An exploratory study on the determinants of performance in regional industry technology development programs

Choo-Hui Park and Jin-Kyo Shin
Keimyung University, Daegu, South Korea

Received 26 May 2017
Revised 2 June 2017
Accepted 4 June 2017

Abstract

Purpose – The purpose of this paper is to analyze the determinants of the performance of regional industrial technology development programs among the regional strategic industrial development program that the central government and Daegu metropolitan city jointly promoted between 2004 and 2012. Specifically, in this research, the authors are trying to identify the effects of R&D capabilities and technical development tasks on technological and managerial performance.

Design/methodology/approach – The dependent variables of this study are technical and economic performance. Technical performance, product and process innovation, economic performance, sales and export increases were measured using five-point Likert scales. The authors added the contribution of sales through technology development to economic performance. The independent variable is the company's R&D capability, measured by the number of R&D staff compared to the average total number of employees from 2004 to 2012. The characteristics of the technology development tasks were measured by technical characteristics, market characteristics and collaborative research types. The technological characteristics were measured by seven factors, including technological change, technical difficulty, potential in commercialization, competition between domestic and foreign competitors, difficulty in introducing overseas technology and the technological gap. Market characteristics were largely divided into complexity, dynamics and competitiveness. The types of collaborative research were divided into whether or not there were collaborative research with the participation of large corporations. The control variables are firm size (number of employees) and firm age. Regression analysis was used to analyze the determinants of performance, and a difference analysis was conducted to determine the effect of collaborative research on performance.

Findings – The main determinants of the regional industrial technology development program performance are the characteristics of the technology development task rather than the internal R&D capability; moreover, the technical characteristics, complexity of the developed product market and participation of large corporations had significant effects on R&D capability. The R&D capacity of firms in internal R&D capacity had a significant effect only on the improvement of technology development ability. Therefore, R&D capacity, which is the main determinant of technology innovation, did not have a significant effect on the performance of short-term technology development tasks. Technological change, technological difficulty, competition between domestic and foreign competitors and the technological gap had positive effects on performance, excluding sales contributions. In addition, the complexity of the developed product market such as the diversification of demand, competitive product and sales distribution channels had positive influences on the performance of technology development programs, unlike dynamics and competitiveness. In this study, the authors cannot confirm the effect of collaborative research on the performance of the technology

Asia Pacific Journal of Innovation and Entrepreneurship
Vol. 11 No. 2, 2017
pp. 125-143
Emerald Publishing Limited
2071-1395
DOI 10.1108/APJIE-08-2017-027

development programs, but they confirmed that collaborative research involving large corporations had a positive influence on performance.

Research limitations/implications – The results of the analysis of the determinants of regional industrial technology development programs suggest some implications in the future evaluation of these regional industrial technology development programs. It is necessary to review the application qualification and merit, advance review of the business plans and confirmation, an examination of the research results and performance of the applicants and a review of the technology and market situation of the project. For this, the authors suggest that the written review from the relevant technical experts be submitted to the evaluation committees. Also, when establishing regional industrial development programs, they should be evaluated thoroughly, including detailed information and contents about the technical and market characteristics of the local industry.

Originality/value – This research is one of the first to investigate the achievements of R&D support programs among regional industrial development programs in Korea. The results of this study can substantially contribute to the development and implementation of the R&D support policies of the central and local governments. Furthermore, the findings suggest guidelines for improving the performance of R&D support programs in the future. A theoretical model for enhancing the efficiency of government R&D support programs may be established, and an empirical analysis may be conducted to provide practical and academic implications for further research.

Keywords Regional industry technology development program, R&D capability, Technological characteristics, Complexity of the product market, Types of collaborative research

Paper type Research paper

1. Introduction

Since the late 1990s, the Korean government has actively promoted regional industrial policies centering on regional strategic industries. Through these efforts, it has developed a variety of strategies for building a regional industrial infrastructure, strengthening innovation capacity and promoting clusters of regional strategic industries by promoting projects in a packaged manner. At present, the regional industrial policy not only broadens the spatial scope, but also covers a wide range of industries such as city and provincial strategic industries, metropolitan economy-leading industries and municipal and district-specialized industries. However, after 2014, the metropolitan project was terminated and the (new) specialized project, which was a city-and-province center project, become a main program in 2015 (Figure 1).

Therefore, analyzing the performance of regional industry development policies that have been promoted since 1999 for the purpose of balancing national development and enhancing the competitiveness of regional industry will provide many implications for establishing a regional industry upbringing policy and for promoting business in the future. The purpose of this study is to investigate the determinants of regional industrial technology development programs among the regional strategic industry development programs that led to the active participation of local companies in regional R & D projects to expand the underdeveloped regional industrial base and to enhance industrial competitiveness.

The characteristics of the Daegu areas are as follows: In 2014, the economically active population of Daegu is 1,245,000, accounting for 4.9 per cent of the nationwide average. The annual growth rate since 2008 is 1.24 per cent, which is higher than the national average (1.16 per cent). As of 2014, Daegu has 192,000 businesses and employs 833,000 people, accounting for 4.5 per cent of the nation's total. Daegu's industrial structure is composed of agriculture, forestry and fisheries (0.4 per cent), mining and manufacturing (23.7 per cent) and service and others (75.9 per cent). Of these, the manufacturing industry is the main industry of machinery, automobile parts and textiles in 2014, and since 2000, the center of

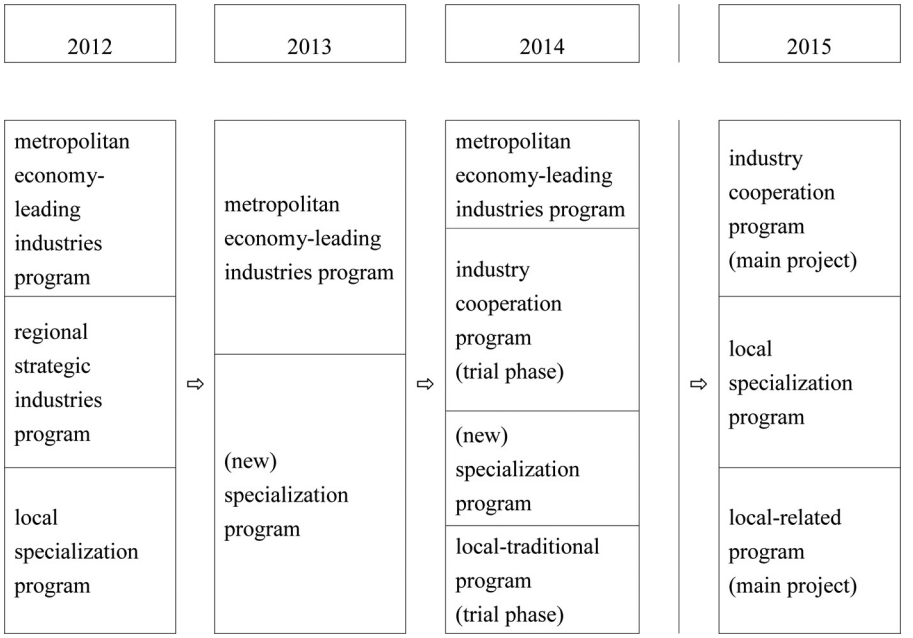

Figure 1. Reorganization of regional industry support programs

manufacturing has been shifting to the machinery and metal industry. In the past 10 years, Daegu's manufacturing structure has changed from 32.0 to 14.5 per cent of the textile industry, 30.1 to 43.1 per cent of machinery and metal industry, 14.4 to 16.8 per cent of auto parts and 5.4 to 7.0 per cent of rubber and plastic. There are 955 research and development organizations in Daegu area which it is accounting for 3.78 per cent of nationwide. And also, there are 20 (2.1 per cent) of public research institute R&D organizations, 15 (1.6 per cent) of university R&D organizations and 920 (96.3 per cent) corporate R&D organization. R&D innovation capacity such as researchers, R&D expenditure and patent registration numbers in Daegu has been steadily increasing, but relatively low compared to other cities.

