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The Effect of Absorptive Capacity on Technology Collaboration Performance: Focusing on the Moderating Roles of Innovation Intermediaries

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Abstract

This study aims to analyze the effect of absorptive capacity on technology collaboration performance and the moderating effect of innovation intermediaries. We set absorptive capacity (potential, realized) as independent variables and technology collaboration performance (relative technology level, development period, cost savings, new product development, collaboration satisfaction) as dependent variables, with innovation intermediaries as a moderating variable. We conducted a survey of 145 ICT companies that experienced technology collaboration and analyzed the data using 101 valid responses. The results show that potential absorptive capacity has a significant effect on new product development and collaboration satisfaction, while realized absorptive capacity has a significant effect on relative technology level, cost savings, and new product development. Furthermore, innovation intermediaries have a moderating effect between realized absorptive capacity and new product development. The contribution of this study to academia and industry is that it highlights absorptive capacity as a key factor influencing technology collaboration performance. The limitations of this study include the lack of accurate measurement of absorptive capacity and innovation intermediaries, as well as a lack of control over external factors. These limitations should be addressed through more in-depth research by systematically defining and measuring them in future follow-up studies.

Keywords : Absorptive Capacity, Technology Collaboration Performance, Innovation Intermediaries

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1. Introduction

In the upcoming era of the Fourth Industrial Revolution, Information and Communication Technologies (ICT) such as hyper-connectivity, intelligence and reality will converge with traditional industries, leading to the creation of new societal environments, the emergence of novel industries, market disruptions, and significant changes in individual lifestyles. In the industrial sector, awareness and significance of technological collaboration are growing more than ever, aligning with the rapidly changing technological landscape.

To effectively advance such technological collaborations, the absorptive capacity of companies engaging in collaboration is crucial. Inherently, the majority of companies find it challenging to independently develop all the technologies necessary for product and service development. Consequently, there is a need for reliance on external technologies or collaboration with external companies for joint development. From this perspective, the capability to leverage external knowledge, rather than relying solely on internally developed technologies, can be considered a core element of innovation capacity [Cohen and Levinthal, 1990]. Despite the importance of technological collaboration activities, effective communication among collaborating parties faces significant constraints. To address these challenges, the role of innovation intermediaries is crucial. However, there is a lack of research on whether they can effectively influence enhancing a company's absorptive capacity [Lee and Jung, 2017].

This study examines the role of absorptive capacity and innovation intermediaries in technological collaboration outcomes. Prior research commonly used absorptive capacity as a mediating or moderating variable, but this study views it as an inherent capability within companies.

It focuses on the impact of technological collaboration with public research institutions on technological performance, emphasizing outcomes like technological level and new product development. The study also explores whether innovation intermediaries play a moderating role in technological collaboration outcomes when not directly involved. Through this study, we aim to present implications on which companies are advantageous for technology collaboration and how innovation intermediaries should encourage and stimulate the Technology Collaboration.

2. Theoretical Background

2.1 Absorptive Capacity

In the digital transformation environment where traditional industries integrate with IT, companies are increasingly shifting towards dependence on external technology utilization to foster continuous innovation and generate performance.

However, despite the increasing ubiquity of the adoption and utilization of external technology, many companies find themselves unable to derive benefits from external technologies [Escribano et al., 2009]. To enhance technological capabilities and gain a competitive advantage by leveraging external technologies, it is essential to have absorptive capacity.

Absorptive capacity is the ability of a company to recognize the value of new external technological information, absorb it, and apply it to commercialization [Cohen and

Levinthal, 1990]. The source of external knowledge becomes a source of corporate innovation. This absorptive capacity is considered a key driver in securing a competitive advantage for the company [Lichtenthaler, 2009].

Preceding studies on absorptive capacity have evolved from Cohen and Levinthal's [1990] research, branching into various streams of research. In the early stages, research focused on theoretical models regarding the essence of absorptive capacity, antecedents, and outcomes. However, empirical studies on these models were not as actively conducted [Lane et al., 2006].

Subsequent research has employed both quantitative and qualitative approaches to measure absorptive capacity [Konstantinos et al., 2011]. Some researchers have used indicators such as R&D expenditure and R&D intensity (R&D expenditure/revenue) [Cohen and Levinthal, 1990; Tsai, 2001], science and technology-related educational expenses [Mowery and Oxley, 1995], the presence of in-house R&D departments [Cassiman and Veugelers, 2002], the number of graduates from universities [Grimpe and Sofka, 2009], and the ratio of R&D personnel to total employees [Spanos and Voudouris, 2009] as variables to measure absorptive capacity.

Zahra and George [2002] proposed a theoretical framework, distinct from previous research, for structuring, measuring, and validating absorptive capacity. In their study, absorptive capacity was conceptualized as a series of four detailed capabilities based on the processes of acquiring, assimilating, transforming, and exploiting knowledge obtained through exploration. These capabilities were argued to be sequential and cumulative in nature, consisting of knowledge acquisition, assimilation, transformation, and exploitation.

