

Chung, Buil; Hyun, Byeong-Hwan

Article

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Meta-Analysis on the Influencing Factors of Technology Commercialization in Korea

Buil Chung^a, Byeong-Hwan Hyun^b

^aDepartment of Business Consulting, Graduate School of Daejeon University, Republic of Korea

^bProfessor, Department of Business Consulting, Graduate School of Daejeon University, Republic of Korea

ABSTRACT

In this study, the various influencing factors presented in the prior studies in Korea relating to technology commercialization were classified and grouped into 8 upper group factors and 16 subgroup factors based on their theoretical background. Meta-Analysis was then conducted to figure out the average effects size of overall influencing factors and to identify the key success factors of technology commercialization. In addition, moderator effects were analyzed based on paper type, data type, and sample size.

The results showed .3576 of correlation coefficient (ESr) as the summary effect size from 72 studies with 18,370 samples and six (6) factors were derived as the key success factors of technology commercialization: Marketing Capability, Strategic Planning, Manufacturing Capability, Internal Cooperation, External Cooperation, and Learning Capability. Moderator effects were found with data type and sample size but no significant results were obtained with the paper type.

Keywords: Meta-analysis, Influencing factors, Determinants, Success factors, Technology commercialization

1. Introduction

Korea has achieved remarkable economic growth over the past three decades and has been a model of bench-marking from many developing countries around the world. The technological innovations that the Korean government has pursued at the national level can be pointed out as the background of this remarkable economic development. The Korean

government has been pushing for R&D by investing in huge budgets and manpower. According to a press release from the Ministry of Strategy and Finance, the budget for the national research and development (R&D) project is 19.7 trillion Korean won in 2018, which represents 4.6% of the national total budget, one of the highest percentages in the world. The purpose of the government's R&D promotion is not to develop technology itself, but to create added value through the utilization of the developed technology, to develop various correlated industries, and to further expand the national economy. Therefore, in order to achieve the purpose of R&D promotion, the developed technology should be transferred to the enterprise and used for commercialization.

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† Byeong-Hwan Hyun

Graduate School of Daejeon University, 62 Daehak-ro, Dong-gu, Daejeon, Republic of Korea,

Tel. 82-42-280-4181 E-mail: bhhyun@dju.kr

As technology transfer and commercialization become increasingly important, the Korean government has been implementing various policies for promoting technology commercialization since the enactment of the Technology Transfer Promotion Act in 2000. At the same time, in academia, various research has been actively conducted with an interest in what factors have a decisive influence on technology transfer and commercialization. This study was designed to confirm the core influencing factors for successful technology commercialization through meta-analysis on prior studies. A review of precedent studies found the following problems. Firstly, through prior literature review, various theoretical backgrounds and influential factors were found. Naturally, different perspectives on the studies are desirable, but it would be beneficial for future study if such influential factors presented in prior research are summarized systematically occasionally. Secondly, it is difficult to generalize the results of various research because some studies focus on specific variables from certain fields through the researcher's perspective. It is necessary to review the research results with an all-encompassing perspective in order to synthesize the studies that have been conducted under a fragmentary point of view. Thirdly, it is quite often that conflicting results are presented between previous studies on the same factors. As an example, Tubbs (2007) claimed that there was a positive relationship between R&D investment and business performance while Venkatraman & Prescott (1990) reported on their study that there was no significant relationship between R&D investment and financial performance. A comprehensive view is needed of these conflicting findings.

Meta-Analysis is very useful for systematically summarizing the influence of variables and sub-variables and verifying whether the characteristics of the subjects are moderator variables that cause the analysis results to change (Borenstein et al., 2009). The purpose of this study is to review the previous research conducted on the factors affecting the technology commercialization and to systematically summarize the theoretical background and various influential factors presented in the previous studies.

Then, the overall average effects size of all influencing factors of technology commercialization will be calculated and the specific effects sizes of various influencing factors will also be computed and compared to each other through meta-analysis so as to identify key determinants of greater importance for successful technology commercialization. In addition, we try to understand whether variables such as paper type, data type, and sample size act as moderator variables that affect the results of meta-analysis. In order to achieve these objectives, the following research questions were set up.

Research question 1. What were the theoretical backgrounds presented in previous research for technology commercialization and what influential factors were studied?

Research question 2. What is the average effect size of overall factors affecting technology commercialization?

Research question 3. What are the key influencing factors for successful technology commercialization and what are the effect size of these factors?

Research question 4. What are the influence of the moderators (data type, paper type, sample size) that affect the result of meta-analysis?

II. Literature Reviews

A. The concept of Technology Commercialization

The research on technology commercialization seemed to be activated ever since the Bayh-Dole Act¹⁾ was enacted in the United States in 1980. In Korea, research on technology innovation began to increase in accordance with the government's promotion policy for science and technology in the 1990s. Since the Technology Transfer Promotion Act was enacted in

1) The Bayh-Dole Act allowed the university to patent research results created by universities based on federal funding and also to own the rights of patented technology, helping to promote technology transfer in the United States.

2000, the research on technology transfer have become the mainstream and after the revision of the Act in 2006 to the Technology Transfer and Commercialization Promotion Act, the research on technology commercialization has increased significantly in 2010s in Korea. Technology commercialization can be classified into broad concepts and narrow concepts depending on the viewpoint of the researchers and application field. The broad concept can be defined as "all activities from the entire process, from acquiring ideas through R&D to selling technology, products, and services to the market" (Jolly, 1997, Cornford, 2004). The narrow concept can be defined to be "an activity of the process of selling technology, products and services to the market after R&D" (Kumar & Jain, 2002). In this study, the concept of technology commercialization is defined as 'the process and activities of value creation from designing, manufacturing, marketing, and sales of products through the application of the technology or R&D outcomes'.

