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Public technology transfer, commercialization and business growth

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A R T I C L E   I N F O

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A B S T R A C T

This study analyzes the conditions for the commercialization of public technologies transferred to the private sector and the subsequent effect on business growth. We focus on the commercial exploitation of technologies transferred by universities and public research institutes (U&PRIs) to companies. The empirical analysis uses detailed information regarding an extensive set of actual instances of public-private technology transfer in Korea (514 cases of technologies transferred by 43 major U&PRIs) to highlight the role of company absorptive capacity and internal innovation capabilities, cooperation with U&PRIs, and the intensity of market competition in determining commercialization success and business growth. We find that the intensity of market competition significantly influenced the paths along which absorptive capacity and internal innovation capacity affected successful commercialization, and successful commercialization in turn affected business growth. Effective partnership is a key factor of the successful commercialization of transferred technologies irrespective of market situations. Absorptive capacity contributes to their short-term success and long-term growth when market competition is strong.

1. Introduction

We study the conditions for the commercialization of public technologies transferred to the private sector and the effect of such technologies on business growth. We focus on the commercial exploitation of technologies transferred by universities and public research institutes (U&PRIs) to companies. The empirical analysis uses detailed information regarding an extensive set of actual instances of public-private technology transfer in Korea to highlight the role of company absorptive capacity and internal innovation capabilities, cooperation with U&PRIs, and the intensity of market competition in determining commercialization success and business growth.

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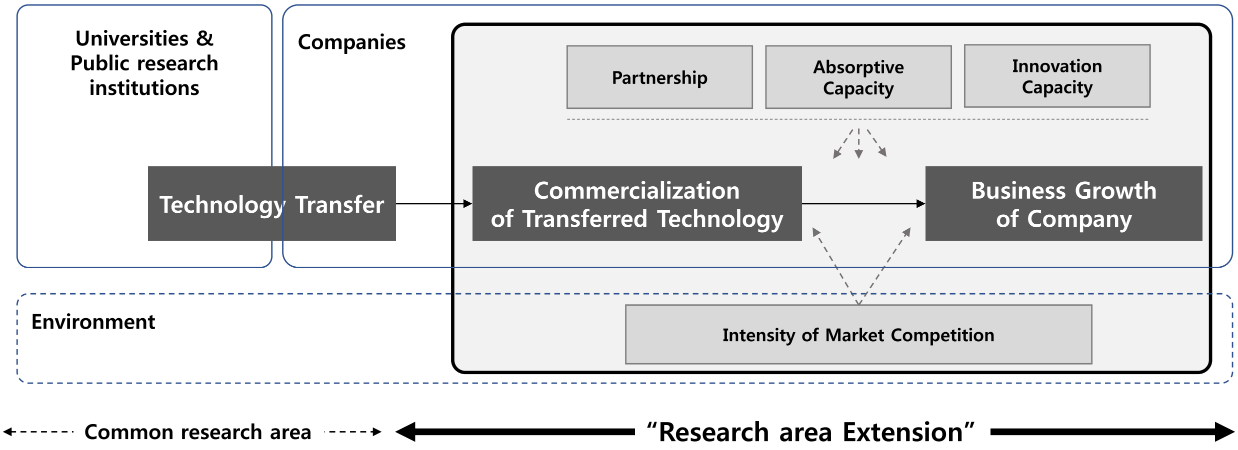

Fig. 1. Conceptual framework.

A long stream of literature has developed during the past few decades around the need of companies to engage in collaborative agreements involving the creation and exchange of technology.[1] While companies could always choose to rely exclusively on internal research efforts, a strategy combining internal efforts with collaboration with other organizations such as those examined herein is advisable especially for companies that lack sufficient internal resources and capabilities. To enhance their competitiveness, companies must not only develop their own research and development (R&D) capacities but also interact actively with other organizations, including U&PRIs, to secure resources for continuous innovation. Through partnership with these external organizations, companies can access the resources and knowledge they need, and overcome their shortcomings (Chesbrough, 2003). Joint R&D projects, joint investments, contract-based research, and licensing are increasingly emerging as new channels via which companies access new knowledge.

Licensing is a common form of collaboration between industry and U&PRIs – public-private partnership (PPP) for short. The Bayh–Dole Act and the Stevenson–Wydler Technological Innovation Act of the US Congress first recognized ownership claims of technologies by U&PRIs back in 1980, paving the ground for active technology transfer in the United States (Pascoe and Vonortas, 2015; Link and van Hasselt, 2019). Legislative changes like these openly urged universities and public research institutes to increase research for the practical solution of social problems over and beyond the classic exploration of scientific truth (Gibbons et al., 1994). With science and technology emerging as central assets for industrial development and economic growth, the technologies developed by U&PRIs can contribute significantly to industrial competitiveness (Mansfield and Lee, 1996; Link and Scott, 2019).

Technology transfer catalyzes positive collaboration among the parties involved in PPP. The road to the successful adoption and commercialization of public technologies by private companies, however, is rife with diverse risks of market failure (Goldhor and Lund, 1983; Agrawal, 2006). There is often a considerable gap between the technologies provided by U&PRIs and those demanded in the market. This gap is the source of unexpected costs and risks (Hellmann, 2007).

