sustainability

MDPI

Article

The Relationship between Patents, Technology Transfer and Desorptive Capacity in Korean Universities

Youngseong Koo [1] and Keuntae Cho [2,*]

[1] Korea Agency for Infrastructure Technology Advancement, 286 Simin-Daero, Dongan-Gu, Anyang 14066, Gyeonggi-Do, Korea; ykoo@kaia.re.kr
[2] Graduate School of Technology Management, Sungkyunkwan University, 2066 Seobu-Ro, Jangan-Gu, Suwon 16419, Gyeonggi-Do, Korea
* Correspondence: ktcho@skku.edu; Tel.: +82-31-290-7602

Abstract: This study sought to examine the relationship between patent rights and technology transfer performances of Korean universities and to analyze the moderating effect of the desorptive capacity of industry-academic cooperation foundations. Through this, we study the impact of universities' patents on both the number of licenses and the license incomes of the universities. We also examine the meaning of the desorptive capacity between them. Regression analysis and structural equation modeling are performed by using the number of patents registered as an independent variable, the number of licenses and license incomes as dependent variables and the desorptive capacity as a moderating variable. The analysis shows that the patent had a positive relationship with both the number of licenses and license incomes. Desorptive capacity had no significant effect between patents and the number of technology transfers. However, it is seen as having a moderating effect between patents and licensing fees from the technology transfers. This paper meaningfully illustrates the desorptive capacity of the industry-academic cooperation foundation from the perspective of outbound open innovation and analyzes the moderating effect of desorptive capacity in relation to patent rights and technology transfer performances.

Keywords: patent; technology transfer; desorptive capacity; industry-academic cooperation foundation; moderating effect

check for updates

Citation: Koo, Y.; Cho, K. The Relationship between Patents, Technology Transfer and Desorptive Capacity in Korean Universities. *Sustainability* **2021**, *13*, 5253. https://doi.org/10.3390/su13095253

Academic Editor: Michele Grimaldi

Received: 24 March 2021
Accepted: 4 May 2021
Published: 7 May 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

With the advent of the concept of open innovation, it was argued that for an organization to develop technology and succeed in the market, it should actively accept ideas not only within, but also outside the organization [1]. Better results can be acquired if external knowledge is appropriately combined with the organization's unique internal technology. As many companies actively promote cooperation, the exchange of resources and knowledge between organizations has gradually increased. Today, not only companies but also various organizations, such as universities and research institutes, are adopting open innovation.

Open innovation is classified into two types. One is the outside-in innovation that draws external ideas and knowledge into the organization. The other is the inside-out innovation that creates new value by exporting knowledge or assets from the organization [1–4]. Internal capacity of the organization has received much attention along with companies' emphasis on the importance of acquiring knowledge and technology from outside the organization to supplement internal R&D and the making of profits by disclosing their own technology to the outside [5–7]. Lichtenthaler [8] divided the organizational capacity into an absorptive capacity and desorptive capacity, which absorbs external knowledge and successfully applies internal knowledge to the outside.

In 2003, South Korea revised the Industrial Education Enhancement and Industry-Academia-Research Cooperation Promotion Act. Korean universities started to establish

an industry-academic cooperation foundation as a corporate body in charge of those businesses related to industry–academia–research cooperation. This laid the institutional framework for universities to contribute to industrial development [9,10]. Universities are reinforcing exchange and cooperation with industry and research institutes through their industry-academic cooperation foundations [11–18].

The Korean government made various efforts to foster human resources reflecting industrial demand and promote cooperation between universities and industries. The Leaders in Industry–University Cooperation program promoted the development of regional universities and local industries. Establishing a start-up education centre expanded start-up education. Universities and companies signed an agreement to create industry–academic cooperation family companies to support joint research between them. This joint research effort supported the establishment of technology holding companies that directly commercialise technology owned by the universities and set up contract departments at the university to flexibly respond to various manpower needs of the company.

