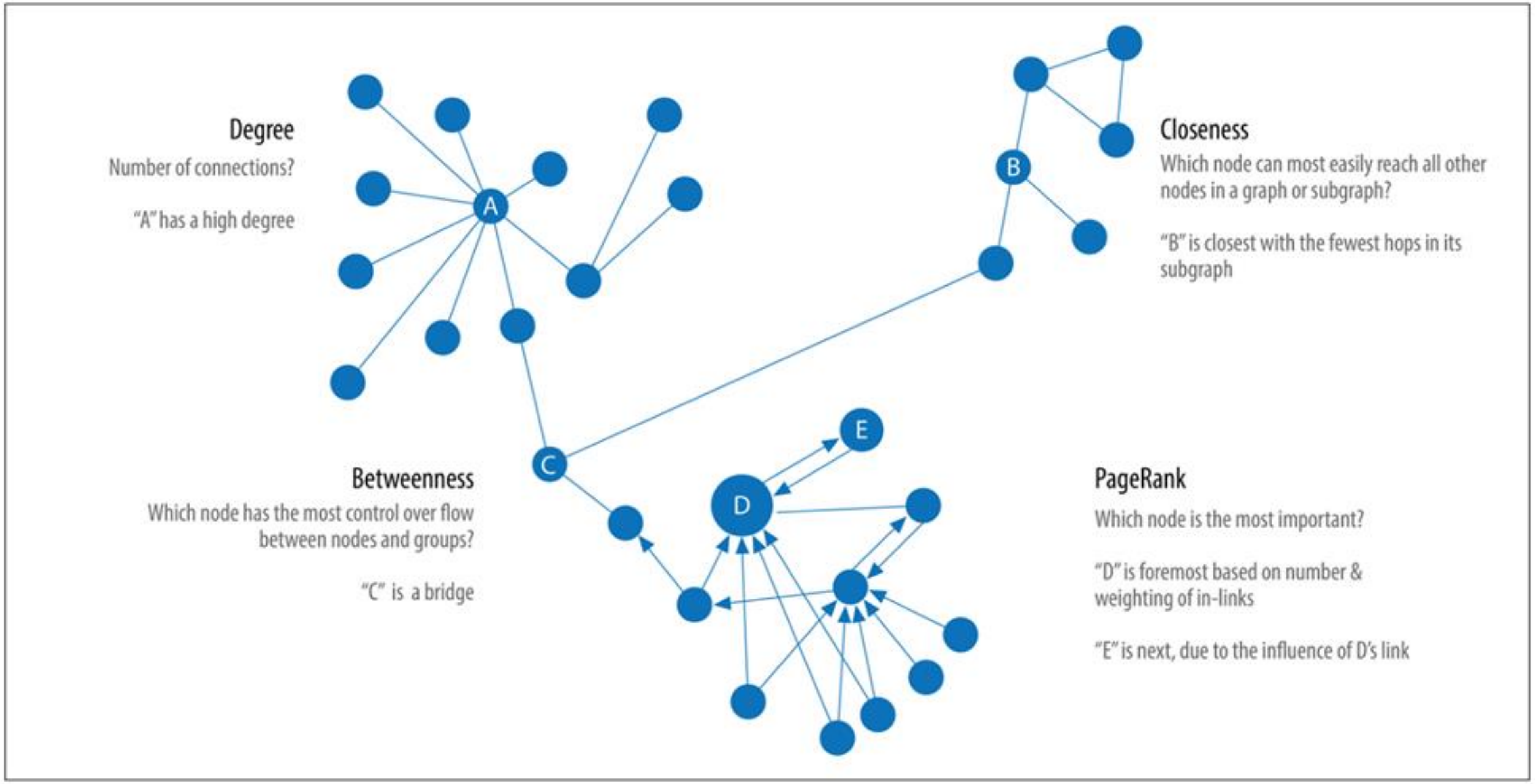
Betwenness

This measure links centrality to the control and influence that actors are potentially able to exert on exchange and communication flows

-**An actor is central in terms of betweenness if he/she is positioned on geodesics linking numerous actors in the reference population**.
The index thus expresses the attitude of control and can be used to measure the degree of influence an actor is able to exert in its relational topology of reference.