Much of the existing literature on technology transfer focuses on the public sector as a source of transferred technologies (Powers, 2003; Thursby and Thursby, 2007; Guerrero et al., 2015; Perkmann et al., 2013; Bozeman et al., 2015) and the private sector as a receptor. This study goes further to examine whether private companies adopting technologies from the public sector have actually succeeded in commercializing them, and how such technology transfer has affected the growth of those companies. The successful commercialization of transferred technologies goes much beyond the arrival of public technologies at companies. It entails the fruitful use of transferred technologies in the form of actual products and services (Heinzl et al., 2013). In our previous research (Min et al., 2019) we have started examining the relationship between the successful commercialization of technology and several factors, also including partnership, absorptive capacity, and market competition. This study extends the scope of analysis further from the short-term commercialization success of transferred technologies to the long-term business growth of the companies (Fig. 1).

We herein explore the role of company absorptive capacity and internal innovation capabilities, cooperation with U&PRIs, and the intensity of market competition in determining commercialization success and business growth. Based on an extensive set of technologies formally transferred from U&PRIs to companies in Korea during a three-year period, we have identified key factors influencing successful technology commercialization and business growth. The empirical analysis is based on a survey of all the 5340 technologies formally transferred during 2009–2011 from 43 major U&PRIs to companies in Korea. We were able to obtain survey results on 1433 of these technologies and focused on 514 in our final analysis reported herein for which complete detailed financial data were available. A number of prior studies on related topics are

[1] Numerous surveys of the literature exist. For a small sample see Hagedoorn et al. (2000), Vonortas and Zirulia (2015), Vonortas (1997). Specifically for small and medium sized companies see Colombo et al. (2006), Street and Cameron (2007), and Kim and Vonortas (2014),

confined to certain industries or organizations due to the unavailability of representative data (Cummings and Teng, 2003; Greiner and Franza, 2003; Agrawal, 2006). This study overcomes this shortcoming by extending across the entire technology spectrum.

Our analysis reveals that the effects of diverse factors on the successful commercialization of transferred technologies and on business growth varied under different market competition environments. Company absorptive capacity contributes significantly to successful commercialization in the short term and this commercialization induces long-term business growth when market competition is strong. When market competition is weak, on the other hand, the internal innovation capacity of companies contributes to their long-term growth even though it seems to not be particularly important for short-term success with technology commercialization. Effective partnership between the technology supplier and the technology adopter is a key factor of the successful commercialization of transferred technologies irrespective of market situations.

The rest of the paper is structured as follows. Section two provides the theoretical background and research model. Section three discusses the research methods and data. Section four discusses the results. Finally, section five concludes.

2. Theoretical background and research model

2.1. Absorptive capacity

To manage rapid changes in the business environment effectively, companies must continually absorb and utilize knowledge and resources from external sources (Chesbrough, 2003). Knowledge adopted from external sources requires some contextual and preceding knowledge that makes it difficult for other organizations to understand or copy (Szulanski, 1996). In other words, the successful acquisition of external knowledge depends as much on the capability of the adopting organization as on the basic nature of the knowledge itself. The organizational capacity of companies, necessary for effective decision-making and execution of plans, also exerts significant influences on company performance.

Cohen and Levinthal (1990) conceptualized this capability of absorbing external knowledge as “absorptive capacity,” defining it as the ability of an organization to assess, adopt, and adapt new knowledge from external sources by using existing knowledge and experience. Zahra and George (2002) identified four dimensions of absorptive capacity or the process by which companies adopt and handle external knowledge. These dimensions include recognition and acquisition, understanding and assimilation, transformation and internalization, and utilization and execution. From the perspective of dynamic capacity, the authors again combined acquisition and assimilation into “potential absorptive capacity,” and transformation and utilization into “realized absorptive capacity.” Potential absorptive capacity is found in the interactions of companies with external environments, while realized absorptive capacity applies to the internal workings of companies. In this paper, we focused on “potential absorptive capacity” (Section 2.2).

In general, the technologies developed by U&PRIs are intended to benefit the public rather than cater to specific clients. There were no specific recipients determined in advance. Companies may adopt these technologies under licensing agreements; the tacit nature of knowledge introduces difficulties in internalizing, applying, and commercializing the technologies they so adopt (Todorova and Durisin, 2007). The outcomes of companies’ attempts at innovation by absorbing and utilizing transferred technologies would thus significantly differ depending on their absorptive capacities.

2.2. Internal innovation capacity

Companies must develop their own capabilities to convert new technical and human resources into assets. Assets that enable companies to achieve and maintain edges in competition should be valuable, rare, inimitable, and irreplaceable (Teece et al., 1997). R&D capacity, which refer to companies’ ability to develop valuable products on a continued basis, enhances company performance over time when it is inimitable and irreplaceable by rivals (Langerak and Hultink, 2006).

According to the endogenous growth theory of Romer (1986), the accumulation of knowledge inside a company, typically the result of R&D investment, allows the company to keep growing by increasing its marginal productivity. R&D investment is thus crucial to the sustainable growth of companies, especially in a knowledge-based economy where R&D investment becomes the most important investment companies could make in their growth potentials (Brown et al., 2009).

Company internal R&D-based innovative activities raise barriers for competitors, thus limiting the attempts by potential rivals to enter the market and strengthening company ability to dominate the market (Lukach et al., 2007). Berchicci (2013) defined R&D capacity as the ability to invest in internal R&D necessary for the buildup of knowledge stock and empirically demonstrated that R&D capacity indeed positively influences the outcomes of companies’ attempts at innovation. Tsai and Wang (2008) demonstrated the positive correlation between R&D investment and the productivity of R&D as well.

