KMAC 경영혁신 연구논문 공모전

Develop Core Technological Competence!

R&D Management of Core Technology Through Technology Convergence Network and Innovation Performance of SMEs

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◆ Why SMEs?!

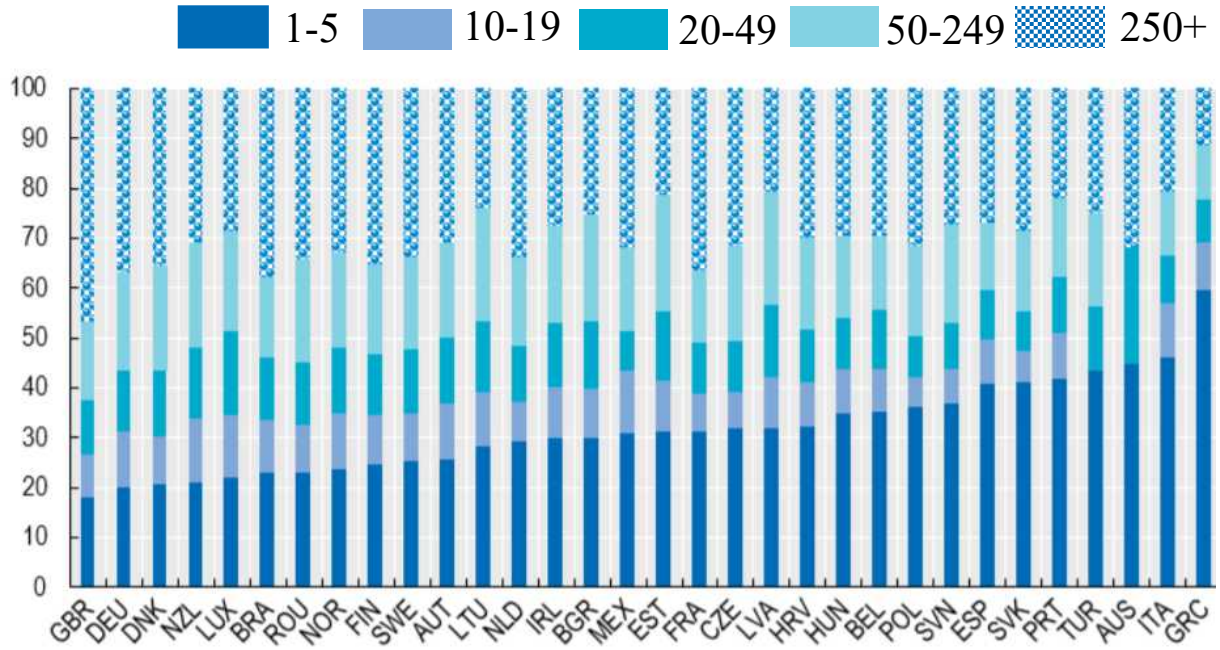
"SMEs play a key role in national economies around the world, generating employment and value added…"

99% of total enterprises

70% of total employment

50-60% of total value added

Source: OECD (2017)



Source: OECD (2017)

◆ Innovation in SMEs

- Since the early work of Schumpeter (1934), innovation has been considered as a central importance to all entrepreneurial activities and source of sustainable competitive advantage

<Two literature streams of innovation in SMEs>

Strategy Perspective

- Due to globalization and rapidly changing technological environment, innovation is even more critical for the success and survivals of SMEs

(Cefis & Marsili, 2006; Madrid-Guijarro, 2009).

Policy Perspective

- Encouraging innovation in SMEs becomes core industrial initiative for many policy maker for economic development of at regional, or national level

(Kang & Park, 2012; Jones and Tilley, 2003)

◆ Achieving innovation in SMEs?

- Despite of its importance of encouraging innovation of SMEs, they have several inherited problems which hamper their innovation (Madrid-Guijarro et al., 2009; Lee et al, 2010; Xie et al., 2012)

➡ *"Barriers of innovation"*

Rapid changing technological paradigm

Market uncertainty

Lack of financial resources
(Smallbone et al., 2003)

Inadequate human resource
(Hewitt-Dundas, 2006)

Technological complexity

Weak technological capability
(Kim et al., 1993; Nooteboom, 1994)

◆ Question?!

*how can SMEs **strategically** overcome those "barriers of innovation" ?*

(Teece, 1996; Raymond & St-Pierre, 2010; Xie et al., 2010)

◆ Innovation strategy for SMEs

➡ Developing *Core Technological Competence!*

Core Technological Competence (Coombs, 1996)

Resource: **Core Technology**

- Technological knowledge where a firm has expertise over other technologies, which are derived from concentrated, long-term involvement in R&D

(Duysters & Hagedoorn, 2000)

Capability: **Organizational capability**

- Capability to deploy and coordinate diverse technologies and expertise with their core technology effectively

(Coombs, 2006)

◆ Why CTC for SMEs ?

1 Core technological competence enhance R&D efficiency (Duysters & Hagedoorn, 2000)

- Compared to distributing limited R&D resources on various fields of technologies. pursuing innovation based on core technology where a firm has relative expertise can be more effective

Core technological capability → Innovation performance (Huang, 2011; Wang et al., 2004)

2 Core technological competence is difficult to imitate (Coombs, 1996)

- Due to "**tacitness**" of technological expertise and accumulated know-how on core technology
- What is even more difficult is **organizational capability** of complex coordination and application of technologies both within production and R&D (Miyazaki, 1999; Hamel and Prahalad 1994)

◆ Why CTC for SMEs ?

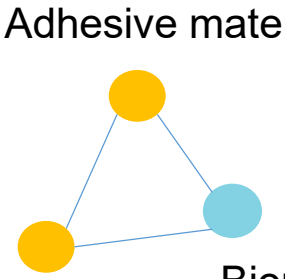
3 Core technological competence enables firm to diversify into various markets (Prahalad & Hamel, 1990)

3M Science. Applied to Life.™

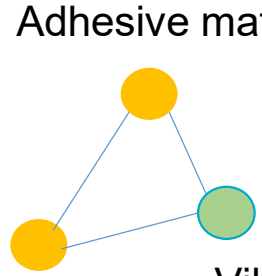
Core technologies of 3M

: Adhesive material, Advanced composite material, Additive manufacturing etc..

Crown adhesive



Adhesive for automobile parts



◆ Limitation of existing studies

1 Existing studies have largely focused on **Multi-national Large enterprises**

➡ *Lack of framework for SMEs to apply and develop CTC in their specific context !!*

Internal R&D strategy

External R&D strategy

Core technological competence ➡

2 Existing measures of CTC is difficult to offer **meaningful strategic implication**

R&D expenditure	The number of patent	R&D intensity	Linkage to scientific community
(McCutchen Jr & Swamidass, 1996)	(Duysters & Hagedoorn, 2000)	(Deeds, 2001)	(Henderson & Cockburn, 1994)

➡ *How can a firm develop their core technological competence ?*

◆ Approach of this study

- This study aims to offer **R&D management strategy** to **develop core technological competence for SMEs**.

- The effort of firm to refine their existing knowledge and to search for new knowledge should be balanced.

