J. Internet Comput. Serv.
ISSN 1598-0170 (Print) / ISSN 2287-1136 (Online)
http://www.jics.or.kr

A Study on the Internalization of Sensor Technology by Comparison of IT Leading Countries☆

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ABSTRACT

The 4th Industrial Revolution is a revolutionary change through intelligence, big fusion and personalization, and the importance of sensor technology that is the basis of core technology is emerging. This study empirically analyzes the derivation of national strategy for R&D of sensor technology, and draws out the effect of technology internalization effort through strategic R&D activities on technical performance and further on national economy. The research and development results are calculated for each type of technology internalization, and the results of the research and development are verified to establish a structure that contributes to the national economic performance. As a national technology internalization strategy, considering its own R&D investment and joint research and development, we examine the impact of each factor on patents and GDP, focusing on causality and ripple effects. For causality analysis, Grandeur causality analysis shows that R&D investment and joint research and development in all countries have mutual causal relationship with GDP. The implications are as follows. First, it is necessary to establish the policy of national economic development through the internalization of technology and knowledge. Second, it is necessary to establish policies according to the type of knowledge internalization. Third, it will be necessary to create an ecosystem environment based on a virtuous relationship between knowledge internalization and national technology and economic development.

☞ keyword : Technology Internalization, Sensor, R&D, Performance, Quantitation Analysis

1. Introduction

There is a high demand for economic and social changes such as increasing the competitiveness of industries and job creation globally, and the development of industry is being made at the core of breakdown technology such as destructive innovation. With the advent of the 4th Industrial Revolution, a national strategy is needed to respond to the rapidly changing future environment and to lead the market in the global industrial environment. The fourth industrial revolution is revolutionary change through intelligence, big fusion, and personalization, and the importance of sensor technology that is the basis of core technology emerges. This study empirically analyzes the derivation of national strategy for R&D of sensor technology, and draws out the effect of technology internalization effort through strategic R&D activities on technical performance and further on national economy. R&D results are calculated by type of technology internalization, and the results of R&D contributed to national economic performance [1].

2. Related Studies

2.1 Technology Internalization Theory

Technology internalization is influenced by market and technology environment, government policy, social/cultural variables, education and learning system, corporate organization and management factors [2]. 'Internalization' is the transformation of the objectivized structure of knowledge into its own subjective structure to make it its own. The internalization of technology is based on a knowledge-based theory, in which the competitive advantage of an organization

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[Received 10 October 2019, Reviewed 7 November 2019(R2 20 January 2020, Accepted 9 March 2020]
☆ This work was supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government(MSIT) (No.2019-0-00136, Implementation of verification platform for ICT based environmental monitoring sensor)

http://dx.doi.org/10.7472/jksii.2020.21.3.61

(Table 1) This step-by-step type of internalization in technology innovation

Technology Innovation Phase	type of internalization	Indicators
Replication	Technology acquisition	number of technology introduction
	Technology Transfer	number of Technology Transfer
imitation	M&A	M&A expenses
digestion	Joint R&D	Number of patents filed through joint research.
	Strategic alliances	Number of strategic alliances
	R&D Consortium	R&D Number of R&D consortiums
	Co-branding	number of Co-branding
innovation	Own R&D	R&D investment

can be formed by explicit or implicit knowledge created through knowledge management activities [3][4][5]. Knowledge management activities that bring such knowledge are influenced and supported by knowledge management strategies, which are guidelines or plans for knowledge management adopted by the organization [6]. In other words, core knowledge can be acquired, created and utilized according to the strategy of the state, and eventually it is created, stored and shared. Thus, the purifying process of knowledge management is measured by internalization of knowledge creation, accumulation, sharing, and utilization [7][8]. The internalization phase of knowledge and the development stage of technology can be considered as simple application of foreign technology in the replication phase, acquisition and extinguishing of peripheral technology in the imitation phase, and own R&D activities in the innovation stage. In the process of knowledge internalization, creation, accumulation, sharing, and utilization are considered to be matched with innovation, digestion, imitation, and Replication [9].

As shown in Table 1 above, the type of innovation and the type of internalization of knowledge can be categorized. In the study on the relationship between innovation and innovation type, only two factors have positive correlation. It is necessary to strategically develop the capacity of technological innovation by identifying specific relationships such as causality.

