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THE EFFECT OF TECHNOLOGY COMMERCIALIZATION CAPABILITIES ON NEW PRODUCT DEVELOPMENT AND BUSINESS PERFORMANCE: THE MODERATING EFFECT OF BUSINESS REFERENCE

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ABSTRACT

In the Fourth Industrial Revolution era, companies face unprecedented competition and market uncertainty, necessitating effective technology commercialization for survival. This study examines how technology commercialization capabilities influence new product development and business performance, particularly investigating business age as a moderating factor. The research analyzed data from 427 Fourth Industrial Revolution manufacturing companies using structural equation modeling, examining relationships between four technology commercialization capabilities (research, absorption, marketing, and manufacturing), new product development, and performance outcomes. Results demonstrated that research, absorption, and manufacturing capabilities significantly impact new product development, with manufacturing capability exhibiting the strongest influence. New product development showed positive effects on both financial and non-financial performance metrics. Notably, business age emerged as a crucial moderator in the relationship between technology commercialization capabilities and new product development. Companies with longer histories displayed stronger effects of research capabilities, while manufacturing and absorption capabilities proved effective regardless of organizational age. These findings enhance our understanding of how different technology commercialization capabilities contribute to business success across various organizational life stages, offering valuable insights for companies aiming to optimize their technology commercialization strategies in an increasingly competitive market environment.

Keywords: Technology Commercialization Capabilities, New Product Development, Business Performance, Fourth Industrial Revolution, Business Age Moderation

1. INTRODUCTION

The entry into the Fourth Industrial Revolution era has led to accelerated technological development and increased market uncertainty. In this environment, companies face unlimited competition due to the standardization of global supply chains (Gil Jong-gu & Kim Jung-hyo, 2019) and are pursuing innovation through the convergence of various technologies for survival (Noh Young-hee & Kim Tae-hoon, 2022).

Corporate technological innovation affects an organization's basic production activities and solves problems or derives new solutions through new ideas secured as a result of research and development and technological development (Zahra and George, 2002). However, the process of bringing technologies developed by companies to market is very complex, and many companies experience the "Death Valley" due to reasons such as lack of funding (Kararm, 2014).

Various capabilities are required for successful technology commercialization. Companies can create innovation through R&D capabilities (Kim Su-jin & Lee Sang-yong, 2018) and improve problem-solving abilities by accepting external knowledge through absorption capabilities (Lim Seol-gyo & Jung Su-jin, 2020).

Through production capabilities, they can convert technology development results into products desired by the market (Han Sung-hyun & Heo Cheol-mu, 2020) and effectively deliver products to consumers through marketing capabilities (Jeon In-sun et al., 2020).

Particularly in the modern market where product life cycles are shortening and consumer purchasing trends are rapidly changing, companies' operational capabilities are becoming increasingly important. Meanwhile, Weber and Tarba (2014) emphasized the importance of internal organizations' ability to flexibly respond to external changes, and the study by Bae Hong-beom et al. (2018) showed that productization capabilities have a positive impact on company performance.

Based on this background, this study aims to analyze the relationships between technology commercialization capabilities, new product development, and commercialization performance. In particular, by targeting small and medium-sized enterprises to verify the moderating effect of business age and comprehensively measuring financial/non-financial performance, we aim to suggest practical technology commercialization methods that can overcome the current three highs phenomenon (high prices, high interest rates, high exchange rates).

To achieve the objectives of this study, four specific research questions were established as follows:

First, to strengthen products and services of domestic companies, we aim to analyze how technology commercialization capabilities - including research capabilities, absorption capabilities, marketing capabilities, and manufacturing capabilities - affect new product development.

Second, we aim to provide strategic objectives for successful technology commercialization of domestic SMEs by identifying the relationship between new product development and technology commercialization performance.

Third, while previously studied venture companies were mostly early-stage technology development companies, technology-leading SMEs tend to have a higher proportion of companies with longer business histories. Therefore, we aim to verify the role of business age in the relationship between technology commercialization capabilities and new product development.

Fourth, we examine how new product development affects technology commercialization performance. For this purpose, we aim to specifically verify technology commercialization performance by measuring both financial and non-financial performance. To commercialize technology, it is necessary to pass both the technology gate and the market gate (Sutopo et al., 2019). The technology gate cannot be passed unless technical issues such as standardization and reliability are resolved. Even if a product incorporating good technology is launched, it is difficult to succeed if consumers in the market do not choose it. Therefore, company-wide

efforts are needed to successfully introduce R&D results to the market without falling into the Death Valley.

