EFFECTIVELY CONNECT ACQUIRED TECHNOLOGY TO INNOVATION OVER A LONG PERIOD

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ABSTRACT

IT (Information and Communication Technology) companies are facing the dilemma of decreasing productivity despite increasing research and development efforts. M&A (Merger and Acquisition) is being considered as a breakthrough solution. From existing research, it has been pointed out that M&A leads to the emergence of new innovations. Purpose of this study was to discuss the efficient ways of acquisition and to resolve the dilemma of productivity decline by clarifying how the technology obtained through M&A leads to the creation of new innovations. Hypothesis 1 was that the technology acquired through M&A is utilized for innovation creation, Hypothesis 2 was that the acquired technology is utilized over a long period of time, and Hypothesis 3 was that a long-term utilization has a positive impact on corporate performance. The results, using sports prosthetics as a case study and using patents as a proxy variable, confirmed all the hypotheses set. We have revealed that long-term utilization of technology obtained through M&A is effective for creating new innovations.

KEYWORDS

Merger and Acquisition; Innovation; Patent; Forward Citation; Sports Prosthetic

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1. INTRODUCTION

Many ICT companies are facing the dilemma of productivity decline despite expanding their R&D efforts (Tou et al., 2019; Tou et al., 2019*b*; Watanabe et al., 2021). To overcome this dilemma, companies are seeking to improve their research processes and acquire and utilize new innovation resources.

One specific means of doing this is through breakthroughs via M&A. Many studies have been conducted on the impact of M&A on innovation from this perspective (James, 1997; De Man & Duysters, 2005; Hagedoorn & Kranenburg, 2006). What is common among these existing studies is that M&A is not only a means of acquiring existing innovation but also leads to the creation of new innovations.

Therefore, it is considered an important study to clarify the mechanism by which technology and patents obtained through M&A lead to the creation of new innovations and discuss efficient corporate acquisitions and M&A methods. This will contribute to solving the dilemma of productivity decline in R&D mentioned earlier.

Research on M&A covers a wide range of topics. As mentioned earlier, studies focusing on the relationship between M&A and innovation have become a hot issue. Ahuja & Katila (2001) discussed the impact of acquisitions on innovation, using the chemical industry as their analysis subject, while Ranft & Lord (2002) discussed knowledge transfer from acquired companies' technology to acquiring companies. Additionally, Bena and Li (2014) discussed the positive effects of M&A on innovation. Igor et al. (2021) discussed the acquisition of start-up companies by existing companies from an innovation perspective.

While the existing research discusses the short-term effects of technology and patents acquired through M&A on new innovation creation, there is a scarcity of studies analyzing the mechanism of the treatment of technology and patents in the medium to long term after M&A completion. Therefore, this study aims to examine the mechanism of creating new innovation by utilizing acquired existing technology in a layered manner over an extended period.

Normally, technology and patents acquired through M&A are expected to be utilized over an extended period. As Pakes & Schankerman (1984) pointed out, patents become obsolete, but the background information that led to the creation of patents, such as experimental methods and experiences of failure, may not necessarily become obsolete, and it is believed that new technology can be created by referring to such information. Therefore, this study hypothesizes as follows:

Hypothesis 1 is that "technologies acquired through M&A are utilized for innovation creation." There are two main effects of M&A on innovation. One is that M&A functions as a means of acquiring existing innovations. By acquiring other companies, companies can obtain their technologies, patents, product lines, customer bases, etc. This allows the acquiring company to improve its innovation capabilities and enhance its competitiveness in the market. This acquisition of existing innovations produces short-term results and many companies use M&A as a strategic tool to improve their market position.

On the other hand, M&A is also expected to lead to the creation of new innovations. This refers to the expectation that new ideas and creative approaches will emerge through M&A and lead to the creation of innovations. Through the combination of the acquiring and acquired companies, synergistic effects can be generated, allowing them to maximize their strengths. Furthermore, because M&A enables companies to more effectively utilize their funds and resources, it is also expected to promote innovation creation. These factors suggest that M&A contributes not only to the acquisition of existing innovations but also to the creation of new innovations. However, the effects of M&A depend on factors such as company strategy, organizational culture, and integration management, and thus it is not always possible to achieve overall results. Whether M&A is successful or not depends on comprehensive factors such as company strategy and culture, and if integration does not go well, it may hinder the creation of innovations or the acquisition of existing ones. In this study, we will examine Hypothesis 1 by assuming that the acquired technology will be utilized over the long term and by considering the factors that affect the contribution to innovation creation underlying this assumption.