This study consists of four parts. Part two introduces the purpose and contents of the regional industrial technology development programs, as well as the results of the program support, characteristics and achievements of the Daegu area. In part three, we present the analytical results of the variables and models for exploring the determinants of the performance of regional industrial technology development programs. Finally, part four discusses the policy implications and future research issues through a review of the research results.

2. Outline of regional industrial technology development program

2.1 Purpose of program, contents and achievement

Since 1999, the Korean government has promoted regional industry support programs, centering on regional strategic industries to support the upgrading of regional industries, support higher added-value, strengthen the competitiveness of companies and form a convergence cluster of strategic industries. The regional industrial support programs, based on the cluster concept, aim to develop independent regions by easing regional disparities and by directly fostering regional industries in doing so. Additionally, it has promoted

various projects in a packaged manner to enhance competencies and to promote the knowledge base of regional industries.

Focusing on the Daegu area, the government concentrated investment in textile, mechatronics, electronic information devices and biotechnology industries through local industrial support program since 1999. In the first phase (1999 $\sim$ 2003), the government invested 100 per cent in the textile industry by the Milano project and in the second stage (2004 $\sim$ 2008) with the aim of establishing a support system for new growth industry, they also invested on textile, mechatronics, including eight infrastructure construction programs, five enterprise support service programs, four human resource development programs and a planning operation program. In the third phase (2009 $\sim$ 2012), aiming at the creation of a cluster of strategic industries expanding convergence cluster, the government support of a total of 20 programs including seven infrastructure construction programs, five enterprise support service programs, four technical support programs, three joint programs and planning operation program. In the second phase, Daegu Strategic Industries' support by sector is in the order of textile (41 per cent), mobile (19 per cent), mechatronics (15 per cent), nanotechnology (13 per cent) and biology. Based on the type of business, technology development program (41 per cent), infrastructure construction program (35 per cent), technical support program (10 per cent) and regional innovation infrastructure construction program (7 per cent) were supported.

In particular, the regional industrial technology development programs led local companies to actively participate in regional R&D projects so as to expand the underdeveloped regional industrial base, strengthen industrial competitiveness and expand the technological innovation base. Specifically, they pursued customized R&D support in consideration of the characteristics of regional strategic industries, and they aimed to enhance regional competitiveness by fostering excellent companies that would lead the industry in terms of promoting regional strategic industries. To achieve this, they have focused on the development of commercialization (industrialization)-oriented technology rather than the development of original technology, by overcoming the formal linkages among the existing industry, education, academia and government.

There are four major strategic industries in the Daegu area, and in the regional industrial technology development programs, there were two reorganizations in the process of developing the regional strategic industries in the second and third phases. During the second phase, the basic technology development program was abolished from 2008, and the common technology development program and the key technology development program were converted into four programs (the local leading industry program, regional strategic planning program, regional linkage program and local-based technology development program). Since 2010, to simplify the program in accordance with the strategic industry conditions, the four programs were reorganized into two programs (task-design-type and free-open-type technology development programs) to support customized R&D, considering the characteristics of the regional strategic industries.

In the case of the Daegu region, the budget, supported by the regional industrial technology development programs in the second and third phases, was approximately 138,616 million won, which constituted an absolute proportion of the total regional industrial support programs, along with the regional industrial infrastructure construction industry. However, in the second phase, it decreased sharply by 62.1 per cent from 100,584 million won to the third phase, with 38,037 million won. This bottom-up type of free-open-type technology development program is more than the top-down type, including the designated type technology development program. In the case of the second phase, the bottom-up-type regional industrial technology development program and the regional

industrial basic technology development program accounted for an absolute proportion of 71,359 million won (70.9 per cent), while the third phase case amounted to 38,037 million won, and free competition technology development business amounted to 14,664 million won, accounting for 38.6 per cent (Figure 2).

2.2 Characteristics and performance of regional industrial technology development programs

Among the participants of regional industrial technology development programs, 59.4 per cent were corporations (incorporated), 23.2 per cent were research institutes (Technopark, Specialized Centers, etc.), 12.8 per cent were private companies and 4.0 per cent were universities and other institutions, such as associations, which accounted for 0.7 per cent. In the third phase, 91.7 per cent was in the form of a corporation (incorporated), while the second phase was only 52.7 per cent, and research institutes accounted for the highest percentage, with 28.3 per cent. In terms of shareholding by corporations (incorporated), the average holding ratio