-Bearing in mind all the pairs of actors in the network, the more central an actor is, the more she/he is localised within pairs of relationships that develop in the network.

Some basic network measures – visual examples



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Interfirm Collaboration Networks: The Impact of Large-Scale Network Structure on Firm Innovation

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The structure of alliance networks influences their potential for knowledge creation. Dense local clustering provides information transmission capacity in the network by fostering communication and cooperation. Nonredundant connections contract the distance between firms and give the network greater reach by tapping a wider range of knowledge resources. We propose that firms embedded in alliance networks that exhibit both high clustering and high reach (short average path lengths to a wide range of firms) will have greater innovative output than firms in networks that do not exhibit these characteristics. We find support for this proposition in a longitudinal study of the patent performance of 1,106 firms in 11 industry-level alliance networks.

Key words: alliances; networks; innovation; patents

Motivation

Quantify and qualify network importance and impact of alliances on the production of knowledge

Aim and research questions

Does the structure of an industry-level interfirm network influence the rate of knowledge creation among firms in the network? If so, what structural properties will enhance firm innovation?

Theoretical background and mechanisms

Alliances represent a conduit of knowledge circulation → variety of different knowledge elements and the scientific and engineering know-how. Relationships can occur directly between firms or indirectly (by means of other firms)

<u>CLUSTERING</u>

A proportion of a firm's partners that are themselves directly linked to each other. Clustering increases the information transmission capacity of a network.
Moreover the multiple pathways between firms also enhance the fidelity of the information received.
The internal density of a cluster can increase the dissemination of alternative interpretations of problems and solutions. An high degree of trust can be found and a common language can be promoted.

<u>REACH</u>

The size of the network and its average path lenght also impacts information diffusion and novel recombination. The likelihood, speed and integrity of knowledge transfer between two firms are directly related to the path lengh separating two firms. **A firm that is connected to a large number of firms by a short average path can reach more information with less risk of distortion**.

Theoretical background and mechanisms

The combination of clustering and reach enables a wide range of information to be exchanged and integrated rapidly, leading to a greater knowledge creation (a sort of multiplicative interaction).

Hypothesis. *Firms participating in alliance networks that combine a high degree of clustering and reach will exhibit more knowledge creation than firms in networks that do not exhibit these characteristics*

Methods – database building

The authors to test the HP use a large, unbalanced panel of U.S. firms for the period 1990-2000.

The panel includes all U.S. firms that were part of the alliance networks of **11 high-technology manufacturing industries**: aerospace equipment; automotive bodies and parts; chemicals; computer and office equipment; household audiovisual equipment; medical equipment; petroleum refining and products; pharmaceuticals; semiconductors; telecommunications equipment and measuring and controlling devices

Industries selected because knowledge creation is a fundamental source of competitive advantage, alliances are actively used as tool to develop innovations, patents are widely used ad IP instruments.

To be included in the panel, each alliance should have at least one firm that was a member of the target industry.

Final db: 1,106 firms in 3,663 alliance. Many of the alliances included more that two participating firms, but because any type of alliance may provide a path for knowledge diffusion (even because the breadth of an alliance’s true activity is often much greater than what is formally reported

Methods – methodology & variable selection

Methodology: Poisson regression because patents are non-negative integer variable

Dependent variable: to capture the knowledge creation of firms, the authors select patent (as external validated source of knowledge)

2 main independent variables (clustering and reach) and their interaction, 3 Firm level control variable, 4 Industry level control variable