Hypothesis 2 is that "technologies acquired through M&A will be utilized over the long term." Technologies acquired through M&A are expected to become core technological assets of a company and generate long-term results. By combining those technologies with existing ones, synergies are created, enabling the development of new products and services, process improvements, and market expansion. However, if the technologies acquired through M&A are not sufficiently compatible with the acquiring company's existing technologies or business models, integration and utilization may become difficult. Additionally, when different companies are integrated through M&A, differences in organizational culture may hinder the utilization and

sustainable results of the technologies. Furthermore, to utilize the technologies acquired through M&A over the long term, appropriate resources and investments are required. To evaluate the success of technology utilization after M&A, with the aim of considering these factors, tracking and evaluating how long the utilization of technologies continues and what results it produces is necessary. Through this, hypothesis 2 will be verified.

And hypothesis 3 is that "the long-term utilization of technology acquired through M&A positively affects corporate performance." Whether technology acquired through M&A is used in the long term depends on whether it is compatible with the business model and strategy. If the technology does not meet the needs or market demands of the acquiring company, the long-term utilization of the technology and its positive impact on performance may be limited. Additionally, the compatibility of organizational culture and management, including appropriate resources and investments, is critical for the long-term utilization of acquired technology. Based on these factors, the relationship between the long-term utilization of technology and corporate performance will be tracked to examine whether the use of acquired technology actually has a positive impact on corporate performance. Specifically, by evaluating performance indicators and metrics over the long term after M&A, hypothesis 3 will be tested.

As a premise for these hypotheses, not only knowledge of experimental procedures and systematized knowledge of failures, but also knowledge for introducing and operating the ISO 9000 family, as well as knowledge for creating new technologies such as document formatting and organizational operating rules, are also defined as technology. Through these hypotheses, we will examine the mechanisms of creating new innovation by utilizing existing technology acquired through M&A in a layered manner for an extended period of time.

The analytical framework is explained in Section 2. Empirical analyses for the hypotheses are conducted in Section 3. In Section 4, the results of the empirical analyses are discussed. Additionally, case studies from other companies are examined, and the limitations of this study are discussed.

2. ANALYSIS FRAMEWORK

Patents are considered an important keyword when considering corporate acquisitions and innovation. Many studies in this field have used patent data to analyze innovation and the economy (Griliches, 1981, 1990, 1998; Jaffe et al., 1993; Nagaoka et al., 2010; Kline et al., 2019). In particular, Ernst (2003) and Breitzman & Thomas (2016) have utilized patent data in the context of M&A. In this study, patents are also used as a proxy variable for innovation.

In order to test the hypothesis of this study, we selected a case where M&A has been conducted and the acquired technology has been utilized over a long period of time. Therefore, we chose to examine the case of sports prosthetics. The reason for this is that there have been active corporate acquisitions in the sports prosthetics product market, and various technologies acquired there have been integrated to create new innovations (Seojin et al., 2022). In this study, we will analyze the relationship between Ossur, which conducts particularly aggressive acquisitions (Hansen & Pedersen, 2006), and Van Phillips, who established the dominant design of current sports prosthetics, and their patents. In order to quantitatively grasp the utilization of existing technology, forward citation analysis of patents will be used. The effectiveness of forward citation analysis has been demonstrated in many studies (Trajtenberg, 1990; Lanjouw & Schankerman, 2004; Hall et al., 2005).

The flow of this study is to first summarize the history of technology development and M&A in sports prosthetics, which is the subject of analysis, and demonstrate that Ossur and Van Phillips

are appropriate subjects for this study. Then, we will analyze the relationship between their M&A and patent development, test the hypothesis, and finally analyze the relationship between Ossur's patents and performance.