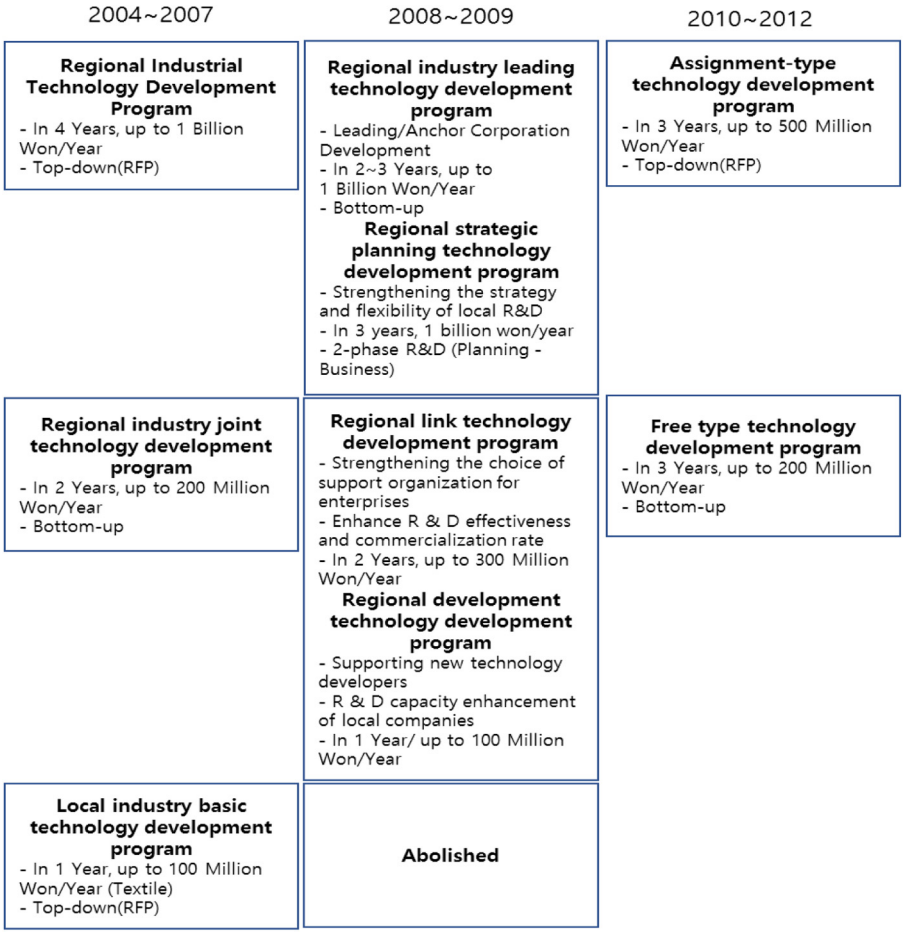

Figure 2.
Local business support program reorganization progress

of a manager was 83.9 per cent, while for employees, it was 7.4 per cent, foreigners accounted for 1.2 per cent and venture capital companies accounted for 7.4 per cent. In addition, the percentage of companies owning shares was 99.8 per cent, 31.8 per cent for employees, 21.1 per cent for venture capitalists and 5.5 per cent for foreigners.

The number of company employees, R&D staff and the importance of local industrial technology development programs are increasing at a fair rate, but there is a large variation among participating companies. The number of employees increased from '04 to '06 and decreased from '07 to '09 due to the global financial crisis. The level of technological innovation in the region has remained constant, regardless of the economic fluctuations due to the expansion of the base of technological innovation in the region through the regional industrial support programs and the active participation of regional companies (Table I).

According to the analysis, 40.3 per cent of the tasks set the final goal of the technology development program as a preparation stage for commercialization. For others, the most prevalent response was the preparation stage for practical applications, while research institutes, universities and other organizations aimed for basic and exploratory research stages. The main objective of the final goal was to develop new products (52.1 per cent), followed by the improvement of existing products, the development of new processes and the improvement of existing processes.

In the case of corporate tasks, the small- and medium-sized enterprises (SMEs; 44.3 per cent) and universities (42.3 per cent) were the most important research partners, whereas the technology development tasks, consisting of independent research and collaborative research with large corporations, accounted for 9.1 and 7.7 per cent, respectively. While collaborative research was the dominant form between SMEs and large corporations, most of the research conducted by other institutions (national research institutes, regional specialization centers, universities, etc.) was performed via project-based research. The major sources of ideas for technology development tasks were mostly from internal sources, followed by industry, conventions, exhibitions, research institutes and universities.

The technical characteristics of the technology development programs are characterized by the difficulty in developing technology and the high possibility of commercialization, while the intensity of domestic and foreign technology development competition was relatively low. Also, the third rather than the second phase showed a higher degree of technical difficulty and commercialization possibility (Figure 3).

Table I.
Status of employees and R&D staff of regional industrial technology development programs in Phases 2 and 3

No. & ratio of participants/year	'04	'05	'06	'07	'08	'09	'10	'11	'12
Number of employees									
Mean	77.7	81.8	80.3	71.6	68.6	68.3	90.9	102.7	111.3
Median	20.0	23.0	24.0	24.0	23.0	22.0	24.0	27.5	27.0
Number of R&D staff									
Mean	8.3	9.4	8.9	8.4	9.5	10.6	10.8	11.4	11.5
Median	3.0	4.0	4.0	4.5	5.0	5.0	5.0	5.0	5.0
Ratio of R&D staff (%)									
Mean	21.1	21.3	22.7	25.2	27.5	28.1	26.9	25.8	23.9
Median	12.5	12.1	14.3	16.9	18.4	19.4	19.0	18.8	17.3

Note: The proportion of R&D personnel refers to the average proportion of R&D personnel by participating companies

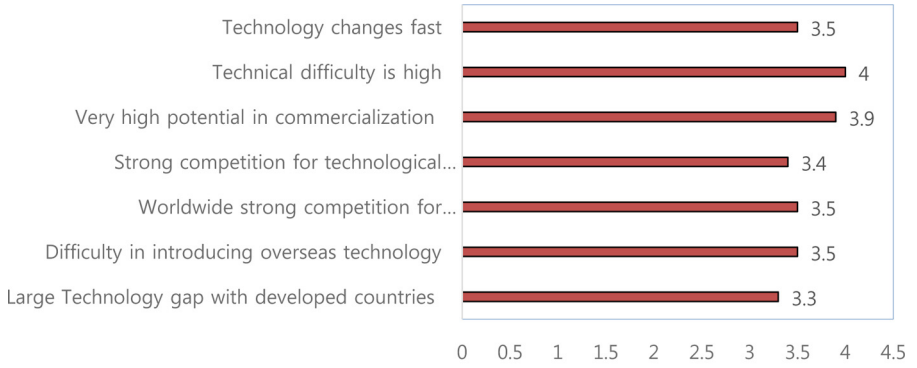

Figure 3. Technological characteristics of local industrial technology development programs in Phases 2 and 3

Note: A high score on a five-point scale means that the technology change is rapid, the technical difficulty is high, the competition is intense, introduction is difficult and the technology gap is large

In terms of the complexity, dynamics and competitiveness, the environmental characteristics of the product market developed through the technology development programs were generally above the average level. Specifically, the diversity of customer demand, the complexity of production technology and the lack of professional technical staff were high (Table II).

It was found that 67.3 per cent of the respondents said that they achieved a technical goal of 100 per cent, which was the primary goal of the technology development program, and they achieved an average goal of 95.9 per cent per task. The achievement level of the target organizations was 97.3 per cent for research institutes, 95.4 per cent for companies, 94.0 per cent for universities and 112.0 per cent for other institutions (Table III).

Environmental characteristics		Mean
Complexity		
1) Diversity of demand	3.8	3.5
2) Diversity of competitive products	3.5	
3) Complexity of production technology	3.7	
4) Variety of distribution and sales channels	3.3	
5) Complexity of government policies and related laws	3.0	
Dynamics		
6) Frequency of new product development by competitors	3.4	3.4
7) Introduction of new technologies by competitors	3.4	
8) Changes in material/technologies related to products	3.5	
9) Changes in product use and demand patterns	3.5	
10) The speed at which products become outdated	3.3	
Competitiveness		
11) The degree of increase in the number of domestic and overseas competitors	3.3	3.4
12) The degree of price competition between competitors	3.5	
13) Increasing production costs and decreasing profitability	3.4	
14) Degree of lack of technical staff	3.6	
15) Slowdown of market growth and demand decline	3.1	

Table II. Environmental characteristics of the product market of local industrial technology development programs in Phases 2 and 3

The reasons for not reaching the target goal of 100 per cent was the lack of a study period (23.5 per cent), followed by a lack of research funds (17.2 per cent), a lack of research and support facilities (16.3 per cent), high goal setting (15.8 per cent) and research environment changes (11.8 per cent).