The government has steadily increased the investment in research and development. As a result, the number of university patents is increasing every year. The quantum of technology licensing and license income which are the result of technology transfer, also show an increasing trend. The number of domestic and international patent applications increased 126.5% from 11,994 in 2009 to 27,163 in 2018. The number of patent registrations at home and abroad increased by 326.3%—from 3649 to 15,557—during the same period. The average annual growth rate of patent registrations over the past decade has been 17.5%, which is approximately 1.8 times higher than that of 9.5% of patent applications. The number of technology transfer contracts was surveyed to 1291 in 2009, up 260.9% to 4659 in 2018. Technical fee revenue in 2018 was 86,960 million Korean Won (KWN), up 190.1% from KWN 29,981 million in 2009. The average annual growth rate for the decade was 15.3% and 12.6%, respectively [10].

Although intellectual property rights, such as patent rights, have increased significantly due to the efforts thus far, it is generally assessed that technology transfer and commercialisation performance are insufficient, based on international standards. Indeed, international competitiveness in industry–academic cooperation is not particularly high. According to the 2020 IMD World Competitiveness Yearbook, Korea's scientific infrastructure indicator was ranked top third in the world, but the sub-factor of knowledge transfer between companies and universities was ranked 30th. New endeavours are required to improve the current status and increase technology transfer and commercialisation.

It is known that patents held by industry–academic cooperation foundations generally have a significant relationship with technology transfer performance such as the number of technology licenses and quantum of license income [19–25]. However, some differences in details exist among researchers. It is also difficult to find cases that have discussed or studied in depth, the ability of the industry–academic cooperation foundation to transmit its internal knowledge outside, that is, the desorptive capacity perspective. Therefore, based on the outbound open innovation theory, we attempt to grasp the desorptive capacity of industry–academic cooperation foundations and analyze empirically, how this affects the relationship between patents and technology transfers of Korean universities.

A regression analysis was conducted to verify the significance of the relationship between the number of university patents and both, the number of licenses and the license income. A survey was conducted to measure the desorptive capacity of industry–academic cooperation foundations. After asking 140 industrial-academic cooperation foundations mentioned on the national survey report in 2018, 116 samples could be obtained. By using the AMOS program, one of the representative statistical analysis tools for a structural equation modelling, the modulating effect of desorptive capacity was checked.

This paper is organised as follows. Section 2 examines previous research on university patent rights and technology transfer performances, as well as the desorptive capacity of open innovation and establishes a hypothesis. Section 3 describes the research model and method. Section 4 contains the results of verifying the hypothesis through statistical

analysis. Section 5 describes the academic significance and policy implications. The final section summarises the conclusions.

2. Literature Review and Hypothesis Setting

2.1. Patent and Technology Transfer Performances

Over the past decades, most countries have witnessed a rising trend of patent filing by universities. This was noticeable in the early days after the passage of the Bayh-Dole Act in the United States and soon became widespread throughout the world [19,20,26,27].

Technology transfer plays a critical role in achieving a university's mission in terms of education, research activities and public service [20,28,29]. University technology transfer can be described as a process in which several phases of activities occur sequentially, such as research expenditure, invention disclosure, patent application, technology licensing and collection of technology fee or income [19]. Patents are important in commercialising research outputs [30]. A university's focus on obtaining patent rights based on research results increases the credibility of the researcher who applied for the patent and is used as input data for research activities in other laboratories. However, in contrast, it hinders the free distribution and sharing of knowledge [31].

Owen-Smith and Powell [32] studied the differences in patent and technology transfers by comparing Elite Private Universities and Big State Universities among the universities in the United States. Despite differences in the perceptions of professors about the advantages of patents by academic fields, such as life science and physics, there was no difference based on the characteristics of universities. Incentives for patents were strengthened when professors were interested in commercialisation, or academic compensation was linked with commercial reward. Drivas et al. [33] studied the difference between university patents supported by the federal government and non-governmental entities in the relationship between patents and the timing of technology transfers. The study concluded that it is difficult to say whether patents supported by the government transfer greater or fewer technologies compared with those supported by non-government entities. However, for the university patents that did not receive government support, the time to market was found to be faster.

Several researchers have studied the relationship between patent rights and technology transfer performances in universities. Regarding the relationship between the university's patents and technology transfer performances, the researchers drew similar conclusions, but the details were slightly different. Therefore, the first hypothesis established in this paper is defined as follows.