B. Theoretical Background in previous studies

In reviewing prior studies, several theories were observed as serving as a background for various influencing factors on technology commercialization such as Resource-Based View(RBV), E-S-P (Environment - Strategy - Performance), Social Capital Theory, and National Innovation System(NIS) etc. Among these theories, three of the most influencing theories are RBV, E-S-P, and Social Capital Theory. The resource-based view (RBV) observed in many studies is a theoretical framework that explains the difference in business performance between companies through the resources possessed by companies (Ravichandran & Lertwongsatien, 2005). Many influencing factors were classified as RBV base. The E-S-P (Environment - Strategy - Performance) emphasized strategies that respond to external environments (Porter, 1985). E-S-P implies that the external environment such as industrial structure, market environment, government policy etc. affect the business performance. Social capital is defined as a characteristic of a social organization that facilitates

cooperation and coordination for mutual benefit, such as network, norms, and trust, based on social interactions and relationships (Putnam, 1993).

C. Influencing Factors in previous studies

In addition to the theoretical background, many of the previous studies have focused on the specific competencies of the firms such as technology innovation capacity, absorption capacity, and technology commercialization competence as influencing factors of technology commercialization. Technology innovation capacity is defined as a characteristic and specific resource of a comprehensive organization that supports and stimulates innovation strategies (Guan and Ma, 2003). Yam et al. (2004) divided the learning capacity, R&D capacity, resource allocation capacity, manufacturing capacity, marketing capacity, organizational capacity, and strategic planning capacity into the factors of technological innovation ability. Romijn and Albaladejo (2002) distinguished innovation success factors from internal and external factors. Internal factors include the CEO's willingness and corporate culture and external factors include external network. Moon (2017) confirmed in his study that the CEO's technically oriented functional background affects the firm's technological innovation performance.

The absorptive competencies are the ability to acquire any resources or information from the outside and the ability to learn what has been learned. Zahra and Hayton (2008) present the impact, importance, and necessity of absorption capacity in enhancing commercialization performance or corporate performance. Chae (2016) observed that the competitive usage of knowledge assets has a positive impact on the performance of an organization. The importance of corporate owned R&D capabilities has been emphasized as an important source of innovation (Romjin and Albaladejo, 2002) and in a recent study, Chae (2017) concluded that the level of advanced manufacturing technology positively contributes to the improvement of a firm's production performance.

The technology commercialization capability

refers to the ability to directly apply the technology to the production and sales activities of the company by digesting and improving the technology. Nevens et al. (1990) described the technology commercialization capability as a competitive advantage to win competitors through cost reduction, quality improvement, and new technology acquisition. Relational capital of social capital theory promotes communication, information sharing among trading partners, and knowledge exchange, and further contributes to organizational performance by influencing knowledge creation through the combination of knowledge (Nahapiet and Ghoshal, 1998). Based on the relational capital, it is possible to establish an inter-organizational cooperation system and external networks, which have an important influence on the success or failure of technology commercialization.

D. Influencing Factors in this Study

In addition to the theoretical background, as reviewed in the previous section, the previous studies have suggested a number of influencing factors as the success factors of technology commercialization. In this study, the various influencing factors provided in prior studies were systematically summarized by applying the MECE (Mutually Exclusive Collectively Exhaustive) method and as the result an influencing factor table was produced, which consisted of 8 upper group and 16 sub-group factors based on combining three theories: RBV, E-S-P, and Social Capital Theory (See Table 1). Then, all the influencing factor data collected from the literature to be analyzed in this study were categorized and coded according to the factor Table 1 so as to conduct meta-analysis on the data.

E. The Performance of Technology Commercialization

The success of technology commercialization is measured by business performance, such as financial

performance and non-financial performance (Cote et al., 2005). In reviewing the previous studies, it was found that the increase of sales amount and operating profit was used as financial performance and the market share, new product launches, and judgment on the success of technology commercialization were used as non-financial performance. In this study, the effects sizes were analyzed for three types of performance (Sales amount increase, Operating profit increase, and Judgement on success of technology commercialization) as dependent variables in previous studies.

F. Meta-Analysis

Meta-Analysis is a comprehensive research methodology that systematically and quantitatively analyzes the diverse research results of individual studies with the same subject. Meta-Analysis has been developed by Glass & Rosenthal (Glass, 1976) and Hunter & Schmidt in the 1970s as a statistical method that analyzes the existing research results in a comprehensive manner (Hunter and Schmidt, 2004). In order to synthesize the existing research results by the meta-analysis, the preceding study to be analyzed should be quantitative research. The results of individual studies are converted into a common unit of effect size, and then are synthesized by applying the meta-analysis statistical method (Cooper, 2010).

The goal of a synthesis is to understand the results of any study in the context of all other studies. First, we need to know whether or not the effect size is consistent across the body of data. If it is consistent, then we want to estimate the effect size as accurately as possible and report that it is robust across the kinds of studies in the synthesis. On the other hand, if it varies substantially from study to study, we want to quantify the extent of the variance and consider the implications. In meta-analysis, we include all of the effects in a single statistical synthesis. This is critically important for the goal of computing and testing a summary effect (Borenstein et al., 2009).