Furthermore, Zahra and George [2002] categorized absorptive capacity into two factors: Potential Absorptive Capacity, and Realized Absorptive Capacity, based on the four components of absorptive capacity. Potential Absorptive Capacity was further divided into Acquisition and Assimilation, while Realized Absorptive Capacity was divided into Transformation and Application. Subsequently, Cesar and Beatriz [2010] conducted empirical research to validate both Potential and Realized Absorptive Capacities.

〈Table 1〉 Components of Absorptive Capacity

Components		Authors
Potential Absorptive Capacity	Acquisition	Zahra and George [2002] Cesar and Beatriz [2010]
	Assimilation	
Realized Absorptive Capacity	Transformation	
	Application	

Jansen et al. [2005] expanded the scope of absorptive capacity by utilizing the concepts of potential and realized absorptive capacities, conducting research on coordination capability and socialization capability. Lane et al. [2006] conducted a comprehensive review of past research on absorptive capacity, proposing three related processes of absorptive capacity explained by the identification of knowledge, assimilation and transformation of knowledge, and application of knowledge.

Lane et al. [2001] argued for the importance of capabilities in understanding external knowledge, assimilating external knowledge, and applying external knowledge for the successful operation of International Joint Ventures (IJVs) with different languages, cultures, and competencies, through research on the technological absorptive capacity, learning, and performance necessary for the success of IJVs.

Lichtenthaler and Lichtenthaler [2009] attempted to connect absorptive capacity and open innovation by proposing a framework for the open innovation process. They complemented the concept of absorptive capacity by merging research on knowledge management, absorptive capacity, and dynamic capabilities, considering internal and external knowledge exploration, possession, and utilization within companies.

Konstantinos et al. [2011] derived research results indicating a direct relationship between the inflow of external knowledge and absorptive capacity, and demonstrated that absorptive capacity directly influences innovation and financial performance.

2.2 Technology Collaboration Performance

ICT companies, engaged in business based on technology, need to rapidly and efficiently acquire knowledge and technology in various fields compared to other companies in the fiercely competitive environment to secure technological competitiveness. At times, they also engage in benchmarking and integrate acquired knowledge and technology in a manner suitable for their internal capabilities. However, since it is not practically easy for individual companies to possess diverse technologies in various fields to maintain technological competitiveness, various forms of technological collaboration have been increasingly employed as a strategic means to overcome such limitations [Kim, 2005].

Technology collaboration can be considered a form of strategic technological alliance, wherein participating companies form collaborative relationships between or among organizations through activities such as joint research and development and technology transfer with the aim of strengthening their product-market positions [Hagedoorn and Schakernraad, 1994]. Inter-firm technological collaboration provides advantages such as sharing technical resources, exchanging technological information, improving investment efficiency, and enhancing the effectiveness of product development timelines. These factors positively impact competitive advantages [Park, 2016].

Due to differences in the level and scope of technology held by companies, as well as variations in methods or know-how for technology development, technological collaboration can take various forms. Furthermore, companies pursuing technological collaboration require mutual trust for successful outcomes in technological collaboration [Barnir and Smith, 2002]. Research on technological collaboration outcomes can be broadly categorized into two streams. One stream focuses on the acquisition of technological knowledge from the collaborative partner, while the other stream concentrates on the results of a company's new product development [Hans, 2016].

<Table 2> Prior Research on Technology Collaboration

Authors	Description
Belderbos et al. [2018]	Companies that work together with universities and research institutions in R&D are more likely to continue collaborating with industry partners.
Stephanie and Patrick [2003]	Imitative firms gain from adopting existing technologies, while radical innovators find greater collaboration effects in joint research with universities.
Xuemei et	R&D collaboration has a reverse

Authors	Description
al. [2023]	U-shaped impact on new product innovation, and absorptive capacity moderates this effect
Hans [2016]	Knowledge acquired through technological collaboration positively influences the number of new product developments
Kim [2013]	Technological collaboration with external partner positively impact technological innovation outcomes, with absorptive capacity exhibiting a moderating effect.
Hwang [2014]	Technological collaboration with customers and affiliates has a positive impact on product innovation
Hwang and Seong [2018]	Technological collaboration between companies and research institute has a positive impact on technological outcomes, but not on economic outcomes.
Park [2016]	Companies with a higher level of technological collaboration demonstrate higher managerial performance

Another outcome of technological collaboration is Collaboration satisfaction. When collaboration is perceived as successful, the collaborating parties feel satisfied, establishing a mutual customer relationship. Regarding the measurement of customer satisfaction, Giese and Cote [2000] suggested that by studying and understanding various types of customers and contexts, satisfaction scales can be customized.

Oliver [1980]'s Expectation Confirmation Theory (ECT) is widely utilized in consumer behavior literature to study consumer satisfaction, post-purchase behavior (e.g., repurchase, dissatisfaction), and general service marketing related to customer satisfaction.

Locke [1976] defined satisfaction in the context of performance as "a pleasurable or positive emotional state resulting from the appraisal of one's job." Later, Oliver [1981] expanded this definition in the consumer context as "a summary psychological state that occurs when emotions surrounding unconfirmed expectations become combined with prior emotions about the consumer experience." Both definitions emphasize cognitive assessments of expectation-performance discrepancies, resulting in psychological or emotional states. Higher performance than low expectations leads to increased confidence, ultimately positively influencing customer satisfaction and intention to continue. Conversely, dissatisfaction and intent to discontinue arise if expectations are not met.