Hypothesis 1 (H1) *The more patents a university holds, the more technology transfer results will be created.*

Hypothesis 1a (H1a) *The number of patents registered has a significant positive effect on the number of technology licenses.*

Hypothesis 1b (H1b) *The number of patents registered has a significant positive effect on license income.*

Kim and Hyun [21] analyzed the factors affecting the technology transfer by universities by dividing them into institutional and strategic resource factors. It was demonstrated that the higher the number of patents, the higher the technology transfer performance. Kim and Lee [22] conducted a study on the achievements of university industry-academia cooperation and capacity factors of universities. By performing multiple regression analysis, it was seen that the number of domestic patent registrations is highly related to the number of technology transfers and the number of international patent registrations affects the technology fees. Like other studies, it was confirmed that patents directly affect the number of licenses and license income [23,34]. Yoon and Park [24] verified the effect of the number of patent applications and registrations on the performance of technology commercialisation. As a result of regression analysis, it was seen that the number of patent applications

and registrations has a very high positive causal relationship with the technology license income. Noh [25] studied the effect of patent on technology transfer performance, based on the survey results of the industry–academic cooperation activities of Korean universities from 2007 to 2011. She concluded that the number of domestic patents applied for had a positive effect and the number of international patents applied for had a negative effect with respect to the number of technology licenses. In addition, the number of domestic patents registered did not have any significant effect, but the number of international patents registered had a positive effect. In the relationship between patents and license incomes, it was seen that only the number of domestic patents applied for had a positive effect. The number of domestic patents registered and the number of international patents applied for and registered had no effect.

2.2. Desorptive Capacity

Most companies and organizations have a strong tendency to carry out innovation-related activities with their internal capabilities, which is called closed innovation. On the contrary, the concept of actively using ideas and technologies outside the organization is called open innovation [1]. In open innovation, the ability to discover knowledge outside the organization is recognised as very important. The ability to identify and fully understand new valuable information and then apply it to internal commercialisation purposes was considered important and this was defined as absorptive capacity [35–39]. Desorptive capacity was proposed as a contradictory concept to absorptive capacity [8]. Desorptive capacity consists of (1) determining opportunities for an entity to apply knowledge externally and (2) transferring knowledge to the recipient [40–43]. From the outbound open innovation perspective, it contrasts with absorptive capacity (which explores external knowledge) and is distinct from connective capacity (which maintains a lasting relationship with external knowledge). Furthermore, the application of knowledge externally contrasts with the innovative capacity exploited internally [44]. Technology alliances or licensing is closely related with the examples of desorptive capacity concept.

Desorptive capacity is defined as the ability to successfully transfer products or technologies owned by a company outside the company, rather than applying them inside the company. Seizing opportunities has been a huge challenge for most companies and sufficient knowledge is considered important for this reason [45,46]. Lucent Technology was a leading company that strengthened its desorptive capacity in the 1990s by granting other companies' permission to use its intellectual property rights [47]. IBM increased sales and achieved beneficial financial outcomes by transferring technology to the outside, based on its strong desorptive capacity [46,48].

From the perspective of closed innovation, intellectual property rights, such as patents, were recognised as an important means to safeguard the unique technologies held by companies [49]. However, in open innovation, a patent means breaking away from the traditional protection method, recognising it as a tradeable asset and utilising it in various ways [1]. Firms either licensed their own patents to external users or began selling patented technology [47]. Applying the concept of desorption capacity, Ziegler et al. [50] conducted an empirical study on 14 companies in the pharmaceutical and chemical industries. Corporate value creation, organizational structure, object and scope of the patent applied were factors that influenced the company's external use of patents. Roldán Bravo et al. [51] analyzed the moderating effect of an ambidextrous organization with the firm's desorptive capacity as an independent variable and supply chain competence as a dependent variable; they found that companies that are committed to balanced and combined exploration and exploitation stand to benefit more from their desorptive capacities.

Although it is known that the patents held by a university affect the number of technology licenses or the license income from the technology transfer, the role of desorptive capacity in this process has not been studied yet. Therefore, for the university's industry–academic cooperation foundation, the following second hypothesis is established.