Through this study, by identifying the relationships between technology commercialization capabilities, new product development, and technology commercialization performance, we will help identify important factors for successful corporate technology commercialization and establish measures to fulfill technology commercialization capabilities that can overcome the current domestic and international economic issues of high prices, high interest rates, and high exchange rates.

2. MATERIALS AND METHODS

Companies that emphasize innovation and R&D are founded with entrepreneurial motivation and create high added value based on new technologies. With a small number of personnel, these companies can sometimes create new industrial ecosystems based on innovative technologies for products and services. In particular, companies focused on R&D, companies focused on applying new knowledge or technology, companies introducing new products, new technologies, or new production methods, and companies pioneering new markets make many new attempts for profit generation and growth.

As the importance of technological innovation and core competencies of startup companies has increased recently, there is growing interest in exploring various factors that influence their formation process. Many companies establish technology innovation strategies by exploring technological changes to discover and utilize new technology innovation opportunities. They also introduce strategic technology innovation systems to organizations and accept new technologies and ideas.

Based on previous studies, we designed a research model to define the concepts of technology commercialization capabilities, new product development, and commercialization performance, and analyze the relationships between each variable. For this study's purpose and research problem verification, we conducted a survey targeting the Fourth Industrial Revolution manufacturing sector. Prior to the main survey, we conducted first and second rounds of consultation and preliminary surveys to modify and supplement potential problems that could arise during the survey process, and finally confirmed the questionnaire.

To increase the reliability of the survey, we commissioned a professional survey company to conduct the questionnaire survey targeting Fourth Industrial Revolution manufacturing, clearly identifying the main targets of the questionnaire.

The main content of this study is organized into five chapters to present the basic direction of research to achieve the technology commercialization research objectives:

Chapter 1 is the introduction, describing the research background and purpose, research methods, and paper composition to present the basic direction of this study.

Chapter 2 presents theoretical considerations of the study, explaining the concepts, types, and previous research on manufacturing companies' technology commercialization capabilities, new product development, technology commercialization performance, and business age.

Chapter 3 describes the research model, hypothesis setting, and survey design.

Chapter 4 describes the verification of research hypotheses through basic data analysis for hypothesis testing, reliability analysis and exploratory factor analysis of measurement variables, correlation analysis, and research hypothesis testing.

Chapter 5 summarizes and organizes the research results to draw conclusions, and presents limitations of the study and future research directions.

3. RESULTS AND DISCUSSIONS

1) Research Model

This study analyzed the relationship between technology commercialization capabilities (research capability, absorption capability, marketing capability, manufacturing capability) and new product development and commercialization performance in the Fourth Industrial Revolution manufacturing sector. Additionally, it analyzed whether company age has a moderating effect on the relationship between technology commercialization capabilities and new product development. To achieve the research objectives, the research model classified technology commercialization capabilities as independent variables into research capability, absorption capability, marketing capability, and manufacturing capability, with new product development as the mediating variable, commercialization performance (financial and non-financial performance) as dependent variables, and company age as the moderating variable.

Previous studies on technology commercialization capabilities show that technological innovation is implemented as a business model and provided as products or services. Technology commercialization is defined as improving technology through new technologies and innovative ideas based on various stages and expertise including technology development, market research, business strategy, funding, and marketing. Based on these concepts, the research model was established as follows

2) Variables and Concepts of the Study

Table 1

Table 1 Variables and Concepts in Research

Classification	Factor	Definition
Independent Variables(Technology Commercialization Capabilities)	Research Capability	Improving productivity through new product and process introduction from R&D investment concept
	Absorption Capability	Ability to recognize the value of new information, absorb, digest, and apply it as one's own capability
	Marketing Capability	Ability to segment markets, identify competing products, establish marketing strategies, and secure marketing channels
	Manufacturing Capability	All activities for efficiently managing development, production, logistics, and services
Mediating Variable	New Product Development	Discovery that developing and launching new products has direct and significant impact on actual business performance
Dependent Variables (Commercialization Performance)	Financial Performance	Traditional performance measurement method serving as business performance indicator along with business operation evaluation

	Non-financial Performance	Indicators that are difficult to express quantitatively as results of management performance evaluation
Moderating Variable	Company Age	Examining the role of company age in the relationship between knowledge-seeking activities and company performance

3) Data Collection

For data collection, surveys were conducted targeting management innovation companies, venture companies, Innobiz, and companies with corporate research institutes in the Fourth Industrial Revolution manufacturing sector. The survey included large corporations, SMEs, small businesses, and sole proprietorships. To ensure validity and reliability, the survey was conducted through a survey agency from March to August 2023, following methods including population selection, sampling frame selection, sampling method determination, sample size determination, and questionnaire finalization.