(Andriopoulos & Lewis, 2009)

◆ Internal R&D strategy to develop Core Tech Comp

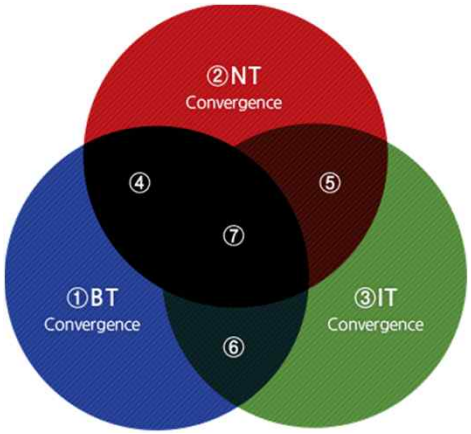
➡ *Technology Convergence Network (TCN) approach*

- TCN captures how heterogeneous technological knowledge are combined into new, common unity of technology

(Porter & Rafols, 2009)

General usage : TC at industry-level

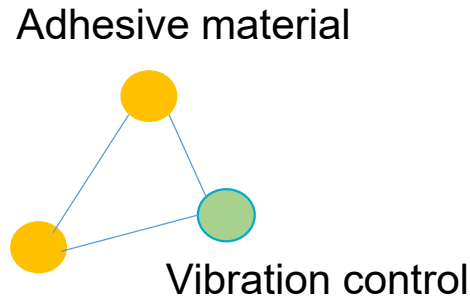
For this study : TC at a firm-level



Convergence of

IT, BT, and NT

Adhesive for automobile parts



◆ Internal R&D strategy to develop Core Tech Comp

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	Industry-level TCN	Firm-level TCN
Principal agent	All R&D entities in an industry	Single firm
Condition	No firm can affect industry-level TCN	Intentional, strategic decision of a firm in converging their technology
Meaning	Visualizing macroscopic TC trend	Representation of a firm's effort to create technological invention

◆ Internal R&D strategy to develop Core Tech Comp

Firm-level TCN ► **Technological capability of a firm** (Yayavaram & Ahuja, 2008; Xu et al., 2017)

- Shows the pattern of a firm utilizing their technological resource to create tech invention
- Converging technologies require high level of technological skills and expertise (Jeong, 2014; Kim, Jung, & Hwang, 2019)

Core technology in TCN ► **Core Tech Competence of a firm**

- Shows the pattern of a firm using core technology in conjunction with other technologies

Firm's capability in using core technology to create technological invention!

◆ Internal R&D strategy to develop Core Tech Comp

Firm-level TCN ▶ **Technological capability of a firm** (Yayavaram & Ahuja, 2008; Xu et al., 2017)

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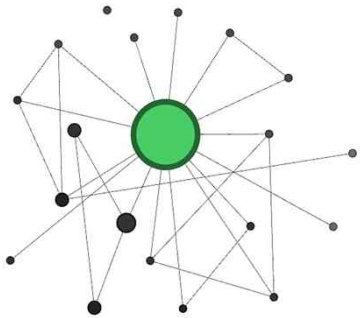
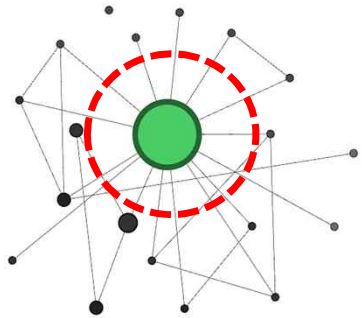
Core technology in TCN ▶ **Core Tech Competence of a firm**

1) Construct a firm-level TCN



2) Identify core technology



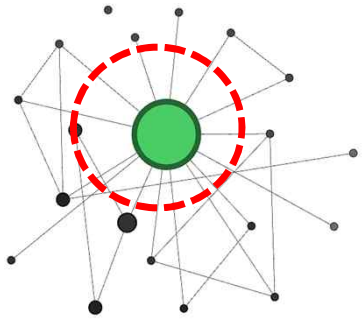
3) Analyze core technology in TCN

- Degree Centrality
- Degree Struchole
- Between Centrality

◆ Internal R&D strategy to develop Core Tech Comp

Q. *In which state of core technology is most beneficial for technological innovation ?*

Analyzing core technology in TCN



Degree Centrality

Degree Structural hole

Betweenness Centrality

Technological innovation performance

◆ External R&D strategy to develop Core Tech Comp

University R&D collaboration

Problems of innovation in SMEs

1. R&D manpower, research infrastructure
2. financial resource to invest in R&D
3. Uncertainty involved in R&D process

What university can offer to SMEs

- R&D human resource, research facility
- Low cost, Government support (Lee & Kang, 2010)
- Risk sharing

University R&D collaboration

- Process innovation (e.g. Un & Asakawa, 2015)
- Product innovation (e.g. Un et al., 2010)
- Financial performance (e.g. George et al., 2012)

◆ External R&D strategy to develop Core Tech Comp

Unresolved Question?

"In which condition should SME conduct University R&D collaboration?"

- Effectiveness of R&D collaboration strategy contingent upon technological competence of firm.

(Grigoriu & Roathermel, 2017; Wang et al., 2015)

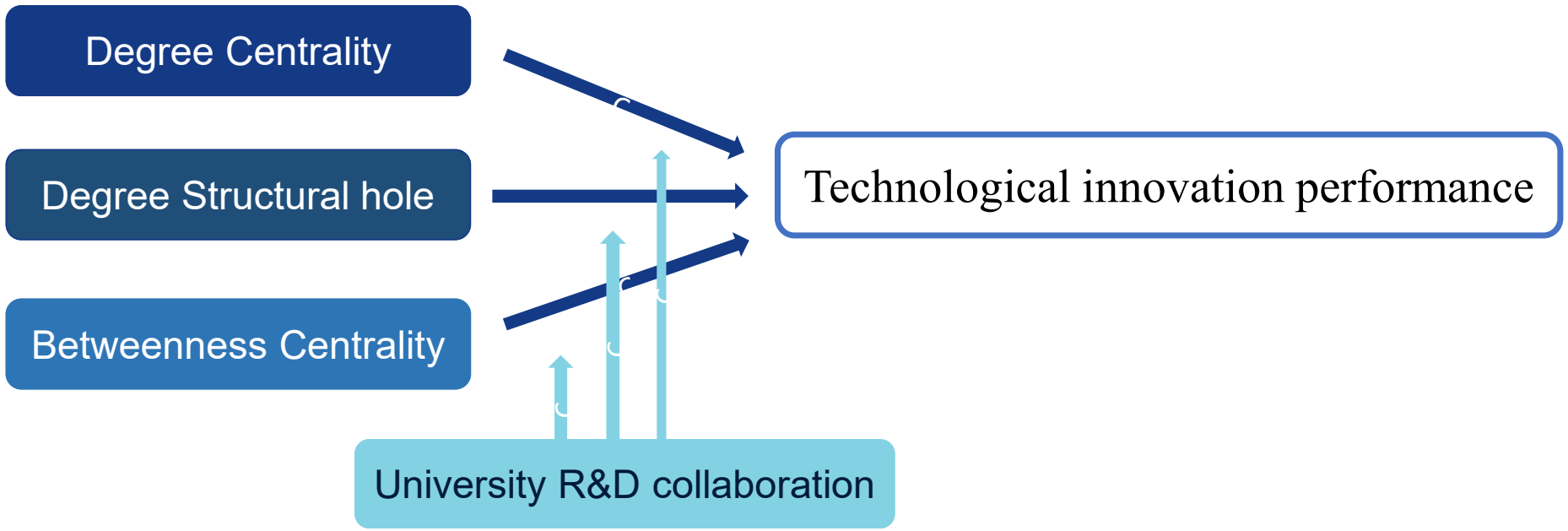
- Without proper absorptive capacity, external R&D can be detrimental.

(Tsai, 2009)

◆ External R&D strategy to develop Core Tech Comp

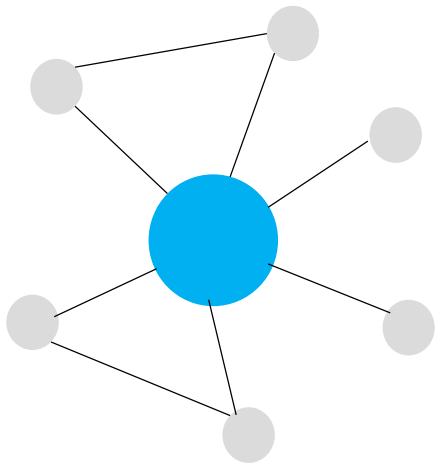
Unresolved Question?