Bhattacherjee [2001] proposed the Post-Acceptance Model (PAM) based on the Expectation Confirmation Theory (ECT) and the Technology Acceptance Model (TAM). In the Post-Acceptance Model, perceived usefulness directly influences the intention to continue using, and indirectly affects the intention to continue use through user satisfaction. Bhattacherjee also argued that expectation confirmation influences perceived usefulness and satisfaction.

〈Table 3〉 Post Acceptance Model (Bhattacherjee, 2001)

Components	Description
Continuance Intention	User's intention to continue service usage
Satisfaction	Overall satisfaction derived from service usage
Perceived Usefulness	User perception of the effects and contributions of service usage
Confirmation	User satisfaction with the alignment between expectations and actual performance

2.3 Innovation Intermediaries

Innovation Intermediaries is a specialized organization or individual that facilitates business, contracts, programs, etc., necessary for technology innovation and successful technology commercialization within or between specific organizations. Innovation intermediaries play a crucial role in the innovation ecosystem, contributing significantly to various disciplines and industries such as technological innovation, technology commercialization, knowledge management, and open innovation.

In the context of innovation intermediaries, numerous prior studies have been conducted; however, there is no consensus on distinguishing roles and functions. The roles often overlap, leading to occasional confusion [Lee and Jung, 2018]. Howells [2006] defined innovation intermediaries as "organizations or institutions acting as agents or brokers in the innovation process between two or more parties." Dalziel [2010] expanded on Howells' definition, characterizing innovation intermediaries as organizations or groups within organizations that directly enable innovation in one or more companies and indirectly enhance the innovation capabilities of industries, regions, or nations based on organizational goals.

Innovation intermediaries need to share knowledge based on their expertise. To achieve this, they must possess in-depth expertise in specific industries or technological fields. They provide valuable knowledge on new technologies, market trends, legal aspects, and more, assisting companies in addressing challenges that may arise during the pursuit of innovation [Bakici et al., 2013].

Howells [2006] was the first to categorize various roles and functions performed by innovation intermediaries in the technological innovation process. These include prediction and diagnosis, information search and analysis, knowledge processing, creation and recombination, technology selection, mediation and negotiation, technological assessment, testing and validation of technology, technological standard certification, technology-related regulations, intellectual property rights, and licensing protection. Subsequent research by Lopez-Vega [2009] classified the roles and functions of innovation intermediaries into three categories: facilitating collaboration, connecting actors involved in innovation, and providing services for stakeholders.

<Table 4> Role of Innovation Intermediaries (Howells, 2006)

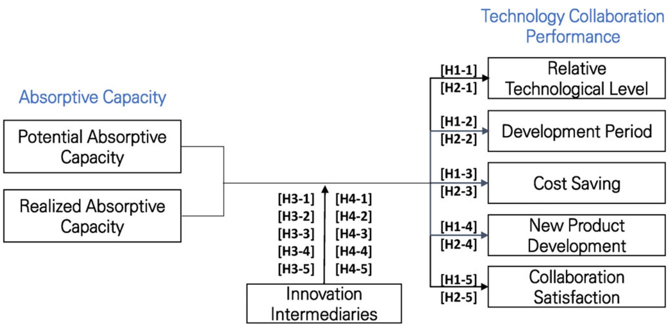
Role	Function
facilitating collaboration	Prediction and diagnosis
	Information search and analysis
	Knowledge processing, creation, and recombination
	Business development
connecting actors	Selection, technology mediation, and negotiation
	Technological assessment
providing services for stakeholders	Testing and validation
	Standard certification
	Verification and regulation
	Intellectual property rights and performance protection

Various studies have been conducted in diverse fields related to innovation intermediaries, primarily focusing on the role of innovation intermediaries in facilitating collaboration and improving a firm's performance through external partnerships. Notably, research has delved into the mediating role of innovation intermediaries. Leal et al. [2014] analyzed the mediating role of potential absorptive capacity and realized absorptive capacity, as proposed by Zahra and George [2002], on the impact of individual innovation performance. Lau and Lo [2015] explored the effects of regional innovation institutions, knowledge management services, and value chain networks on a firm's technological absorptive capacity and innovation performance from a regional innovation perspective. Lin et al. [2016] examined the relationship between innovation intermediaries and firm innovation performance, verifying the mediating effects of absorptive capacity. They found that higher absorptive capacity expands the scope of external technological exploration and simultaneously reduces the costs associated with exploration, influencing a firm's absorptive capacity and innovation. Liu et al. [2013] analyzed the mediating effects of absorptive capacity and supply chain agility on the relationship between a firm's information technology level and its performance. Shou et al. [2013] studied the impact of innovation intermediaries on the innovation process of small and medium-sized enterprises (SMEs), revealing that innovation intermediaries and resource- and information-based collaboration affect performance through absorptive capacity. Gassmann et al. [2011] highlighted the role of innovation intermediaries in industrial convergence and process innovation. Ferreras et al. [2015] investigated performance differences based on the depth and breadth of external technological exploration and identified the mediating effect of technological absorptive capacity in this process.