There is a wide consensus that R&D forms a crucial part of business growth strategies and that R&D investment is key to companies’ sustainable growth. Nevertheless, the uncertainty over the outcomes of R&D and the length of time it takes to earn returns cause companies to hesitate. R&D investment is a double-edged sword in this regard (Coad et al., 2016).

In this study, we confine our attention to how internal innovation capacity affects the commercialization of transferred technologies and company long-term growth.

2.3. Public–private partnership

The difference in perspectives, roles, and positions between U&PRIs and companies often presents the biggest obstacle to working together. The public and private sectors pursue different values, and hold different expectations of each other, which lead to an escalating tension in some cases (Baycan and Stough, 2013). Public researchers may hold an edge over the amount of technical information they possess, while private companies hold an edge over the amount of business-related information they possess (Agrawal, 2006). This asymmetry of knowledge may tempt parties to a technology transfer arrangement to make opportunistic choices to maximize their respective gains at the expense of one another (Williamson, 1993; Link and Scott, 2005). The cost of transaction generally stems from the asymmetry of information. Companies could reduce this asymmetry by expanding their networks (Gulati et al., 2000), and mutual trust among network participants could reduce the overall cost of transaction by reducing their opportunistic behavior.

Strong mutual trust would mitigate fear of possible opportunistic behavior of other parties (Dodgson, 1993). Trust enables partners to effectively share and transfer knowledge without worries of unwanted leakage and free riding. The sense of confidence could expedite the sharing of knowledge and ideas (Dyer and Chu, 2003).

The nature of interaction between partners has been identified as a key factor for the sustainability of PPP (Geisler, 1995). Different types of interaction across the different developmental stages are necessary based on dynamic capabilities framework (Heaton et al., 2019). Smooth collaboration forms an important concern of management in PPP as it can greatly facilitate the sharing of information between partners (van Rijnsoever and Hessels, 2011). Continuous communication between partners is crucial to the effective delivery and coordination of information, the facilitation of knowledge development, and the development of shared understanding on complex problems. Effective collaboration is thus a fundamental element of a successful performance (Grant, 1996; Takeishi, 2001; Slater and Mohr, 2006). In this study, we examine whether and to what extent the appropriate and effective systems of communication between partners promote the successful commercialization of transferred technologies.

2.4. Intensity of market competition

Since Schumpeter much research has been conducted on the correlation between market competition and companies' innovative activities (Kamien and Schwartz, 1982). The neoSchumpeterian hypotheses posited a positive relationship between innovation, company size, and market concentration. It was hypothesized that companies' innovative activities are influenced by their monopolistic power over the market, which would enable them to appropriate the results of innovation, and by their size, which would determine their ability to carry out innovation. That is, large corporations are better able than SMEs to carry out innovation. In addition, innovation occurs more actively in concentrated industries.

A very extensive literature since then has gone back and forth on the issue (Cohen, 2010). Arrow (1962) for instance contradicted this hypothesis arguing that monopolistic companies have fewer and weaker incentives to innovate than companies facing competition. Arrow explains innovation as a function of the intensity of market competition, not so much as a function of firm size. Whether they are dominant or small, companies would seek to innovate themselves to win over the competition. The Arrow hypothesis would be valid if monopolistic companies indeed stopped further R&D, complacent with the surplus profits they are already making, while their competitors continue to focus on R&D to raise their profitability. If, however, monopolistic companies used the current surplus profits they are making to invest in R&D to fend-off potential competition, Schumpeter would have a valid point.

The debate has created a view that the relationship between competition and innovation follows an inverted U–shaped relationship (Aghion et al., 2005): innovation may be most prominent in moderately competitive markets, whereas monopolistic or highly competitive markets are relatively less innovative.

Overall, it is fair to say that the empirical literature has yet to reach consensus on the topic. Depending on the models of analysis, variables, or data sets used, these empirical studies offer quite different conclusions (Cohen, 2010). Although the intensity of market competition is an important factor in and of itself, it is not sufficient to explain the outcomes of companies' innovative activities. Little is known about the technology transfer outcomes between companies and U&PRIs under various market competition environments. While firms may be indifferent to technology transfer from U&PRIs in general, intensification of market competition might lead some of them to consider acquiring new technologies externally form other parties, also including U&PRIs. Herein we examine how the state of market competition combines with companies' chosen strategies in leading to certain outcomes.

2.5. Research model

Based on the foregoing consideration, we set up a research model illustrated in Fig. 2.

We posit the following specific research hypotheses:

H1. The absorptive capacities of companies positively affect the chances for successful commercialization of technologies transferred from external sources.

H2. Effective communication between the public source of the technology and the private recipient positively affects the chances for successful commercialization of the respective technologies.