3. Methodology

3.1 Data collection and analysis variables

This study examines the effect of the type of technology internalization on performance. Collecting the characteristics of technical knowledge, organizational characteristics, technological learning activities and performance factors such as technical knowledge, commercial performance, and strategic performance, which are the determinants of technology internalization as suggested below, as data acquisition targets. However, it is difficult to acquire all variables and collects possible data. The level of technology that represents organizational characteristics secures the technology level score of sensor technology in Korea, USA and Japan provided by IITP. Among the performance factors, the production cost and the intellectual property rights can be considered as the index of the technical performance. The production cost is calculated by adding the value added ratio of the industrial relation table provided by the Bank of Korea to the intellectual property right, and acquire data on technology transfer due to commercial performance factors. The production cost is secured by data provided by the Bank of Korea's Input - Output Table with the added value of medical instruments, cameras, and projectors with high utilization of sensor technology. As shown in Table 2 below, analytical variables were analyzed using available data.

3.2 Hypothesis setting and research model

In order to examine the performance relations of the

(Table 2) The analytical variables

variable			. object	year	Measure	reference
Technology Internalization	Innovation level	R&D expenses (US$ millions)	Korea, USA, Japan	2000~ 2017	Total research and development expenses for high-tech objects..	NTIS (www.ntis.go.kr)
	Replication · imitation · digestion level	Joint R&D	Korea, USA, Japan	2000~ 2017	Number of patents filed with foreign developers	OECD statistics.
	Organizational characteristics	Tech. level	Korea, USA, Japan	2015~ 2017	Tech. level scoring through expert interviews..	IITP (www.iitp.kr)
Performance factors	Technical performance	Value added ratio	Korea	2005, 2006, 2008, 2009, 2010, 2012	Value Added / Total Revenue	Industry Input-Output Table(Bank of Korea)
		Number of patents	Korea, USA, Japan	2000~ 2017	Number of patent applications	KIPRIS (www.kipris.or.kr)
	Commercial performance	Royalty fee	Korea	2012~ 2016	Royalty fee./ Amount of the year	NTIS (www.ntis.go.kr)
GDP (US$ millions)			Korea, USA, Japan	2000~ 2017	GDP	

promising strategies according to the technology internalization process, hypotheses are drawn based on the existing literature on the technical and economic effects of the technology internalization type. It reflects the IT technology of Korea and examines the impact of its own research and development strategy, which is selected at the innovation stage, and the internalization strategy, such as joint research and development strategy.

3.2.1 Technology internalization and performance relation 1: Self-development

Self-development is a strategy that can be selected when it becomes a capability to promote innovation on its own. It can monopolize performance by developing the necessary technology as its own resources. It means that innovation is possible through the development of own technology by building capacity through national technological and economic performance. In the resource base theory, technology innovation capacity is a very important resource for ensuring sustainable success and can be regarded as an important result of innovation activity. Although there is a condition that it should be equipped with innovation capability, there are many merits that can be enjoyed through self-development. In developed countries, R&D efforts are being made through R&D activities, which is an important source of generating results. However, it is necessary to look at the causal relationship and the circulation structure between each factor, as countries that have the ability to promote innovation as well as the impacts of R&D investment and performance are expected to generate performance through their own innovation. In the related research, path analysis was carried out under the recognition of such problems. Reference [10] analyzes causal relationships among 16 metropolitan cities and provinces of about 10 years using R&D costs, patent applications, and GRDP (Gross Regional Domestic Product). As a result, R&D expenditure has a significant causal relationship with patent applications, while patent applications have a significant causal relationship with GRDP. Therefore, we propose Hypothesis 1-1 as follows based on the result that innovation capability can be achieved by having capability through innovation.

- Hypothesis 1-1: Own R&D investment (Knowledge internalization 1) has a causal relationship with technical performance and economic performance.

3.2.2 Internalization and performance relationship 2: Collaboration

According to the dynamic capability approach research, it is a key factor of continuous competitive advantage to integrate and combine existing resources and capabilities in response to the changing environment. Therefore, knowledge can be obtained not only from the knowledge resources possessed by the organization but also by utilizing the knowledge resources obtained by forming a network with external organizations. As a result of the empirical studies, the main effect of joint R&D on sales growth is not significant, but the interaction with technology capacity is significant, so it is necessary to have technical competence in order for R&D. Therefore, in this study, the hypothesis for the causal relationship between Joint R&D and technological and economic performance is set as follows, based on the result that cooperation for internal technology internalization is the process of creating external performance through internal competence.

- Hypothesis 1-2: Joint R&D (Knowledge Internalization 2) has a causal relationship with technical performance and economic performance.