"In which condition should SME conduct University R&D collaboration?"



◆ Hypothesis development

1 Degree Centrality of core technology



Equation : $$C_D = \frac{\sum_{i=1}^{n} a(i,j)}{n-1}$$

Focus : The number of direct linkage of core technology in TCN

Meaning : How diverse technologies have been converged with core technology in R&D process?

Benefit

- Learn diverse ways of utilizing their core technology
- Enhance capability in new technologies

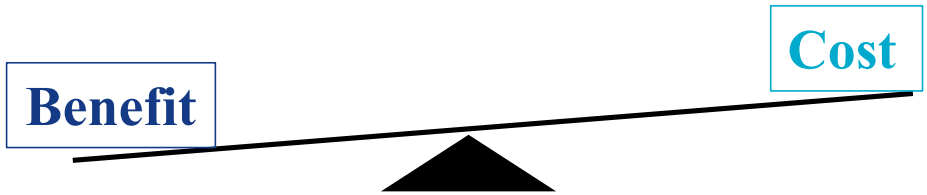
Cost

- High risk and uncertainty involved in TC activity
- Less attention to improvement of core technology itself

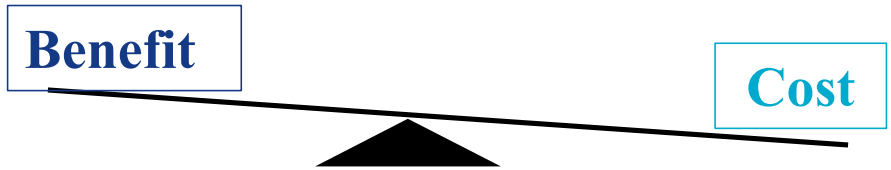
◆ Hypothesis development

1 Degree Centrality of core technology

Low → *Moderate* → *High*



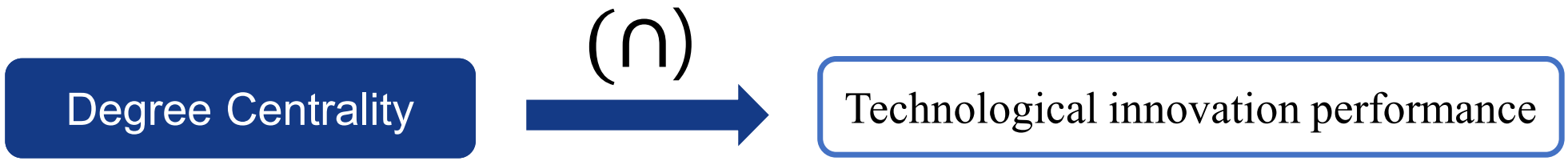
- Able to apply core technology in various technical problems and contexts
- Less cost of not investing in core technology itself



- Too much resource invested to convergence of core technology
- Lack of attention on refining core technology

◆ Hypothesis development

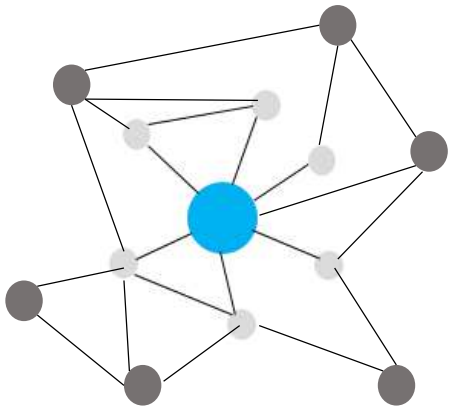
1 Degree Centrality of core technology



H1. Degree centrality of core technology has inverted U-shaped relationships with innovation performance of SME

◆ Hypothesis development

2 Degree structural hole of core technology



Equation : $S_D = [\sum_j (1 - \sum_q p_{iq} m_{jq})]/C_j$

Focus : Measures the redundancy of linkages within neighboring groups of core technology in TCN

Meaning : The degree of technology convergence among complementary technologies of core technology

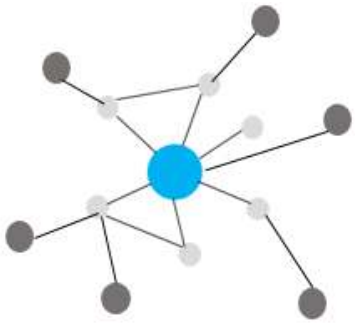
Degree SH of core technology ↑
- **Few** complementary technologies are converged each other

Degree SH of core technology ↓
- Complementary technologies have been **actively converged**

◆ Hypothesis development

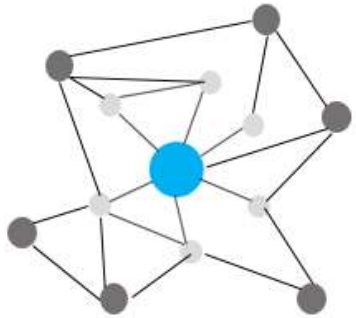
2 Degree structural hole of core technology

Degree SH of core technology ↑



✓ **Few** complementary technologies are converged each other

Degree SH of core technology ↓



✓ Complementary technologies have been **actively converged**

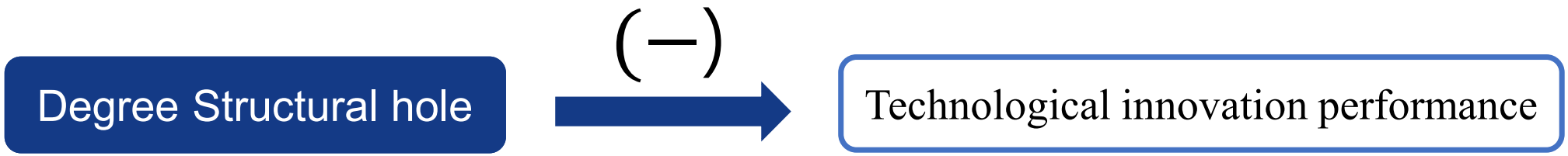
- Considering technology convergence require high technological capability, (Jeong, 2014; Kim, Jung, & Hwang, 2019)

Degree SH of core technology ▶ Technological competence in **complementary technologies**

- Competence in both core technology and its complementary technologies enhance CTC

◆ Hypothesis development

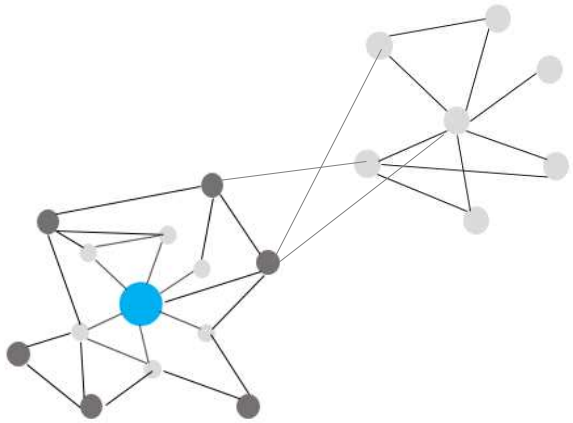
2 Degree structural hole of core technology



H2. Degree structural hole of core technology has negative relationship with innovation performance of SME

◆ Hypothesis development

3 **Betweenness Centrality** of core technology



Equation : $C_B = \sum_i^n \sum_{<k}^n \frac{g_{ik}(j)}{g_{ik}} \frac{2}{(n-1)(n-2)}$

Focus : Measures the centralization of core technology with respect to the whole TC network structure

Meaning : The degree of influence of core technology in the whole knowledge base and R&D process of firm