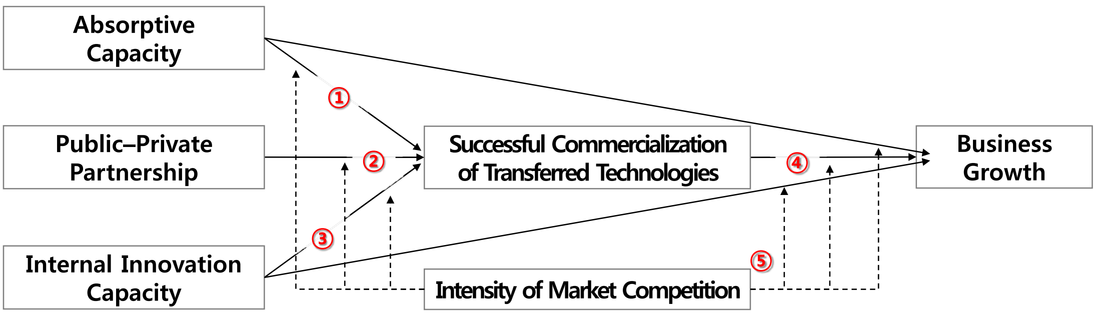

Fig. 2. Research Model (multi group structural model).

Table 1
Second survey: distribution of 514 survey-responding technologies.

Type		*N*	%	Type		*N*	%
Company Size*	Large	39	11.5	Transfer Mode	Exclusive license	141	27.4
	Medium	44	13.0				
	Small	256	75.5		Non-exclusive license	284	55.3
Overall (Companies)		339	100.0				
Tech. Area	Machinery/materials	113	22.0		Transfer patent	33	6.4
	Electric/electronics	121	23.5		Technical support or other	56	10.9
	ICT	132	25.7	Type of Tech.	Patent	250	48.7
	Chemicals	46	8.9				
	Biotechnology	54	10.5		SW Program	59	11.5
	Energy	9	1.8		Know-how	200	38.9
	Knowledge services	28	5.4		Other	5	1.0
	Other	11	2.1	Overall (Technology Transfers)		514	100.0

* Categorized by number of employees: Large (1000 and over), Medium (300~999), Small (under 300).

H3. The internal innovation capacities of companies positively affect the chances for successful commercialization of technologies transferred from external sources.
H4. The successful commercialization of technologies transferred from external sources positively affects company growth.
H5. The intensity of market competition moderates the paths of effects along H1–H4.

3. Research method

3.1. Data and sample

This study investigates technology transfer by 43 leading U&PRIs to Korean industry from 2009 to 2011.[2] During that period, 3347 companies adopted a total of 5340 formally transferred technologies by U&PRIs, representing the full population of observed instances of technology transfer in the country. (a complete population). Almost a third of the companies adopted two or more technologies from the same U&PRIs.

A survey was conducted from July to September 2013 to investigate the commercialization of transferred technologies regardless of commercialization success. In total, 1038 companies shared information on the 1433 technologies they adopted from U&PRIs. The analysis herein is based on 514 of these technologies corresponding to 339 firms for which detailed financial reports were also available. Table 1 summarizes information on the distribution of 514 survey-responding technologies.

3.2. Variable definition

3.2.1. Absorptive capacity

Absorptive capacity is the ability to make use of external knowledge through the sequential process of exploration, transformation, and application (Cohen and Levinthal, 1990). Even though absorptive capacity undoubtedly contributes to the effectiveness of companies' strategic behavior, some analysts have been skeptical about the use of the concept, citing the difficulty of its operationalization, the elusive nature of how it specifically works, and the difficulty of its measurement (Lane et al., 2002). George et al. (2001) measures absorptive capacity in terms of the amount of R&D investment and the number of patents held. Tsai (2001), on the other hand, measures it as a ratio of R&D investment to revenue.

[2] The study was supported by the Korea Institute for Advancement of Technology, a quasi non-governmental R&D agency.

Table 2
Levels of success with the commercialization of transferred technologies.

N	Failed	Less Than the Investment	On a Par with the Investment	Less Than Three Times the Investment	Less Than 10 Times the Investment	10 Times the Investment or Greater	Subtotal
Frequency	349	8	20	65	39	33	514

As discussed earlier, this study defines absorptive capacity not as a single concept but as a complex sum of multiple factors. We focus on “potential absorptive capacity” pertaining to recognition & acquisition, and understanding & assimilation of external environments (Zahra and George, 2002). Referring to the qualitative survey results cited in Szulanski (1996), Jansen (2005), and Kim and Atuahene-Gima (2010), absorptive capacity is defined as a composite concept measured across five dimensions (five-point Likert scale): (1) quick recognition of market changes, (2) response to rival companies, (3) adoption of successful examples, (4) change of execution strategies, and (5) consideration of cyclical market changes.

3.2.2. Partnership

Recognizing that transferred technologies involve codified and tacit knowledge, we examine whether the public–private partnership enabled companies to absorb and utilize both types. Agrawal (2006) uses the number of hours researchers spent between the signing of the licensing agreements and the generation of first revenue (obtained from interviews with researchers) as an explanatory variable. Continuous communication using a variety of channels is crucial to the effective technology transfer and successful commercialization of transferred technologies. This study measures the intensity of partnership in terms of five variables, including (1) additional technical instruction from researchers, (2) human resource exchange, (3) additional policy funds provided, (4) technical information provided, and (5) support for additional joint R & D projects (five-point Likert scales). The average score is used as the partnership variable.