3.2.3 Relationship between technical performance and economic growth

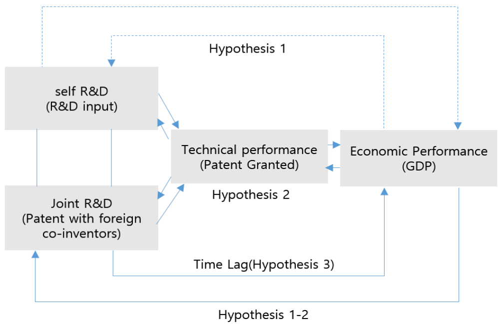
An empirical analysis of the effects of R&D activities on the outcomes of hypotheses 1-1 and 1-2 reveals that there is an indirect effect on economic performance and a direct effect on3the performance of science and technology. Therefore, in the case of R&D activities whose main purpose is to increase performance, it is possible to create technical performance firstly and to contribute to improvement of economic performance through this. Therefore, in this study, there is a causal relationship between technical performance and economic performance. Hypothesis 2 is as follows.

Hypothesis 2: There is a causal relationship between technical performance and economic performance.

A number of studies have found that there is a certain time lag between input and output of research and development resources. Based on the results of time delay effect between R&D input and performance in existing research, this study also hypothesizes that the activity for technology internalization takes time to affect technical performance and economic performance. Hypothesis 3: R&D investment and joint research and development (knowledge internalization activities) take time to influence technological and economic performance.

3.3 Research Model

The purpose of this study is to analyze the impact of national technology internalization strategy on national technological and economic performance. According to this structure, this study constitutes the flow of causal relationship that R&D investment and joint R&D are input, resulting in output, leading economic performance. Based on this, the research model is set up as shown in Figure 1, and the analysis method is the Vector Auto regression Analysis (STATA).



(Figure 1) The research model

3.4 Research Methodology

In this study, we will use the Vector Autoregressive Model (VAR) to examine causal relationships between domestic R&D, joint R&D, technical performance, and economic performance. Although the general regression model derives the dependent variable Y from several explanatory variables, the assumption is that the effect of the explanatory variable is constant even if the time changes. This is because it does not reflect changes in the influence of explanatory variables that may change with time. This model is similar to the simultaneous equations system, but it has a characteristic that it differs from the simultaneous equations because it is structurally analyzing the error term of the model and part of the identification constraint is applied to the covariance matrix of the error term. The causal relationship between endogenous and exogenous variables can be analyzed through analysis of causality (Granger Causality). In addition, based on any economic theory, the hypothesis is not set up, but the actual situation is analyzed using the information of the actual observed time series. That is, the VAR model is a simple model that analyzes the results by using the parallax variables for all the variables in the model simultaneously as explanatory variables. It is advantageous that there are not many variables included in the model due to the characteristics of the VAR model. However, it is necessary to be careful in selecting and interpreting the variables because the estimation or analysis result is derived only by the selected variables. The result may vary depending on the order of the variables used, the sample period, and the parallax length. In general, the autoregressive model of univariate stable time series Z_1 is as follows. Where ϵ_1 is the white noise process with a mean of 0 and a variance of $\sigma\epsilon^2$.

$$Z_t = \Theta_1 Z_{t-1} + \cdots + \Theta_p Z_{t-p} + \epsilon$$

If the above equation is composed of N multivariate normal time series, then it becomes $X_t = (X_1, X_2, \cdots, X_{Nt})$, which is a vector autoregressive model VAR (p) composed of autoregressive process with p time difference.

$$X_t = C + \sum_{i=1}^{p} \Theta_i X_{t-i} + \epsilon$$

Where C is the (N × 1) constant vector, Θ_i is the (N × N) matrix of time-varying regression coefficients between the current variable and the parallax variables, and B is the vector white noise process E(ϵ_1)=0 of (N × 1). The above expression Z represents four variables: R&D investment, R&D cooperation, sensor technology performance, and national competitiveness. Θ is the scalar value at time k and ϵ_t is the error term. The parallax length p for the VAR model can be determined using the Akaike (AIC) or Schwartz (SIC) statistic, which minimizes the following statistics using the covariance matrix Σ_p for the estimation error. Therefore, in this study, the present study considers both the existing research model and the empirical method, repeatedly analyzes from the first to the fourth, and observes the principle of the VAR model. This study analyzes the results using Granger Causality Test and Impulse Response Function which are most used in academic research among VAR models. The IRF is most effective at estimating the time it takes to increase the R&D investment, joint R&D, and technological achievements at the present time to improve the national economic performance, and to derive the ripple effect and delay time mathematically.

