

SMEs' External Technology Collaboration Network Diversity and Productivity Improvement : The Moderating Effect of the Chief Technology Officer-Driven Technology Development

Yong Sauk Hau[†]

School of Business, Yeungnam University

중소기업의 외부 기술협력 네트워크의 다양성과 생산성 향상 : 최고기술크영자가 주도하는 기술 개발의 조절효과

허 용 석[†]

영남대학교 경영대학

Productivity improvement is one of the important goals which firms' technology developments aim at. Firms' improved productivity from technology development means that their inputs can produce more outputs through technology development, which makes firms' productivity improvement from technology development more and more important in the age of technology advance and convergence like today. This research empirically analyzes the influence of the external technology collaboration network diversity on the productivity improvement of the small and medium-sized enterprises (SMEs) from technology development and the moderating effect of the chief technology officer (CTO)-driven technology development on this influence. This study constructs the research model reflecting the moderating impact of the CTO-driven technology development and tests it with the ordinary least squares regression through the IBM SPSS version 23 by using the 2,000 data about South Korean SMEs. This research empirically reveals two points. One is that SMEs' external technology collaboration network diversity has a positive influence on their productivity improvement from technology development. The other is that the positive effect of SMEs' external technology collaboration network diversity on their productivity improvement from technology development is moderated by the CTO-driven technology development. The two points revealed in this study present two meaningful implications in not only the practical but also academic point of view. The practical implication is that it is effective for SMEs to use CTOs in increasing their productivity improvement from technology development. The academic implication is that making technology collaboration with more diverse external partners can increase SMEs' productivity improvement from technology development.

Keywords : SME, External Technology Collaboration Network Diversity, Productivity Improvement, Chief Technology Officer

1. Introduction

Productivity improvement is one of the important targets which firms’ technology developments aim at [8, 16, 17]. Productivity indicates the ratio of the inputs which a company provides to the outputs which the company generates [8]. Other things being equal, firms’ improved productivity from technology development means that their inputs can produce more outputs through technology development [8, 13, 15, 16, 17], which makes firms’ productivity improvement from technology development more and more important in the age of technology advance and convergence like today [8, 14, 17].

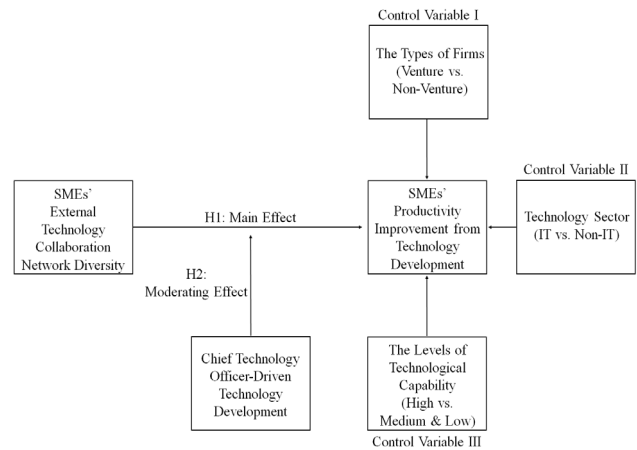
This study pay special attention to the influence of the external technology collaboration network diversity on the productivity improvement of the small and medium-sized enterprises (SMEs) from technology development and the moderating effect of the chief technology officer (CTO)-driven technology development on this influence, which extant studies on SMEs’ management of technology pay little attention to. Therefore, this study has the purpose of illuminating the roles of the external technology collaboration network diversity and chief technology officer-driven technology development with regard to SMEs’ productivity improvement, which makes this research focus on the two research questions as follows;

- (i) What is the impact of the external technology collaboration network diversity on SMEs’ productivity improvement from technology development?
- (ii) What is the effect of the CTO-driven technology development on the impact of the external technology collaboration network diversity on SMEs’ productivity improvement from technology development?

2. Theory and Research Model

This study constructs the research model treating the CTO-driven technology development as the moderator in line with the two research questions as the <Figure 1> shows.