3.2.3. Internal innovation capacity

Typical measures of the company innovation capacity include R&D spending and R&D intensity (R&D spending divided by the revenue). Some researchers use the R&D concentration along with the number of patents held by companies to gauge their internal innovation capacities (e.g., Acha, 2000). Schoenecker and Swanson (2002) used R&D spending, the number of patents, the number of new products launched, and R&D intensity as indicators of internal innovation capacity, concluding that it is positively correlated to the revenue growth rate and the return rate on investment. In this study, we use R&D intensity over three years, from 2010 to 2012, and divide the company sample into five groups (less than 1%, less than 3%, less than 5%, less than 10%, and 10% or above.)

3.2.4. Commercialization of transferred technologies

It is difficult to accurately define commercialization success of a transferred technology (Hamel, 1991; Laursen and Salter, 2006). Through the adoption of technologies transferred U&PRIs, companies can reduce R&D costs, speed up market entry, acquire supplementary assets, reduce business unpredictability, and share resources (Dodgson, 1993; von Stamm, 2004; Nieto and Santamaría, 2007). These achievements can be divided into technical, financial, and physical performance.

Mohr and Spekman (1994) argued that the outcome of commercialization is best measured by assessing how much of the initial goals or targets were achieved by the adopting companies as technology transfer is often used to meet diverse objectives. This study followed this route and used the respondents’ general assessment of whether the adopted technologies helped them achieve their initial goals. The gains that these companies had, as a result of acquiring the technologies (in the form of increased revenue or decreased business cost) in proportion to the costs of acquiring the technologies, were described by a five-point Likert scale (Table 2).

3.2.5. Business growth

A wide variety of indicators, such as market capitalization, the number of employees, the increase in revenue, and value-added have been used to measure the growth of companies (García-Manjón and Romero-Merino, 2012). Prior empirical results have tended to vary widely depending on which of these diverse indicators are used to measure companies’ growth. Song and Montoya-Weiss (2001), for instance, used the return-on-investment (ROI) rate. Belderbos et al. (2004) used the rate of growth in companies’ values-added. Cefis and Marsili (2006) used the likelihood of companies’ survival in association with each type of collaboration with external partners. In this study, we use the average annual rate of growth in revenue, from 2013 to 2015, as the measure of company growth.

3.2.6. Market competition

Following Geroski (1990), this study looked into five alternative measures of the intensity of market competition: (1) product life cycles; (2) the pace of change in customer demand (Jaworski and Kohli, 1993; Olson et al., 2005); (3) the pace of technological change (Kim and Atuahene-Gima, 2010); (4) the level of competitor activities (Cui et al., 2005); and (5) the pace of new products being launched (five-point Likert scales). Subsequently, companies were allocated into two groups,

Table 3
Variables.

Variable	Type	Description
(Independent variables)		
Absorptive capacity	Likert scale (five-point)	• Quickly recognizes market changes • Quickly responds to competitors' changes • Regularly considers market outcomes • Adopts successful examples • Changes execution strategies based on customer feedback
Partnership	Likert scale (five-point)	• Received technical instructions from the technology provider • Exchanged research workforce with the technology provider • Received policy funding for commercialization (facilities and operation) • Received relevant and additional information • Undertook additional joint R&D projects
Internal innovation capacity	Ordinal scale	• Five levels of the ratios of R&D investment to revenue, 2010–2012 (i.e., less than 1%, less than 3%, less than 5%, less than 10%, and 10% or greater)
(Moderator variable)		
Intensity of market competition	Likert scale (five-point)	• The life cycle of the product is quite short. • Customers regularly demand new products and services. • The pace of technological change is fast. • Competitors' behavior is unpredictable and poses intense competition. • Success is possible only through the regular launching of new products or services.
(Dependent variable)		
Level of success with commercialization	Likert scale	• Gains in proportion to the cost of technology (either increased revenue or decreased business cost), that is, 0 (failed), 1 (very low), 2 (low), 3 (moderate), 4 (high), 5 (very high)
Business growth	Ratio scale	• Rate of growth in companies' revenue, 2013–2015

one facing high levels of market competition and the other facing low levels, using the overall mean level of competition defined on the basis of the aforementioned fine measures.

Table 3 sums up the variables and their operationalization used in this study.

3.3. Testing variable validity and reliability

Table 4 summarizes the reliability and validity tests on some of the variables. An exploratory factor analysis was conducted to test the validity of the concepts. Excluding the item whose commonality fell short by 0.4, the lowest level of factor loading reached over 0.6, and the explained variation exceeded 59%, ensuring the conceptual validity of the variables used. The value of Cronbach's alpha, used to determine the consistency in the participating companies' responses, also surpassed 0.7, indicating a high level of reliability.

Table 5 lists the means, standard deviations, and correlation coefficients of all variables. The correlation coefficients are generally 0.4 or less, leading us to conclude that the risk of multicollinearity in the subsequent path analysis was not significant.

4. Results

4.1. Testing the fitness of the research model

To test the fitness of our research model (Fig. 2), we applied the normed fit index (NFI) and the comparative fit index (CFI); the root mean square error of approximation (RMSEA), which is an absolute fit index; and the parsimonious NFI (PNFI). In general, if the incremental fit index value including the NFI and the CFI is greater than 0.9, the model fit can be interpreted as good (Hu and Bentler, 1999). The RMSEA, developed to overcome the problems of the $\chi 2$ statistics resulting

Table 4
Validity and reliability tests of the variables.