4. Empirical analysis and verification of research hypotheses

4.1 Verification of research hypothesis

In order to verify the model of this study, we constructed and analyzed VAR (2) model. As shown in Table 3, the model of VAR (2) was constructed and analyzed as a variable of R&D investment, joint research and development, patent performance, and GDP from 2000 to 2017 in Korea, Japan and the United States. Japan has shown that R&D investment two years ago, joint R&D 1-2 years ago, and GDP a year ago have a positive effect on the current R&D investment. It is influenced by joint research and development. Japan's patent performance was positively influenced by R&D investment two years ago and joint R&D investment one year ago. GDP was positive for R&D investment two years ago, but two

(Table 3) Technical statistical analysis

country	R&D invest(US$ million)				R&D co-operation(case)				Patent(case)				GDP(US$ million)			
	Eve	Mid	Min	Max	Eve	Mid	Min	Max	Eve	Mid	Min	Max	Eve	Mid	Min	Max
Korea	13265	11958	4414	26311	279	298	86	410	55774	56869	8300	93420	1,313,504	1,396,414	90,768	1,877,123
Japan	30265	37287	6673	55108	752	772	533	906	63591	66270	16482	90806	4,339,115	4,416,321	3,404,323	5,369,479
USA	116368	129737	62736	158249	5821	5723	4171	7578	254388	235046	83802	448937	14,337,421	14,477,635	10,284,779	18,624,475