Table 1. Influential Factors of Technology Commercialization

Theory	Upper Group	Sub Group	Variables	Studies
Resource Based View	R&D competency	R&D capability	Number of researchers, Quality of inventor,	Berchicci(2013)
		R&D budget	Total research expenses, Research fund support	Jaruzelski et al. (2005)
	CEO competency	CEO capability	Entrepreneurial spirit, Executive competency, Chief Executive Support,	Coulthard (2007) Romijn and Albaladejo (2002)
	Company characteristic	Company age	Company age, Company history,	Hall and Bagchi (2002)
		Company size	Number of employees, Sales amount,	Becheikh et al. (2006)
	Absorption competency	Dedicated organization	Number of dedicated staff, Commercialization team,	Donovan (2006)
		Learning capability	Technology absorption capacity, Learning ability,	Nietro and Quevedo (2005)
	Commercialization competency	Strategic Planning	R&D strategic planning, Process Innovation ability Establish project strategy,	Camison and Villar (2014)
		Manufacturing capability	Manufacturing ability, Production ability,	Chen (2009) Laird and Sjoblom (2004)
		Marketing capability	Competitor Analysis, Identify customer needs, Sales competitiveness,	Lin et al. (2006)
	Technology competency	Technology accumulation	Intangible resources, Intellectual property, Technical Assets,	Ahmadi et al (2014) Spann et al (1993)
		Technology characteristics	Technical perfection, Technology excellence, Technical specificity,	Yam et al (2004)
E-S-P	Environment	Market environment	Market size and potential, Market volatility, Entry barrier,	Wu et al. (2015) Luo et al. (2006)
		Government policy	Government support, Tax exemption policy, Purchasing public sector,	Siguaw at el. (2006)
Social Capital	Relationship	External cooperation	Cooperative Partnerships, External network, trust, R & D cooperation,	Bengtsson and Kock (2000) Hagedoorn (1993)
		Internal cooperation	Diffusion of information, Organizational flexibility, Organizational Culture,	Sung and Carlsson (2003)

Effect size is a standardized measure for synthesizing the results of studies presented on various scales. In the field of social sciences, the standardized mean difference (d) or correlation (r) is mainly used as the measure of the mean difference between the two groups or as the size of the correlation between the two

variables. In the medical field, the odds ratio or the risk ratio is also used as an effect size in verifying the rate of occurrence of an event (treatment, success, etc.) as well as the standardized mean difference (d) and correlation (r). Although the interpretation of effect sizes is not as easy as percentages or ratios, the existing

theorem will help us to understand it. Beason et al. (2006) reported that 'effect size is expressed in standard deviation units, so that it can be compared between any studies and used for meta-analysis.'

In the case of individual study, it is difficult to generalize the analysis results because the related variables and results are different according to experimental design such as the researcher's point of view, the research sample, and scale. In meta-analysis, it is possible to present the direction and effects size of the relationship between the variables regardless of the scale used in the individual studies. Therefore, in many studies, meta-analysis method is used to compare the influence of the variables. In the meta-analysis, by the integration of individual research the number of populations increases so that the statistical power of the analysis also increases, making it possible to overcome the limitation of low statistical power and small sample size of individual studies and perform a more accurate parameter analysis (Borenstein et al., 2009). In addition, by examining whether the characteristics of selected studies affect the significance test or effect size as a moderator variable, it is possible to investigate new results that can otherwise be unknown through individual studies (Cooper, 2010).

In Korea, there has been a considerable accumulation of research results related to technology commercialization, and in order to synthesize the results of these individual studies, it has become necessary to conduct a meta-analysis. A recent literature survey found that meta-analysis studies were conducted by Montoya and Calantone (1994) and Song et al (2008) in foreign countries. However, no meta-analysis has yet been found for the studies related to the technology commercialization in Korea.

III. Methods

A. Data

The purpose of this study is to identify the key

success factors of technology commercialization by analyzing the results of prior studies related to technology commercialization and influential factors. In this study, the correlation (r) between the influence factors and the success of technology commercialization was set as the effect size. Meta-Analysis was conducted in accordance with the standard research procedure of Meta-Analysis in order to ascertain the effect size of various influencing factors on technology commercialization.

Data selection - This study set up the research papers as the target data and searched articles on the journals and theses for master and doctoral in universities published in Korea until the end of 2017 through the major academic database in Korea: RISS (Research information service), KISS (Korean Academic Information), DBpia (Nuri Media), and e-Article (Korean Academy of Sciences). As a result, 4,543 articles (1,392 journals, 3,151 theses) were found through the database with the following key words: technology transfer, technology commercialization, success factors, influential factors, and determinants. In addition, 37 papers were further excavated through the references of articles. So, a list of a total of 4,580 research papers was obtained.

After reviewing the list of these literatures, the duplicate literatures were unified. By reviewing titles and abstracts, the papers not related to the research topic were excluded. The conference proceedings were also excluded because the paper presented at the conference was not considered a complete one in Korea. The researchers improve their papers by reflecting the comments from conference presentation and submit the papers to be published in the journals through peer-reviews. For this reason, the conference proceedings in Korea are not evaluated equally with the journal articles.

Also, after excluding the papers without its full text secured, 336 papers were obtained. By reviewing the text, only the empirical studies were selected and by examining the statistical analysis of individual studies, only the papers with the correlation coefficient (r) or the papers with results that can be converted into correlation coefficients by the formula were

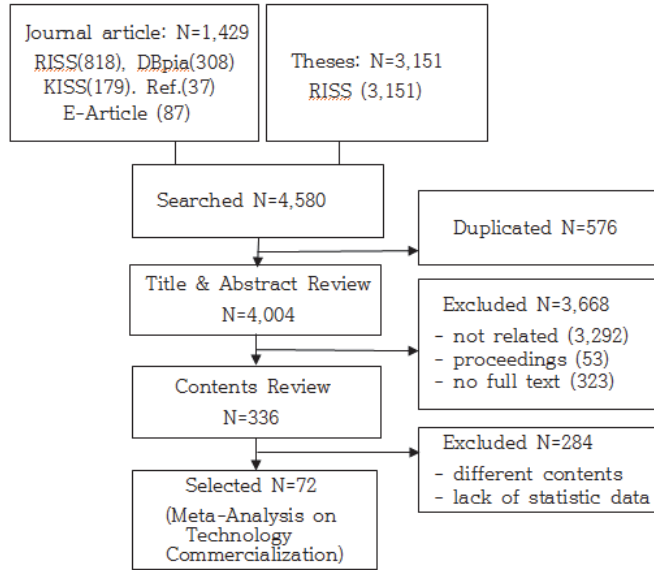


Figure 1. Flow chart of Study selection

selected. Additionally, 72 research papers were selected as the final target data. The flowchart of study selection is shown in Figure 1.