Factor	Variable	Factor Analysis				Reliability
		Factor Loading	Commonality	Eigen value	Explanatory Variable (%)	Cronbach's α
Absorptive capacity	(1) Quickly responds to market changes	.829	.688	3.251	65.019	0.862
	(2) Quickly responds to competitors' changes	.825	.681			
	(3) Regularly considers market outcomes	.848	.719			
	(4) Actively adopts successful examples	.696	.484			
	(5) Changes execution strategies based on customer feedback	.824	.680			
Market competition	(1) The life cycle of the product is quite short.	.638	.407	2.367	59.184	0.766
	(2) Customers regularly demand new products or services.	.807	.651			
	(3) The pace of technological change is fast.	.836	.699			
	(4) Competitors' behavior is unpredictable and poses intense competition. (Removed)	*(0.587)*	*(0.344)*			
	(5) Success is only possible by regularly launching new products or services.	.781	.611			

Table 5
Descriptive statistics and pearson correlations.

Variable	Mean	SD	1	2	3	4	5
1. Absorptive capacity	3.76	0.60	1				
2. Partnership	2.80	0.91	0.22**	1			
3. Internal innovation capacity	3.51	1.37	0.12**	0.01	1		
4. Successful commercialization	1.10	1.71	0.08	0.37**	−0.11*	1	
5. Business growth	2.38	12.23	−0.02	0.06	−0.01	0.12**	1

$N = 514$.
* $p < 0.05$,.
** $p < 0.01$ (both sides).

Table 6
Tests on the fitness of the research model.

Index	χ^2	df	NFI	CFI	RMSEA	PNFI
Overall	2.129	2	0.986[a]	0.999[a]	0.011[a]	0.099
High market competition	0.151	1	0.998[a]	1.000[a]	0.000[a]	0.100
Low market competition	1.976	1	0.967[a]	0.981[a]	0.069[b]	0.097

[a] Good.
[b] Normal.

from the multiplicity of the observed variables or the largeness of the sample size, indicates strong fitness when it is 0.05 or below, moderate to good fitness when it is 0.08 or below, and lacking fitness when it is 0.10 or greater (Bollen and Long, 1992). The PNFI represents the parsimony of the given research model. The smaller it is, the more fit the model is (James et al., 1982).

We sought to determine the structural correlations of internal innovation, partnership and absorptive capacities to companies' growth through the successful commercialization of transferred technologies by examining the entire sample, on the one hand, and by distinguishing between two different market situations, where the competition is strong and where the competition is weak, on the other. As Table 6 shows, our research model displays excellent fitness in all the three situations.

4.2. Multi-group analysis conditioned on market competition intensity

The multi-group structural model analysis involves testing statistical differences among the groups using path coefficients. The structural model used in this study is a path model for which it is not necessary to verify the measurement invariance with respect to each factor. Accordingly, we used the path coefficients between the factors to test differences

Table 7
Model parameters with high and low market competition.

Path	Total ($N = 514$)			High Market Competition ($N = 309$)			Low Market Competition ($N = 205$)		
	$B(\beta)$	CR	p	$B(\beta)$	CR	p	$B(\beta)$	CR	p
Absorptive capacity → Succ. comm.	0.039 (0.014)	0.329	0.742	**0.251 (0.093)**	**1.748**	**0.081**	−0.206 (−0.066)	−0.988	0.323
Partnership → Succ. comm.	**0.696 (0.370)**	**8.884**	***	**0.698 (0.391)**	**7.381**	***	**0.753 (0.375)**	**5.578**	***
Internal innovation capacity → Succ. comm.	**−0.142 (−0.113)**	**−2.771**	**0.006*** **	−0.049 (−0.039)	−0.739	0.460	**−0.222** (−0.178)	**−2.716**	**0.007*** **
Succ. comm. → Business growth	**0.913 (0.128)**	**2.888**	**0.004*** **	**1.632 (0.176)**	**3.080**	**0.002*** **	0.211 (0.081)	1.175	0.240
Internal innovation capacity → Business growth	0.108 (0.012)	0.273	0.785	−0.498 (−0.042)	−0.748	0.454	**0.620 (0.191)**	**2.757**	**0.006*** **
Absorptive capacity → Business growth	−0.648 (−0.032)	−0.721	0.471	−1.385 (−0.055)	−0.963	0.336	−0.645 (−0.079)	−1.154	0.249

* $p < 0.1$,.
** $p < 0.05$,.
*** $p < 0.01$.