(Table 4) Explanatory and dependent variable in country comparison

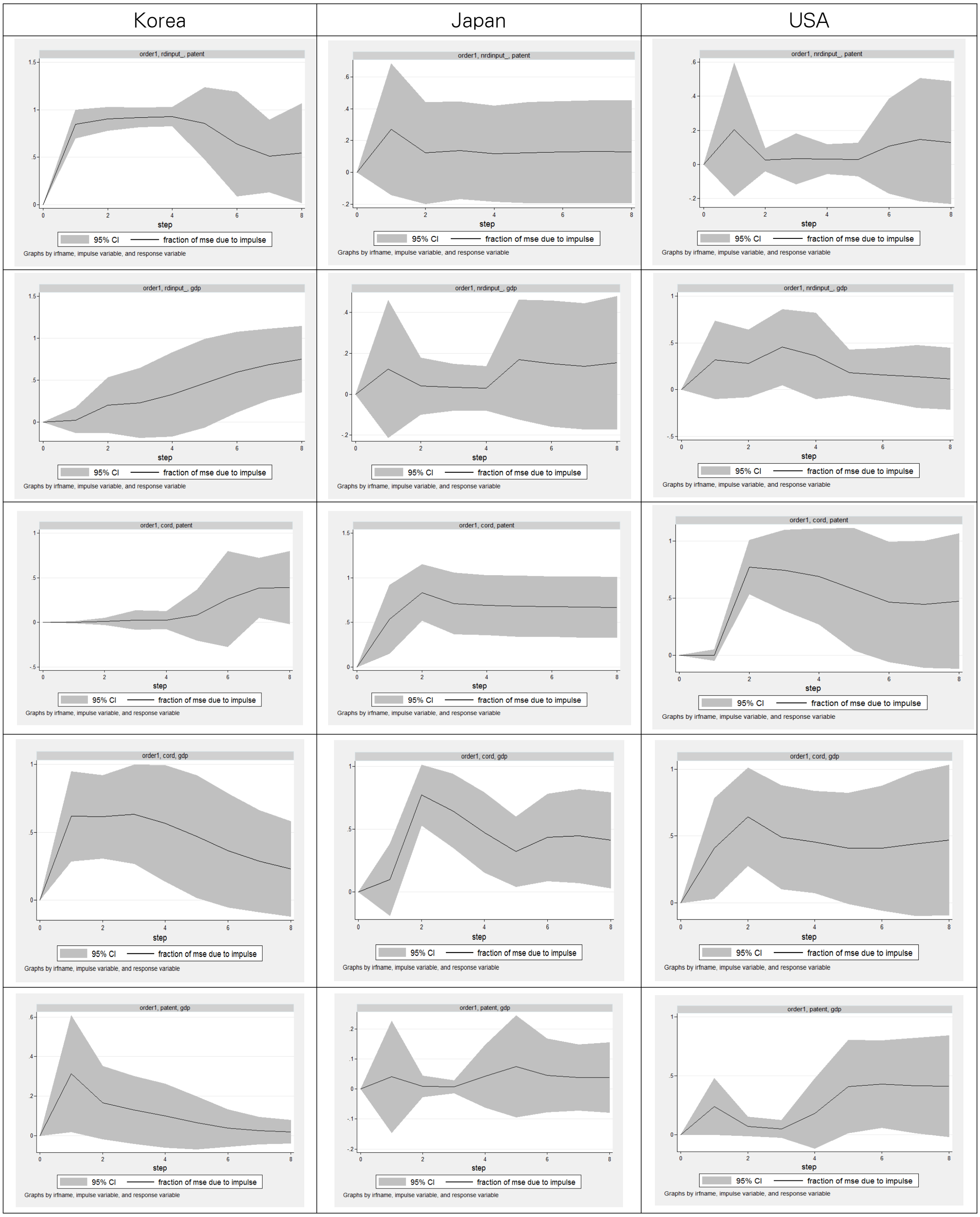
Country	Explanatory variable	dependent variable			
		R&D(t)	Co-R&D(t)	PT(t)	GDP(t)
Korea	R&D(t-1)	-0.140	-0.042***	1.319	-31.021
	R&D(t-2)	0.869***	0.026***	0.590	35.715***
	Co-R&D(t-1)	52.734***	1.797***	-61.589	2223.119***
	Co-R&D(t-2)	17.119	1.109***	-32.793	1163.392
	PT(t-1)	0.354***	0.012***	0.972**	6.535
	PT(t-2)	-0.430***	-0.012***	-0.622	-11.156***
	GDP(t-1)	-0.006***	-0.001***	0.013	-0.126
	GDP(t-2)	-0.003	-0.001	0.006	-0.014
Japan	R&D(t-1)	-0.291**	-3.926	34.703	-12457.64***
	R&D(t-2)	0.682***	17.509***	460.119***	22941.61***
	Co-R&D(t-1)	0.072***	0.766**	83.029***	2212.868***
	Co-R&D(t-2)	0.054***	0.109	16.531	-499.313
	PT(t-1)	-0.002***	-0.015*	-0.235	-7.604
	PT(t-2)	-0.001***	-0.005	-0.491***	-12.880***
	GDP(t-1)	0.001***	0.001**	-0.010**	0.497***
	GDP(t-2)	-0.001***	-0.001	0.011***	0.493***
USA	R&D(t-1)	-0.105	10.351	50.729	5719.112
	R&D(t-2)	-0.665***	30.616**	-1742.114***	17812.93***
	Co-R&D(t-1)	0.007	1.065***	103.033***	1000.055***
	Co-R&D(t-2)	-0.006	-1.355***	-38.981***	-682.611***
	PT(t-1)	0.001*	0.002	0.644***	-1.831
	PT(t-2)	0.001**	0.007**	0.294**	6.366***
	GDP(t-1)	-8.85e-06	0.001	-0.060***	0.507***
	GDP(t-2)	-1.24e-06	0.001	0.032**	0.224

* R&D: high-tech R&D costs, Co-R&D: patent applications with foreign developers, PT: sensor technology patents. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

years ago was negative. In the United States, a year ago, joint research and development had a positive impact on patent performance, and GDP was found to be affected by patent performance two years ago.

Table 4 shows the following. As a result of Granger causality analysis based on VAR (2), in Japan, the circulation structure was shown by the mutual causal relationship between research and development investment, joint research and development, patent performance, and GDP. GDP, but patent performance did not cause GDP. In the US, both R&D investment and joint R&D did not cause patent outcome, and patent performance was analyzed as causality of GDP. In Korea, both R&D investment and joint research and development show causality of patent outcome, and especially causality with GDP. In the case of Japan, there is a mutual causal relationship between R&D investment and patent performance, patent performance and GDP, and joint research and development with GDP. In the United States, both R&D investment and joint R&D did not cause patent outcome, and patent performance - GDP, GDP - R&D investment and joint R&D had a causal relationship with each other.

In order to measure the ripple effect of each variable, the impulse response function is analyzed and the result shown in Figure 2 is obtained. Only 5% significance level is analyzed. In Japan, the joint research and development showed that patent performance and GDP increased after two years, and the effect of the increase was immediately declined. In the United States, the joint research and development effect of patent performance and GDP increased after two years, and then it fell. In particular, the ripple effect after two years of patent performance is very large. On the other hand, patent outcome have the effect of increasing GDP after a quicker one year.