Hypothesis 2 (H2) *A university's desorptive capacity has a positive moderating effect on the patent and technology transfer performance.*

Hypothesis 2a (H2a) *A university's desorptive capacity has a positive moderating effect on the number of patents registered and the number of licenses.*

Hypothesis 2b (H2b) *A university's desorptive capacity has a positive moderating effect on the number of patents registered and the license income.*

Yoo [52] conducted study on companies working on research and development (R&D) projects and then analysed data to derive items that can measure desorptive capacity. Exploratory factor analysis was conducted on 24 variables that can measure desorptive capacity and 14 items were presented. Kim et al. [53] analyzed the relationship model between R&D investment and corporate performance. After analysing the four relationships of mediation, independent, moderating and spurious, it was confirmed that desorptive capacity acts as a moderating relationship between R&D investment and corporate performance. It was also found that the higher the desorptive capability, the stronger the positive relationship between R&D investment and corporate performance.

Studies on the desorptive capacity of companies and their impact have been conducted but to our knowledge, no similar analysis on the effect of desorptive capacity for universities has been attempted. Choi [54] demonstrated that companies with superior desorptive capacity show greater performance in technology transfer. However, questions remain still as to whether such results can also be expected by the universities. The research model for the first (H1) and the second hypotheses (H2) is shown in Figure 1.

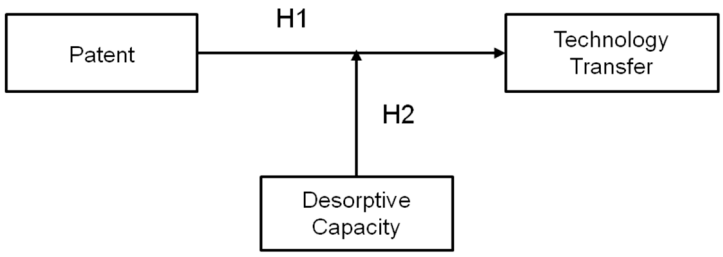


Figure 1. Research Model.

3. Research Method

3.1. Analysis Method and Variables Definition

Regression analysis was performed to test the first hypothesis (H1) by using SPSS, a statistical analysis program. Through regression analysis, the influence of the independent variable on the dependent variable was tested. Additionally, the significance of the regression equation and the fit of the model were verified.

In previous studies on patents and technology transfers, the independent variable was set differently by the researchers: the number of patents applied [34], the number of patents registered [22] and both the number of patents applied and registered [25]. Patent applications and patent registrations were selected as independent variables.

For the technology transfer performance, the number of licenses and license income were selected as dependent variables. Two models were analyzed using each as a measurement variable. Dividing technology transfer performances into the number of licenses and the license income, the dependent variables were classified based on the number of licenses (Model 1) or the license income (Model 2).

To reflect the time lag between patent and technology transfer performances, data were collected at the interval of 1 year by referring to the method of analysis used by Carlsson and Fridh [20]. To minimise outliers in the data, measurements were collected over 4 years. As a result, the accumulated data for 4 years from 2014 to 2017 were used for patent registrations and data for another 4 years from 2015 to 2018 were applied to statistical analysis for the number of licenses and license income in this study.

For the second hypothesis (H2), the verification of the moderating effect of desorptive capacity was analyzed using structural equation modelling (SEM), which is widely used in various academic fields as a statistical technique to verify causal relationships and correlations between variables. The SEM model is a combination of confirmatory factor analysis and path analysis. It is known to have the advantage of creating complex research models with ease [55].

Desorptive capacity of the university's industry–academic cooperation foundation was set as a moderating variable in each model. To measure the desorptive capacity used as a moderating variable, 14 questionnaire items were designed by referring to existing literature studies [52,54]. Each questionnaire item used a 7-point Likert scale, ranging from 1 for 'not at all' to 7 for 'absolutely agree'.