Technical achievements such as intellectual property rights (patents, etc.), research papers and the technology transfer of local industrial technology development programs have continuously increased since the project was launched. Table IV shows the continuous effects of the program in terms of technological achievements, such as intellectual property rights, research papers and technology transfer due to technology development activities continuously from 2004 to 2009. The number of outcomes per 100 million won of cumulative project costs is also increasing. Therefore, it is evident that the budget invested in regional industrial technology development programs has had a substantial effect on research performance.

Table III.
Achievement of the technical goal of the regional industrial technology development programs in Phases 2 and 3

Organization/no. & % of achievement goal		Less than 50%		50~80%		80~100%		Over 100%		No response	
Total	682	5	(0.7)	31	(4.5)	185	(27.1)	459	(67.3)	2	(0.3)
Companies	492	5	(1.0)	27	(5.5)	132	(26.8)	326	(66.3)	2	(0.4)
Research institutes	158			1	(0.6)	41	(25.9)	116	(73.4)		
Universities	27			3	(11.1)	12	(44.4)	12	(44.4)		
Others	5							5	(100.0)		

Table IV.
Technical performance of the regional industrial technology development programs in Phases 2 and 3

No. of achievement/year	'04	'05	'06	'07	'08	'09	'10	'11	'12	Total
Intellectual property rights										
Overseas										
Patent	4	9	12	27	37	26	17	5	–	137
Registration	–	4	3	8	11	6	8	6	5	51
Domestic										
Patent	23	57	80	111	180	182	97	86	63	879
Registration	22	45	86	106	128	128	94	94	51	754
S/W register	4	4	6	5	15	10	2	1	–	47
Total	53	119	187	257	371	352	218	192	119	1,868
Research paper										
Overseas										
SCI	8	12	56	36	29	16	6	2	–	165
Peer-reviewed journal	–	2	6	9	12	8	3	3	–	43
Preceding papers	–	10	27	28	34	34	8	7	4	152
Domestic										
SCI	–	–	7	2	11	2	2	5	–	29
Peer-reviewed journal	13	9	21	40	41	40	23	17	5	209
Preceding papers	26	35	97	85	118	132	68	43	6	610
Total	47	68	214	200	245	232	110	77	15	1,208
Technology transfer										
Technology transfer	64	189	104	158	424	162	80	7	2	1,190
Technology transfer institutions	55	46	80	108	175	110	43	6	–	623
Venture	–	–	1	2	8	3	1	–	–	15
Total	119	235	185	268	607	275	124	13	2	1,828

In addition to technological achievements, there is a technical ripple effect due to technological development programs such as the improvement of the technical development ability of the executing agency, the expansion of technical development investment, the spread of other products and other fields of development technology. First, 92.2 per cent responded that the technology development ability of the related field improved through the execution of the program, and 52.5 per cent responded that the investment in technology development expanded. Second, 87.6 per cent of the respondents said that the technology developed through the project had a significant impact on other products and fields. The utilization of the developed technology was provided for other research and upgrade studies (52.5 per cent), participation in conventions (41.2 per cent) and educational instructions (38.1 per cent). Third, it was found that the developed technology contributed greatly to the high added-value of the product. In addition, it contributed to the improvement of product quality, finding new ideas, solving product problems and training technical staff. Finally, there were many evaluations indicating that the local industry technology developing program was effective in the development of the regional strategic industry; furthermore, it influenced the revitalization of relevant industry, the cultivation of technical manpower and so on.

As the economic performance of the regional industrial technology development programs has been continuously expanding since 2004, project-related sales and exports have increased significantly. In addition, there have been economic results related to the profitability of companies such as new product creation, the import substitution effect, production cost reduction and the reduction of royalties. In addition, job creation and the research workforce were increased due to technology development programs.

As shown in Table V, the average sales related to tasks have steadily increased from 278.8 m won in 2004 to 1,229.2m won in 2012, and the average export amount has also increased steadily since 2004. As a result of the regional industrial technology development programs, the effects of import substitution, employment creation and the number of professional researchers have continuously grown from 2004 to 2012. The developed technology has contributed 33.1 per cent to the sales of products and has reduced the average time to entry into the related market by 2.9 years; moreover, the economic life of the developed technology has increased up to 8.6 years. Thus, these local industrial technology development programs have had a positive effect on the economic performance of enterprises.

The results of the regional industrial technology development programs can be summarized as follows: first, despite the weak industrial structure of the region, it was

Table V. Economic performance of the regional industrial technology development programs in Phases 2 and 3

Performance/year	'04	'05	'06	'07	'08	'09	'10	'11	'12
Total revenue	26,429	28,006	31,479	30,070	33,034	34,499	41,491	46,256	38,525
Revenue related to project	278.8	231.4	555.6	731.8	921.6	997.9	1,206.7	1,187.4	1,229.2
Export amount	83.3	174.2	225.9	392.4	526.5	848.8	945.1	951.4	787.3
Import substitution amount	1,275.0	617.4	769.4	593.6	511.2	719.8	774.2	661.2	640.0
Number of new products	21.7	2.5	2.7	3.6	4.3	5.1	6.1	5.5	2.6
Increase of employment	2.5	2.3	3.1	2.6	4.0	4.7	4.3	3.0	2.8
Professional researchers	5.4	5.6	5.9	3.0	6.2	6.4	7.2	3.7	3.1
Loyalty savings	40.0	20.0	110.0	165.5	167.7	182.0	352.6	304.3	–
Production cost savings	115.0	71.4	122.6	179.1	196.0	271.5	273.1	70.2	40.9

Notes: Revenue and employment figures are an average, and '12 is expected; Unit: million won, person

found that the technological development program accomplished the desired achievement in the strategic industry field. It contributed to the high value-added business of the local strategic industry and the competitiveness of the market by carrying out support projects through selection and concentration, focusing on the specialization field of the strategic industry. It also created synergies through the revitalization of industry–university–government relations, based on our willingness to support industry continuously.

Second, to solve the difficulties of local enterprises, along with the technology development program, an integrated support system was built by securing facilities and professional manpower from product material development to commercialization. In detail, a support network for strategic industries was established and revitalized, centering on Technopark and Specialized Centers. The corporate support system was also strengthened through the establishment of expert pools for solving difficulties of the local enterprises, agreements between innovative resources, such as the joint use of equipment, and revitalized community management and participation by each strategic industry.

Third, despite the high-cost efficiency and commercialization success rate of the regional industrial technology development programs, issues were raised based on the constant duplication problem (borrowing the central unit program without planning) and a lack of strategy. This was due to the lack of differentiation from the central unit projects, the stage of technology development, the period of support, the support target and the development of excellent companies that would lead the industry in terms of fostering regional strategic industries. This was due to a lack of support for innovation-led policies, such as customized support policies.