Out of 500 distributed questionnaires, 460 were collected, and 427 were used for analysis after excluding 33 incomplete or insincere responses. The questionnaire consisted of 46 items covering technology commercialization capabilities, new product development, and commercialization performance.

Table 2

Table 2 Internet Survey Questionnaire Analysis		
Distributed Questionnaire	**Collected Questionnaires**	**Valid Questionnaires**
500	460	427

4) Analysis Methods

The survey analysis was conducted to examine the distribution patterns of respondents for each measurement variable and to analyze whether the measurement items follow a normal distribution. All items except demographic characteristics were measured using a 5-point Likert scale.

Research hypotheses and models were established, particularly focusing on relationships between factors analyzed through structural equation modeling. AMOS 24.0 and SPSS 26.0 statistical programs were used for empirical analysis.

First, descriptive statistics and frequency analysis were conducted to understand sample characteristics. Second, reliability analysis was performed using Cronbach's Alpha (α) coefficient. The first and second results were omitted as basic findings.

Therefore, this study conducted confirmatory factor analysis based on exploratory factor analysis results, examined convergent and discriminant validity through concept reliability, AVE, and correlation analysis, performed multicollinearity analysis and normality testing, and finally conducted hypothesis testing through structural equation modeling, including moderating effect analysis through multiple group analysis and mediation effect analysis through Sobel Test.

4. CONCLUSIONS AND RECOMMENDATIONS

1) Exploratory Factor Analysis of Measurement Variables

First, as shown in <Table>, the exploratory factor analysis results for all measurement variables showed appropriate primary factor loadings of 0.4 or

higher, and the seven factors explained 75.956% of the total variance. Additionally, KMO analysis and Bartletts test were conducted to verify the suitability of the factor analysis results. The KMO (Kaiser-Meyer-Olkin) value was .964, which being above 0.9 indicates excellent sampling adequacy, suggesting that the variable selection through exploratory factor analysis was relatively appropriate. Bartletts test of sphericity showed an approximate chi-square of 11594.431, p=.000, confirming the appropriateness of the factor analysis results.

Using Cronbachs Alpha coefficient to estimate internal consistency between items of the finally confirmed factors, the analysis showed reliability coefficients of .927 for research capability, .897 for absorption capability, .910 for marketing capability, and .914 for manufacturing capability within technology commercialization capabilities. Additionally, new product development showed .896, and within commercialization performance, financial performance showed .890 and non-financial performance showed .876. All research variables reliability coefficients in the final exploratory factor analysis were above 0.7, indicating that internal consistency and reliability were secured.

Table 3

Table 3 Hypothesis Verification

연구변인		측정변인	비표준화 경로계수	표준오차	표준화 경로계수	t값	p값	개념 신뢰도	AVE	Alpha
	→	Research capabilities 1	0.870	0.042	0.821	20.736	0	0.91	0.669	0.907
Research capabilities	→	Research capabilities2	0.951	0.045	0.834	21.261	0			
	→	Research capabilities3	1		0.843					
	→	Research capabilities4	0.993	0.048	0.819	20.669	0			
	→	Research capabilities5	0.881	0.048	0.758	18.35	0			
Absorption capacity	→	Absorption capacity 1	0.919	0.047	0.811	19.411	0	0.921	0.699	0.897
	→	Absorption capacity 2	0.971	0.051	0.8	19.049	0			
	→	Absorption capacity 3	0.954	0.048	0.821	19.771	0			
	→	Absorption capacity 4	1		0.832					
	→	Absorption capacity 5	0.874	0.052	0.728	16.72	0			
	→	Marketing competency	0.929	0.037	0.865	25.138	0	0.937	0.748	0.927
Marketing competency		1								
	→	Marketing competency2	0.947	0.043	0.813	22.247	0			
	→	Marketing competency 3	1		0.888					
	→	Marketing competency 4	0.956	0.04	0.845	23.994	0			
	→	Marketing competency5	0.954	0.041	0.831	23.222	0			