To verify the moderating effect, an interaction variable was created between the independent variable and the moderating variable and the interaction effect with the dependent variable was analyzed. In order to confirm that a moderating variable has a moderating effect, a significant relationship must first be established between the independent variable (X) and the dependent variable (Y). Next, whether the moderating variable (Z) has a significant relationship with the dependent variable (Y) was examined. Finally, after creating an interaction term (X×Z) of the independent variable (X) and the moderating variable (Z), whether this represents a significant relationship to the dependent variable was checked [56]. In order to prevent the multicollinearity problem that may occur in the interaction term, the independent and the moderating variables were obtained by subtracting the average value and then each term was multiplied, which is called mean centring [57]. In this study, the AMOS program was used to construct and analyse the structural equation model.

3.2. Sample Selection and Data Collection

Data for both independent and dependent variables were obtained from Higher Education in Korea Service which is operated by the Centre of University Information Disclosure of Korean Council for University Education. The centre collects major information on Korean universities every year and discloses them to the general public via a website. All data on patents and technology transfers of universities' industry-academia cooperation foundations required for this study were downloaded from the website.

In Higher Education in Korea Service, a total of 167 universities posted data on the results of patents and technology transfers that occurred between 2014 and 2018. Among them, 27 universities had no cases in technology licensing or license income during the survey period. Therefore, 140 universities were selected as the sample.

Data on the desorptive capability of industry–academic cooperation foundations were obtained through a questionnaire. The survey was conducted from July to August in 2018. In order to obtain reliable results on the desorptive capacity, the head of the foundation or team leaders of the department in charge of technology transfers or intellectual property rights were asked to answer the survey. All surveys were conducted using Google's online questionnaire and the response results were automatically saved to a file. After excluding duplicate responses from the same organization and questionnaires with inadequate responses, a total of 116 responses were collected.

Table 1 shows the collected data for independent and dependent variables by year from 2014 to 2018. The number of patents applied and registered gradually increased to 10.1% and 12.5%, as compared to 3 years before. During the same period, the number of licenses and license income increased significantly to 19.8% and 28.1%, respectively.

Table 1. Variable data of the sample (N = 116).

Variables		FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	% Increase
Number of Patents Applied	Sum	16,776	18,352	19,197	18,472	-	10.1%
	Ave	144.6	158.2	165.5	159.2	-	
Number of Patents Registered	Sum	10,778	9420	10,738	12,129	-	12.5%
	Ave.	92.9	81.2	92.6	104.6	-	
Number of Licenses	Sum	-	3432	4016	3667	4112	19.8%
	Ave.	-	29.6	34.6	31.6	35.5	
License Income (KWN million)	Sum	-	59,792.5	64,656.6	66,266.9	76,598.8	28.1%
	Ave.	-	515.5	557.4	571.3	660.3	

4. Research results

4.1. Analysis of Sample Characteristics, Reliability and Goodness-of-Fit

For the sample of 116 industry–academic cooperation foundations, the average number of patents applied and registered per year from 2014 to 2017 were 156.9 and 92.8 cases. Desorptive capability was calculated as an average of 65.6 points. For 4 years from 2015 to 2018, the average number of licenses per year was about 32.8 cases and the average annual license income was about KWN 576.1 million. Table 2 summarises the descriptive statistics for the main variables and the results of the correlation analysis.

Table 2. Descriptive statistics and correlation of variables.

Variables	Average	Standard Deviation	1	2	3	4	5
(1) Desorptive Capacity	65.6	14.036	1				
(2) Number of Patents Applied	156.9	219.468	0.218 *	1			
(3) Number of Patents Registered	92.8	131.621	0.211 *	0.993 **	1		
(4) Number of Licenses	32.8	31.672	0.272 **	0.711 **	0.717 **	1	
(5) License Income (mil. KWN)	576.1	867.570	0.264 **	0.934 **	0.936 **	0.754 **	1

(Notes) *: significant at the 5 percent level, **: significant at the 1 percent level.

The significance probability of the major variables was lower than the significance level, so all the results were shown to be significant. All variables have a positive correlation. The correlation coefficient between the number of patents registered and the license income is 0.936. There is relatively high level of correlation among the number of patents registered, the number of licenses and license income.