Model estimated in one year, two years and three years lag

$$
\begin{aligned}
&Patents_{it+1(2,3)} \\
&= f(Clustering_{jt}, Reach_{jt}, Clustering * Reach_{jt}, \\
&\quad R\&D\ Alliance\ \%_{jt}, R\&D\ Intensity_{jt}, Centrality_{it}, \\
&\quad Local\ Efficiency_{it}, Centralization_{jt}, Density_{jt}, \\
&\quad Presample\_Patents_{it},
\end{aligned}
$$

Methods – main independent variables

Clustering : the percentage of a firm's alliance that are also partnered with each other (localized pocket of dense connectivity ≠ global density). It is the weighted overall clustering coefficient that measures the proportion of triples for which transitivity hold. The factor of 3 ensures the fact that the values range between 0 and 1 (each triangle implies 3 connected triples)

$$Clustering_w = \frac{3 \times (\text{number of triangles in the graph})}{(\text{number of connected triples})}$$

Reach: average distance weighted network. It considers number of firms that can be reached by any path from a given firm and path length it takes to reach them. "n" represent the number of nodes and "d" the minimum distance from a focal node "i" to a partner "j"

$$Average\ distance\ weighted\ reach = \left[\sum_n \sum_j 1/d_{ij}\right] \Big/ n,$$

Methods –control variables

Firm

- **Pre-sample patents:** the sum of patents obtained by the firm 5 years before the studied period
- **Betweenness centrality**: Does a more central position in the network may support the knowledge generation process
- **Local efficiency**: how much does the firm’s local network influence knowledge generation? it captures the extent to which a firm’s partners are nonredundant, indicating eventually the presence of non structural holes

Industry

- **Network density**
- **Centralization**: highly centralized networks are those in which all ties tun through one or a few nodes
- **Industry R&D intensity**: to control for the differences in the emphasis on and costs. It considers annual R&D expenditures in each firms
- **Proportion of alliances for R&D, technology transfer or licensing**