Coding - The data of this study consisted of 72 papers. We set coding standards for data extraction, created coding manuals and coding tables, and coded the previous research results. Coding items consisted of researcher, title, issuing institution, year of publication, influencing factors on technology commercialization, source of data, number of sample, method of research, and statistics of research results. The data was coded by two researchers in order to ensure the reliability of the evaluation between the coding staff. In the coding process, the items with mutual differences were finalized upon consensus through thorough discussion between the evaluators.

B. Method

Effect size calculation - In order to conduct an integrated analysis of the research results through Meta-Analysis method, the statistics of the research results presented in various forms should be converted into standardized effect size. Commonly used effect

sizes include the effect size on the standardized mean difference (ES_{sm}), the effect size of correlation coefficient (ES_r), and the effect size of the odds ratio (ES_{or}). This study used the correlation coefficient (r) as the effect size (ES_r) because this is a Meta-Analytic study incorporating the correlations of technology commercialization and the related variables. The correlation coefficient is a measure of the degree in which two data measured in a series are related to each other. Pearson's ratio metric coefficient 'r' is the most common correlation coefficient. Since the effect size of the correlation coefficient (r) may be biased due to the asymmetric distribution of 'r', the individual 'r' values are converted to Fisher's Z, which has a symmetric distribution. Fisher's Z is used to calculate the mean value of the analysis result, then converted back to the Pearson's correlation coefficient 'r' for ease of interpretation (Shadish and Haddock, 1994).

<Formular: Pearson's $r \rightarrow$ Fisher's Z >

$$Fisher's\ Z = 0.5 \times \ln\left(\frac{1+r}{1-r}\right)$$

<Formular: Fisher's $Z \rightarrow$ Pearson's r >

$$r = \frac{e^{2z} - 1}{e^{2z} + 1}$$

Weighted mean effect - In the calculation of the mean of individual studies' effect sizes (*ES*) converted to Fisher's *Z*, the method used calculated the average value of the given inverse weights, reflecting the large and small sample sizes. Because each study has different characteristics, weights must be given to reflect the characteristics (here, the sample size) so that the average effect size can be calculated properly. To obtain the weighted average effect size, we have to first find the weight. Generally, the weight is the inverse of the variance, and the larger the sample, the larger the weight. Weighted mean effects are the sum of the effect sizes multiplied by the weights; that is, the sum of the weighted effect sizes divided by the sum of the weights.

Confidence interval - After obtaining the mean effect size for the entire meta-analysis target, the standard error and the confidence interval (CI) of each study are calculated. The standard error of the effect size is an estimate of the standard deviation in the population. The smaller the sample, the larger the standard error. The larger the sample, the smaller the standard error. The confidence interval (CI) of the effect size means the interval that the parameter is estimated to include, that generally produces the lower and upper bounds of the 95% confidence interval. The smaller the standard error, the narrower the confidence interval and the greater the accuracy of the population estimate. If the confidence interval does not contain zero, the value is statistically significant.

Homogeneity test - After the average effect size of the studies is obtained, the homogeneity of the study is tested. The homogeneity test is conducted to determine whether the size of the effect being analyzed is well representative of the effect size of the population. The homogeneity test statistic is presented as the *Q* value. The homogeneity statistic value *Q* follows χ^2 distribution ($df = k-1$) because the homogeneity test quantity *Q* is the same as χ^2 distribution. If the *Q* value is significant at the significance level *p*, nullity is rejected, which means it is heterogeneous and it can be concluded that this is not data extracted from the same population. The

goal of the meta-analysis is not simply to derive the mean of the effect size, but to understand the overall pattern of the effect size. In general, meta-analysis results in different sizes of effects derived from each individual study. The difference between these effect sizes is called the heterogeneity of the effect size. In other words, the heterogeneity of effect size means that the degree of distribution of effect size from each study and the size of between-study effect is inconsistent (Borenstein et al., 2009).

Unit of Analysis - Meta-analysis is a research method that integrates and analyzes the statistical results of individual studies and suggests the integrated effect size. In this study, we applied the 'Comparison or Estimates as Unit' analysis, which allows multiple effect sizes in the analyzed papers. The reason for choosing this method is that all research papers related to technology commercialization include multiple variables in one study. Studies are most often presented with multiple effect sizes in a single study, requiring special attention in the analysis process. In the case of analyzing multiple effect sizes calculated in the same study as if they are independent data, various problems may arise which are contrary to the assumption of independence of data. The most representative example is that the weight is excessively given in calculating the average effect size. In order to prevent the problem of independent hypothesis that may occur in the analysis process, Meta-Analysis was performed by applying the 'Shifting Unit of Analysis' method proposed by Harris Cooper (Cooper, 2010). Applying this method will only reflect a single effect size in the analysis for the same study at each level of analysis, such as analysis of the study unit, analysis of upper group, or subgroup analysis.

Meta-Analysis model - There are fixed effects model and random effects model as the calculation method of meta-analysis. Whether the researcher chooses which of the two methods to select is based on whether or not the research studies assume the same population effect and what the purpose of the analysis is (Borenstein et al., 2009). The fixed effect model assumes the homogeneity of the population of all

studies, while the random effect model assumes the heterogeneity of the population and acknowledges the between-study variance. In this study, the meta-analysis was conducted using the random effects model because the heterogeneity of the population was estimated as the sample of each study and the study designs were different.

Statistical Software - Analysis was performed using R version 3.3.2 (2016-10-31) statistical software.