In prior research, the predominant focus has been on utilizing innovation intermediaries as independent or mediating variables. However, considering that many companies successfully engage in technological collaborations even without innovation intermediaries, there is a need to view innovation intermediaries as moderating variables. Research should be conducted to verify which counterpart or context exhibits a more significant moderating effect when innovation intermediaries are absent.

3. Research Model and Hypotheses

In this study, we established the following research model through a literature review of prior studies. The independent variable is technology absorptive capacity, which consists of two sub-factors: potential absorptive capacity and realized absorptive capacity. The dependent variable is technology collaboration performance, composed of five sub-factors: relative technological level, development period, cost saving, new product development, and collaboration satisfaction.



〈Figure 1〉 Research Model

Additionally, to examine the moderating effect of innovation intermediaries between technology absorptive capacity and technology collaboration performance, we utilize innovation intermediaries as a moderating variable.

The relationship between absorptive capacity and technology collaboration performance

- H1-1: Potential absorptive capacity will have a positive and significant impact on relative technological level.
- H1-2: Potential absorptive capacity will have a positive and significant impact on development period.
- H1-3: Potential absorptive capacity will have a positive and significant impact on cost saving.
- H1-4: Potential absorptive capacity will have a positive and significant impact on new product development.
- H1-5: Potential absorptive capacity will have a positive and significant impact on collaboration satisfaction.
- H2-1: Realized absorptive capacity will have a positive and significant impact on relative technological level.
- H2-2: Realized absorptive capacity will have a positive and significant impact on development period.
- H2-3: Realized absorptive capacity will have a positive and significant impact on cost saving.
- H2-4: Realized absorptive capacity will have a positive and significant impact on new product development.
- H2-5: Realized absorptive capacity will have a positive and significant impact on collaboration satisfaction.

The moderating effect of innovation intermediaries on relationship between absorptive capacity and technology collaboration performance

- H3-1: Innovation intermediaries will have a moderating effect between potential absorptive capacity and relative technological level.
- H3-2: Innovation intermediaries will have a moderating effect between potential absorptive capacity and development period.
- H3-3: Innovation intermediaries will have a moderating effect between potential absorptive capacity and cost saving.
- H3-4: Innovation intermediaries will have a moderating effect between potential absorptive capacity and new product development.
- H3-5: Innovation intermediaries will have a moderating effect between potential absorptive capacity and collaboration satisfaction.
- H4-1: Innovation intermediaries will have a moderating effect between realized absorptive capacity and relative technological level.
- H4-2: Innovation intermediaries will have a moderating effect between realized absorptive capacity and development period
- H4-3: Innovation intermediaries will have a moderating effect between realized absorptive capacity and cost saving.
- H4-4: Innovation intermediaries will have a moderating effect between realized absorptive capacity and new product development.
- H4-5: Innovation intermediaries will have

a moderating effect between realized absorptive capacity and collaboration satisfaction.

3.1 Operational definition and Measurement of variables

In this study, two independent variables, five dependent variables and one moderating variable were established based on previous research. The operational definitions and measurement of the variables are as follows.

〈Table 5〉 Operational definition of Independent Variables

Variables	Operational Definition	Measurement
Relative Technological Level	Technological level compared to the highest technology country due to technological cooperation	Technological level after technical cooperation compared to the highest technology country (%)
Development Period	Shortened technology development period through technological cooperation	Shortening effect compared to expected development period (%)
New Product Development	Contribution to new product development through technological cooperation	Contribution to new product development (%)
Cost Saving	Technology/product development costs reduced through technological cooperation	Savings effect compared to expected cost (%)
Collaboration Satisfaction	- Overall satisfaction - Contribution - Sufficiency - Continuous use - Recommendation	Likert Scale (1-5)

〈Table 6〉 Operational definition of Dependent Variables

	Operational Definition Variables	Measurement
Innovation Intermediaries	Support technology collaboration between suppliers and consumers (coordinating)	Dummy (0,1)

〈Table 7〉 Operational definition of Moderating Variable

Variables	Operational Definition	Measure ment
Potential Absorptive Capacity	- Know competitors' technologies - Catch external environment change - Collaborate with external partners - Internal technology development - Utilizing internal resources - Benchmarking in the same industry - External technology diffusion	Likert Scale (1-5)
Realized Absorptive Capacity	- Have knowledge delivery system - Can replace existing technology - Can apply external technologies - Share information among employees - Can utilize experience to product - Can create Intellectual property - Can expand new product portfolio	Likert Scale (1-5)

4. Methods and Data Collection

In this study, data were collected through a survey targeting 145 ICT companies in Korea that transferred technologies from government-funded research institutions. The survey was conducted from October 4 to 20, 2023, using methods such as email and postal distribution, and a total of 105 surveys were collected (response rate of 72.4%). For accuracy and reliability in empirical analysis, 4 surveys that were deemed insincere or not properly filled out were excluded from the analysis, leaving a total of 101 valid datasets.