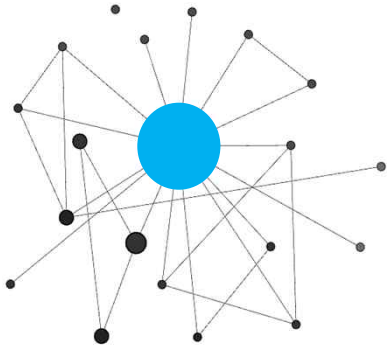
Btw Cen of core technology ↑
- Centrality positioned in whole TC network

Btw Cen of core technology ↓
- Positioned in periphery area of whole TC network

◆ Hypothesis development

3 **Betweenness Centrality** of core technology

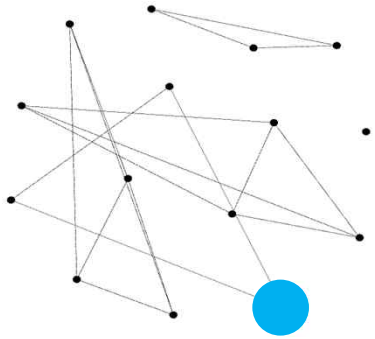
Btw Cen of core technology



- Core technology is centrally positioned in whole TC network

㈜ 슈프리마 HQ

Btw Cen of core technology



- Core technology is located in the periphery area of whole TC network

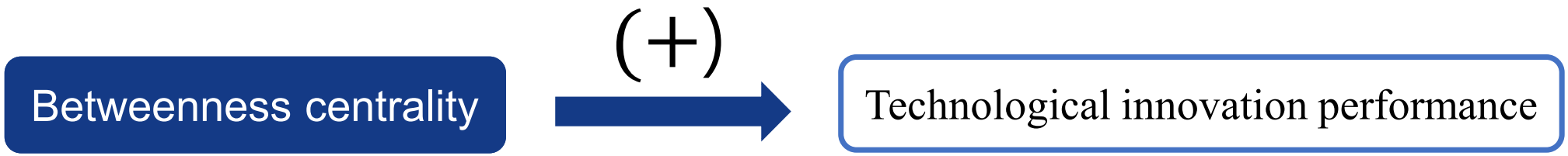
㈜ PNP 네트워크

Centralization of core technology

- ✓ Efficiency of R&D investment (Guan & Liu, 2016)
- ✓ Cognitive distance in converging core technology
- ✓ Influence of core technology in whole R&D (Xu et al., 2017)

◆ Hypothesis development

3 Betweenness Centrality of core technology

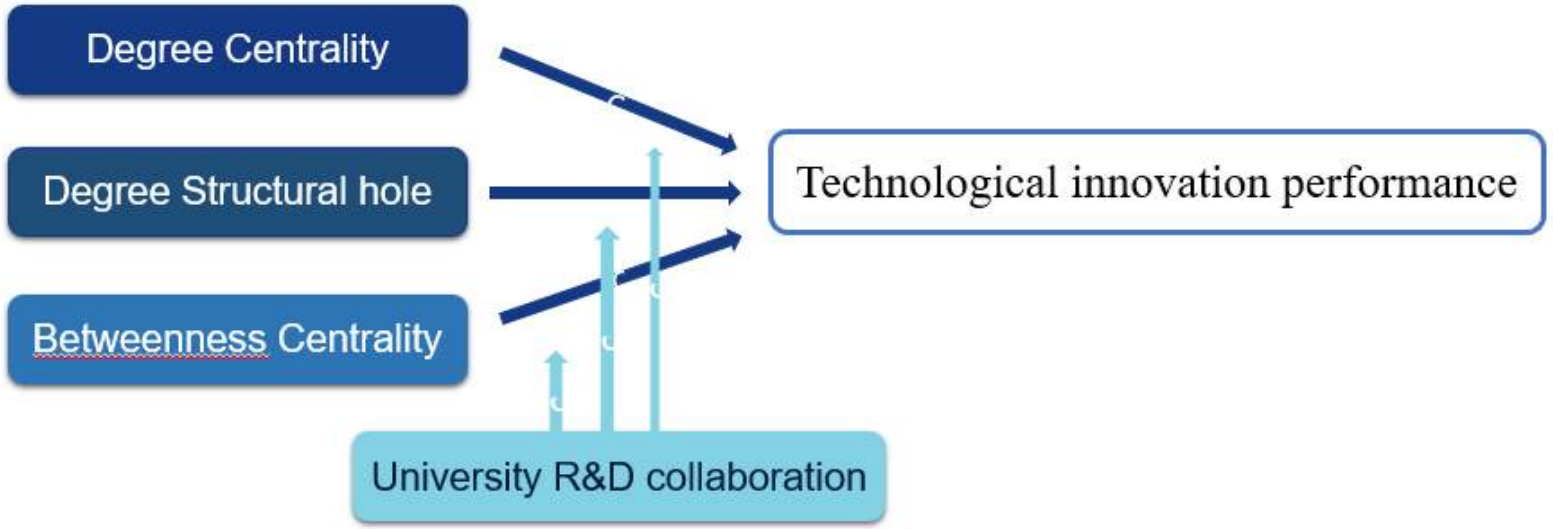


H3. Betweenness centrality of core technology has positive relationship with innovation performance of SME

◆ Hypothesis development

4 University R&D collaboration

- Considering several benefits that are offered by university for innovation in SMEs



"Positive moderation effect of University R&D Collaboration"

◆ Data & Sample

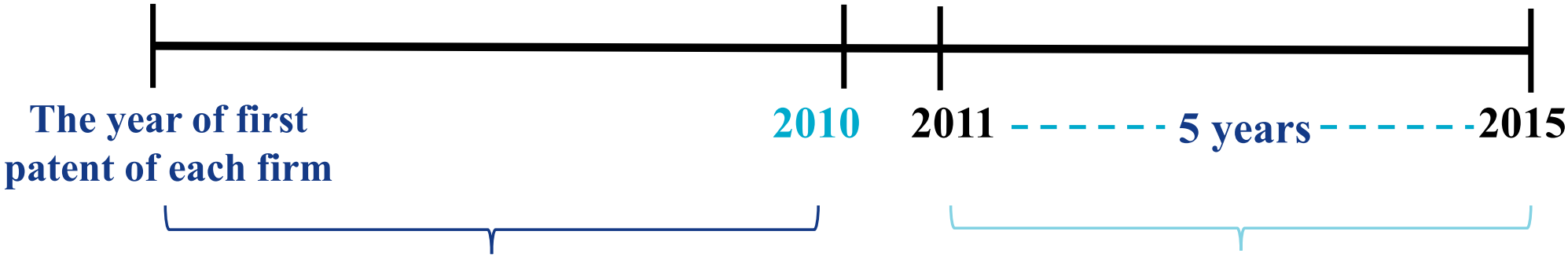
Sample

- Final sample **:** **547** Korean SMEs in ICT industry
- List of SMEs were obtained in **SMINFO database**, which are offered by Ministry of SMEs and Startups (MSS)
- SMEs in ICT industry are distinguished based on industry code (C26, C28)
  - ✓ C26: Manufacture of electronic components, computer; visual, sounding and communication equipment
  - ✓ C28: Manufacture of electrical equipment

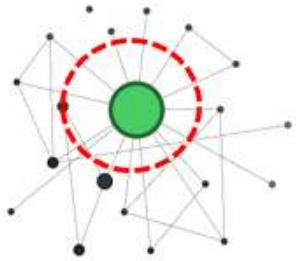
Data source

- For patent data, **KIPRIS** (From 1970 to 2017)
  - ✓ KIPRIS: a web-based patent data searching engine managed by the Korean Intellectual Property Office (KIPO)
- For financial information of firm, **KISVALUE**
  - ✓ KISVALUE: firm database which is managed by NICE information service corporation of Korea.