IV. Results

A. Descriptive Statistics

The general characteristics of the papers included in this study are shown in Table 2 below. A total of 72 papers was used in the Meta-Analysis of this study, with a total of 18,370 samples. The studies analyzed were published from 1998 to 2017, and the growing activity of research for technology

commercialization since 2009 has been recognized. In terms of paper type, 26 journal articles (36.1%), 23 master theses (31.9%), and 23 doctoral theses (31.9%) have relatively uniform distribution. When looking at the data type, 60 surveys accounted for 83.3% of the total, and overwhelmingly more than 12 secondary data (16.7%).

B. Publication Bias

Funnel plot - If we cannot cover all the studies and synthesize only the results of some studies when we synthesize the results of previous studies related to the research topic, the problem of representativeness of the sampled studies may arise. Mostly studies that do not deny zero-hypotheses are not reported, and studies that yield positive and statistically significant results are published more easily. Therefore, it cannot be said that all of the published studies are high-quality studies, but they are likely to be statistically significant results. This is called publication bias. In the meta-

Table 2. General Characteristics of Data

Year	Paper	Sample	Paper type			Data type	
			Journal	Master	Doctoral	Survey	Secondary
1998	1	127	1			1	
2004	1	120		1		1	
2005	1	72			1	1	
2006	1	160			1	1	
2007	1	156			1	1	
2008	1	254			1	1	
2009	3	850	2		1	3	
2010	9	1,490	2	4	3	8	1
2011	2	158	1	1		2	
2012	6	1,153	3	3		4	2
2013	4	679	2	2		4	
2014	9	2,157		3	6	6	3
2015	12	2,,156	7	2	3	11	1
2016	15	5119	6	5	4	12	3
2017	6	3,719	2	2	2	4	2
Total	72	18,370	26	23	23	60	12

Note: Paper=number of papers, Sample=number of sample

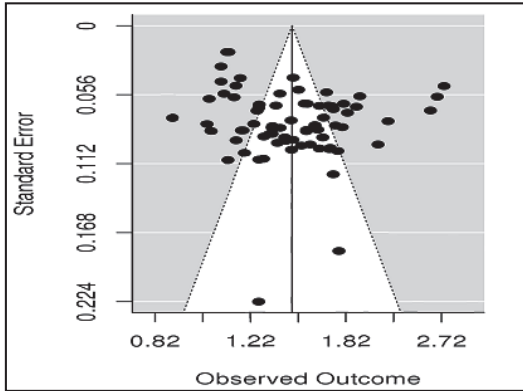


Figure 2. Funnel Plot

analysis, a good way to show the relationship between sample size and effect size is through a funnel-shaped plot, or funnel plot. In the funnel plot, the horizontal axis is composed of the effect size (Fisher's Z) and the vertical axis is composed of the standard error. The studies with large sample size appear toward the top of the graph and generally cluster around the mean effect size. The studies with smaller sample size appear toward the bottom of the graph and tend to be spread across a broad range of values.

When this funnel picture is symmetrical about the vertical line, it can be concluded that there is no publication bias. A funnel plot is shown in Figure 2 to verify the publication bias of this study. As can be seen in the figure, the studies are biased to some degree asymmetrically.

Fail-safe N - If it is judged that there is bias in publishing, then the next step is to see how much bias is involved, i.e. how credible the overall result is. For this, a fail-safe N (safety factor) method is generally used. In this study, the fail-safe N analysis was performed using Rosenthal's calculation method, and the results are shown below in Figure 3. As shown in the results, 50,846 additional studies should be added to the analysis in order for the overall effect to be insignificant ($p > 0.05$).

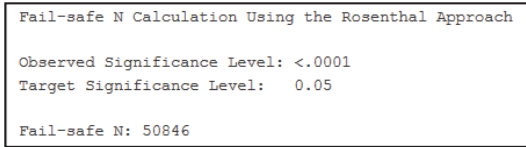


Figure 3. Fail-safe N calculation

Rosenthal (1979) asserted that if the number of fail-safe N is above a certain level, the study is generally credible and he presented the criterion for this N as $5k + 10$ (k: number of studies). In this study, the Rosenthal's criterion is $5 * (72) + 10 = 370$, and the number of fail-safe N is 50,846, which is much more than 370. Therefore, we can claim that this study is reliable.

C. Overall average Effect Size

In this study, Meta-Analysis on 72 research papers was conducted and the overall average effect size was examined. As shown in Table 3, the overall average effect size calculated using the random effect model is .3576, the lower limit of the 95% confidence interval is .3046, the upper limit is .4085, and the significance level is statistically significant at $p < .0001$. This can be regarded as the large effect size according to the effect size criterion proposed by Cohen (1988)².

In meta-analysis, it is important to know the average size of the effect but understanding the overall pattern of effect sizes is also very important. From the meta-analysis, the heterogeneity of the effect size derived from the study is grasped. The heterogeneity of the effect size represents the extent of the effect size distribution of each study, meaning that the effect size between studies is inconsistent. Table 4 shows the results of the homogeneity test.

Among the statistics showing the degree of heterogeneity of the effect size, the Q value representing

2) Cohen (1988) interprets the correlation coefficient effect size (ESr) in a meta-analysis as a small effect size ($ESr \leq .10$), a medium effect size ($ESr = .25$), and a large effect size ($ESr \geq .40$) respectively.