The collected data were statistically analyzed using SPSS 29. The analysis started with frequency analysis, followed by the analysis of the validity and reliability of variables related to independent variables (potential absorptive capacity, realized absorptive capacity) and the dependent variable (collaboration satisfaction). Subsequently, correlation analysis among independent variables, dependent variables, and moderating variables was conducted. After completing the verification of variables, multivariate analysis of variance (MANOVA) was conducted for 2 independent variables and 5 dependent variables (relative technological level, development period, cost saving, new product development, collaboration satisfaction). Multiple regression analysis was then performed to elucidate the causal relationships between independent and dependent variables. Finally, the analysis was concluded by verifying the moderating effect of the innovation intermediaries.

5. Results

5.1 Validity and Reliability Analysis

In this study, prior to hypothesis testing for the variables in the research model, a factor analysis was conducted to enhance the substantive validity of the research findings and evaluate the validity of survey items for each variable. The analysis method involved using principal component analysis, and Varimax was employed to maintain independence among the factors.

A factor analysis was conducted on the detailed measurement items of the independent variable, absorptive capacity (ACAP1-16), and the dependent variable, collaboration satisfaction (CSAT1-5), resulting in three groups. Factor 1 was extracted with a total of 8 items (ACAP11, 9, 16, 13, 10, 15, 14, 12), showing an eigenvalue of 5.485, and it was named 'Realized Absorptive Capacity'. Factor 2 was extracted with a total of 8 items (ACAP5, 6, 2, 7, 1, 8, 3, 4), showing an eigenvalue of 4.994, and it was named 'Potential Absorptive Capacity'. Factor 3 was extracted with a total of 5 items (CSAT2, 1, 3, 5, 4), showing an eigenvalue of 4.431, and it was named 'Collaboration Satisfaction'.

〈Table 8〉 Results of Validity and Reliability

Item	Factor 1	Factor 2	Factor 3	Cronhach's Alpha
ACAP11	**.894**	.091	-.096	Realized Absorptive Capacity .933
ACAP9	**.856**	-.014	-.037	
ACAP16	**.826**	.198	.059	
ACAP13	**.808**	.316	-.018	
ACAP10	**.803**	.162	-.040	
ACAP15	**.799**	.108	035	
ACAP14	**.762**	.152	.094	
ACAP12	**.746**	.186	.014	
ACAP5	.088	**.856**	.061	Potential Absorptive Capacity .906
ACAP6	.190	**.782**	.143	
ACAP2	.195	**.759**	.178	
ACAP7	.230	**.753**	.065	
ACAP1	.154	**.734**	.183	
ACAP8	.148	**.724**	.137	
ACAP3	.088	**.708**	.270	
ACAP4	.065	**.689**	.213	
CSAT2	.040	.191	**.928**	Collaboration Satisfaction .965
CSAT1	-.002	.186	**.925**	
CSAT3	.0.08	.271	**.924**	
CSAT5	-.062	.129	**.905**	
CSAT4	.002	.250	**.886**	

Next, a reliability analysis was conducted for the three variables derived through Factor Analysis. The reliability of Potential Absorptive Capacity was .906, Realized Absorptive Capacity was .933, and Collaboration Satisfaction was .965. All variables demonstrated a high reliability with values exceeding 0.7. As there were no items undermining the reliability of any of the three factors, all factors will be utilized in the analysis.

5.2 Correlation Analysis

To verify the correlation of the relationships between the scales, correlation analysis was conducted. The analysis results showed significant relationships among the variables overall, except for a relatively lower correlation between realized absorptive capacity and collaboration satisfaction, as well as between relative technological level and collaboration satisfaction. This indicates that the validity of the variables used in this study has been confirmed for their application.

To understand the impact of absorptive capacity on technology collaboration performance, this study conducted Multivariate Analysis of Variance (MANOVA).

In the study, before conducting Multivariate Analysis of Variance (MANOVA), the assumption of homogeneity of covariance matrix for covariates is checked. The sample sizes for the intervals of the independent variables, potential absorptive capacity, and realized absorptive capacity, are different. As each variable is composed of the average values of 8 sub-factors, for the convenience of the study, the decimal points of each independent variable are truncated to form 5 groups with scores ranging from 1 to 5. As a result, potential absorptive capacity is classified into 4 groups (2, 3, 4, 5), and realized absorptive capacity is classified into 5 groups (1, 2, 3, 4, 5). Next, since the correlation between dependent variables should be similar in all groups, Box's test of homogeneity of covariance was employed. The homogeneity of covariance test results for dependent variables showed that Box's M was 66.915, the F-value was 1.298, and the significance level was greater than 0.05. Therefore, it indicates that there is a similarity in the correlation between dependent variables across all groups.

Results of Box's Test for Homogeneity of Covariance Matrices

〈Table 10〉 Results of Box's Test for Homogeneity of covariance Matrices

Box's M	F	df1	df2	p
66.915	1.298	45	10091.610	0.87

〈Table 9〉 Results of Correlation Analysis Multivariate Analysis of Variance (MANOVA)

Variable	1	2	3	4	5	6	7
PACAP	1						
RACAP	.355**	1					
TECH	.261**	.378**	1				
DEVEL	.230*	.211*	.248*	1			
COST	.254*	.358**	.219*	.517**	1		
NPD	.362**	.526**	.275**	.433**	.746**	1	
CSAT	.404**	.037	.105	.315**	.328**	.225*	1

Then, a Levene test for the equality of error variances was conducted. The results of the homogeneity test for error variance for each of the five dependent variables (Relative Technological Level, Development Period, Cost Savings, New Product Development, Collaboration Satisfaction) showed that the p-values for Relative Technological Level (.219), Development Period (.123), and Cost Savings (.339) are greater than 0.05. However, New Product Development (.046) and Collaboration Satisfaction (.046) yielded very small p-values less than 0.05, indicating that these samples can be considered as drawn from the same population.

