

Small and Medium Enterprises' External Technology R&D Information Network Diversity and Green Management Performance

Yong Sauk Hau

School of Business, Yeungnam University

중소기업의 외부 기술 연구개발 정보 네트워크의 다양성과 녹색 경영 성과

허용석

영남대학교 경영대학

Abstract As the environmental pollution and the global warming have become more and more serious, the green management has been growing more and more critical to small and medium enterprises. In order to explore factors positively influencing small and medium enterprises' green management performance, this study presents the two major implications through the ordinary least squares regression based on the 2,200 data from the small and medium enterprises in the Republic of Korea. First, small and medium enterprises' external technology R&D information network diversity positively influences their green management performance from technology R&D. Second, small and medium enterprises' production process improvement is a partial mediator between their external technology R&D information network diversity and green management performance from technology R&D.

Key Words : External Technology R&D Information Network, Green Management, Small and Medium Enterprises, Production Process Improvement, Technology Convergence

요 약 환경오염과 지구 온난화가 더욱 더 심각해지면서 녹색 경영이 중소기업에 더욱 더 중요해지고 있다. 본 연구는 중소기업의 녹색 경영 성과에 양(+)의 영향을 미치는 요인들을 분석하기 위해 한국의 2,200개의 중소기업 데이터를 대상으로 실시한 최소자승 회귀분석 결과를 통해 다음과 같은 두 가지 주요 시사점들을 제공한다. 첫째, 중소기업의 외부 기술 연구개발 정보 네트워크의 다양성은 기술 연구개발로 인한 녹색 경영 성과에 정(+)의 영향을 미친다. 둘째, 중소기업의 기술개발로 인한 생산 공정의 개선은 외부 기술 연구개발 정보 네트워크의 다양성이 기술개발로 인한 녹색 경영 성과에 미치는 양(+)의 영향을 부분적으로 매개 한다.

주제어 : 외부 기술 연구개발 정보 네트워크, 녹색 경영, 중소기업, 생산 공정 개선, 기술 융합

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Corresponding Author: Yong Sauk Hau
(School of Business, Yeungnam University)
Email: augustine@yu.ac.kr

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1. Introduction

As the environmental pollution and the global warming have become more and more serious, the green management has been growing more and more critical to enterprises [1, 2, 3, 5]. Especially, the South Korea has been ranked as the 10th nation in the world that emits the largest amount of carbon dioxide [4]. Therefore, the South Korea Government has already implemented various policies which fosters the green growth for the South Korea [4, 5], leading South Korean enterprises to change themselves into green firms [1, 6]. Small and medium enterprises' role in the economy of the South Korea is so critical [6, 7, 8, 9, 10] that their active participation in the green management is essential for the diffusion of the green management for the success in the green growth for the South Korea [6, 10]. Therefore, in order to find out the factors positively influencing the green management performance of small and medium enterprises, this study attempt to empirically explore the main effect of small and medium enterprises' external technology R&D information network diversity on their green management performance from technology R&D and the mediating impact of their production process improvement from technology R&D on this main effect. In accordance with this research purpose, this study presents the research question as follows:

- (i) What is the effect of the external technology R&D information network diversity of small and medium enterprises on their green management performance from technology R&D?
- (ii) What is the impact of the production process improvement from technology R&D of small and medium enterprises on this effect of their external technology R&D information network diversity on the green management performance from technology R&D?

To answer these research questions based on empirically analyses, this study constructs a research model under the theoretical background of the open innovation perspective [11, 12] and empirically tests it by using 2,200 data of small and medium enterprises.

2. Theoretical Background and Research Model

This study constructs a research model with two hypotheses on the theoretical basis of the open innovation perspective [11, 12]. The hypothesis 1 treats the main effect of the external technology R&D information network diversity of small and medium enterprises on their green management performance such as the energy and greenhouse gas reduction from technology R&D. The hypothesis 2 covers the mediating influence of small and medium enterprises' production process improvement from technology R&D between their external technology R&D information network diversity and green management performance.

The green management is referred to as reducing the amounts of the energy used at work and the carbon dioxide emitted in the course of enterprises' management activities for their business [6, 13]. Therefore, the green management puts its main focus on reducing the energy and the greenhouse gas in the course of enterprises' activities for business [6, 13]. The production process improvement from technology R&D is effective in reducing the consumption of the energy and the emission of the carbon dioxide [13]. But, the reality in business is that a lot of small and medium enterprises do not possess sufficient resources and competences for successful technology R&D [14, 15]. The open innovation perspective [11, 12, 16] emphasizes the importance of utilizing and absorbing the external technology R&D information from exterior sources such as universities, suppliers, buyers, etc. to increasing the success rate in technology R&D of small