3. EMPIRICAL ANALYSIS

3.1. History of M&A in Sports Prosthetics

First, we will examine the history of the development of sports prosthetics for track and field events, as well as M&A activity by prosthetic-related companies such as Ossur. Table 1 shows the timeline of this history.

In summary, sports prosthetics were first developed in the 1980s by American inventor Van Phillips. The "Cheetah" was introduced in 1992, establishing the dominant design for the product. In 2000, Flex-Foot, which was founded by Van Phillips, was acquired by Ossur. In 2017, Freedom Innovations, which followed in the footsteps of Flex-Foot, was acquired by Ottobock. Therefore, the current leading two companies are built on the technical legacy of Van Phillips. Therefore, it can be said that without Van Phillips' patent, the development of sports prosthetics would not have been possible.

From the above, it is confirmed that active M&A is being carried out for sports prosthetic products, and various acquired technologies are being integrated to create new innovations. In particular, it is clear that technological development centered around Van Phillips and Ossur is being pursued, which demonstrates the validity of this research's analytical focus.

Table 1 History of Track-and-Field Sports Prosthetic Leg Development and Related Companies Activities

Year	Event
1976	Van Phillips, a junior at Arizona State University, was struck by a motorboat and has his left foot amputated just above the ankle.
1977	Van Phillips joined the Biomedical Engineering Program at Northwestern University and began conceptualizing a prosthetic limb that enables users to jump and rebound.
1981& after	After graduating from Northwestern University, Van Phillips worked as a development engineer at the University of Utah's Center for Biomedical Design. His R&D projects focused on restoring ligaments and tendons instead of bones. He worked on the development of sockets, linings, and attachments for prosthetic limbs, continuously exploring materials and designs to make jumping possible. Inspired by the C-shape of a cheetah's hind legs, he started creating prototypes using carbon graphite for its high energy return, lightweight, and durability. With the assistance of aerospace materials engineer Dale Abildskov, he tested hundreds of models he developed himself. His final design took an L-shape with an added "heel." When the user put weight on the heel, it functioned like a spring, converting the weight into energy during stepping, allowing users to run and jump.
1984	Van Phillips, Dale Abildskov, and others founded Flex-Foot Inc.
1988	Flex-Foot products made their debut at the Paralympics.
1992	Sports prosthetics were established in their current design (establishment of the dominant design).
1996	Flex-Foot launched the "Cheetah."
1998	Van Phillips received the Brian Blatchford Memorial Prize from the International Society for Prosthetics and Orthotics.
1999	Van Phillips founded the Second Wind Foundation to provide inexpensive and durable prosthetics similar in shape to Flex-Foot to people worldwide.
2000	Van Phillips sold Flex-Foot to Ossur, an Icelandic assistive devices manufacturer.
2002	Flex-Foot's development division remained in Utah, and Freedom Innovations was established.
2017	Freedom Innovations was acquired by Ottobock, a German manufacturer of assistive devices.
2020	Freedom Innovations was split off under the direction of the U.S. Federal Trade Commission (FTC), with Carbon footwear acquired by Proteor, a French assistive equipment manufacturer.

Sources: Massachusetts Institute of Technology Lemelson-MIT Program website, National Paralympic Heritage Trust website.

3.2. Analysis of the Impact from Van Phillips' Patents to Ossur's Patents

Next, as a verification of Hypothesis 1, "technologies acquired through M&A will be utilized for innovation creation," an analysis will be conducted on the effect of Van Phillips' patented inventions on Ossur's patents. Before proceeding with the analysis, it should be noted that the

acquisition of Flex-Foot had a significant business impact, acquiring about half of the sales in 2000.

Table 2 shows the list of patents previously created by Van Phillips. Ossur also acquired patents and related information shown in Table 2 through M&A. As Van Phillips' patents can be assumed to have a positive impact on Ossur, the analysis will proceed from that perspective.

Table 2 Patents Created by Van Phillips.