Manufacturing capability	→	Manufacturing capability1	1		0.89			0.932	0.733	0.914
	→	Manufacturing capability2	0.983	0.044	0.817	22.555	0			
	→	Manufacturing capability3	0.923	0.044	0.781	20.789	0			
	→	Manufacturing capability4	0.995	0.042	0.838	23.689	0			
	→	Manufacturing capability5	0.948	0.042	0.816	22.544	0			
New product development	→	New product development1	0.898	0.042	0.831	21.603	0	0.916	0.731	0.896
	→	New product development 2	0.91	0.043	0.821	21.193	0			
	→	New product development 3	1		0.861					
	→	New product development 4	0.887	0.044	0.802	20.374	0			
Financial performance	→	Financial performance 1	0.905	0.046	0.798	19.521	0	0.883	0.655	0.876
	→	Financial performance 2	0.953	0.049	0.794	19.38	0			
	→	Financial performance 3	0.913	0.05	0.764	18.303	0			
	→	Financial performance 4	1		0.835					
non-financial	→	non-financial	0.888	0.044	0.808	20.139	0	0.915	0.73	0.89
Performance		Performance 1								
	→	non-financial	0.888	0.045	0.795	19.646	0			
		Performance2								
	→	non-financial	1	0.048	0.825	20.808	0			
		Performance 3								
	→	non-financial	1		0.848					
		Performance 4								

2) Confirmatory Factor Analysis of Measurement Variables and Convergent Validity Test

Based on the exploratory factor analysis results, a confirmatory factor analysis was conducted to secure the validity of measurement variables in structural equation modeling. Individual observed variables must have standardized coefficients of 0.7 or higher (minimum 0.5) to be considered reliable, indicating no measurement issues. In this study, measurement model reliability was secured using 0.7 as the criterion.

Convergent validity is assessed through three criteria: regression coefficients (Critical Ratio, C.R.) for each factor should be greater than 1.96, Average Variance Extracted (AVE) should be above 0.5, and Composite Reliability (CR) should be 0.7 for good convergent validity, while values between 0.6 and 0.7 are considered acceptable. Based on these three criteria, the confirmatory factor analysis results of this study showed that all factor loadings were above 0.7 with C.R. values exceeding 1.96, and both AVE and composite reliability met the threshold criteria, thus confirming convergent validity.

Table 4

Table 4 Fit of Confirmatory Factor Analysis Model

	Absolute fit index						**Incremental Fit Index**		
	x^2	x^2/p	SRMR	RMSEA	GFI	AGFI	NFI	TLI	CFI
fit index	***p≥0.05***	***≤3.0***	***≤0.08***	***≤0.08***	***≥0.9***	***≥0.9***	***≥0.9***	***≥0.9***	***≥0.9***
Model fit	1172.989	2.648	0.0426	0.062	0.858	0.83	0.901	0.928	0.936

3) Discriminant Validity Test

Pearson's linear correlation coefficients were measured between research variables to verify the linear relationships among variables. The results of the correlation analysis are shown in. Correlation coefficients with absolute values less than 0.2 indicate no relationship, values less than 0.4 indicate weak relationships, values between 0.7-0.8 indicate strong correlations, and values above 0.9 indicate very strong relationships (Lee, 2021, Kang et al., 2001).

The correlations between research factors ranged from r=.086 to r=.457, showing positive correlations. The correlations between independent and mediating variables were found to be between r=.158 and r=.347, while those between independent and dependent variables showed low correlations ranging from r=.142 to r=.457. The correlations between mediating and dependent variables showed r=.408 for financial performance and r=.345 for non-financial performance.

Table5

Table 5 Correlation Analysis Between Research Variables

	an independent variable				**An intermediary variable**	**Dependentvariable**		**A controlling variable**
	Research capabilities	Absorption capacity	Marketing competency	Manufacturing capability	New product development	Financial performance	non-financial performance	business performance
Research capabilities	*0.669*							0
Absorption capacity	0.162	*0.699*						0
Marketing competency	0.338	0.086	*0.748*					0
Manufacturing capability	0.379	0.124	0.348	*0.733*				0
New product development	0.325	0.158	0.226	0.347	*0.731*			0

Financial performance	0.334	0.142	0.314	0.424	0.408	*0.655*		0
non-financial performance	0.304	0.165	0.305	0.457	0.345	0.321	*0.730*	0
business performance	0.013	0.001	0.001	0.007	0.002	0.001	0.008	-

Diagonal value: AVE square root, diagonal down: correlation coefficient squared value Pearson's Linear Correlation Coefficient(r), p<.01

4) Multicollinearity Analysis and Normality Test

There exists a high linear relationship among independent variables, and to verify this, a multicollinearity analysis was conducted using the Variance Inflation Factor (VIF), where values exceeding 10 typically indicate multicollinearity issues. Although multicollinearity was initially ruled out due to correlation coefficients between measured variables being below 0.7, it was further verified using tolerance and VIF values. The tolerance values of measured variables (which should be above 0.1) ranged from 0.277 to 0.605, and VIF values (which should be below 10) ranged from 1.652 to 3.606, confirming the absence of multicollinearity problems.