〈Table 11〉 Levene's Test for the Equality of Error Variance

Dependent Variables	F	df1	df2	p
Relative Technological Level	1.374	8	87	.219
Development Period	1.649	8	87	.123
Cost Saving	1.149	8	87	.339
New Product Development	2.080	8	87	.046
Collaboration Satisfaction	2.078	8	87	.046

Next, to examine the overall significance of the relationships between two independent variables (potential absorptive capacity with four groups and realized absorptive capacity with five groups) and five dependent variables (relative technological level, development period, cost saving, new product development, collaboration satisfaction), multivariate tests were conducted. Three different test methods, including Pillai's trace, Wilks' lambda, and Hotelling's trace, were employed for the multivariate tests. The MANOVA significance test results revealed that both potential absorptive capacity (Pillai's trace = 0.367, F(15, 255) = 2.371, p = 0.003 / Wilks' lambda = 0.646, F(15, 229.528) = 2.628, p = 0.001 / Hotelling's trace = 0.529, F(5, 245) = 2.881, p = 0.001) and realized absorptive capacity (Pillai's trace = 0.441, F(20, 344) = 2.131, p = 0.004 / Wilks' lambda = 0.612, F(20, 276.230) = 2.202, p = 0.003 / Hotelling's trace = 0.550, F(20, 326) = 2.241, p = 0.002) significantly influenced the dependent variables. Finally, the interaction between the two independent variables (potential absorptive capacity * realized absorptive capacity) also had a significant impact on the dependent variables (Pillai's trace = 0.541, F(30, 435) = 1.761, p = 0.009 / Wilks' lambda = 0.543, F(30, 334) = 1.883, p = 0.006 / Hotelling's trace = 0.693, F(30, 407) = 1.879, p = 0.004).

〈Table 12〉 Results of Multivariate Analysis

Methods	value	F	df1	df2	p
Potential absorptive capacity					
Pillai's trace	.367	2.371	15	255	.003
Wilks' lambda	.646	2.628	15	230	.001
Hotelling's trace	.529	2.881	5	245	.001
Realized absorptive capacity					
Pillai's trace	.441	2.131	20	344	.004
Wilks' lambda	.612	2.202	20	276	.003
Hotelling's trace	.550	2.241	20	326	.002
Potential * Realized absorptive capacity					
Pillai's trace	.541	1.761	30	435	.009
Wilks' lambda	.543	1.883	30	334	.006
Hotelling's trace	.693	1.879	30	407	.004

Finally, the effects of independent variables (Potential Absorptive Capacity and Realized Absorptive Capacity) on inter-unit effects (main effects and interaction effects) were tested. For 'Potential Absorptive Capacity,' statistically significant main effects were observed in Relative Technology Level (F=5.478, p=0.002), Development Period (F=2.999, p=0.035), and Collaboration

Satisfaction (F=7.647, p=0.001), while no significant effects were found in Cost Saving (F=0.973, p=0.410) and New Product Development (F=1.802, p=0.153).

For 'Realized Absorptive Capacity,' statistically significant main effects were observed in Relative Technology Level (F=6.107, p=0.001) and Collaboration Satisfaction (F=3.379, p=0.013), while no significant effects were found in Development Period (F=0.719, p=0.581), Cost Saving (F=1.294, p=0.279), and New Product Development (F=1.035, p=0.394).

The interaction effect of 'Potential Absorptive Capacity * Realized Absorptive Capacity' showed statistically significant interaction effects only in Relative Technology Level (F=5.280, p=0.001). There were no significant effects in Development Period (F=1.284, p=0.273), Cost Saving (F=1.367, p=0.237), New Product Development (F=0.989, p=0.438), and Collaboration Satisfaction (F=2.132, p=0.058).

5.3 Multiple Regression Analysis

To verify the hypotheses of this study, a multiple regression analysis was conducted to examine the impact of absorptive capacity (potential absorptive capacity, realized absorptive capacity) on technology collaboration performance (relative technological level, development period, cost saving, new product development, collaboration satisfaction). The R^2 values representing the explanatory power of the models ranged from .072 to .312, indicating an explanatory power of 7.2% to 31.2%. The Durbin-Watson values ranged from 1.383 to 2.066, and as these values are close to 2 and not close to 0 or 4, it can be interpreted that there is no correlation among the residuals, making the regression model appropriate. The F-values ranged from 3.795 to 22.258, and the significance level was .001 to .026 ($p < .05$), indicating that the regression line model is suitable.