No.	Patent Number	Date of Patent	Patent Title
1	11,020,251	2021/6/1	Methods and apparatus for improved interface between the human body and prosthetic or similar devices
2	11,013,621	2021/5/25	Prosthetic energy storing and releasing apparatus
3	7,879,110	2011/2/1	Foot prosthesis having cushioned ankle
4	7,655,049	2010/2/2	Socket insert having a bladder system
5	7,648,533	2010/1/19	Foot prosthesis having cushioned ankle
6	7,354,456	2008/4/8	Foot prosthesis having cushioned ankle
7	7,279,011	2007/10/9	Foot prosthesis having cushioned ankle
8	7,169,190	2007/1/30	Active shock module prosthesis
9	7,063,727	2006/6/20	Foot prosthesis having cushioned ankle
10	7,060,104	2006/6/13	Energy storing foot prosthesis with improved plantar flexion
11	6,899,737	2005/5/31	Foot prosthesis having cushioned ankle
12	6,887,279	2005/5/3	Active shock module prosthesis
13	6,811,571	2004/11/2	Universal prosthesis with cushioned ankle
14	6,527,811	2003/3/4	Foot prosthesis with modular foot plate
15	6,511,512	2003/1/28	Active shock module prosthesis
16	6,478,826	2002/11/12	Shock module prosthesis
17	6,406,500	2002/6/18	Foot prosthesis having curved forefoot
18	6,280,479	2001/8/28	Foot prosthesis having cushioned ankle
19	6,254,643	2001/7/3	Prosthetic device incorporating low ankle design
20	6,206,934	2001/3/27	Ankle block with spring inserts
21	6,165,227	2000/12/26	Attachment construction for prosthesis
22	6,071,313	2000/6/6	Split foot prosthesis
23	6,019,795	2000/2/1	Curved prosthesis
24	5,993,488	1999/11/30	Prosthesis with resilient ankle block
25	5,976,191	1999/11/2	Foot prosthesis having curved forefoot
26	5,899,944	1999/5/4	Prosthetic foot incorporating compressible members
27	5,888,238	1999/3/30	Plug mounted prosthesis
28	5,824,112	1998/10/20	Prosthetic device incorporating low ankle design
29	5,800,569	1998/9/1	Prosthesis with resilient ankle block
30	5,776,205	1998/7/7	Split foot prosthesis
31	5,766,265	1998/6/16	Prosthetic foot having curved integral support
32	5,728,177	1998/3/17	Prosthesis with foam block ankle
33	5,728,176	1998/3/17	Attachment construction for prosthesis
34	5,725,598	1998/3/10	Prosthetic leg
35	5,593,457	1997/1/14	Foot prosthesis having auxiliary ankle construction

36	5,593,455	1997/1/14	Plug mounted prosthesis
37	5,549,714	1996/8/27	Symes foot prosthesis
38	5,514,186	1996/5/7	Attachment construction for prosthesis
39	5,514,185	1996/5/7	Split foot prosthesis
40	5,509,938	1996/4/23	Prosthetic foot incorporating adjustable bladder
41	5,486,209	1996/1/23	Foot prosthesis having auxiliary ankle construction
42	5,464,441	1995/11/7	Prosthetic leg
43	5,458,656	1995/10/17	Energy-storing prosthesis leg pylon vertical shock leg
44	5,443,529	1995/8/22	Prosthetic device incorporating multiple sole bladders
45	5,425,782	1995/6/20	Alignment fixture for prosthetic device
46	5,387,246	1995/2/7	Prosthetic ski leg
47	5,376,141	1994/12/27	Low-profile symes foot prosthesis
48	5,290,319	1994/3/1	Prosthetic foot incorporating adjustable bladders
49	5,217,500	1993/6/8	Prosthetic leg
50	5,181,933	1993/1/26	Split foot prosthesis
51	5,181,932	1993/1/26	Foot prosthesis having auxiliary ankle construction
52	5,037,444	1991/8/6	Prosthetic foot
53	4,822,363	1989/4/18	Modular composite prosthetic foot and leg
54	4,547,913	1985/10/22	Composite prosthetic foot and leg

Plotting from 1985 when Van Phillips first obtained his patent, Fig. 1 shows the trend of patents for Van Phillips (Inventor) and Ossur (Assignee).