The hypothesis 1 deals with the main effect of SMEs’ external technology collaboration network diversity on their productivity improvement from technology development. Productivity improvement requires successful technology developments which enable firms to operate their systems with less inputs but generate more outputs [8, 17]. According to Chesbrough [5, 6, 7], it is a very effective strategic action



<Figure 1> Research Model

to extend the internal knowledge landscape of firms which are scanty of internal technology R&D resources and capabilities by using the external technology collaboration in order to make more successful technology development. Hau [12] has empirically revealed the positive and significant effect of SMEs’ external technology collaboration network diversity on their technology development capability. Deeds and Rothaermel [10] and Hagedoorn [11] empirically support the important role of R&D partnerships with various external technology partners in increasing firms’ internal R&D capability. Therefore, this study makes the hypothesis 1 related to the positive effect of SMEs’ external technology collaboration network diversity on their productivity improvement from technology development as follows;

H1 : SMEs’ external technology collaboration network diversity has a positive influence on their productivity improvement from technology development.

The hypothesis 2 deals with the moderating effect of the CTO-driven technology development on the positive impact of SMEs’ external technology collaboration network diversity on their productivity improvement from technology development. CTO indicates a senior manager who specializes in the management of technology [1]. The management of technology for firms requires various knowledge from the fields of science, engineering, economics, psychology, and management [4, 9, 14, 17]. Furthermore, the domains of the management of technology are very wide, including new technology planning, technology demand forecasting, technology R&D, and technology commercialization [2, 3, 9, 14, 17]. Therefore, it will be more effective for such experts in the

management of technology as CTOs to drive SMEs' technology development in making their external technology collaboration result in more productivity improvement, which leads to the hypothesis 2 as follows;

H2 : The positive effect of the external technology collaboration network diversity on SMEs' productivity improvement from technology development is stronger when their technology development is driven by CTOs.

This research uses the three control variables in the research model : (i) the types of firms (venture vs. non-venture), (ii) technology sector (IT vs. non-IT), (iii) The levels of technological capability (high vs. medium & low).

3. Research Methodology

3.1 Data, Measurement and Analysis Tool

This study examined the main and moderating effect in the two hypotheses in the research model by analyzing the 2,000 data about the SMEs in the Republic of Korea in the 2013 SMEs' Technology Statistics (2013 SMETS). The 2013 SMETS was the survey about SMEs' technology development and performance from 2011 to 2012, being run by the Small & Medium Business Administration and the Korea Federation of Small and Medium Business (KBIZ) in 2013.

In order to measure the causal variable in the research model, this research used the measurement adapted from Tsai [18] for the external technology collaboration network heterogeneity of the SMEs in the Republic of Korea on which this study focused. In other words, through the adapted Tsai [18]'s measurement, this study gauged how many different types of external partners each SME collaborated with to develop technology from 2011 to 2012 among such six types of the external technology collaboration partners as (1) conglomerates, (2) other SMEs, (3) foreign organizations and enterprises, (4) private research institutes, (5) universities, and (6) national research institutes.

In measuring the outcome variable in the research model, this study used the five point scale which gauged the degree of the productivity improvement that each SME made through its technology development from 2011 to 2012. The number one in the five point scale stood for "very low including no degree" and the number five in it indicated "very

high degree."

This study used three dummy variables with the value of either one meaning "yes" or zero meaning "no" for the moderating variable and three control variables in the research model. In other words, this study checked whether each SME's CTO played the most important role in developing technology, whether each SME was a venture company, whether its technology sector belonged to IT, and whether its level of technological capability was high or not. The IBM SPSS version 23 was used as the analysis tool to test the research model. The <Table 1> reports the descriptive statistics of the 2,000 data in terms of the causal variable and the relative frequency and portion of the moderating variable and control variables.

<Table 1> The Profile of the Data Analyzed

Variable	Option	Value	Portion(%)
CTO-Driven Technology Development	Yes	67	3.4
	No	1,933	96.6
The Types of Firms	Venture	547	27.4
	Non-Venture	1,453	72.6
Technology Sector	IT	310	15.5
	Non-IT	1,690	84.5
The Levels of Technological Capability	High	393	19.7
	Medium & Low	1,607	80.3
The External Technology Collaboration Network Diversity	Mean	0.52	
	Standard Deviation	0.87	
	Maximum	6	
	Minimum	0	
Productivity Improvement from Technology Development	Mean	1.95	
	Standard Deviation	1.31	
	Maximum	5	
	Minimum	1	

3.2 Analysis Model

This research empirically tested the significances of the hypothesis 1 and 2 by running the ordinary least squares (OLS) regression based on the following analysis model;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \epsilon$$

In this analysis model for this research, Y stands for SMEs' productivity improvement from technology development, β_0 for the constant term in the regression, X_1 for SMEs' external

technology collaboration network diversity, β_1 for the regression coefficient of the X_1 , X_2 for the types of firms (venture vs. non-venture), β_2 for the regression coefficient of the X_2 , X_3 for the technology sector (IT vs. non-IT), β_3 for the regression coefficient of the X_3 , X_4 for the levels of the technological capability (high vs. medium & low), β_4 for the regression coefficient of the X_4 , and ϵ for error term in the regression.