Results for the impact on Relative

〈Table 13〉 Main Effects of Technology Collaboration Performance by Independent Variables

Independent variables	Dependent Variables	F	p	ηp2
Potential Absorptive Capacity	**Relative Technology Level**	**5.478**	**.002****	**.159**
	Development Period	**2.999**	**.035***	**.094**
	Cost Saving	.973	.410	.032
	New Product Development	1.802	.153	.059
	Collaboration Satisfaction	**7.647**	**.001*****	**.209**
Realized Absorptive Capacity	**Relative Technology Level**	**6.107**	**.001*****	**.219**
	Development Period	.719	.581	.032
	Cost Saving	1.294	.279	.056
	New Product Development	1.035	.394	.045
	Collaboration Satisfaction	**3.379**	**.013***	**.134**
Potential x Realized Absorptive Capacity	**Relative Technology Level**	**5.280**	**.001*****	**.267**
	Development Period	1.284	.273	.081
	Cost Saving	1.367	.237	.086
	New Product Development	.089	.438	.064
	Collaboration Satisfaction	2.132	.058	.128

*p<.05, **p<.01, ***p<.001

〈Table 14〉 Results of Multiple Regression Analysis

Dependent variables	Independent Variables	t	p	ε
Relative Technological Level	Constant	6.098	.001**	-
	Potential Absorptive Capacity	1.472	.144*	.874
	Realized Absorptive Capacity	**3.295**	**.001*** **	**.874**
	$R=.402$, $R^2=.161$, Adjusted $R^2=.144$, $F=9.423$, $p=.001$, Durbin-Watson=1.752			
Development Period	Constant	.370	.713	-
	Potential Absorptive Capacity	1.669	.092	.874
	Realized Absorptive Capacity	1.424	.158	.874
	$R=.268$, $R^2=.072$, Adjusted $R^2=.053$, $F=3.795$, $p=.026$, Durbin-Watson=1.383			
Cost Saving	Constant	-2.157	.033*	-
	Potential Absorptive Capacity	1.452	.150	.874
	Realized Absorptive Capacity	**3.067**	**.003** **	**.874**
	$R=.382$, $R^2=.146$, Adjusted $R^2=.129$, $F=8.396$, $p=.001$, Durbin-Watson=1.754			
New Product Development	Constant	-3.476	.001***	-
	Potential Absorptive Capacity	**2.241**	**.027** *	**.874**
	Realized Absorptive Capacity	**5.079**	**.001*** **	**.874**
	$R=.559$, $R^2=.312$, Adjusted $R^2=.298$, $F=22.258$, $p=.001$, Durbin-Watson=1.594			
Collaboration Satisfaction	Constant	4.673	.001***	-
	Potential Absorptive Capacity	**4.555**	**.001*** **	**.874**
	Realized Absorptive Capacity	-1.235	.220	.874
	$R=.419$, $R^2=.176$, Adjusted $R^2=.159$, $F=10.459$, $p=.001$, Durbin-Watson=2.066			

*p<.05, **p<.01, ***p<.001.

Technological Level are as follows: the t-value for potential absorptive capacity is 1.472, with a significance level of .144, resulting in the rejection of hypothesis [H1-1]. On the other hand, the t-value for realized absorptive capacity is 3.295, with a significance level of .001, leading to the acceptance of hypothesis [H2-1]. The tolerance limits for collinearity statistics are all 0.874, indicating no issues with multicollinearity.

Results for the impact on Development Period are as follows: for potential absorptive capacity, the t-value is 1.699, with a significance level of .092, resulting in the rejection of hypothesis [H1-2]. Similarly, for realized absorptive capacity, the t-value is 1.424, with a significance level of .158, leading to the rejection of hypothesis [H2-2]. The tolerance limits for collinearity statistics are all 0.874, indicating no issues with multicollinearity.

Results for the impact on Cost Saving are as follows: regarding potential absorptive capacity, the t-value is 1.452, with a significance level of .150, resulting in the rejection of hypothesis [H1-3]. However, for realized absorptive capacity, the t-value is 3.067, with a significance level of .003, leading to the acceptance of hypothesis [H2-3]. The tolerance limits for collinearity statistics are all 0.874, indicating no issues with multicollinearity.

Results for the impact on New Product Development are as follows: the t-value for potential absorptive capacity is 2.241, with a significance level of .027, resulting in the acceptance of hypothesis [H1-4]. Additionally, for realized absorptive capacity, the t-value is 5.079, with a significance level of .001, leading to the acceptance of hypothesis [H2-4]. The tolerance limits for collinearity statistics are all 0.874, indicating no issues with multicollinearity.

Results for the impact on Collaboration Satisfaction are as follows: for potential absorptive capacity, the t-value is 4.555, with a significance level of .001, resulting in the acceptance of hypothesis [H1-1]. Conversely, for realized absorptive capacity, the t-value is -1.235, with a significance level of .220, leading to the rejection of hypothesis [H1-3]. The tolerance limits for collinearity statistics are all 0.874, indicating no issues with multicollinearity.

5.4 Moderating Effect Analysis

To verify the hypotheses of this study, moderating effect analysis was conducted to examine the impact of Innovation Intermediaries's moderating effect between absorptive capacity and technology collaboration performance.