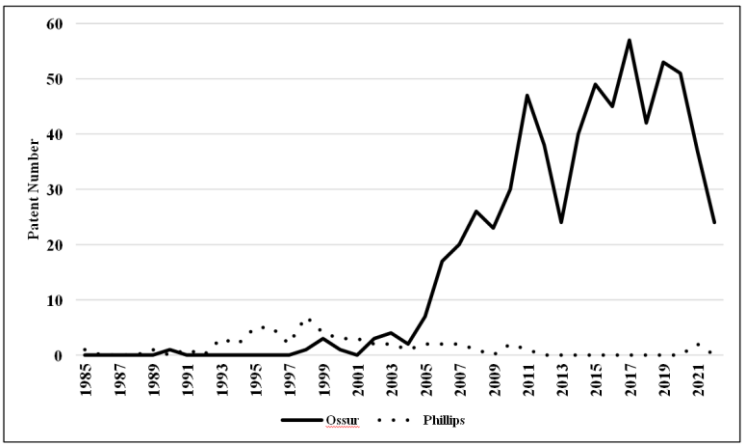

Fig. 1. Patent Trends for Van Phillips and Ossur (1985-2022).

To observe the impact of Van Phillips' patents on Ossur's patents, the following model ((1) equation) is set up. The model represents the effect of Van Phillips' patents on Ossur's patents. To measure how much time lag Van Phillips' patents have on Ossur's patents, the concept of time lag is incorporated into the model. The analysis period is set as 20 years from 1990 to 2010. As the acquisition was made in 2000, the impact will be measured in the 10 years before and after the acquisition.

$$OP_t = a'VP_{t-l} + b' \quad (1)$$

OP: Ossur patents number, *VP*: Van Phillips patents number, *a',b'*: parameters, *t*: time, *l*: time lag.

The analysis results are shown in Table 3.

Table 3 Regression Analysis Results between Ossur's Patents and Van Phillips' Patents.

time lag	***a'*** **(t-value)**	***b'*** **(t-value)**	***adj. R^2***	***DW***
0 year	-1.681 (-1.553)	9.225 (2.955)	0.069	0.373
5 years	0.233 (0.227)	4.911 (1.683)	-0.053	0.163
10 years	3.285 (6.041)	0.309 (0.219)	0.651	1.318
15 years	7.785 (4.852)	2.250 (1.550)	0.543	1.454

The hypothesis 1 holds true when the Van Phillips patent has a positive effect on the Ossur patent, that is, when the value of a' is positive. Therefore, the analysis result supporting hypothesis 1 is seen in the time lags of 10 and 15 years. In addition, focusing on the results obtained with 10 and 15 years of time lags, it can be statistically significant, indicating that Van Phillips patent had a positive impact on Ossur patents 10 years after the acquisition. This analysis analyzes patents only, so it became clear that Van Phillips has influenced Ossur's patent acquisition more than 10

years after obtaining the patent.

From these results, hypothesis 1, that "technology acquired by M&A is utilized in innovation creation," is verified, especially with a time lag of around 10 years. However, considering the time it takes to conduct research to obtain a patent, the time to write the patent document, the publication period, and the examination period, the effects of acquisition are assumed to have been manifested more than 10 years ago.

3.3. Forward Citation Analysis on Van Phillips's Patents

We aim to verify Hypothesis 2, which states that "acquired technology through M&A is utilized over a long period of time." To understand the impact of Van Phillips' patents on Ossur's patents in detail, we use citation information from US patents. Table 4 summarizes the patents obtained by Van Phillips, their patent dates (Patent of Date), and the number of citations. As shown in Table 2, Van Phillips wrote a total of 54 patents.

There are two types of citations in patents: backward citations and forward citations. Backward citations refer to the confirmation of already patented technologies by examiners to ensure novelty and progressiveness during patent examination. On the other hand, forward citations refer to citations made by examiners during the examination of other patents. Patents with more forward citations are considered valuable (Carpenter et al., 1981; Albert et al., 1991; Harhoff, 1999).

Therefore, in this study, we focus on Van Phillips' forward citations.

Table 4 Forward citation count of Van Phillips patents[a].