3. Exploratory analysis

3.1 Variables and models

The importance of technological innovation in the new enterprise can be judged by how much the interest of the researchers is increasing. Technology innovation has become a key factor in sustainable competitive advantage, and it is also the most important challenge for SMEs (O'Regan *et al.*, 2006). As the perception that technological innovation is a driving force for improving corporate competitiveness is increasing, many studies suggest various technological innovation determinants. Among these, R&D capability and technical characteristics have been mentioned as very important influencing factors. In the previous studies, Becheikh *et al.* (2006) systematically summarized 108 empirical studies related to technological innovation from 1993 to 2003 and have found that the research and development capacity, networking and market factors of a company are very important for technological innovation and management performance. Van der Panne *et al.* (2003) also examined the factors affecting the success and failure of technological innovation based on 43 studies related to technological innovation projects from 1972 to 1999, and as a result that R&D capability, market and technology factors positively impact on technological innovation.

R&D capability is a core competency for shortening the development period of new products, and is an essential factor for enhancing new product development performance (Dutta *et al.*, 1999). Souitaris (2002) also argues that corporate R&D activities are an important source of innovation, and that R&D capabilities have a positive impact on a firm's innovation performance. Huiban and Boushina (1998) showed that R&D capacity is very important in radical innovation with technological experts, which is a key determinant of technological innovation (Freel, 2003; Romijn and Albaladejo, 2002).

Hall and Bagchi-Sen (2002) also showed a positive relationship between R&D capacity and technological innovation performance, and Hadjimanolis (2000) found a positive relationship between the R&D capacity of SMEs and technically innovative performance, respectively. Freel (2003), moreover, found that R&D capabilities have a positive impact on the likelihood of introducing new products. In addition, the many previous empirical studies suggested that the R&D capability has a positive effect on technological innovation and management performance (Kirkley, 2016; Lee *et al.*, 2014; Shin *et al.*, 2009; Hwang and Shin, 2015; Keizer *et al.*, 2002; Landry *et al.*, 2002; Thamhain, 2003).

Technical characteristics are an opportunity to supply the technical ideas necessary for technology development. In some cases, technical characteristics are recognized through various organizations, institutions and environments. In the case of high technological change, technological difficulty, competition between domestic and foreign competitors and the technological gap, technological innovation will produce active technological innovations, but if not, then the technological innovation will be limited (Song, 2000). In addition, the industry determines the technical characteristics, and with high technical characteristics, a higher frequency of new products is introduced. Furthermore, there are differences in the frequency of innovative new product development (Kotabe and Swan, 1995) and the rate of technology commercialization (Schoomhoven *et al.*, 1990), which depend on the industry. All organizations cannot escape the influence of the environment, and management decisions are diversified as the environment changes.

Michie and Sheehan (2003) demonstrate that intra-firm competition and market growth have positive effects on technological innovation. In other words, they found that as competition intensifies among industries, technology demand increases as market demand increases. In addition, Smolny (2003) argued that technological innovation is faster, as the competition between technology development firms is competitive or the technical difficulty is high. Zahra (1993) also demonstrated that the faster the rate of change of technology, the faster the innovation appears. Souitaris (2001) shows that the more demand and competition, products are diversified. And the more technological innovation created when the sales channels complex and increases of technology development competition among competitors are strong. In addition, Yoon and Lilien (1985), Kim and Choi (2016) pointed out that as competition intensifies among competitors in the market, competition for technology development among competitors becomes more intense.

The external environment is the primary source of uncertainty for managers who need to identify opportunities and threats (Duncan, 1972), and the dynamics of the environment are highly correlated with changes in corporate behavior. In particular, since the environment is changing rapidly nowadays, SMEs are forced to rely more on environmental characteristics. In previous studies, uncertainty in the environment increased innovation (Song and Kim, 2005; Chandy *et al.*, 2003). Because technological innovation is generally an expensive process that cannot recover costs, companies in a stable environment feel less need to pay for such innovation costs (Miller, 1988). In other words, companies in a dynamic environment are constantly innovating to outpace their competitors and to meet the needs of changing customers. An uncertain environment will have a positive impact on technological innovation activities that change the product or technology as a result of affecting the firm's strategy formulation. In the study of Miller and Friesen (1982), high environmental dynamics improved innovation performance, and Kim and Park (2009) also showed that environmental uncertainty has a positive effect on technological innovation capacity. In a study by Lee and Kim (2012) on Chinese SMEs,

the higher the domestic and foreign market environment factors, the more positive the financial performance was.

Cooperative activities for technology development and collaborative research can have a positive impact on tasks and firm performance. Kaufmann and Todtling (2001) show that there is a difference in technological innovation depending on the type of collaborative research with Universities and research institute. In addition, Landry *et al.* (2002) reported that R&D by interaction with suppliers and customers has a positive effect on technological innovation. Nieto and Quevedo (2005) also reported that formal and informal acquisitions of technology and knowledge have positive effects on technological innovation. Bae and Jung (1997) suggest that the size and utilization of technology cooperation have a positive effect on firm performance. In particular, technical performance is influenced by the size and diversity of formal technical cooperation, and commercial performance is influenced by the size of formal technical cooperation. Oh (2006) analyzed the effects of tasks, and R&D subject and procedural characteristics on technological and commercial goal achievement, and performance satisfaction, focusing on government-funded core technology development projects. As a result, the higher the strategic importance of the project and the higher the possibility of commercialization, the higher the possibility of success of the joint research. Also, when companies pursue industry–university cooperation, they consider the partner's joint research experience and the degree of research and development ability much more, as compared to the case of industry–industry cooperation. Specifically, when the host organization is a large corporation, it is more prominent than the case of SMEs. In the analysis by the hosting institution, when the large corporation is the main institution, it is found that the overall achievement of the collaborative research is higher in achieving the early goal than the small business, relatively speaking. In addition, there are many studies that show that network-based collaborative research and acquisition of formal/informal knowledge have a positive effect on technological innovation (Barba-Sanchez and Atienza-Sahuquillo, 2011; Love and Roper, 2001; Landry *et al.*, 2002, Papadakis and Bourantas, 1998; Ritter and Gemunden, 2003; Sung, 2006).

In this study, we analyzed 492 projects, except for the projects that were not supported by the main organizer and the projects that were not supported by the regional industrial technology development programs from January 1, 2004 to December 31, 2012, respectively. The purpose was to analyze the determinants of the performance of the regional industrial technology development programs in terms of the above-mentioned variables (Table VI).