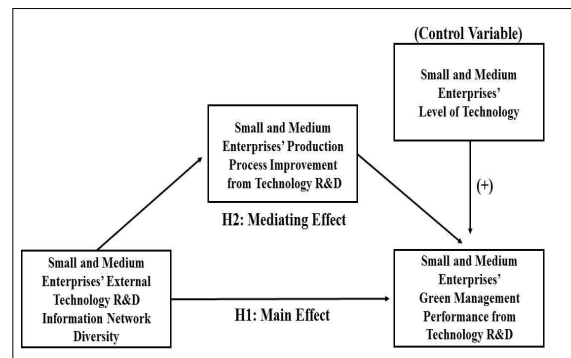
and medium enterprises. In line with this perspective, Hau (2015) [14] has empirically shown that the external technology R&D information network diversity of small and medium enterprises positively influences their new technology R&D capability. Therefore, this research hypothesizes the positive impact of the small and medium enterprises' external technology R&D information network diversity on their green management performance such as the energy and greenhouse gas reduction from technology R&D in the following hypothesis 1;

H1 : Small and medium enterprises' external technology R&D information network diversity positively influences their green management performance from technology R&D.

Enterprises' technology R&D is so information and knowledge-intensive [17, 18, 19, 20, 21] that successful production process improvement from technology R&D requires various technological information [17, 20, 21, 22, 23]. It is effective for small and medium enterprises short of internal competences and resources to get and use external technology R&D information in making their technology R&D more successful [11, 12, 14, 15, 16]. In line with this, Hau(2017)[21] has empirically confirmed that small and medium enterprises' external technology R&D information network diversity in the information technology domain positively influences their production process improvement from technology R&D. Furthermore, the production process improvement from technology R&D is one of useful ways of reducing the energy and the greenhouse gas at work [13]. Therefore, by considering the positive impact of the external technology R&D information network diversity on the production process improvement from technology R&D which positively influences the green management performance such as energy and greenhouse gas reduction at work, this study constructs the following hypothesis 2;

H2 : Small and medium enterprises' production process improvement from technology R&D mediates the influence of the external technology R&D information network diversity on their green management performance from technology R&D.

This study makes use of small and medium enterprises' level of technology as the control variable in the research model. The [Fig. 1] indicates the research model.



[Fig. 1] Research Model

3. Research Methodology

This research utilized a sort of secondary data authorized by the South Korea Government, which was named as the 2014 Small and Medium-Sized Enterprises' Technology Statistics (2014 SMETS). This was a survey of the technology R&D in small and medium companies in the Republic of Korea in 2013, being conducted by the Korea Federation of Small and Medium Business (KBIZ) and the Small & Medium Business Administration. This study analyzed the 2,200 data in the 2014 SMETS.

This study measured the degree of small and medium enterprises' external technology R&D information network diversity by applying the adapted Watson (2007)[24]'s measurement to the technology R&D contexts of the small and medium enterprises in

the Republic of Korea. In more details, this study gauged the number of the different types of external technology R&D information sources used by each small and medium enterprise for its technology R&D in such eight types as (1) competitors in the same domain in business (2) buyers, (3) suppliers, (4) universities, (5) global or domestic conferences, seminars, and expos, (6) national or private research organizations, (7) private service organizations such as private research institutes or consulting firms and (8) global or domestic special journals or books.

This research utilized the five point scale for the measurement of the degree of the production process improvement from technology R&D, ranging from the value of one denoting ‘no degree or very low degree’ to the value of five standing for ‘very high degree’.

The prior goal of the green management is to reduce the energy used at work and the greenhouse gas in the course of firms’ management activities [6, 13]. Therefore, in measuring the green management performance from technology R&D, this research gauged the degree of the greenhouse gas and energy reduction by using the five point that ranged from the value of one standing for ‘no degree or very low degree’ to the value of five denoting ‘very high degree’.

This study used a dummy variable and checked whether the level of each small and medium enterprise’s technology belonged to high level or not for the measurement of the control variable.

The study applied the ordinary least squares (OLS) regression to test the research model with the Sobel test [25], and the Baron and Kenny test [26] through the IBM SPSS version 23.

The <Table 1> reports the feature of the data for this study in regard to small and medium enterprises’ number of R&D workers, total R&D cost, and total sales in 2013.

<Table 1> The Data for This Study

Variable	Minimum	Maximum	Average	Standard Deviation
The Number of R&D Workers	1	197	6.608	10.525
Total R&D Cost (South Korean Million Won)	1	26,817	585.592	1,096.215
Total Sales (South Korean Million Won)	0	216,371	18,218.662	27,764.901

4. Research Model Testing Results

4.1 The Main Effect of Small and medium Enterprises’ External Technology R&D Information Network Diversity

The analysis results have empirically shown that small and medium enterprises’ external technology R&D information network diversity positively influences their green management performance (regression coefficient = 0.022, p-value = 0.011), which supports the hypothesis 1 at the significant level of 0.05. The analysis results have indicated that small and medium enterprises’ level of technology, the control variable, positively influences the green management performance (regression coefficient = 0.131, p-value = 0.000)

4.2 The Mediating Impact of Small and Medium Enterprises’ Production Process Improvement

This study has performed the Sobel test [25] to statistically investigate the mediating influence of small and medium enterprises’ production process improvement through the z-value from equation for the Sobel test [25] as follows:

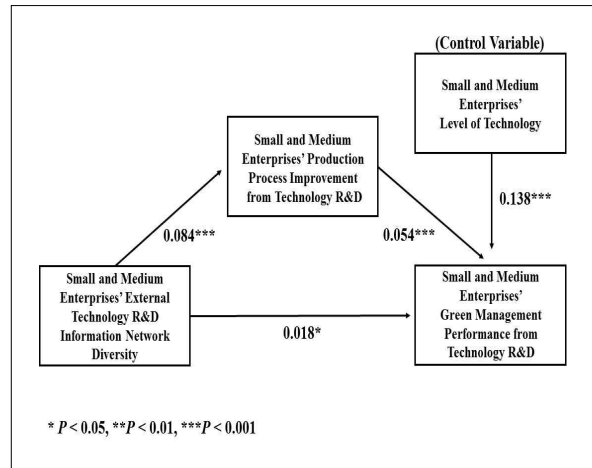
$$Z\text{-value} = \frac{\alpha_1 \times \alpha_2}{\sqrt{(\alpha_1^2 \times SE_{\alpha_2}^2 + \alpha_2^2 \times SE_{\alpha_1}^2)}}$$

In this equation to generate the z -value, α_1 denotes the unstandardized regression coefficient of small and medium enterprises' external technology R&D information network diversity on their production process improvement from technology R&D and α_2 denotes the unstandardized regression coefficient of small and medium enterprises' production process improvement on their green management performance. SE_{α_1} and SE_{α_2} denotes the standard errors of the α_1 and the α_2 , respectively. The z -value from this formula is 3.440, confirming the significant mediating role of small and medium enterprises' production process improvement from technology R&D between their external technology R&D information network diversity and green management performance.

This study has made the Baron and Kenny test [26] to examine if the mediating effect of the production process improvement is either partial or perfect. Without considering the mediating influence of the production process improvement from technology R&D, the main impact of the external technology R&D information network diversity on the green management performance is positive and significant (regression coefficient = 0.022, p -value = 0.011). However, this main effect has been reduced by 18% (regression coefficient = 0.018, p -value = 0.042) with considering the mediating influence of the production process from the production process improvement. This confirms that small and medium enterprises' production process improvement from technology R&D is a partial mediator between their external technology R&D information network diversity and green management performance from technology R&D according to Baron and Kenny [26].

In a word, the statistical analysis results from both the Sobel test [25] and the Baron and Kenny test [26] have supported the hypothesis 2, confirming that small and medium enterprises' production process improvement from technology R&D significantly and

partially mediates the main impact of the external technology R&D information network diversity on their green management performance from technology R&D. The [Fig. 2] reports the research model testing results.



[Fig. 2] Research Model Testing Results

5. Conclusion

5.1 Implication

New technology developments based on technological disruptions and technology convergence have been happening with high speed [17, 18, 19, 20, 32], which will make the green management more and more important to small and medium enterprises. Therefore, in order to find out the factors positively influencing the green management performance of small and medium enterprises, this study has attempted to empirically explore the main effect of small and medium enterprises' external technology R&D information network diversity on their green management performance from technology R&D and the mediating impact of their production process improvement from technology R&D on this main effect.

This study provides the following three implications which has scarcely been explored in the recent studies on small and medium enterprises including Hau(2016)[14], Hau(2017)[21], Sohn, Lee, and Kim(2017)[27], Kim and

Hwang(2016)[28], Hau(2015)[29], Lee and Kim(2016)[30], and Lee and Lee (2012)[31] through the OLS regression results based on the 2,200 data of small and medium enterprises.

First, the external technology R&D information network diversity of small and medium enterprises positively influences their green management performance. This finding illuminates the point that it is effective to use external technology R&D information from various exterior sources in increasing small and medium enterprises' green management performance.

Second, small and medium enterprises' production process improvement from technology R&D partially mediates the influence of the external technology R&D information network diversity on their green management performance. This means that the external technology R&D information network diversity of small and medium enterprises positively influences not only their green management performance but also production process improvement from technology R&D.

Third, the production process improvement from technology R&D of small and medium enterprises positively impacts their green management performance from technology R&D. This suggests that small and medium enterprises should make more production process improvement from technology R&D to increase their green management performance from technology R&D.

5.2 Limitation

There are several shortages in this research. First, the findings in this study can give useful implications only to the small and medium enterprises in the Republic of Korea. Second, taking more control variables including small and medium enterprises' level of technology in this study into consideration will be able to generate more rigorous statistical analysis results. Third, reflecting meaningful moderators into the research model will be able to make more useful implications.

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허 용 석(Hau, Yong Sauk)



- 1999년 2월 : 성균관대학교 경영학
과(경영학사)
- 2001년 8월 : 서울대학교 경영대학
(경영학석사)
- 2010년 8월 : KAIST 경영대학(경
영공학박사)
- 2013년 3월 ~ 현재 : 영남대학교 경
영학과 조교수
- 관심분야 : 기술경영, 지식경영
- E-Mail : augustine@yu.ac.kr