Table 3. Overall Average Effect Size

Model	<i>k</i>	<i>ES_r</i>	95% <i>CI</i>		<i>Z</i>	<i>p</i>
Random Effects Model	72	0.3576	0.3046	- 0.4085	12.3000	< 0.0001

Note: *k*=Number of Study, *ES_r*= Effect Size, *CI*= confidence interval, *Z*=Z-Score, *p*=*p*-value

Table 4. Test of Homogeneity

<i>k</i>	<i>Q</i>	<i>df (Q)</i>	<i>p</i>	<i>I²</i>	<i>I²</i>
72	1,146.74	71	< 0.0001	0.060	93.8%

Note: *k* = number of effect unit, *Q* = total variance, *I²*: variance of the true effects
df =degrees of freedom(*k*-1), *I²*: the proportion of true variance

Table 5. Moderator effects by Paper Type (Meta ANOVA)

Paper Type	<i>k</i>	<i>ES_r</i>	95% <i>CI</i>		<i>Q</i>	<i>I²</i>
Journal	26	0.3703	0.2864	- 0.4486	186.97	86.6%
Master	24	0.3048	0.2124	- 0.3918	295.44	92.2%
Doctoral	22	0.3967	0.3074	- 0.4791	485.40	95.7%

Qbetween=2.24, *df* (Q)=2, *p*=0.3270 ; Qwithin=967.80, *df* (Q)=69, *p* < 0.0001

Note: *k* = number of effect unit, *ES_r*= Effect Size, *CI*= confidence interval
Qbetween = between-study variance, Qwithin = within-study variance

the total variance depends on χ^2 distribution and is influenced by the degree of freedom (*df*). T^2 is the absolute value of the actual variance, and I^2 is the percentage of the actual variance. In general, if the I^2 value is 25%, the heterogeneity is interpreted to be small, if I^2 is 50%, it is about medium size, and if I^2 is 75% or more, heterogeneity is interpreted to be very large (Borenstein et al, 2009). In this study, the *Q* value of 1146.74 was significant at *p* < .0001, and the I^2 value was 93.8%, indicating a very high heterogeneity.

D. Moderator Effects

Since the results of the analysis of total effect size was seen to be high heterogeneity, the moderator effect analysis was conducted to find out the background showing heterogeneous results. In the meta-analysis, the moderator effect analysis allows us to verify the influence of the variables that influence the mean effect size, that is, the moderator. Moderators are the variables that affect the relationship between independent variables and dependent variables, which

are study-level variables in meta-analysis. In this study, we analyzed the moderator effect by setting the paper type, data type, and sample size as moderator variables.

Moderator Analysis for Paper Type - Table 5 shows the effect size of the paper type as moderator variable. As a result of meta-ANOVA analysis, the doctoral thesis showed the greatest effect size of .3967, Journal was the next (.3703), and the effects size of Master's thesis was the smallest (.3048). The between-study variance (*Q*between) was 2.24, indicating that the effect size difference between the paper types was not statistically significant (*p* = .327). However, the within-study variance (*Q*within) is significant at *p* < .0001, indicating that the effect size of each individual study is still heterogeneous

Moderator Analysis for Data Type - The data used in prior studies was divided into two types: survey data and secondary data. These two were analyzed to verify moderating effects. The meta-ANOVA analysis revealed that moderating effect existed with data type. As seen on table 6, the effects size (.3966) of survey data was much higher than secondary data (.1577). The between-study variance (*Q*between) was

Table 6. Moderator effects by Data Type (Meta ANOVA)

Data Type	<i>k</i>	<i>ES_r</i>	95% <i>CI</i>		<i>Q</i>	<i>I²</i>	
Survey	60	0.3966	0.3494	-	0.4419	685.17	91.4%
Secondary	12	0.1577	0.0401	-	0.2710	62.48	82.4%

Qbetween=15.22, df (Q)=1, p<0.0001 ; Qwithin=747.64, df (Q)=70, p < 0.0001

Note: *k* = number of effect unit, *ES_r*= Effect Size, *CI*= confidence interval
 Qbetween = between-study variance, Qwithin = within-study variance

Table 7. Moderator effects by Sample Size (Meta regression)

	Estimate	SE	95% <i>CI</i>		<i>Z</i>	<i>p</i>	
Intercept	0.4139	0.0346	0.3461	-	0.4816	11.9780	<.0001
Sample N	-0.0001	0.0001	-0.0003	-	0.0000	-1.9343	0.0531

QM=3.741, R²=18.54%, T²=0.049, I²=91.91%,

Note: SE=Standard Error, Z=Z-Score, QM=Model Q, R2=Ratio of explained variance

15.22 which was statistically significant at $p < .0001$. Such results are interpreted that the respondents of the survey responded more positively to the results of the technology commercialization than the objective indicators, and that the high effect size of the questionnaire influenced the increase in overall average effect size between the technology commercialization and the influence factors. Table 6 shows the result of moderator effect analysis by data type.

Moderator Analysis for Sample Size - For the sample size which is a continuous variable, the moderator effect was analyzed through Meta-Regression analysis. On Table 7, the regression coefficient of the moderator variable is -0.0001 ($Z = -1.9343$, $p = .0531$), and QM (model $Q = 3.7414$, $df = 1$, $p = .0531$) is statistically significant. The regression equation shows that the regression model is significant at the level of $p < .1$. On the other hand, R^2 , which is the ratio of the between study variance explained by the moderator variables is 18.54% indicating that the explanatory power is not so large.

From the above results, the regression equation can be presented as 'Y = .4139-0.0001 x sample size'. This tells us that as sample size increases, the effect size will decrease slightly.

E. Influencing Factor Analysis

Upper Group Analysis - The various factors in prior studies were systematically classified by theoretical backgrounds and categorized by similar concepts into eight upper group factors. In this process, the Shifting Unit of Analysis method proposed by Cooper (2010) was applied to prevent violation of the assumption of independence. In other words, the effect size of sub-factors belonging to each upper group factor was averaged by individual study level so that only one average effect size was used as the data to be analyzed thereby preventing redundant calculation errors. In this way, a total of 258 effect units were used for meta-analysis of upper group influencers and the results were shown in table 8.

The size of the effects is summarized in the following order: Commercialization competency (.4401) > Absorption competency (.4160) > Relationship (.4155) > CEO competency (.3434) > R&D competency (.3134). The between-study variance (Qbetween) among the upper group factors was 28.05, which was significant at $p < .001$, indicating statistically significant differences among the upper group factors.