Performance variables were classified into technical and economic performance. Technical performance is measured as the technological productivity product innovation and production innovation with five-point Likert scales. Economic performance is measured as the sales and export increase. In addition, the contribution of sales through technology development to economic performance was added. Given that this is a performance analysis of the technology development program rather than an enterprise performance analysis, the factors determining the business performance are divided into internal R&D capability and characteristics of the technology development program. The internal R&D capability of companies was measured by whether or not they registered the R&D institutes and the proportion of the R&D staff. The characteristics of the technology development program were measured by the technical characteristics, market characteristics and collaborative research types. The technological characteristics were measured by seven factors, including technological change, technical difficulty, potential in commercialization, competition between domestic and foreign competitors, difficulty in introducing overseas technology

Variables	Measurement
Project achievement	
Technical performance	Improvement of technology development ability in related fields
	Product innovation: Average of contribution on quality improvement, product high value-added, product troubleshooting
	Production innovation: Average of contribution on increasing productivity, contributing to production, problem solving at workplace
Economic performance	Increase in sales and exports: average of contribution of sales increase and export increase
	New technology revenue contribution: the percentage of developed technology contributed to sales of the product
R&D capability	Number of registered R&D institutes
	The ratio of R&D staff to the total number of employees in 2004∼2012
The characteristics of the technology development program	
Technical characteristics	Technology changes fast
	Technical difficulty is high
	Very high potential in commercialization
	Strong competition for technological development in the domestic market
	Worldwide strong competition for technological development
	Difficult to introduce overseas technology
	Large technology gap with developed countries
Market characteristics	
Complexity	Diversity of consumers' demand
	Diversity of competing products
	Complexity of production technology
	Variety of distribution and sales channels
	Complexity of government policies and related laws
Dynamics	Frequency of new product development by competitors
	Introduction of new technologies by competitors
	Changes in material/technology related to products
	Changes in product use and demand patterns
	The speed of when products become obsolete
Competitiveness	Increase of domestic and overseas competitors
	Price competition among competitors
	Increasing production costs and falling profitability
	Lack of experts
	Slow in market growth and demand declines
Types of collaborative research	Dummy variable indicating joint research
	Dummy variable indicating large companies participate in joint research
Control variables	
Firm's age	Years since establishment
Size	Average number of employees from 2004 to 2012

Table VI.
Definition of variables and measurement

and the technological gap using five-point Likert scales. The market characteristics were largely divided into complexity, dynamics and competitiveness. The types of collaborative research were divided into whether or not they were collaborative research. The control variables were firm size (number of employees) and firm age (Figure 4).

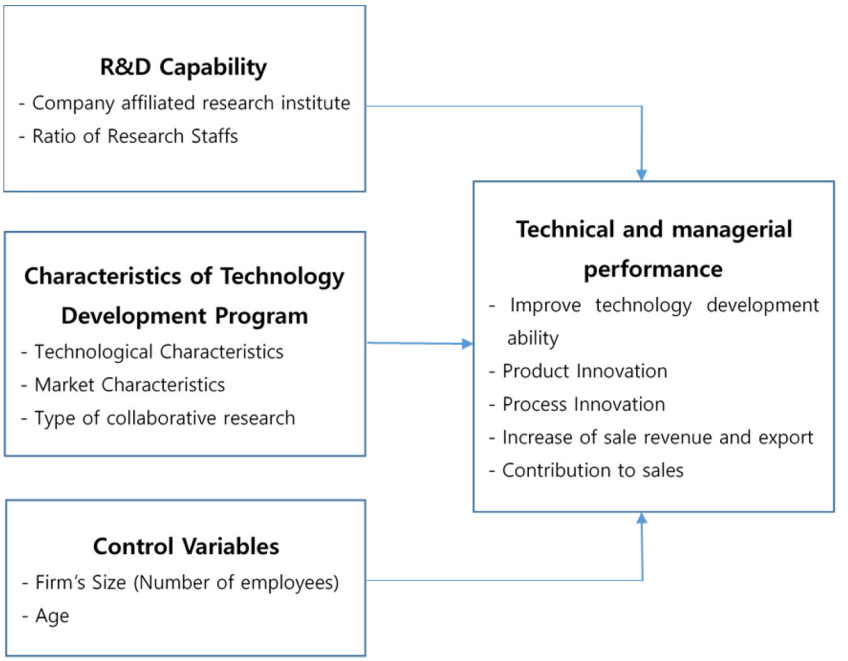

Figure 4.
A model of analysis

3.2 Results of the analysis

Table VII presents the results of analyzing the effects of R&D capability and technical development program characteristics on technical and economic performance of the regional industrial technology development programs, while controlling for the size and age of the firms. For the R&D capabilities, the presence of a company-affiliated research institute had no effect on technological or economic performance. The proportion of R&D staff had a positive effect on the improvement of technology development capability with regard to technological performance, but it had a negative effect on sales and exports with respect to economic performance. In terms of the technological development program, technical characteristics had a positive influence on the improvement of technology development capability, product innovation and process innovation. For economic performance, both sales and exports had a positive influence on it. For market characteristics, complexity positively influenced the technological achievement improvement of technology development, product innovation, sales of economic performance and increase of exports. Dynamics had a significant negative impact on sales and exports, while competitiveness had a positive impact on process innovation and a negative impact on sales contribution with respect to economic performance. Finally, the relationship between technological and economic performance and the type of collaborative research (characteristics of joint research, participation of large corporations) in the technological development program showed that collaborative research had no effect on the dependent variables. However, the participation of large corporations had a positive effect on the contribution of sales in terms of technology achievement improvement, process innovation and economic performance. Firm size had a significantly negative impact on sales and export growth in regard to product innovation, process innovation and economic performance, such as sales and an

Variables	Technological performance			Economic performance	
	Improve technology development capability	Product innovation	Process innovation	Increase of sales and exports	Contribution to sales
R&D capability					
Company-affiliated research institute	0.044 [0.309]	0.019 [0.663]	0.024 [0.580]	0.051 [0.277]	0.049 [0.374]
Proportion of R&D personnel	0.085 [0.060]	0.038 [0.393]	0.038 [0.411]	0.104 [0.036]	0.061 [0.291]
Technology development project characteristic					
Technical characteristics	0.149 [0.004]	0.255 [0.000]	0.185 [0.001]	0.267 [0.000]	0.070 [0.299]
Complexity	0.255 [0.000]	0.110 [0.039]	0.079 [0.143]	0.204 [0.001]	0.095 [0.166]
Dynamics	0.032 [0.556]	0.031 [0.566]	0.088 [0.104]	0.124 [0.038]	0.007 [0.928]
Competitiveness	0.043 [0.373]	0.054 [0.265]	0.189 [0.000]	0.044 [0.407]	0.109 [0.093]
Joint research	0.032 [0.457]	0.005 [0.906]	0.029 [0.498]	0.008 [0.858]	0.005 [0.931]
Participation of large corporations	0.153 [0.000]	0.022 [0.601]	0.087 [0.045]	0.071 [0.131]	0.137 [0.014]
Control variables					
Size of the firm	0.025 [0.587]	0.164 [0.000]	0.197 [0.000]	0.147 [0.003]	0.001 [0.985]
Firm age	0.023 [0.622]	0.032 [0.500]	0.002 [0.972]	0.010 [0.847]	0.101 [0.085]
adj-R^2	0.136	0.147	0.121	0.159	0.032
F	8.597 [0.000]	9.333 [0.000]	7.593 [0.000]	8.474 [0.000]	2.090 [0.025]

Note: [ ] means the level of significance

Table VII. Regression analysis on the determinants of the performance of the regional industrial technology development programs in Phases 2 and 3

increase of exports. On the other hand, firm age had a significant negative impact on sales contribution only in regard to economic performance.