The reliability is first checked, to make multiple items into a single item. As a result of the analysis, the Cronbach's alpha coefficient was calculated as 0.943, a relatively high value, indicating that the reliability of the measurement items was secured. After each item was deleted, the maximum value of the Cronbach's alpha coefficient was 0.942, which is less than 0.943 for all items, so all items were considered valid and added together to form a single item.

In order to determine the fit of the research model, the absolute fit indices and incremental fit indices from the AMOS analysis results were reviewed. Among the absolute fit indices, the goodness of fit index (GFI) is the most commonly used in structural equation models and represents the extent to which the variance and covariance in the covariance matrix of the sample data is explained by the estimated covariance matrix. GFI varies from 0 for 'non-conformance' to 1 for 'perfect fit' and usually a value above 0.9 can be said to be an excellent level [58]. In this research model, the GFI of the model was 0.960 and was judged to be very good. Among the incremental fit indices, the normed fit index (NFI) is the basic fit which is obtained by dividing the difference between χ^2 of the null model and χ^2 of the proposed model by χ^2 of the null model. NFI of the model was 0.966 which was judged to be very good. As the comparative fit index (CFI) is known to be the least affected

by the sample size, it compensates for the shortcomings of NFI. The value of CFI is 0.968. Therefore, it was judged that the fit of this research model is sufficiently secured.

4.2. Patent and Technology Transfer

To test the first hypothesis on the relationship between patent and technology transfer performances, a regression analysis was conducted. As shown in Table 2, patent application and patent registration have a strong correlation coefficient of 0.993 that caused a multicollinearity problem. In the stepwise multiple regression analysis, patent application variable was excluded. So, the number of patents registered was finally chosen as the independent variable.

The regression equation was considered as valid because the data generally followed a normal distribution. In the relationship between the number of patents registered and the number of licenses, the significance probability was below the significance level, so hypothesis H1a was adopted. The relationship between the number of patents registered and the license income also showed significant results and hypothesis H1b was also adopted. In conclusion, it was confirmed that patent registration has a significant relationship with both the number of licenses and the license income, in a highly positive manner. The analysis results are summarised in Table 3.

Table 3. Regression analysis results.

Model		R^2	Unstandardized Coeff. B	Unstandardized Coeff. S. E.	Standardized Coefficient (β)	t	*p*
1	(Constant)		16.803	2.523		6.661	0.000
Patents Registered		0.514	0.173	0.016	0.717	10.983	0.000
2	(Constant)		3.408	34.859		0.098	0.922
Patents Registered		0.876	6.171	0.217	0.936	28.426	0.000

4.3. Moderating Effect of Desorptive Capacity

To investigate the moderating effect of the desorptive capacity, the structural equation model was constructed as shown in Figure 2.

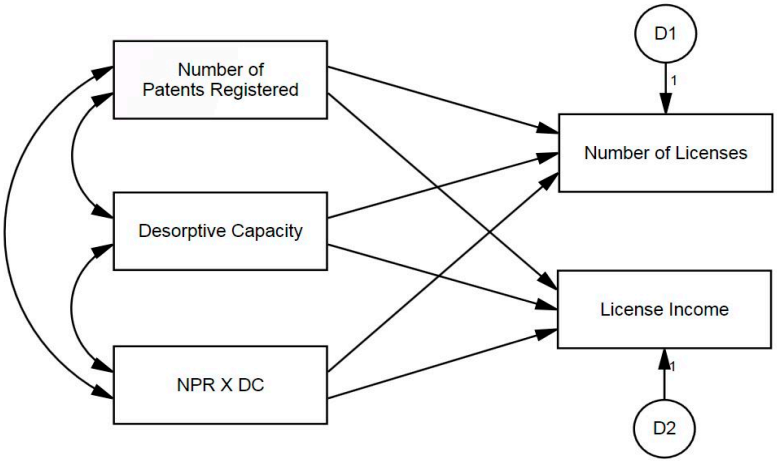


Figure 2. SEM analysis model.

As discussed in the previous section, the two models for the different dependent variables, the number of licenses and the license income, were simultaneously analyzed in a structural equation model. The results of the analysis are summarised in Table 4.

Table 4. Analysis results of SEM.