Subgroup Analysis - In order to identify the specific influential factors that are crucial to technology commercialization, sub-group analysis was conducted. The factors in eight (8) upper groups were divided into sixteen (16) subgroup factors with a total of

Table 8. Effect Size of Upper Group Factors

Upper Group	<i>k</i>	<i>ES_r</i>	95% <i>CI</i>		<i>Q</i>	<i>T</i> ²	<i>I</i> ²
A1 R&D	36	0.3134	0.2150	- 0.4056	1096.78	0.100	96.8%
A2 CEO	28	0.3434	0.2437	- 0.4378	525.30	0.083	94.9%
A3 FIRM	20	0.1068	-0.0312	- 0.2409	644.71	0.092	97.1%
A4 SORB	27	0.4160	0.3040	- 0.5167	907.55	0.111	97.1%
A5 COMM	48	0.4401	0.3646	- 0.5098	1063.03	0.094	95.6%
A6 TECH	35	0.2915	0.2253	- 0.3551	334.77	0.039	89.8%
B1 ENVIR	30	0.2732	0.1910	- 0.3516	418.33	0.052	93.1%
C1 REL	34	0.4155	0.3202	- 0.5025	670.58	0.100	95.1%

Sum of *k*=258, *Q*_{between}=28.05, *df*=7, *p* < 0.001

Note 1: *k*=Number of effect unit, *ES_r*= Effect Size, *CI*= confidence interval, *Q* = total variance, *T*²: variance of the true effects, *I*²: the proportion of true variance, *df*=degree of freedom, *p*=*p*-value
 2: A1 R&D=R&D competency, A2 CEO=CEO competency, A3 FIRM=Company characteristic, A4 SORB=Absorption competency, A5 COMM=Commercialization competency, A6 TECH=Technology competency, B1 ENVIR=Environment, C1 REL=Relationship,

Table 9. Effect Size of Sub Group Factors

Subgroup Factors	<i>k</i>	<i>ES_r</i>	95% <i>CI</i>		<i>Q</i>	<i>T</i> ²	<i>I</i> ²
A1a Res_capa	29	0.3350	0.2159	- 0.4443	1162.11	0.1203	97.6%
A1b Res_budg	12	0.1783	0.0503	- 0.3005	170.71	0.0471	93.6%
A2a CEO_capa	28	0.3444	0.2437	- 0.4378	525.30	0.0827	94.9%
A3a Co_age	11	0.0205	-0.1005	- 0.1409	143.07	0.0367	93.0%
A3b Co_size	17	0.1726	0.0305	- 0.3079	517.66	0.0841	96.9%
A4a Sorb_org	14	0.3511	0.2191	- 0.4706	384.72	0.0703	96.6%
A4b Sorb_learn	16	0.4332	0.2628	- 0.5774	571.41	0.1511	97.4%
A5a Plan_capa	29	0.4375	0.3307	- 0.5332	786.88	0.1113	96.4%
A5b Mfg_capa	28	0.4044	0.3157	- 0.4862	456.08	0.0687	94.1%
A5c Mktg_capa	23	0.4444	0.3426	- 0.5359	388.42	0.0801	94.3%
A6a Tech_accu	26	0.2732	0.1921	- 0.3506	247.06	0.0418	89.9%
A6b Tech_char	16	0.2638	0.1691	- 0.3536	169.45	0.0352	91.1%
B1a Env_market	13	0.2920	0.1166	- 0.4497	258.80	0.1046	95.4%
B1b Evn_Gvnt	21	0.2277	0.1506	- 0.3021	172.16	0.0283	88.4%
C1a Coop_ext	28	0.3994	0.3240	- 0.4698	240.18	0.0471	88.8%
C1b Coop_in	17	0.4446	0.3022	- 0.5676	364.09	0.1144	95.6%

Sum of *k*=258, *Q*_{between}=66.69, *df*=15, *p* < 0.0001

Note 1: *k*=Number of study, *ES_r*= Effect Size, *CI*= confidence interval, *Q* = total variance, *T*²: variance of the true effects, *I*²: the proportion of true variance, *df*=degree of freedom, *p*=*p*-value
 2: A1a Res_capa=R&D capability, A1b Res_budg=R&D budget, A2a CEO_capa=CEO capability, A3a Co_age=Company age, A3b Co_size=Company size, A4a Sorb_org=Dedicated organization, A4b Sorb_learn=Learning capability, A5a Plan_capa=Strategic Planning, A5b Mfg_capa=Manufacturing capability, A5c Mktg_capa=Marketing capability, A6a Tech_accu=Technology accumulation, A6b Tech_char=Technology characteristics, B1a Env_market=Market environment, B1b Env_Gvnt=Government policy, C1a Coop_ext=External cooperation, C1b Coop_in=Internal cooperation,

328 effects size unit which were used in meta-analysis. In the process of meta-analysis, the Shifting Unit of Analysis method was also applied. The analysis results were presented in table 9.

The effects sizes can be categorized in three groups based on Cohen (1992)'s guide: the core factor group with large effects sizes (.36 - .50), important factor group with medium effects size (0.21 - 0.35), and

Table 10. Effect Size of Dependent Variables

Dependent Variables	<i>k</i>	<i>ES_r</i>	95% <i>CI</i>	<i>Q</i>	<i>T</i> ²	<i>I</i> ²
Y1 Sales_Inc	22	0.3292	0.2400 - 0.4129	345.49	0.0477	93.9%
Y2 OP_Inc	25	0.2993	0.1973 - 0.3948	438.37	0.0704	94.5%
Y3 Succ_Judgnt	52	0.3633	0.2922 - 0.4305	943.05	0.0797	94.6%
<i>Sum of k=99, Q_{between}=1.15, df=2, p=0.5637</i>						

Note 1: *k*=Number of study, *ES_r*= Effect Size, *CI*= confidence interval, *Q* = total variance, *T*²: variance of the true effects, *I*²: the proportion of true variance, *df*=degree of freedom, *p*=*p*-value
 2: Y1 Sales_Inc=Sales amount increase, Y2 OP_Inc=Operating profit increase, Y3 Succ_Judgnt=Judgement on success of TC (technology commercialization),

minor factor group with small effect size (0.05 - 0.20). The core factors will be discussed in more detail in the discussion section later. The minor factors are characterized as R&D budget (.1783), Company age (.0205), and Company size (.1726). Among these factors, the Company age factor is statistically insignificant because the CI (Confidence Interval) is between -.1005 and .1409, including zero (0). The between-study variance (*Q_{between}*) was 66.69, which was significant at *p* < .0001 at *df*=15, indicating statistically significant differences among the sub group factors.