◆ Empirical setting



Independent variables



- Degree Centrality
- Degree Structural hole
- Betweenness Centrality

✓ Computed by UCINET 6 (Borgatti et al., 2002).

Dependent variables

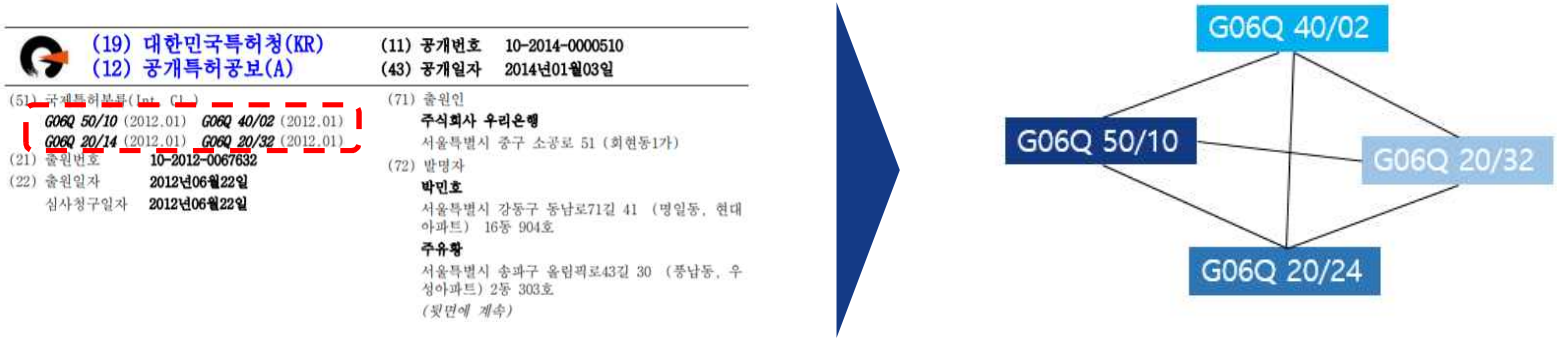
Technological innovation performance

✓ Measured by the number of newly applied patents

(Yayavaram & Ahuja, 2008; Guan & Liu, 2016)

◆ Construction of TCN

- **547 TC networks for each of 547 SMEs**
- Technological field: Patent IPC code
- TC network based on **co-occurrence network** of technology classification code (IPC code)



◆ Identification of Core technology

- Percentage share of certain IPC to whole IPC occurrences $= \frac{IPC_i}{\sum_{i=1}^{n} IPC_i}$

Core technology if the value of $\frac{IPC_i}{\sum_{i=1}^{n} IPC_i} > 7\ \%$ (higher standards compared to 3% suggested by)

Granstrand et al. (1997), Phene et al. (2012) Shin et al. (2017)

◆ Variables

Dependent variable

- ***the number of patent newly applied*** during five-year of observation period (2011 – 2015)

Independent variable

- Degree Centrality, Degree Structural hole, Betweenness Centrality

Moderation variable

- University R&D collaboration: the number of patent co-applied by firm and university during observation period

(Henderson et al., 1998; Geuna and Nesta, 2006)

Control variables

Firm age	Firm size	Sales
Return to Sale	Diversity of Knowledge	University R&D collaboration
Number of core knowledge element	Total number of R&D collaboration	

◆ Statistical Method

- Negative binomial regression

$$\text{Innovation performance}_i = \exp(\beta_1 + \beta_2 Deg_{Cen} + \beta_3 Deg_{Structhole} + \beta_4 Btw_{Cen} + \beta_5 Deg_{Cen} * UnR\&D + \beta_6 Deg_{struc} * UnR\&D + \beta_7 Btw_{Cen} * UnR\&D + \beta_8 w_1 + \beta_9 w_2 + \beta_{10} w_3 + \beta_{11} w_4 + \beta_{12} w_6 + \beta_{13} w_7 + \beta_{14} w_8 + \beta_{15} w_9 + + \varepsilon_i)$$

$$w_i = control\ variables, \quad i = 1, \ldots, 9$$

- As our dependent variable is count variable, well-known examples of generalized linear model are Poisson regression and Negative binomial regression.
- However, our data shows over-dispersion, i.e., variance of outcome variables take larger value than conditional mean, this study used negative binomial regression.

◆ Results

Table 1

Simple correlation matrix

Variables	Mean	S.D	1	2	3	4	5	6	7	8	9	10	11
1. DV	10.297	17.74											
2. Firm age	16.323	78.285	-0.1385										
3. Firm size	93.261	78.285	0.2437	0.1611									
4. Firm sale	3299	3663	0.2501	0.1428	0.5494								
5. Returns to sales	146.7	708.07	0.2558	0.037	0.2613	0.4904							
6. Diversity of knowledge	28.294	29.373	0.5251	0.0985	0.192	0.279	0.3508						
7. Number of core elements	2.877	1.520	0.0293	-0.0226	0.0249	0.0011	0.0391	-0.0729					
8. Total R&D collaboration	0.638	1.503	0.2781	-0.0617	0.1595	0.2311	0.0602	0.1899	-0.0723				
9. University collaboration	0.159	0.683	0.2163	-0.0682	0.0695	0.0699	-0.0058	0.0692	-0.0094	0.5408			
10. Degree centrality	0.297	0.171	-0.0333	-0.1904	-0.1323	-0.0747	-0.021	-0.2378	-0.0122	-0.0058	0.0107		
11. Degree structural hole	0.495	0.246	-0.2981	-0.0549	-0.1655	-0.1734	-0.0983	-0.5079	0.0407	-0.2081	-0.1245	-0.142	
12. Betweenness centrality	0.089	0.104	0.1387	-0.075	-0.0427	-0.031	-0.0212	0.062	-0.0821	0.0415	0.0313	0.6134	-0.4063

◆ Results

Table3. Results of negative binomial regression

Variables	Core technology portfolio and Innovation performance					
	Model1	Model2	Model3	Model4	Model5	Model6
Control variables						
Firm age	-0.044***	-0.044***	-0.043***	-0.044***	-0.042***	-0.043***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Firm size	0.001**	0.001**	0.001***	0.001**	0.001***	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sales	0.000**	0.000**	0.000**	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Returns to Sale	-0.000***	-0.000***	-0.000**	-0.000**	-0.000***	-0.000**
	(0.000)	(0.000)	(0.000	(0.000)	(0.000)	(0.000)
Diversity of Knowledge	0.016***	0.017***	0.016***	0.012***	0.016***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Number of core element	0.065**	0.066**	0.053*	0.060*	0.069**	0.054*
	(0.032)	(0.032)	(0.032)	(0.031)	(0.031)	(0.031)
Total R&D collaboration	0.135***	0.135***	0.133***	0.125***	0.133***	0.126***
	(0.040)	(0.040)	(0.004)	(0.039)	(0.039)	(0.038)
Total University collaboration	0.140*	0.137*	0.130*	0.133*	0.123	0.124
	(0.079)	(0.080)	(0.079)	(0.078)	(0.079)	(0.077)
Independent variables						
Degree centrality		0.147	2.399***			1.178
		(0.316)	(0.898)			(0.947)
(Degree centrality)^2			-2.889***			-2.621**
			(1.072)			(1.099)
Degree structural hole				-0.799***		-0.567**
				(0.223)		(0.260)
Betweenness centrality					1.340***	1.620***
					(0.465)	(0.617)
Constamt	1.683***	1.623***	1.327***	2.215***	1.520***	1.939***
	(0.152)	(0.199)	(0.224)	(0.213)	(0.160)	(0.329)
Number of observation	547	547	547	547	547	547
Log likelihodd	-1700.3304	-1700.2214	-1696.8123	-1694.2227	-1695.9039	-1688.0748