No.	Patent Number	Date of Patent	Citation Number
1	11,020,251	2021/6/1	0
2	11,013,621	2021/5/25	0
3	7,879,110	2011/2/1	59
4	7,655,049	2010/2/2	15
5	7,648,533	2010/1/19	10
6	7,354,456	2008/4/8	16
7	7,279,011	2007/10/9	27
8	7,169,190	2007/1/30	67
9	7,063,727	2006/6/20	110
10	7,060,104	2006/6/13	14
11	6,899,737	2005/5/31	30
12	6,887,279	2005/5/3	63
13	6,811,571	2004/11/2	93
14	6,527,811	2003/3/4	35
15	6,511,512	2003/1/28	59
16	6,478,826	2002/11/12	78
17	6,406,500	2002/6/18	45
18	6,280,479	2001/8/28	77
19	6,254,643	2001/7/3	22
20	6,206,934	2001/3/27	112
21	6,165,227	2000/12/26	51
22	6,071,313	2000/6/6	117
23	6,019,795	2000/2/1	27
24	5,993,488	1999/11/30	81
25	5,976,191	1999/11/2	50
26	5,899,944	1999/5/4	83
27	5,888,238	1999/3/30	21
28	5,824,112	1998/10/20	54
29	5,800,569	1998/9/1	76
30	5,776,205	1998/7/7	98
31	5,766,265	1998/6/16	41
32	5,728,177	1998/3/17	80
33	5,728,176	1998/3/17	38
34	5,725,598	1998/3/10	56
35	5,593,457	1997/1/14	49
36	5,593,455	1997/1/14	23
37	5,549,714	1996/8/27	44
38	5,514,186	1996/5/7	40
39	5,514,185	1996/5/7	108
40	5,509,938	1996/4/23	109
41	5,486,209	1996/1/23	69
42	5,464,441	1995/11/7	27
43	5,458,656	1995/10/17	84
44	5,443,529	1995/8/22	100
45	5,425,782	1995/6/20	44
46	5,387,246	1995/2/7	97

47	5,376,141	1994/12/27	110
48	5,290,319	1994/3/1	92
49	5,217,500	1993/6/8	84
50	5,181,933	1993/1/26	137
51	5,181,932	1993/1/26	105
52	5,037,444	1991/8/6	110
53	4,822,363	1989/4/18	148
54	4,547,913	1985/10/22	146
			3531

a: Acquired data on August 18, 2022.

Table 5 List of Assignees who Forward Cited Van Phillips' Patents.

Rank	**Company names, organization names, and personal names**	**Citation Number**
1	Ossur	842
2	Freedom Innovations	441
3	Bioquest Prosthetics	385
4	Christensen; Roland J.	316
5	Massachusetts Institute of Technology	275
6	Bionx Medical Technologies	152
7	Phillips; Van L.	145
8	Townsend; Barry W. et.al	97
9	Ottobock	75
10	iWALK	67
11	Ohio Willow Wood	54
12	Victhom Laboratory	43
13	Applied Composite Technology	38
14	Implus Footcare	36
15	Laghi; Aldo A.	34
16	Chas. A. Blatchford & Sons	27
17	Phillips; Van L., Ossur	22
18	Ability Dynamics	20
19	Flex-Foot	20
20	Phillips; Van L. et.al	17

Table 5 presents a list of Assignees who have cited Van Phillips' patents in their own patents. The company with the highest number of citations is Ossur, indicating that Ossur has referenced Van

Phillips' patents 842 times during the examination of their own patents. Following Ossur is Freedom Innovations, a company formed by designers who became independent from Flex Foot. Other prosthetic-related companies, such as Bioquest Prosthetics and Ottobock, are also included in the list. Notably, there are a total of 868 forward citations related to Ossur, which includes cases where Van Phillips and Ossur are joint Assignees, ranking 17th.

Table 6 The Ratio of Ossur's Reference in Forward Citations of Van Phillips' Patents.