Additionally, descriptive statistics were used to verify whether the research variables to be used in the final study satisfied the normality assumption. To apply structural equation modeling, the multivariate normality assumption must be satisfied. This was examined through the most common method of checking skewness (absolute value should be less than 3) and kurtosis (absolute value should be less than 8) for each variable.

5) Hypothesis Testing Results Using Structural Equation Modeling

The results of the hypothesis testing for the research model are as follows. Maximum Likelihood Estimation (MLE), which assumes multivariate normality, was used for hypothesis testing of the research model. The model fit was evaluated using absolute fit indices, which assess how well the hypothetical model fits the data absolutely, and incremental fit indices, which evaluate the fit of the proposed model relative to the baseline model. For absolute fit indices, RMSEA values below 0.08 and SRMR values below 0.05 are considered acceptable, while for incremental fit indices, TLI and CFI values above 0.9 are considered acceptable (Bae, 2017). Since χ^2 values can be affected by sample size and the distribution of observed variables, it is advisable to judge the model fit using other fit indices (Bae, 2017).

Table 6

Table 6 Fit of Hypothesis Verification Model

	Absolute fit index						**Incremental Fit Index**		
	x^2	x^2/df	SRMR	RMSEA	GFI	AGFI	NFI	TLI	CFI
fit index	**p≥0.05**	**≤3.0**	**≤0.08**	**≤0.08**	**≥0.9**	**≥0.9**	**≥0.9**	**≥0.9**	**≥0.9**
Model fit	1345.212	2.976	0.0475	0.068	0.835	0.808	0.887	0.914	0.922

The purpose of this study was to examine the relationships between corporate technology commercialization capabilities, new product development, and commercialization performance, and to verify the moderating effect of business age on the relationship between technology commercialization capabilities and new product development, thereby proving the importance and necessity of these variables.

Based on previous research, technology commercialization capabilities were categorized into research capability, absorption capability, marketing capability, and manufacturing capability as independent variables. Commercialization performance (financial and non-financial performance) was set as dependent variables, new product development as a mediating variable, and business age as a moderating variable between technology commercialization capabilities and productization capabilities to establish the final research model.

5. THE RESEARCH FINDINGS CAN BE SUMMARIZED AS FOLLOWS

First, corporate productization capabilities showed that research capability, absorption capability, and manufacturing capability are key influencing factors in new product development, with manufacturing capability having a particularly prominent effect compared to other technology commercialization capabilities.

Second, new product development has significant impacts on both financial and non-financial performance, with the impact on financial performance being slightly higher than non-financial performance.

Third, examining the moderating effect of business age on technology commercialization capabilities and new product development revealed that business age acts as a key factor in new product development. Specifically, research capability showed a more positive role in new product development for companies with longer business histories, while manufacturing and absorption capabilities showed positive effects on new product development regardless of business age. However, no moderating effect of business age was found in the relationship between marketing capability and new product development.

Therefore, this study showed that corporate technology commercialization strengthens new product development, which in turn can improve both financial and non-financial business performance. The following conclusions can be drawn:

Corporate technology commercialization capabilities have a close relationship with commercialization performance improvement through enhanced new product development.

New product development can be improved by strengthening research capability, absorption capability, and manufacturing capability among technology commercialization capabilitie

Companies with shorter business histories showed greater improvement in new product development. Companies with shorter histories showed stronger effects of absorption and manufacturing capabilities on new product development. Conversely, research capability showed more positive effects on new product development in companies with longer histories.

Finally, marketing capability did not affect new product development. Marketing capability is a learning capability necessary for corporate environmental adaptation, emphasizing the ability to recognize, absorb, and commercialize the value of new information, focusing on knowledge internalization and managerial and strategic aspects. This is closely related to new product development. Therefore, further research appears necessary to examine how marketing capability, as a sub-factor of technology commercialization capabilities, affects new product development.

CONFLICT OF INTERESTS

None.

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