(Figure 2) Comparison between countries in R&D, Co-R&D, Patent

5. Conclusions

As a national technology internalization strategy, considering its own R&D investment and joint research and development, we examine the impact of each factor on patents and GDP, focusing on causality and ripple effects. For causality analysis, Grandeur causality analysis shows that R&D investment and joint research and development in all countries have mutual causal relationship with GDP. The relationship between R&D investment and joint R&D and patent performance shows that Korea and the United States have unilateral causality, and Japan has a causal relationship between R&D investment and patent performance. Korea and the United States showed a unidirectional causal relationship in different directions. In Korea, R&D investment and joint R&D are the causal factors of patent outcome. However, in the US, patent outcome is rather a result of research and development investment and joint research and development respectively. In Japan, the R&D investment and the patent performance show mutual causal relations, but the joint research and development is proved to be caused by the patent performance. In addition, the relationship between patent performance and GDP shows that patent performance and GDP are mutually causal in Japan and the United States, and patent performance in Korea is attributed to GDP. As a result of the impulse response analysis conducted for the analysis of the ripple effects, Korea showed that the increase in the R&D investment at present tends to increase the patent performance in one year. It takes two years. This is because the results of the previous research indicate that results are generated in a shorter period of time than the result of 4 years of R&D investment. This is because sensor technology focuses on research rather than basic research. In addition, the effect lasts for up to 4 years, which is similar to the results of previous studies. However, since the effect is seen in 1 year, the effect is expected to persist until the 4th year. The effect of the increase in R&D investment is not only a short term but also an effective factor for maintaining the performance over the next three years. Joint research and development between Japan and the United States took two years to increase patent performance, but the effect was immediately reduced. Japan and the United States may think that the time required to increase patent performance through joint research and development is rather long. In both countries, the technology level is generally high, it is difficult to expect immediate results through joint research and development. The hypothesis and adoption in this study are summarized in Table 5, 6 below.

(Table 5) hypotheses

Hypothesis
1-1. In-house R&D investment (knowledge internalization 1) has a causal relationship with technical performance and economic performance.
1-2. Joint research and development (instruction internalization 2) has a causal relationship with technical performance and economic performance.
2. There is a causal relationship between technical performance and economic performance.
3. R&D investment and joint research and development (knowledge internalization activities) take time to affect technological and economic well-being.

(Table 6) hypotheses and adoption by country

Country	Hypothesis	Adoption
KOREA	1-1	accepted
	1-2	accepted
	2	Some accepted
	3	accepted
JAPAN	1-1	accepted
	1-2	accepted
	2	accepted
	3	accepted
USA	1-1	accepted
	1-2	accepted
	2	accepted
	3	accepted

In the case of a country with a high level of technology, the technology internalization activity is causally related to the national economic development, and at the same time, the patent performance is causally related to the national economic development. In other words, if the level of technology is low according to the technical competitiveness of the country, the effort to internalize the technology directly affects the development of the national economy. However, it is difficult to expect direct economic development through technological achievements. It can be thought that the achievements, technological achievements and national economic development all have a direct relationship. In the process of policy promotion of major countries in the world for knowledge internalization, the type of knowledge internalization can be categorized according to the stage of research and development, and the following policy implications can be derived through country comparison according to the type. First, it is necessary to establish policies for national economic development through internalization of technology and knowledge. As a result of the research analysis, the internalization of technology has a direct effect on the development of the national economy and it affects the GDP irrespective of the technical level of the country. Therefore, prior to the technology internalization strategy, it is necessary to select the appropriate type considering the current state of the country, the level of the environment, and the environment to achieve technological and economic improvement through differentiated policies. Second, it is necessary to establish policies according to the type of knowledge internalization. In particular, in Korea, research and development investment and joint research and development are found to be causal factors in both technical performance and economic performance, suggesting that related policies should be established as a type of internalization of sensor technology. Development is required. Third, it will be necessary to create an ecosystem environment based on a virtuous relationship between knowledge internalization and national technology and economic development. In all three countries, Korea, Japan and the United States, R&D investment and joint research and development are establishing economic performance and cyclical relationship. According to the results of the analysis, the technology internalization activity is causally attributable to the technological achievement, but the technological achievement does not act as a causal factor that actively leads the technology internalization activity and serves as a mediator to connect the technical achievement to the economic performance The internal circulation of technology internalization seems not to take place. Therefore, it is necessary to establish a system that enables reinvestment of patent achievement in research and development activities and a system that enables the technology itself to smoothly enter the market so that technical achievements can be linked to economic performance.

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