Phillips Patent	Citation Number by Ossul (A)	Total Citation Number (B)	A/B
7879110	11	59	18.6%
7655049	1	15	6.7%
7648533	9	10	90.0%
7354456	9	16	56.3%
7279011	19	27	70.4%
7169190	16	67	23.9%
7063727	47	110	42.7%
7060104	3	14	21.4%
6899737	22	30	73.3%
6887279	4	63	6.3%
6811571	31	93	33.3%
6527811	14	35	40.0%
6511512	6	59	10.2%
6478826	29	78	37.2%
6406500	10	45	22.2%
6280479	27	77	35.1%
6254643	0	22	0.0%
6206934	56	112	50.0%
6165227	23	51	45.1%
6071313	28	117	23.9%
6019795	1	27	3.7%
5993488	26	81	32.1%
5976191	6	50	12.0%
5899944	27	83	32.5%
5888238	0	21	0.0%
5824112	11	54	20.4%
5800569	21	76	27.6%
5776205	0	98	0.0%
5766265	3	41	7.3%
5728177	26	80	32.5%
5728176	1	38	2.6%
5725598	11	56	19.6%
5593457	1	49	2.0%
5593455	0	23	0.0%
5549714	0	44	0.0%
5514186	9	40	22.5%
5514185	8	108	7.4%
5509938	23	109	21.1%
5486209	9	69	13.0%
5464441	0	27	0.0%
5458656	3	84	3.6%
5443529	25	100	25.0%
5425782	2	44	4.5%
5387246	27	97	27.8%
5376141	47	110	42.7%

5290319	25	92	27.2%
5217500	33	84	39.3%
5181933	29	137	21.2%
5181932	25	105	23.8%
5037444	29	110	26.4%
4822363	23	148	15.5%
4547913	26	146	17.8%
	Average		**23.8%**

Table 6 shows the extracted data from Table 5, which includes only the forward citations of Van Phillips' patents made by patent examiners, and adds the citation ratio to Ossur. Of all the forward citations of Van Phillips' patents, 23.8% were made to Ossur. What we can learn from Tables 5 and 6 is that Ossur is the company that is utilizing Van Phillips' patents more than any other company.

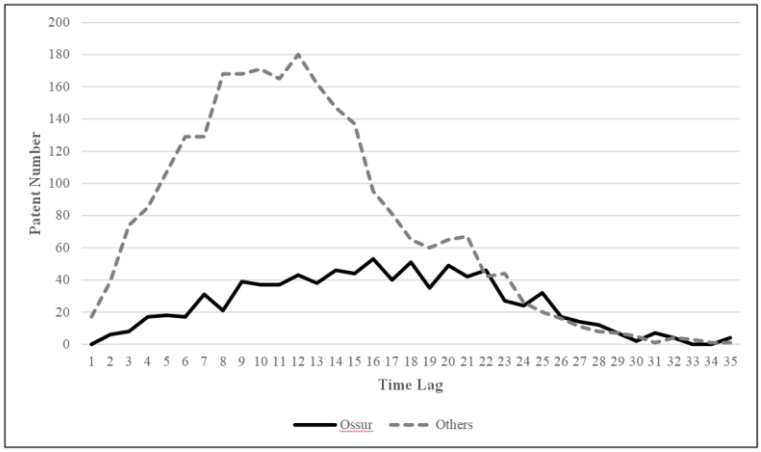

Fig. 2 Comparison of Citation Numbers in Van Phillips' Patents.

Fig.2 shows the time trend of forward citations of Van Phillips' patents. The Y-axis represents the number of patents, while the X-axis shows the time lag (in years) between the filing date of Van Phillips' patent and the filing date of the forward-cited patent. For example, if Van Phillips' patent was filed in January 2010 and the forward-cited patent was filed in January 2020, the time lag would be 10 years. Each line represents "Others," excluding self-citations by Ossur and Ossur and Van Phillips.

The mean and standard deviation of Ossur and Others in Fig. 2 are shown below.

There is a significant difference of average time lag in Ossur (M = 16.140, SD = 6.651) compared to others (M = 12.083, SD = 5.944), t (1377) = 15.898, P<.001.

The results show that patent examiners are citing Van Phillips' patents an average of 16.1 years for Ossur and 12.1 years for other companies. This suggests that Ossur is using Van Phillips' patents for a longer period of time, possibly through the acquisition of Flex Foot, and the difference is approximately 4 years. Thus, the hypothesis 2, "Technology acquired through M&A is utilized over a long period of time" has been verified.