Dependent Variables Analysis - In the previous studies to be analyzed, three factors were detected as dependent variables that measure the success of technology commercialization: Sales amount increase, Operating profit increase, and Judgment on success of technology commercialization. In this study, the effects size of these dependent variables were calculated by meta-analysis and the results are shown in table 10. On the table, the judgment on success of technology commercialization showed the highest effect size of .3633, then the Sales amount increase (.3292), and lastly the Operating profit increase (.2993) were presented in order. The between-study variance (*Q_{between}*) was 1.15 which was not statistically significant.

V. Discussion and Suggestion

In this study, a meta-analysis was conducted on

72 prior studies related to technology commercialization conducted in Korea. As a preparation of meta-analysis, the various influencing factors presented in the precedent studies were classified and grouped into 8 upper group influence factors and 16 sub group influence factors based on the theoretical background. The results of meta-analysis showed that the overall average effects size was .3576 of correlation coefficient (*ES_r*), corresponding to the high side of medium effect size. This is meaningful in that it is the average effect size calculated by combining the study results of 72 prior researches with 18,370 samples.

By rating the effects sizes calculated by meta-analysis, the subgroup factors were categorized into three levels as shown in table 11, and six (6) factors were derived as Key Success Factors of Technology Commercialization. Among these six core factors, three factors (Marketing Capability, Strategic Planning, Manufacturing Capability) belonged to the Commercialization Competency factor in upper group, two factors (Internal Cooperation, External Cooperation) came from the Relationship factor in upper group, and the other one factor was under Absorption Competency of the upper group factor.

Such results could be interpreted in that among the many factors required for technology commercialization process, the factors of Commercialization Competency are the most essential factors and Internal and External Relationship are also the other essential influencing factors. In addition, Learning capability to accept and digest good technology is also very important for successful technology commercialization.

Among these core factors, Relationship is a special factor to attract keen attention. The other core factors

Table 11. Classification of Technology Commercialization

Effect size	Subgroup Influencing Factors	Effects Size	Category
0,36 - 0,50 (large effects size)	Internal Cooperation	(0.4446)	Core Factors (Key Success Factors)
	Marketing Capability	(0.4444)	
	Strategic Planning	(0.4375)	
	Learning Capability	(0.4332)	
	Manufacturing Capability	(0.4044)	
	External Cooperation	(0.3994)	
0,21 - 0,35 (medium effects size)	Dedicated Organization	(0.3511)	Important Factors (General Factor)
	CEO Capability	(0.3444)	
	R&D Capability	(0.3350)	
	Market Environment	(0.2920)	
	Technology Accumulation	(0.2732)	
	Technology Characteristics	(0.2638)	
0,05 - 0,20 (small effects size)	R&D Budget	(0.1783)	Minor Factors
	Company Size	(0.1726)	
	Company age	(0.0205)	

Note: Company age (0.0205) is no significant at $p=.05$

of Commercialization Competency and Absorption Competency are the internal resources of the enterprise and can be developed by the companies themselves. On the other hand, the Relationship factor requires mutual cooperation and multilateral cooperation among various stakeholders in the process of technology commercialization, such as technology development entity, technology transfer organization, technology commercialization enterprise, market traders, government agency, and experts in various fields. The key success factor of Internal and External Cooperation can be achieved only by mutual efforts by all stakeholders involved in the technology commercialization process.

Given these characteristics of Relationship factors, it is necessary not only to entrust the establishment of such cooperation partnerships to the enterprises but also required to provide the necessary supportive policies by the government so that the stakeholders in the technology commercialization process can establish mutual cooperation and multilateral cooperation partnership systematically. It is important for the government to provide education and guidance to companies and institutions involved in technology commercialization and to expand government budget to support technology commercialization.

One of the objectives of this study was to identify

the moderator effects that affect the effects size of meta-analysis. The results of moderator effects analysis showed that there was no statistically significant moderate effect on the paper type, but the analysis on the data type revealed that the effects size of survey data was significantly higher than secondary data. In Table 2, survey data was used in 60 studies (83.3%) and secondary data was used only in 12 studies (16.7%). Such big portions (83.3%) of studies using survey data which generate higher effects size might influence the overall average effects size to increase in some degree. These results suggest that researchers need to use more objective data such as financial statements and secondary data in their studies to produce more balanced research results in the future. For the sample size, the result of meta-regression analysis presented weak moderator effects ($p < .1$, $R^2 = 18.54\%$) of sample size, indicating that as sample size increases, the effect size will decrease slightly.

This study has implication for identifying key success factors for technology commercialization in Korea through meta-analysis and proposing the government's policy support. In addition, this is the first study of meta-analysis in synthesizing the accumulated prior studies related to technology commercialization in Korea. However, locally, this

study is limited to technology commercialization research in Korea. Therefore, it is necessary to expand the scope of research to an international level in the subsequent studies. Also, this study was generally focused on the influencing factors for technology commercialization. In the follow-up research, more specific influencing factors of technology commercialization by sectors such as industry, region, and company size can provide more useful reference material to government policy makers and field staff.

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