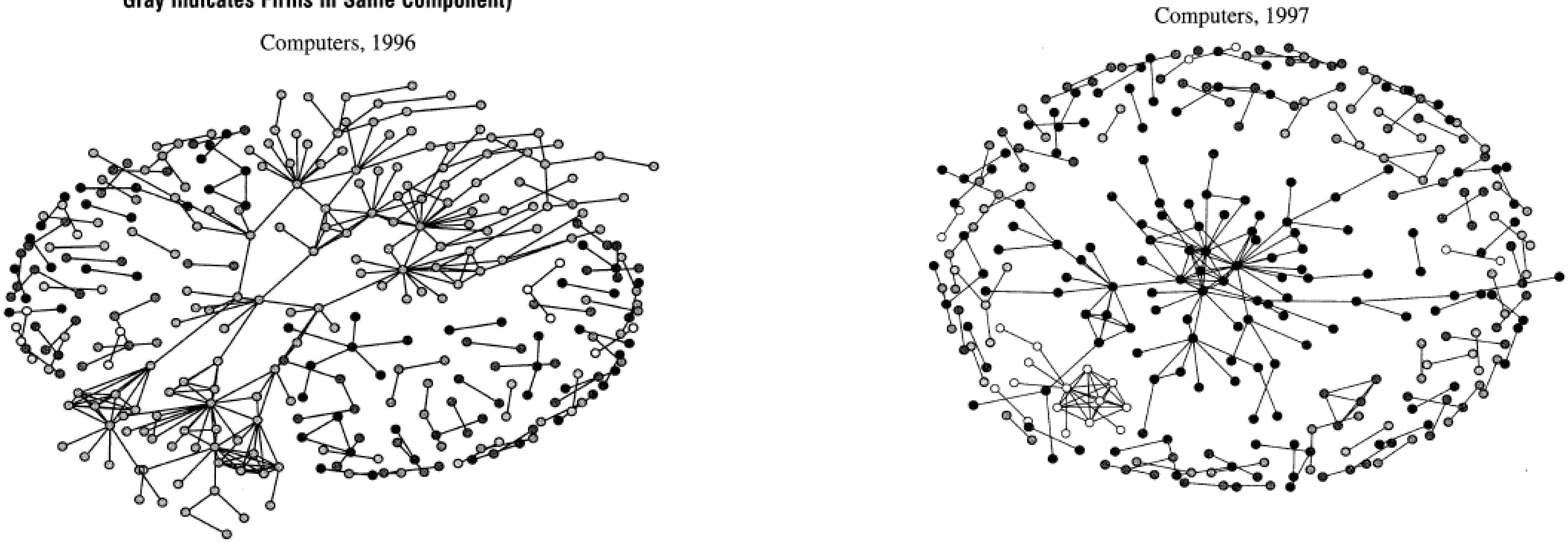
Descriptive statistics

Table 1 Network Size and Component Structure, Averages over 1992–2000

Industry	Average number of firms from industry in alliances[a]	Average number of alliances per firm	Average network size (nodes)[b]	Percent in main component (%)
Aerospace	9	3.05	28	46
Automotive	15.67	3.43	53.2	37
Chemicals	45.17	2.97	199.8	11
Computers and office equipment	79.67	4.48	347	45
Household audiovisual equipment	9	1.5	28.3	10
Measuring and controlling	22.67	1.96	48.33	21
Medical equipment	66.17	1.66	172.33	7
Petroleum refining and products	5.3	2.65	24.83	18
Pharmaceuticals	218.33	2.54	510	64
Semiconductors	58.67	3.51	204	55
Telecommunication equipment	44.83	6.53	266.33	54

Descriptive statistics

Figure 1 Network Size and Component Structure (Common Shade of Gray Indicates Firms in Same Component)



Results

Table 2 Panel Negative Binomial Regression Models with Fixed and Random Effects ($N = 1,106$; $Obs = 3,444$)