In order to check the significance of the moderating impact of the CTO-driven technology development, this research examined the significance of β_1 at the significant level of 0.05 by running the OLS regression in the analysis model depending on whether the CTO played the most important role in technology development or not.

4. Empirical Analysis Results

The OLS regression results have empirically proved that all of the hypotheses in the research model are supported. They have revealed that the external technology collaboration network diversity has a significant and positive impact on SMEs' productivity improvement from technology development ($\beta_1 = 0.06$, t-value = 2.05), supporting the hypothesis 1. They have shown that the effect of the external technology collaboration network diversity on SMEs' productivity improvement from technology development is significant and positive ($\beta_1 = 0.43$, t-value = 2.44) when CTOs play the most important role in technology development but the effect is not significant ($\beta_1 = 0.05$, t-value = 1.55) when CTOs do not play the most important role in technology development, supporting the hypothesis 2. The <Table 2> summarizes the empirical analysis results.

<Table 2> The Empirical Analysis Results

Regression Coefficient	Model I	Model II	Model III
β_1	0.06*	0.43*	0.05
β_2	-0.24***	-0.21	-0.249***
β_3	-0.35***	-0.53	-0.35***
β_4	0.01	-0.07	0.01

Note : *P < 0.05; **P < 0.01; ***P < 0.001; Model I is for the total group (n = 2,000); Model II is for the CTO-driven technology development group (n = 67), Model III is for the CTO-not driven technology development group (n = 1,933).

5. Conclusion

5.1 Summary of Findings

This research has empirically revealed two points. One is that SMEs' external technology collaboration network diversity has a positive effect on their productivity improvement from technology development. The other is that the positive impact of SMEs' external technology collaboration network diversity on their productivity improvement from technology development is moderated by the CTO-driven technology development.

5.2 Implications

The two points revealed by this study present meaningful implications in not only the practical but also academic point of view. The practical implication is that it is effective for SMEs to use CTOs in increasing their productivity improvement from technology development. CTOs are referred to as senior technology managers and experts in the management of technology development [1]. This study has empirically proved that CTOs play a significant role in increasing the positive impact of SMEs' external technology collaboration network diversity on their productivity improvement from technology development, which widens and deepens Alder and Ferdows [1]'s research on CTOs. More specifically, according to the analysis results based on the 2,000 data in this study, the positive impact of the external technology collaboration network diversity on SMEs' productivity improvement is significant only in the SMEs whose technology development is driven by their CTOs. This means that SMEs' using CTOs for the management of their technology is an effective way of increasing the positive impact of SMEs' external technology collaboration network diversity on their productivity improvement from technology development.

The academic implication is that making technology collaboration with more diverse external partners can increase SMEs' productivity improvement from technology development. This finding is in accordance with the essential logic of the open innovation perspective that making use of more external knowledge can increase firms' innovation performance [5, 7, 17]. But, based on the 2,000 data from South Korean SMEs, this study deepens the research stream in the open innovation perspective by empirically revealing that it is useful to increasing such an important SMEs' performance

as the productivity improvement from technology development for SMEs to make use of the external knowledge through technology collaboration with more various external partners. In other words, the more various partners SMEs make external technology collaboration with, the more productivity improvement from technology development they can make, which sheds a new light on the positive effect of SMEs' open innovation through external technology collaboration on their productivity improvement from technology development.

5.3 Limitations

There are limitations in this study to be overcome for better future research. The research subject of this study is limited to South Korean SMEs. So, it will be better to consider more various foreign SMEs in the research subjects of future studies. The role of CTOs in the management of technology is so various that it will produce more insightful implications for future research to empirically analyze the role of CTOs in a variety of performances from their management of technology. The analyses on not only the impact of the density of SMEs' external technology collaboration network but also the ways of their participation in external technology collaboration on their productivity improvement from technology development will be able to enrich future studies' implications for the field of SMEs' management of technology.

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ORCID

Yong Sauk Hau | <http://orcid.org/0000-0001-9817-4815>