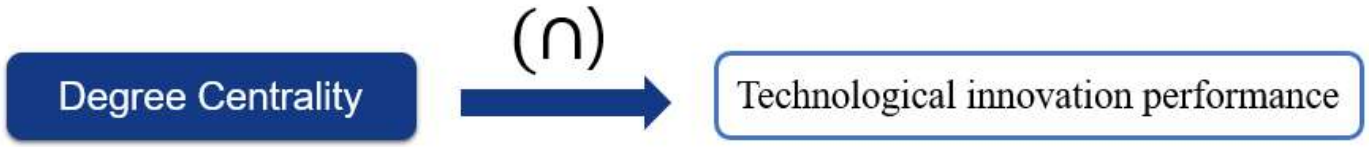
◆ Results

1 Degree Centrality of core technology

	Core technology portfolio and innovation performance					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Degree Centrality		0.147 (0.316)	2.389*** (0.901)			1.178 (0.947)
(Degree Centrality)^2			-2.881*** (1.074)			-2.621** (1.099)
Degree Structural hole				-0.827*** (0.227)		-0.567** (0.260)
Betweenness Centrality					1.336*** (0.467)	1.620*** (0.617)

***:p<0.01, **:p<0.05, *:p<0.1; standard errors in parentheses

Hypothesis 1 supported



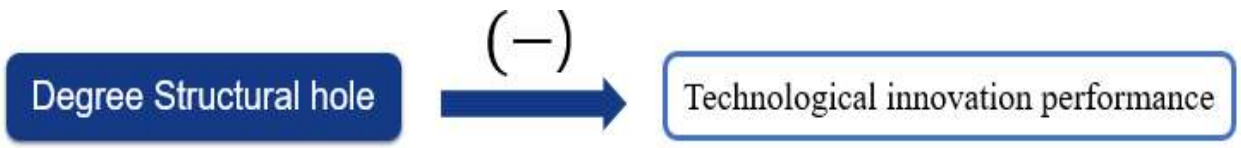
◆ Results

2 Degree Structural hole of core technology

	Core technology portfolio and innovation performance					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Degree Centrality		0.147 (0.316)	2.389*** (0.901)			1.178 (0.947)
(Degree Centrality)^2			-2.881*** (1.074)			-2.621** (1.099)
Degree Structural hole				-0.827*** (0.227)		-0.567** (0.260)
Betweenness Centrality					1.336*** (0.467)	1.620*** (0.617)

***:p<0.01, **:p<0.05, *:p<0.1; standard errors in parentheses

Hypothesis 2 supported



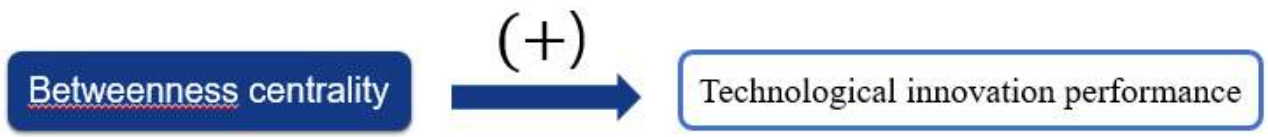
◆ Results

3 Betweenness Centrality of core technology

	Core technology portfolio and innovation performance					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Degree Centrality		0.147 (0.316)	2.389*** (0.901)			1.178 (0.947)
(Degree Centrality)^2			-2.881*** (1.074)			-2.621** (1.099)
Degree Structural hole				-0.827*** (0.227)		-0.567** (0.260)
Betweenness Centrality					1.336*** (0.467)	1.620*** (0.617)

***:p<0.01, **:p<0.05, *:p<0.1; standard errors in parentheses

Hypothesis 3 supported



◆ Results

Table4. Results of negative binomial regression

Variables	Interaction of core technology and university collaboration				
	Model1	Model2	Model3	Model4	Model5
Control variables					
Firm age	-0.044***	-0.043***	-0.044***	-0.042***	-0.044***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Firm size	0.001**	0.001**	0.001**	0.001**	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sales	0.000**	0.000**	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Returns to Sale	-0.000***	-0.000**	-0.000***	-0.000***	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Diversity of Knowledge	0.016***	0.016	0.013***	0.016***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Number of core element	0.065**	0.047	0.054*	0.063**	0.043
	(0.032)	(0.032)	(0.031)	(0.031)	(0.031)
Total R&D collaboration	0.135***	0.132***	0.127***	0.135***	0.126***
	(0.040)	(0.040)	(0.039)	(0.040)	(0.038)
Total University collaboration	0.140*	-0.125	-0.084	-0.061	-0.195
	(0.079)	(0.227)	(0.137)	(0.119)	(0.239)
Independent variables					
Degree centrality		2.110**			0.792
		(0.920)			(0.972)
(Degree centrality)^2		-2.652**			-2.239**
		(1.087)			(1.118)
Degree structural hole			-0.843***		-0.689***
			(0.224)		(0.266)
Betweenness centrality				1.144**	1.412**
				(0.470)	(0.625)
Degree centrality X University collaboration		0.895			-0.593
		(1.665)			(1.882)
(Degree centrality)^2 X University collaboration		-0.341			1.496
		(2.721)			(2.671)
Degree structural hole X University collaboration			0.609*		0.532
			(0.349)		(0.401)
Betweeneess centrality X University Collaboration				1.517*	0.960
				(0.835)	(1.043)
Constant	1.720***	1.409***	2.241***	1.555***	2.129***
	(0.154)	(0.231)	(0.213)	(0.160)	(0.344)
Number of observation	547	547	547	547	547
Log likelihodd	-1703.0245	-1695.583	-1692.7749	-1694.2296	-1685.148

◆ Results

4 Moderation of University R&D collaboration

❖ Degree centrality of core technology

	Moderating role of University R&D Collaboration		
	Model 2	Model 3	Model 4
Degree Centrality	1.960** (0.900)		
(Degree Centrality)^2	-2.568** (1.071)		
University collaboration	-0.171 (0.227)		
Degree Centrality X University Collaboration	0.961 (1.649)		
(Degree Centrality)^2 X University Collaboration	-0.414 (2.681)		