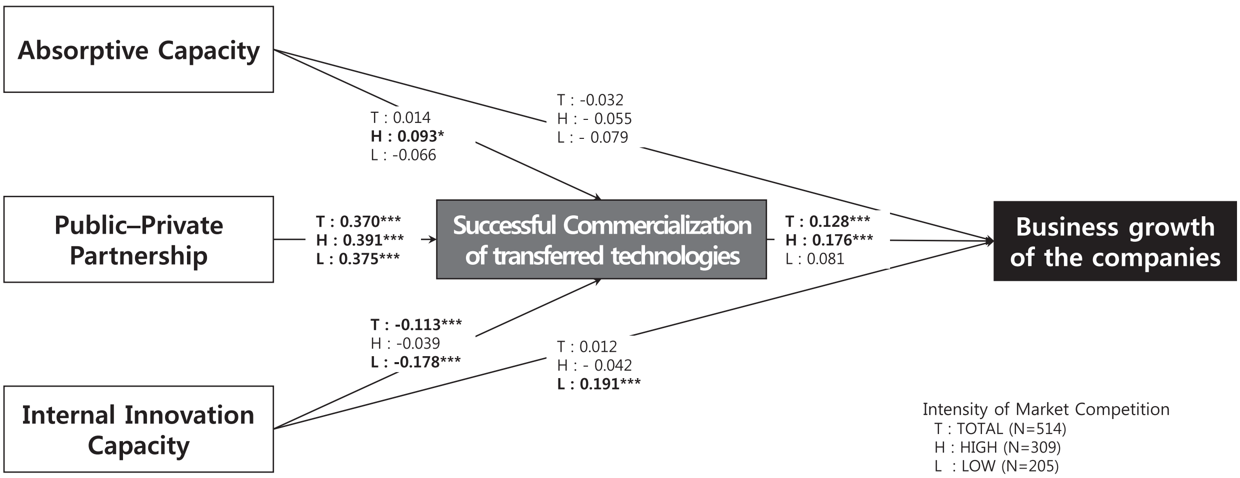

Fig. 3. Multiple-Group Structural Model in Market Competition: High and Low.

among the groups when the intensity of market competition was high and low. The results of the analysis are shown in Table 7 and Fig. 3.

First, we analyzed the whole sample without discriminating among the two groups of technology adopters facing different intensity of market competition. Partnership ($\beta = 0.370$, $p < 0.01$) and internal innovation capacity (β=−0.113, p<0.01) exert statistically significant effects on the successful commercialization of transferred technologies, the former variable a positive effect and the latter a negative effect. Absorptive capacity has a positive effect but statistically insignificant ($\beta = 0.014$, $p > 0.1$). The successful commercialization of transferred technologies exerts a statistically significant positive effect on business growth ($\beta = 0.128$, $p < 0.01$).

Second, we analyzed the two groups of different market intensity separately. In the group of high market competition intensity, absorptive capacity ($\beta = 0.093$, $p < 0.1$) and partnership ($\beta = 0.391$, $p < 0.01$) exert both positive and statistically significant effects on the successful commercialization of transferred technologies. In turn, successful commercialization exerts a statistically significant positive effect on business growth ($\beta = 0.176$, $p < 0.01$). In the group of low market competition intensity, partnership ($\beta = 0.375$, $p < 0.01$) and internal innovation capacity (β =−0.178, $p < 0.01$) exert statistically significant effects on the successful commercialization of transferred technologies. Now, however, the effect of internal innovation capacity turns negative as was the case of the whole sample reported in the previous paragraph. Successful commercialization again has a positive but statistically insignificant effect ($\beta = 0.081$, $p > 0.1$) on business growth.

Partnership turns out to be the most important and consistent determinant for successful commercialization regardless of the extent of market competition (high $\beta = 0.391$, low $\beta = 0.375$). Successful commercialization is also consistently important in boosting business growth. The role of absorptive capacity is positive in the whole sample and the sub-sample

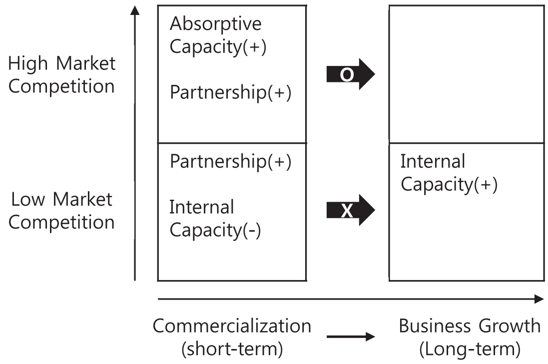

Fig. 4. Affecting variables on four quadrants divided into market competition and performance.

of high market competition. The effect of internal innovation capacity changes from positive to negative between high and low levels of market competition.

We have additionally verified that the path coefficients in the structural model are statistically different between the two groups defined by high and low levels of market competition (Annex A).

4.3. Discussion

Fig. 4 below summarizes observed differences of the effects of diverse variables on the successful commercialization of transferred technologies and on business growth under different market competition environments. The level of intensity of market competition made significant difference to the paths along which absorptive capacity and internal innovation capacity affected successful commercialization, and successful commercialization affected business growth. With strong market competition, the greater the absorptive capacity and the stronger the public–private partnership, the stronger the positive effect on the successful commercialization of transferred technologies.

With weak market competition, the strength of public–private partnership again positively affected successful commercialization. Internal innovation capacity was not a contributing factor to business growth.

Overall, effective partnership is a key factor to the successful commercialization of transferred technologies irrespective of the level of market competition. Company absorptive capacity contributes to short-term successful commercialization and long-term business growth when market competition is strong. Companies placed in a strong market competitive environment will seek to gain competitive advantage as quickly as possible by boosting absorptive capacity and internal innovation capacity in order to efficiently adopt technologies developed by U&PRIs. Interestingly, when market competition is weak, internal innovation capacity does not appear beneficial to the company's short-term success with technology commercialization. This result may be indicative of lower incentives of firms under low competitive pressure to innovate.