	$Patents_{it+1}$			$Patents_{it+2}$			$Patents_{it+3}$		
	1	2	3	4	5	6	7	8	9
Fixed effects									
Constant	1.136** (0.354)	0.582 (0.359)	0.604 (0.360)	1.257** (0.327)	1.663** (0.333)	1.614** (0.324)	1.433** (0.337)	1.859** (0.369)	1.825** (0.368)
Presample Patents	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)
Density	−0.248 (1.154)	−0.624 (1.358)	−0.527 (1.468)	−0.411 (1.529)	−2.220 (1.808)	−2.637 (1.843)	−2.012 (1.861)	−1.598 (2.509)	−1.674 (2.134)
Centralization	−0.014 (0.008)	−0.014 (0.008)	−0.012 (0.008)	−0.018** (0.006)	−0.016* (0.007)	−0.035** (0.006)	0.019** (0.007)	0.019** (0.007)	0.019* (0.007)
Ind. R&D Intensity	2.739 (2.668)	2.867 (2.522)	2.877 (2.581)	0.741 (2.366)	−0.088 (2.373)	−0.246 (2.327)	−7.126** (2.478)	−6.754** (2.504)	−6.754** (2.504)
R&D Alliance %	−0.112 (0.275)	0.223 (0.275)	0.222 (0.289)	0.068 (0.217)	−0.131 (0.223)	−0.188 (0.191)	−0.040 (0.248)	−0.305 (0.264)	−0.312 (0.304)
Efficiency	−0.199** (0.068)	−0.189** (0.072)	−0.190** (0.073)	−0.303** (0.091)	−0.321** (0.095)	−0.327** (0.087)	−0.267** (0.097)	−0.272** (0.089)	−0.270** (0.088)
Betweenness	0.003 (0.006)	0.003 (0.005)	0.003 (0.005)	0.005 (0.006)	0.004 (0.007)	0.002 (0.006)	−0.001 (0.009)	−0.001 (0.010)	−0.001 (0.010)
Clustering		0.420** (0.136)	0.507* (0.235)		0.346** (0.127)	−0.141 (0.196)		0.234 (0.183)	−0.319 (0.279)
Reach		0.010** (0.003)	0.011** (0.003)		−0.012** (0.003)	−0.020** (0.004)		−0.007* (0.003)	−0.009* (0.004)
Clustering × Reach			−0.015 (0.030)			0.081** (0.023)			0.014* (0.007)
Log Likelihood	−4,646.65	−4,637.32	−4,637.12	−4,597.46	−4,586.78	−4,577.98	−4,468.75	−4,464.64	4,464.46
Random effects									
Constant	1.118** (0.309)	0.542 (0.339)	0.541 (0.339)	0.984** (0.307)	1.342** (0.303)	1.256** (0.290)	0.920** (0.296)	1.333** (0.331)	1.214** (0.321)
Presample Patents	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)
Density	1.444 (0.900)	0.250 (1.092)	0.243 (1.166)	0.527 (1.197)	−1.872 (1.394)	−2.451 (1.352)	−1.454 (1.434)	−1.286 (1.618)	−1.538 (1.654)
Centralization	−0.021** (0.006)	−0.020** (0.007)	−0.021** (0.007)	−0.021** (0.006)	−0.020** (0.006)	−0.027** (0.005)	0.016* (0.006)	0.017* (0.007)	0.013* (0.006)
Ind. R&D Intensity	0.887 (2.429)	1.030 (2.408)	1.027 (2.424)	−0.357 (2.231)	−0.818 (2.151)	−0.590 (2.135)	−8.029** (2.278)	−7.987** (2.343)	−8.101** (2.460)
R&D Alliance %	0.014 (0.230)	0.383 (0.214)	0.384 (0.222)	0.208 (0.215)	−0.017 (0.187)	−0.090 (0.158)	0.106 (0.220)	−0.139 (0.233)	−0.153 (0.274)
Efficiency	−0.342** (0.062)	−0.336** (0.069)	−0.336** (0.069)	−0.396** (0.079)	−0.436** (0.081)	−0.435** (0.073)	−0.297** (0.087)	−0.307** (0.080)	−0.312** (0.078)
Betweenness	0.008 (0.005)	0.007 (0.004)	0.007 (0.005)	0.003 (0.005)	0.004 (0.005)	0.001 (0.005)	−0.000 (0.008)	−0.001 (0.008)	−0.001 (0.008)
Clustering		0.554** (0.106)	0.548** (0.212)		0.485** (0.116)	−0.101 (0.186)		0.152 (0.159)	−0.422 (0.344)
Reach		0.008** (0.003)	0.008* (0.003)		−0.013** (0.003)	−0.022** (0.003)		−0.008* (0.003)	−0.011** (0.004)
Clustering × Reach			0.001 (0.028)			0.082** (0.019)			0.043* (0.020)
a	0.707** (0.047)	0.716** (0.047)	0.710** (0.048)	0.675** (0.047)	0.684** (0.048)	0.690** (0.480)	0.650** (0.046)	0.652** (0.046)	0.652** (0.046)
b	0.358** (0.021)	0.360** (0.022)	0.360** (0.022)	0.321** (0.019)	0.328** (0.020)	0.334** (0.02)	0.291** (0.018)	0.290** (0.018)	0.293** (0.018)
Log likelihood	−8,520.70	−8,509.78	−8,509.78	−8,425.33	−8,407.95	−8,392.95	−8,198.66	8,194.98	−8,193.03

Notes. All models include firm, time period, and industry effects. Standard errors are in parentheses.
$^{*}p < 0.05$, $^{**}p < 0.01$ (two-tailed tests for all variables).

implications

High information capacity and diversity of information together facilitate innovation production

Possible limitations for generalization of results :

- Duration of alliances
- Attributes/properties of the network are not addressed
- Different nature of tacit and explicit knowledge
- Results could be limitated to industries that use frequently alliances as a strategic tool