***:p<0.01, **:p<0.05, *:p<0.1; standard errors in parentheses

◆ Results

5 Moderation of University R&D collaboration

❖ Degree Structural hole of core technology

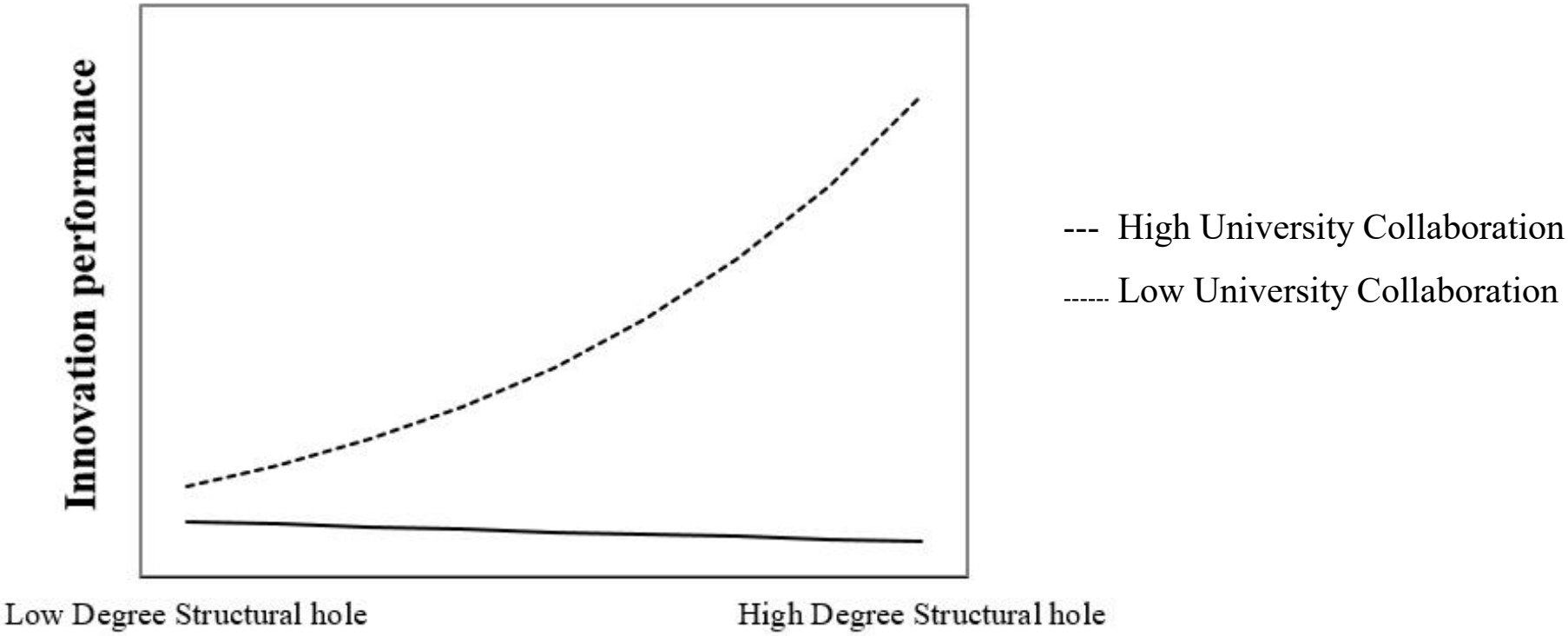
	Moderating role of University R&D Collaboration		
	Model 5	Model 6	Model 7
Degree Structural hole		-0.870*** (0.227)	
University Collaboration		-0.08 (1.137)	
Degree Structural hole X University Collabo		0.607* (0.350)	

***:p<0.01, **:p<0.05, *:p<0.1; standard errors in parentheses

◆ Results

5 Moderation of University R&D collaboration

❖ Degree Structural hole of core technology



◆ Results

6 Moderation of University R&D collaboration

❖ Betweenness Centrality of core technology

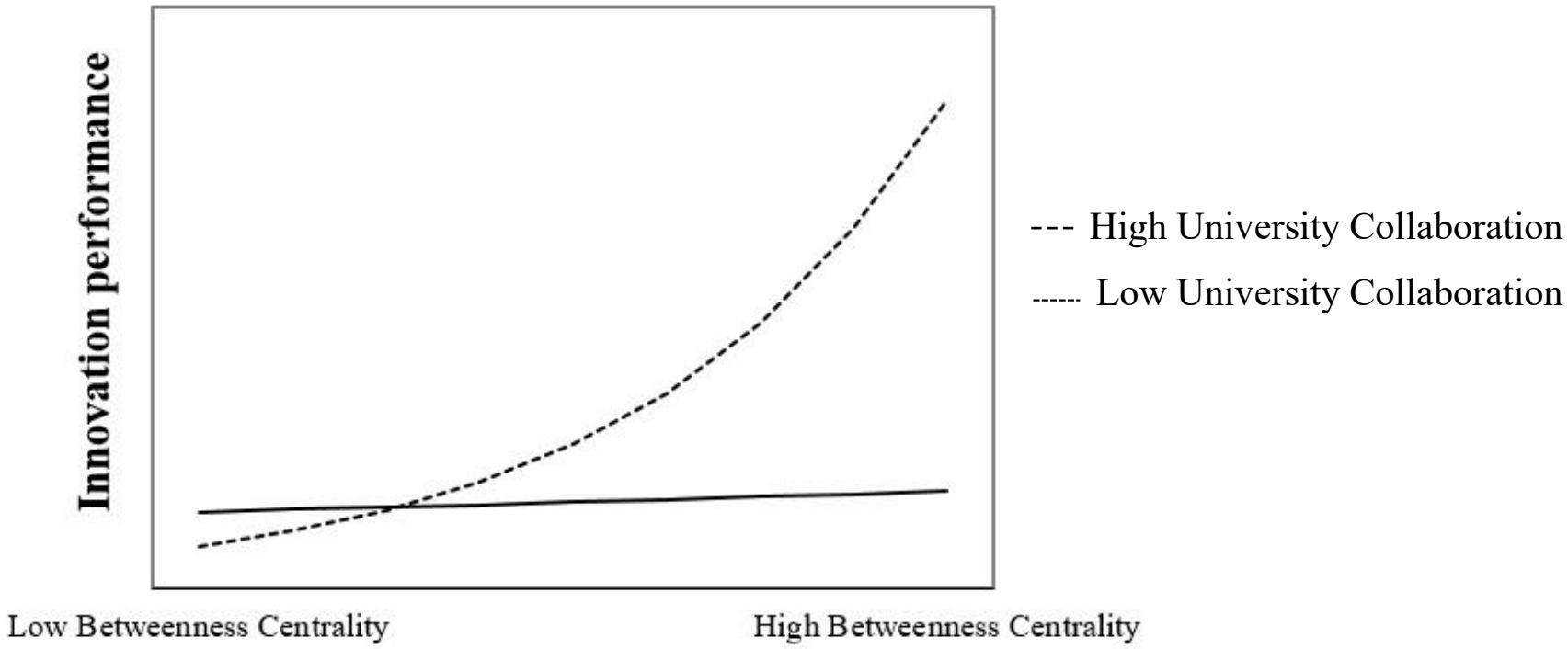
	Moderating role of University R&D Collaboration		
	Model 5	Model 6	Model 7
Betweenness Centrality			1.142*** (0.471)
University Collaboration			-0.061 (0.120)
Betweenness Cenrality X University Collaboration			1.515** (0.8358)

***:p<0.01, **:p<0.05, *:p<0.1; standard errors in parentheses

◆ Results

6 Moderation of University R&D collaboration

❖ Betweenness Centrality of core technology



◆ Discussion

Contributions

- This study expands the application scope of technology convergence by focusing on firm-level TC network.
  - ✓ most prior studies have focused on macroscopic technology convergence which often occurs at industry-level or entire technological domains
- This study contributes to strategy research for SMEs.
  - ✓ Core technological competence is mostly discussed in the context of large, multi-national enterprises,
  - ✓ This study offer strategic framework to apply the CTC for specific context of SMEs!

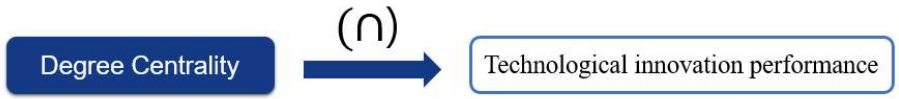
➡ *" How to develop core technological competence in SMEs "*

◆ Discussion

Implications

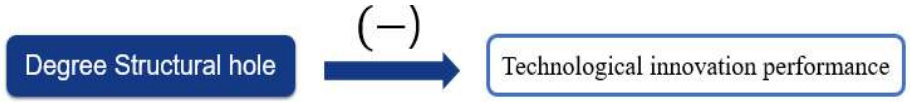
R&D Management strategy for innovation of SMEs

1 Degree centrality Perspective



✓ **Too much or too little** TC activity of core technology is harmful for future technological innovation.