In examining the moderating effects of innovation intermediaries on the relationship between absorptive capacity and relative technological level, the results indicated that the p-values for Potential ACAP moderation (potential absorptive capacity x innovation

<Table 15> Results of Moderating Effect Analysis

Dependent variables	Independent Variables	t	p	ε
Relative Technological Level	Constant	69.905	.001**	-
	Innovation Intermediaries	1.268	.208	.782
	Potential ACAP Moderation	.727	.469	.428
	Realized ACAP Moderation	-.672	.503	.430
Development Period	Constant	19.081	.001***	-
	Innovation Intermediaries	6.305	.001***	782
	Potential ACAP Moderation	-.438	.662	.428
	Realized ACAP Moderation	-.145	.885	.430
Cost Saving	Constant	18.104	.001***	-
	Innovation Intermediaries	11.843	.001***	782
	Potential ACAP Moderation	-.618	.538	.428
	Realized ACAP Moderation	1.445	.152	.430
New Product Development	Constant	28.472	.001***	-
	Innovation Intermediaries	11.188	.001***	782
	Potential ACAP Moderation	-.893	.374	.428
	Realized ACAP Moderation	**3.520**	**.001*****	**.430**
Collaboration Satisfaction	Constant	52.396	.001***	-
	Innovation Intermediaries	1.904	.060	782
	Potential ACAP Moderation	-.782	.436	.428
	Realized ACAP Moderation	1.450	.150	.430

*p<.05, **p<.01, ***p<.001

intermediaries) and Realized ACAP moderation (realized absorptive capacity x innovation intermediaries) were both 0.469 and 0.503, respectively, leading to the rejection of hypotheses [H3-1] and [H4-1].

Similarly, when investigating the relationship between absorptive capacity and development period with the moderating effects of innovation intermediaries, the p-values for Potential ACAP moderation and Realized ACAP moderation were both 0.662 and 0.885, respectively, resulting in the rejection of hypotheses [H3-2] and [H4-2].

Furthermore, in exploring the impact of absorptive capacity on cost reduction with the moderating effects of innovation intermediaries, the p-values for Potential ACAP moderation and Realized ACAP moderation were both 0.538 and 0.152, respectively, leading to the rejection of hypotheses [H3-3] and [H4-3].

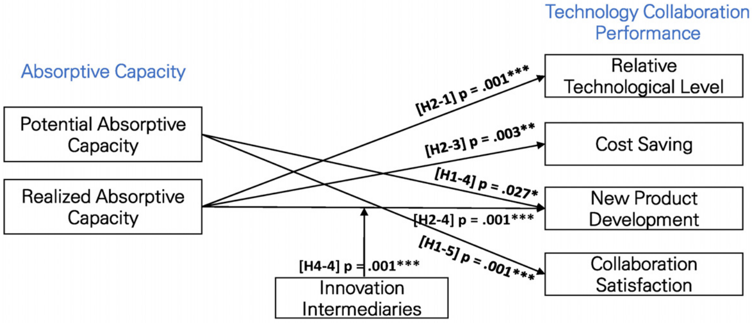
In the context of the relationship between absorptive capacity and new product development with the moderating effects of innovation intermediaries, the p-value for Potential ACAP moderation was 0.374, leading to the rejection of hypothesis [H3-4], while the p-value for Realized ACAP moderation was 0.001, resulting in the acceptance of hypothesis [H4-4].

Lastly, when investigating the impact of absorptive capacity on collaboration satisfaction with the moderating effects of innovation intermediaries, the p-values for Potential ACAP moderation and Realized ACAP moderation were both 0.538 and 0.152, respectively, leading to the rejection of hypotheses [H3-5] and [H4-5].

6. Conclusion

The conclusion and implications of this study are as follows. First, The higher the Absorptive Capacity of small and medium-sized enterprises (SMEs) in the ICT sector, the greater the success in new product development. New products achieve high levels of completeness when every stage, from the exploration and learning of technology to its utilization and transformation, is appropriately harmonized. Therefore, both potential absorptive capacity and realized absorptive capacity exert influence on the development of new products.

Second, Companies with high potential absorptive capacity tend to exhibit high satisfaction with technological collaboration. Companies with high Potential Absorptive



〈Figure 2〉 Research Results

Capacity typically excel in exploring and learning early-stage technologies. These companies, facing challenges in developing proprietary technologies on their own, find satisfaction in technological collaboration as it allows them to absorb technology at the initial stages through collaborative efforts

Third, The higher the Realized Absorptive Capacity, the greater the Technological level, Cost savings, and success in new product development. And Forth, Companies with higher Realized Absorptive Capacity, when engaged in more innovation intermediaries activities, yield even greater success in new product development. Therefore, departments performing the role of innovation intermediaries should focus their efforts on identifying companies with high Realized Absorptive Capacity. By mediating technological collaborations with these companies, they can strive to generate productization outcomes with minimal resources and maximum impact.

The limitations of this study include the difficulty in structurally measuring the absorptive capacity of ICT small and medium-sized enterprises (SMEs). Additionally, there are constraints in controlling external factors that may influence the outcomes of technological collaboration. Lastly, the verification of the moderating effect was based on the presence or absence of innovation intermediaries activities (dummy measurement), highlighting the need for a more detailed measurement of innovation intermediation. These aspects should be addressed and improved in future research endeavors.

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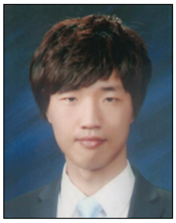

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