Table VII shows that the main determinants of regional industrial technology development performance are characteristics of the technology development program rather than internal R&D capabilities. Among them, the technical characteristics, complexity of the developed product market and the participation of large corporations had a positive effect. The proportion of R&D staff among firms' internal R&D capacity had a significant influence on the achievement of improved technology development capability. R&D capability, which is a major determinant of technological innovation, had no significant effect on the performance of short-term technology development projects. Technological change, technological difficulty, competition between domestic and foreign competitors and the technological gap had positive effects on performance, excluding sales contributions. In addition, the complexity of the developed product market, such as the diversification of demand, competitive products and sales distributions, had a positive effect on the performance of technology development programs, unlike dynamics and competitive performance. This study could not confirm the effect of collaborative research on the performance of the technology development program, but concluded that collaborative research involving large corporations had a positive effect on the performance. In addition, additional analyses were conducted, and the results are presented in Table VIII. The type of collaborative research was classified into eight categories; there was a meaningful difference between the types of improvement in technology development capability and product

Research type/performance	Technical performance			Economic performance	
	Improve technology development capability	Product innovation	Production innovation	Increase of sales and exports	Contribution to sales
Single research	4.04	3.81	3.13	2.97	31.73
Collaborative research	4.15	3.82	3.26	3.08	33.12
Industry-industry	4.06	3.70	3.18	3.08	27.78
Participation	4.50	4.34	3.92	4.25	20.00
No participation	3.61	3.61	3.07	2.86	28.18
Industry-research institute	4.29	3.95	3.37	3.18	38.29
Industry-university	4.04	3.66	3.14	2.90	34.71
Industry-industry-research institute	4.14	3.79	3.22	3.05	23.39
Participation	4.25	3.58	3.46	3.13	32.00
No participation	4.13	3.81	3.19	3.04	22.50
Industry-industry-university	4.09	3.80	3.27	2.94	37.20
Participation	4.50	3.83	3.50	3.00	46.00
No participation	4.00	3.80	3.22	2.92	35.00
Industry-university–research institute	3.94	3.74	3.25	3.03	26.85
Industry-industry-university-research institute	4.19	3.86	3.25	3.19	37.30
Participation	4.44	3.79	3.46	3.17	53.50
No participation	4.10	3.89	3.23	3.20	30.36
F					
Types of collaborative research	$p < 0.003$	$p < 0.063$	$p < 0.255$	$p < 0.531$	$p < 0.115$
Participation of large corporations	$p < 0.000$	$p < 0.087$	$p < 0.005$	$p < 0.276$	$p < 0.038$
Interaction effects	$p < 0.641$	$p < 0.094$	$p < 0.172$	$p < 0.250$	$p < 0.367$

Table VIII.
Analysis of performance difference according to the type of collaborative research and participation of large corporations

innovation at the levels of 1 and 10 per cent, significantly. Particularly, the technology development programs in which large corporations participated showed high performance in all sectors with regard to performance.

4. Discussion

4.1 Summary of results

This study analyzed the determinants of performance for 492 industrial technology development programs in the Daegu area at Phases 2 and 3. The main results are summarized as follows. First, the presence of R&D capability in company-affiliated research institutes had no effect on technological or economic performance, which is a dependent variable. On the other hand, the proportion of R&D staff in R&D capability was positively influenced only in improving the technology development capability of technical achievement.

Second, the technical characteristics of the technology development program had a positive effect on technical performance (technology development ability improvement, product innovation, process innovation) and economic performance (sales and export increases), excluding the contribution of sales. Third, the complexity, which is the market characteristic of the technology development program, positively influenced the increase in technology development ability, product innovation, economic performance and the increase in exports. The market characteristics of dynamics had no significant effect on the

dependent variables. Competitiveness, which is a market characteristic, had a positive effect on the process innovation of technological performance. Therefore, the complexity of the developed product market, such as the diversity of demand, competitive product and sales distribution, had a positive effect on the performance of the technology development program, unlike the dynamics and competitive performance. Fourth, although the joint research type of collaborative research, which is a part of the technology development program, did not have any influence on the dependent variable, participation in large corporations was positively related to technological performance, such as improvement in the technology development capability, process innovation and economic performance. It had a significant effect.

4.2 Policy implications and future research agendas

The results of analyzing the determinants of the regional industrial technology development programs in the second and third phases suggest some implications in the future evaluation of regional industrial technology development programs. It is necessary to review the application qualification and merit, advance review of the business plans and confirmation, an examination of the research results and performance of the applicants, and a review of the technology and market situation of the project. For this, we suggest that the written review from the relevant technical experts be submitted to the evaluation committees. Also, when establishing the regional industrial development plan, the program should be evaluated thoroughly, including detailed information and contents of the technical and market characteristics of the local industry. To improve the current evaluation system, which is much more focused on the performance of the technological development goal, it is necessary to evaluate between the market characteristics of new product lines and the feasibility of the program. Additionally, it is important to have specialized evaluators who can evaluate the programs in all aspects at the same time. Moreover, consideration should be given to collaborative research with large corporate projects to complement R&D capability, commercialization for developed products and an expanded demand. The type of collaborative research that was introduced as an independent variable in this study was not as significant as other independent variables. However, there was some difference in the analysis of collaborative research and participation in large corporations. Therefore, rather than introducing the type of collaborative research as an independent variable, it can be used as a moderating variable for the relationship between R&D capability and its performance, technical and market characteristics and business performance. In the case of adopting it as a moderating variable, it is necessary to subdivide the type of collaborative research; industry to industry, industry to research institute, industry to university, and whether to participate in large corporations. In the future, it is necessary to consider the characteristics of the industry, the characteristics of the participants, the level of the company's technology and the stage of industrial growth.

References

Bae, J.T. and Jung, J.W. (1997), "A study on the relationship between technology cooperation activities and performance of domestic SMEs", *Journal of Korea Small and Medium Business*, Vol. 19 No. 2, pp. 157-178.

Barba-Sanchez, V. and Atienza-Sahuquillo, C. (2011), "Reasons to create a new venture: a determinant of entrepreneurial profiles", *African Journal of Business Management*, Vol. 5 No. 28, pp. 11497-11504.

Becheikh, N., Landry, R. and Amara, N. (2006), "Lessons from innovation empirical studies in the manufacturing sector: a systematic review of the literature from 1993-2003", *Technovation*, Vol. 26 No. 5, pp. 644-664.

Chandy, R.K., Prabhu, J.C. and Antia, K.D. (2003), "What will the future bring? Dominance, technology expectations, and radical innovation", *Journal of Marketing*, Vol. 67 No. 3, pp. 1-18.

Duncan, R.B. (1972), "Characteristics of organizational environments and perceived environmental uncertainty", *Administrative Science Quarterly*, Vol. 17 No. 3, pp. 313-327.

Dutta, S., Narasimhan, O. and Rajiv, S. (1999), "Success in high-technology market: is marketing capability critical?", *Marketing Science*, Vol. 18 No. 4, pp. 547-568.