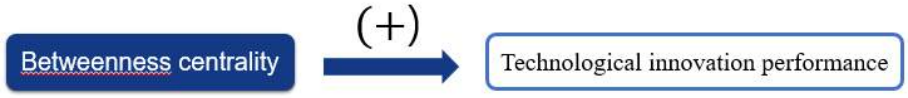
2 Degree structural hole Perspective



✓ Having capabilities in

*not only core technology but also **complementary technologies of core technology** are important.*

3 Betweenness Centrality Perspective



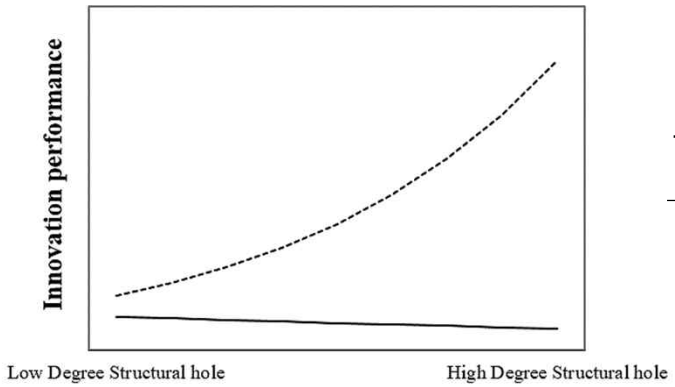
✓ Manage core technology to have **wider relation with other technologies** and to have a higher influence in overall firm R&D activity.

◆ Discussion

Implications **R&D Management strategy for innovation of SMEs**

4 University R&D collaboration

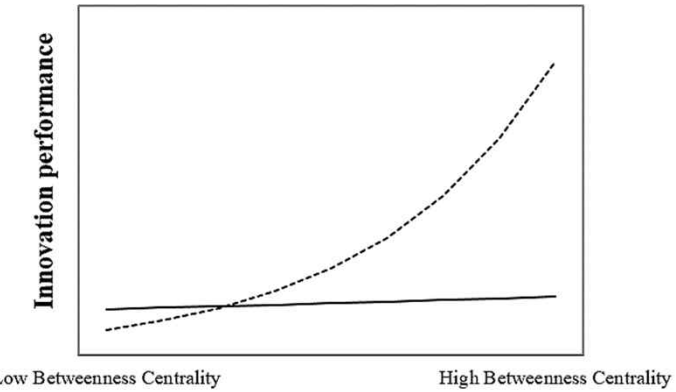
Degree structural hole



--- High University Collaboration

_ Low University Collaboration

Betweenness Centrality



Beneficial for innovation when SME's

- Core technology has high degree structural hole value

➡ Weak capability in complementary technologies

(Grigoriu & Rothaermel, 2017)

Beneficial for innovation when SME's

- Core technology has high betweenness centrality
- When Btw Cen is low, **adverse impact on innovation**

◆ Discussion

Limitations and Future research

- Firstly, this study relies heavily on patent data.
  - ✓ Several innate limitations it has to capture innovation performance
    - ➡ Conduct another analysis based on **product data** (product functionality, design etc.)
- Secondly, this study focuses only on university as a potential R&D partner.
  - ✓ Best way to suggest university as good collaborator is comparing with other types of partner
    - ➡ Comparison with strategic alliance and university collaboration
- Third, this study only considers SMEs in single industry, the ICT industry.
  - ➡ Research on SMEs in other high-tech industries such as biopharmaceutical, mechanical engineering etc.

THANK YOU!

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michaelkim7788@gmail.com

◆ Appendix

Why UI collabo instead of strategic alliance for SMEs

- Strategic alliance can be ineffective strategy for SMEs and for their competence due to following reasons:

(Prahalad & Hamel, 1990; Hamel, 1991; Lei & Slocum, 1992)

1st, Technological alliances are **more probable to fail** than expected

(Kale & Singh, 2009; Wittmann, Hunt & Arnett, 2009)

2nd, Technological alliances require **considerable managerial attention** (Hitt, Hoskisson & Ireland, 1990)

3rd, Technological alliances may **negatively affect internal R&D process** due to trade-off relationship

(Higgins & Rodriguez, 2006; Laursen & Salter, 2006)

4th, SME may difficult to absorb external knowledge from partner due to **weak absorptive capacity**

(Cohen & Levinthal, 1989)

- Instead of strategic alliance, this study suggest ***R&D collaboration with university*** as effective knowledge sourcing strategy for SMEs and their competence.

(Zeng et al., 2010)

◆ Appendix

Barriers of innovation for SMEs

Source: Survey results of Lee et al., (2010)

Ranking	Barriers of Innovation for SMEs
1	Difficulties in finding suitable manpower in a labour market
2	Short of suitable manpower within the firm
3	Market uncertainty in innovative product
4	Imitation possibilities of technology innovation
5	Short of ability in R&D planning and management

◆ Appendix

Table 2

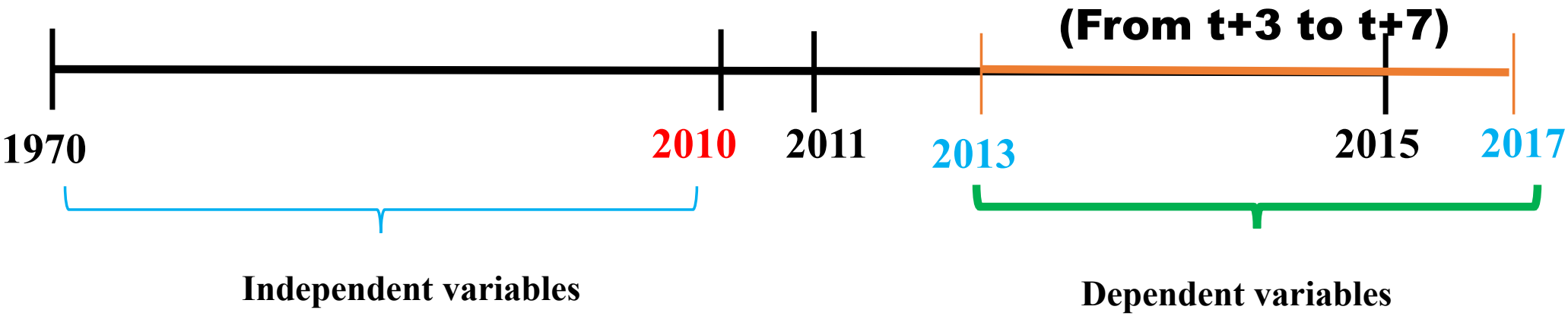
Results of Variance Inflation Factor(VIF) test

Variable	VIF	1/VIF
Betweenness centrality	1.96	0.509636
Degree centrality	1.93	0.517161
Firm Sales	1.85	0.540990
Diversity of knowledge	1.83	0.546234
Degree structural hole	1.75	0.570411
Total R&D collaboration	1.56	0.642896
Returns to sales	1.48	0.675413
Firm size	1.48	0.675418
University collaboration	1.43	0.700979
Firm age	1.08	0.921989
Number of core elements	1.02	0.975691
Mean	1.58	

- Free from the threat of multicollinearity problem as mean and maximum value of VIF is lower than recommended ceiling of 5. (Cohen et al., 2003; Hair et al., 1995)

◆ Appendix

◆ Robustness check



- For robustness check, this study set 2-year time lag and conduct additional regression and found no significant change in (1) direction of coefficient, and (2) statistical significance.

◆ Appendix

◆ Identification of core technology

- Granstrand et al., (1997), Phene et al., (2012), and Shin et al., (2017) all used ***percentage share*** of technological subfield for identification and used ***three-percentage*** as minimum standard for core technology
- However, SMEs are different from LE and MNC in terms of R&D intensity, the number of patent, patent propensity etc.

  ➡ ***Same standard or different standard?***

- Instead of simply following prior studies, we set minimum standard as **seven-percentage** compared to three-percentage suggested by Granstrand et al., (1997).

  - Audretsch and Acs (1991) who compared the number of patent in large firms and SMEs found that large firms tend to have patents twice as that of SMEs.
  - Andries and Feams (2013) also found that the number of patents in large firms is slightly more than double of that in SMEs.