5. Conclusion

This study examines in detail the extent to which important factors identified in the economics literature – such as recipient company absorptive capacity, internal innovation capacity, and effective partnership between the supplying U&PRI and the receiving company – affect the successful commercialization of technologies transferred from the public sector. It goes a step further to also investigate how commercialization success affects company growth over time. The empirical analysis is based on detailed information from a broad survey of all 5340 technologies transferred from the 43 major Korean U&PRIs to the private sector during a three-year period (2009–2011) securing a wide and representative sample of the Korean manufacturing sector with the 514 cases of such technology transfer that ultimately provided complete information on all factors of interest. The examined sample of transferred technologies contains both successful and unsuccessful cases of technology commercialization across sectors and organization types in a rapidly advancing country that has not been subject to such treatments frequently before.

This study departs from the established literature that tends to focus solely on the process of technology transfer by expanding the scope of analysis onto the outcome of technology transfer, that is, technology commercialization and the effect on business growth. The study thus provides useful implications for the development of company strategies for successful commercialization and also broadens policymakers' perspective on fostering the ecosystem for innovation.

The results point out that the effects of the examined factors on the success of the commercialization of the transferred technology and on the growth of the company differ according to the intensity of the market competition facing the company. When encountering strong competition, companies need to use active and open innovation strategies for exploring, adopting, and utilizing external technologies and knowledge to ensure their survival and growth. When market competition is relatively weak, the successful commercialization of transferred technologies does not indicate the same statistically significant effect on company long-term growth.

High levels of market competition are related to strong positive effects of the recipient firm's absorptive capacity, internal innovation capabilities and effective technology supplier-recipient (public–private) partnership on the successful commercialization of transferred technologies. Weak market competition is shown to be positively correlated to a strong influence of effective public–private partnership on successful technology commercialization. It is important to stress that effective public–private partnership was found to be a key factor to the successful commercialization of transferred technologies irrespective of market situations. Company absorptive capacity contributes to short-term successful commercialization and long-term business growth when the market competition is strong. When the market competition is weak, internal innovation capacity is beneficial to company long-term growth but may undermine the company's short-term success with technology commercialization. The latter result may be indicative of lower incentives to innovate in concentrated markets.

Future research would need to consider the reasons for adopting public technologies. Whether companies adopt technologies for the incremental improvement of existing products or for achieving radical innovation through the introduction of new (to the market) products will make a significant difference to the prospects and outcomes of technology transfer. This different motivation of adopting U&PRIs' technologies may explain more clearly the observed differences in the effects of internal innovation capacity and absorptive capacity on business growth in different market environments. Finally, while this study uses the intensity of market competition as a conditioning factor, future research may also take into account additional important characteristics distinguishing across sectoral innovation regimes.

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Supplementary materials

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Annex A

Differential path coefficients for high and low levels of market competition

It is necessary to verify whether the path coefficients in the structural model are statistically significant differences between the two groups (paths). We analyzed their structures, with a view to comparing them to the default model to whose path coefficients the constraint families were applied. The critical ratios for differences (CR) of the model that constrain the paths between the two groups of companies reveal significant inter-group differences in the models on the absorptive capacity leading to successful commercialization, the internal innovation capacity leading to successful commercialization, and successful commercialization leading to business growth (Table 8).

The difference of the effect of absorptive capacity on successful commercialization between the two groups was significant at $p < 0.1$. When market competition was high, greater absorptive capacity meant a stronger positive effect on successful commercialization ($\beta = 0.09$, $p < 0.1$). When market competition was low, the effect of greater absorptive capacity on successful commercialization turned negative but without statistical significance ($\beta = -0.07$, $p > 0.1$; Table 7).

Table 8
Comparison of the difference in market competition: high and low.

Path constraints	X^2	Df	CR[a]	ΔX
Default model	2.129	2		
Absorptive capacity → Succ. comm.	**5.371**	**3**	**−1.805**[*]	3.242
Partnership → Succ. comm.	2.238	3	0.331	0.109
Internal innovation capacity → Succ. comm.	**4.827**	**3**	**−1.645**[*]	**2.698**
Succ. comm. → Business growth	**8.522**	**3**	**−2.539**[**]	**6.393**
Internal innovation capacity → Business growth	4.651	3	**1.591**	**2.522**
Absorptive capacity → Business growth	2.358	3	0.479	0.229

[a] Critical ratios for differences.
[*] $p < 0.1$,.
[**] $p < 0.05$.

The same cannot be said for the effect of partnership on successful commercialization: no statistically significant difference between the two groups was detected. The variable exerted positive effects in both cases (HIGH: $\beta = 0.39$ and $p < 0.01$; LOW: $\beta = 0.37$ and $p < 0.01$).

The difference of the effect of internal innovation capacity on successful commercialization between the two groups was significant at $p < 0.1$. Surprisingly, the effect was found negative in both groups, but with statistical significance only in the case of low market competition (HIGH: $\beta = -0.04$ and $p > 0.1$; LOW: $\beta = -0.18$ and $p < 0.01$).

The difference of the effect of successful commercialization on business growth between the two groups was significant at $p < 0.05$. While the effect was positive for both groups, it was statistically significant only for high market competition (H: $\beta = 0.18$ and $p < 0.01$; L: $\beta = 0.08$ and $p > 0.1$).

Finally, the difference of the effects of internal innovation capacity and absorptive capacity on business growth was not statistically significant between the two groups. Internal innovation capacity exerted a statistically significant positive effect when the market competition was low ($\beta = 0.19$ and $p < 0.01$).

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