Freel, M.S. (2003), "Sectoral patterns of small firm innovation, networking and proximity", *Research Policy*, Vol. 32 No. 5, pp. 751-770.

Hadjimanolis, A. (2000), "A resource-based view of innovativeness in small firms", *Technology Analysis and Strategic Management*, Vol. 12 No. 2, pp. 263-281.

Hall, L.A. and Bagchi-Sen, S. (2002), "A study of R&D, innovation, and business performance in the Canadian biotechnology industry", *Technovation*, Vol. 22 No. 4, pp. 231-244.

Huiban, J. and Boushina, Z. (1998), "Innovation and the quality of labour factor: an empirical investigation in the French food industry", *Small Business Economics*, Vol. 10 No. 4, pp. 389-400.

Hwang, S.J. and Shin, J.K. (2015), "Technological innovation in SMEs: modeling the role of determinants", *Asia Pacific Journal of Small Business*, Vol. 37 No. 3, pp. 25-52.

Kaufmann, A. and Todtling, F. (2001), "Science-industry interaction in the process of innovation: the importance of boundary-crossing between systems", *Research Policy*, Vol. 30 No. 5, pp. 791-804.

Keizer, J.A., Dijkstra, L. and Halman, J.I.M. (2002), "Explaining innovative efforts of SMEs: an exploratory survey among SMEs in the mechanical and electrical engineering sector in the Netherlands", *Technovation*, Vol. 22 No. 1, pp. 1-13.

Kim, M.G. and Park, J.H. (2009), "A study on the relationship between external environment, Innovation drivers, Innovation capacity, and Innovation performance in Domestic SMEs", *Preceding Paper, Korean Management Association Conference*, *Pyeongchang, 17-19 August*.

Kim, Y. and Choi, J. (2016), "The role of a large competitor's entry and level of innovativeness in consumer adoption of new product", *Asia Pacific Journal of Innovation and Entrepreneurship*, Vol. 10 No. 1, pp. 168-182.

Kirkley, W.W. (2016), "Creating ventures: decision factors in new venture creation", *Asia Pacific Journal of Innovation and Entrepreneurship*, Vol. 10 No. 1, pp. 151-167.

Kotabe, M. and Swan, K.S. (1995), "The role of strategic alliances in high technology new product development", *Strategic Management Journal*, Vol. 16 No. 8, pp. 621-636.

Landry, R., Amara, N. and Lamari, M. (2002), "Does social capital determine innovation? To what extent?", *Technological Forecasting & Social Change*, Vol. 69 No. 7, pp. 681-701.

Lee, J.G. and Kim, T.I. (2012), "A study on the influencing factors on the global performance of Chinese small and medium enterprises", *Trade Information Research*, Vol. 14 No. 3, pp. 1-28.

Lee, S., Sawng, Y.W., Lee, Y. and Park, S.Y. (2014), "Incremental and radical innovation in new product development: comparison of large corporations and small-to medium-sized enterprises", *Asia Pacific Journal of Innovation and Entrepreneurship*, Vol. 8 No. 2, pp. 23-42.

Love, J.H. and Roper, S. (2001), "Location and network effects on innovation success: evidence for UK, German and Irish manufacturing plants", *Research Policy*, Vol. 30 No. 4, pp. 643-661.

Michie, J. and Sheehan, M. (2003), "Labour market deregulation, 'flexibility' and innovation", *Cambridge Journal of Economics*, Vol. 27 No. 1, pp. 123-143.

Miller, D. (1988), "Relating Porter's business strategies to environment and structure: analysis and performance implications", *Academy of Management Journal*, Vol. 31 No. 2, pp. 280-308.

Miller, D. and Friesen, P.H. (1982), *Organization: A Quantum View*, Prentice-Hall, Englewood Cliffs, NJ.

Nieto, M. and Quevedo, P. (2005), "Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort", *Technovation*, Vol. 25 No. 10, pp. 1141-1157.

Oh, J.B. (2006), "An empirical study on joint R&D projects for government support: focusing on common core infrastructure technology development projects", *Industrial Organizations Research*, Vol. 14 No. 3, pp. 111-146.

O'Regan, N., Ghobadian, A. and Sims, M. (2006), "Fast tracking innovation in manufacturing SEMs", *Technovation*, Vol. 26 No. 2, pp. 251-261.

Papadakis, V. and Bourantas, D. (1998), "The chief executive officer as corporate champion of technological innovation: an empirical investigation", *Technology Analysis and Strategic Management*, Vol. 10 No. 1, pp. 89-98.

Ritter, T. and Gemunden, H.G. (2003), "Network competence: its impact on innovation success and its antecedents", *Journal of Business Research*, Vol. 56 No. 9, pp. 745-755.

Romijn, H.A. and Albaladejo, M. (2002), "Determinants of innovation capability in small electronics and software firms in Southeast England", *Research Policy*, Vol. 31 No. 7, pp. 1053-1067.

Schoomhoven, C., Eisenhardt, K.M. and Lyman, K. (1990), "Speeding products to market: waiting time to first product introduction in new firms", *Administrative Science Quarterly*, Vol. 35 No. 1, pp. 177-207.

Shin, J.K., Lim, J. and Hwang, S. (2009), "Determinants of technological innovation in SMEs", *Business Management Review*, Vol. 16 No. 4, pp. 1-23.

Smolny, W. (2003), "Determinants of innovation behaviour and investment estimates for West-German manufacturing firms", *Economics of Innovation and New Technology*, Vol. 12 No. 5, pp. 449-463.

Song, K.S. and Kim, H.J. (2005), "A study on the issue of individual innovation and organizational innovation", *Management Information Research*, Vol. 16, pp. 59-76.

Song, W.J. (2000), "Comparative analysis of technology innovation patterns by industry", *Science and Technology Policy*, Vol. 123, pp. 152-165.

Souitaris, V. (2001), "Strategic influences of technological innovation in Greece", *British Journal of Management*, Vol. 12 No. 2, pp. 131-147.

Souitaris, V. (2002), "Firm-specific competencies determining technological innovation: a survey in Greece", *R&D Management*, Vol. 32 No. 1, pp. 61-77.

Sung, T. (2006), "Determinants of technological innovation activities", *Journal of Business Research*, Vol. 21 No. 4, pp. 283-304.

Thamhain, H.J. (2003), "Managing innovative R&D teams", *R&D Management*, Vol. 33 No. 3, pp. 297-311.

van der Panne, G., van Beers, C. and Kleinknecht, A. (2003), "Success and failure of innovation: a literature review", *International Journal of Innovation Management*, Vol. 7 No. 3, pp. 309-338.

Yoon, E. and Lilien, G.L. (1985), "New industrial product performance: the effects of market characteristics and strategy", *Journal of Product Innovation Management*, Vol. 2 No. 3, pp. 134-144.

Zahra, S.A. (1993), "New product innovation in established companies: associations with industry and strategy variables", *Entrepreneurship Theory and Practice*, Vo. 18 (Winter), pp. 47-69.

Corresponding author
Choo-Hui Park can be contacted at: juliapark@kmu.ac.kr