3.4. Analysis of the Long-Term Use of Technology

To test Hypothesis 3, "The long-term use of technology acquired through M&A positively affects a company's performance," a regression analysis was conducted on Ossur's sales revenue and the Ossur patents that have been utilizing Van Phillips' patents for a long time.

Fig. 3 illustrates the trend of Ossur's sales revenue and patents. The data is reported from 1999 because Ossur was listed on the Iceland stock exchange in the same year. Furthermore, Ossur is a company that generates innovative products through active development of welfare devices such as prosthetics and M&As.

Fig. 3 Trend of Ossur's Sales Revenue and Patents (1999-2021).

Fig. 3 shows the growth of innovation through the growth of Ossur's sales revenue and patent portfolio. Based on the study by Watanabe (1992), which argues that innovation and technology serve as strategic resources for companies, it can be explained that revenue can be influenced by the number of patents. Additionally, Ossur acquired TeamOlmed in 2013 to gain sales channels. Since the acquisition of sales channels contributes to revenue, it is necessary to incorporate its impact into the regression model. Specifically, a dummy variable is used to capture the effect of the acquisition after 2013. Based on the above discussion, the model ((2) equation) is presented below.

$$OS = aOP + bD + c \quad (2)$$

OS: Ossur Sales Revenue, *OP*: Ossur Patent Number, D: dummy variable, *a*,*b*,*c*: parameters.

The analysis results are shown in Table 7.

Table 7 Regression Analysis Results between Ossur's Sales Revenue and Patents.

a **(t-value)**	***b*** **(t-value)**	***c*** **(t-value)**	***adj. R²***	***DW***
8.240 (5.654)	115.171 (1.985)	97.478 (3.002)	0.851	1.534

The analysis results in Table 7 show that the parameter a has a positive sign, indicating that patents have a positive effect on sales. Furthermore, all of the t-values, adjusted R-squared, and

Durbin-Watson statistics are statistically significant, suggesting that patents are a significant determinant of sales for Ossur. This indicates that patents are an important strategic resource for Ossur.

Therefore, the verification of hypothesis 3, that "technologies acquired through M&A will have a positive impact on the company's performance in the long run," has been demonstrated.

4. CONCLUSION

This study discusses strategies for overcoming the dilemma faced by ICT companies where expanding R&D does not necessarily lead to increased productivity, and focuses on M&A as one of these strategies. The study aims to reveal the mechanism by which acquired technology can lead to the creation of new innovations and to discuss efficient methods for corporate mergers and acquisitions to improve productivity in R&D activities.

The study considers a mechanism in which acquired technology is utilized in a layered manner over a long period of time as important for creating new innovations. Three hypotheses were tested: "Technology acquired through M&A is utilized in innovation creation," "Technology acquired through M&A is utilized over a long period of time," and "Long-term utilization of technology acquired through M&A has a positive impact on corporate performance."

Through the verification of these hypotheses, it was revealed that the long-term layered utilization of acquired technology is effective in creating new innovations. In addition, the study provides specific examples and recommendations for efficient corporate mergers and acquisitions to improve productivity in R&D activities by examining the historical evolution of relationships between M&A stakeholders. For example, in the case of prosthetic technology, Ossur has not only acquired Flex Foot but has also undertaken many other M&As (Hansen & Pedersen, 2006), and the ability to utilize technology acquired over a long period of time may be associated with the experience gained from this strategy as well as with internal organization and systems.

This study addresses the dilemma faced by ICT companies where expanding R&D does not necessarily lead to increased productivity and discusses efficient methods for corporate mergers and acquisitions to improve productivity in R&D activities by revealing the mechanism by which acquired technology can lead to the creation of new innovations.Similar to Ossur, there are Japanese electronics manufacturers such as Kyocera, MinebeaMitsumi, and NIDEC that utilize M&A for technology development and profitability. By including these companies as part of the analysis in the future, it is believed that the universality of the theories proposed in this study can be demonstrated.

In addition, the sample size of the time-series data examined in this study is small. While the analysis results showed high statistical significance, this poses a limitation to the research.

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