Classification	Standardized Coefficient	Unstandardized Coefficient B	Unstandardized Coefficient S.E.	C.R.	*p*
(Model 1)					
Num. of Licenses ← Patent Registered	0.690	0.166	0.016	10.547	*
Num. of Licenses ← Desorptive Capacity	0.128	0.290	0.148	1.960	0.050
Num. of Licenses ← NPR × DC	0.033	0.001	0.001	0.511	0.609
(Model 2)					
License Income ← Patent Registered	0.918	6.053	0.199	30.463	*
License Income ← Desorptive Capacity	0.080	4.952	1.868	2.651	0.008
License Income ← NPR × DC	0.139	0.071	0.015	4.702	*

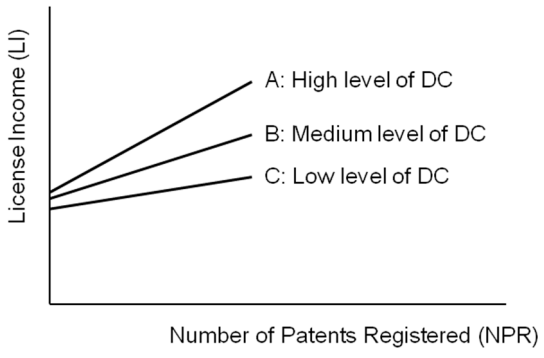
(Notes) *: significant at the 0.1 percent level.

In the case of Model 1, the significance probability of both the independent variable and the moderating variable on the dependent variable was less than the significance level. However, hypothesis H2a was rejected because the *p*-value of the significance probability for the interaction variable was 0.609, out of the significance level. Although there is a positive causal relationship between the number of patents registered and the number of licenses (H1a), it was seen that the desorptive capacity did not have a moderating effect.

For Model 2 that analyzed the relationship between patent registration and license income, all the *p*-values for the independent variable, the moderating variable and interaction variable fall within the significance level. The desorptive capacity was found to have a moderating effect on the patent registration and the license income. Therefore, hypothesis H2b was adopted.

In the relationship between the number of patents registered and license income in Model 2, the standardised coefficient was 0.918, a relatively high value. In the relationship between the desorptive capacity and license income, the standardised coefficient was 0.080. To determine the moderating effect in the relationship between the interactive variable and the dependent variable, the standardised coefficient was 0.139. The critical ratio, which indicates the statistical significance of the path coefficient, is significant because all of the values tafor Model 2 are greater than ±1.96 and the *p*-values are also very low [58].

Figure 3 shows the moderating effect in a graph suggested by Jang et al. [59], to help understand the desorptive capacity of industry–academic cooperation foundations in Korean universities. In this graph, line B represents the average level of desorptive capacity. If the desorptive capacity is higher by as much as one standard deviation than the average, it comes to line A. On the contrary, where the desorptive capacity is lower by the amount of the standard deviation, then it comes to line C.



Line - A: LI = 7.050 NPR + c1 (DC = μ + σ)

Line - B: LI = 6.053 NPR + c2 (DC = μ)

Line - C: LI = 5.056 NPR + c3 (DC = μ - σ)

Figure 3. Graph explains the moderating effect of desorptive capacity.

Based on the unstandardized coefficients of the structural model obtained in Table 4, the values of the license income (LI), the number of patents registered (NPR) and the desorptive capacity (DC) can be expressed as a linear equation:

$$LI = (1.395 + 0.071 \times DC) \times NPR - 1.638 \times DC + 432.272 \quad (1)$$

As shown in Figure 3, the license income is much higher for the group with high desorptive capacity compared to the case where the desorptive capacity is average or low. The difference will be greater if the number of patents registered increases.

5. Discussion

The academic significance of this study is three-fold. First, it has reiterated that there is a high causal relationship between the patent rights held by universities and both the technology transfer cases and income. While this result is consistent with existing research findings [22,24], there were also differences with existing literature. Noh [25] posited that the number of domestic patent registrations has no effect on technology transfers. In addition, she stated that both the number of domestic and international patent registrations do not affect the technology license income. Contradictory results were obtained in this study. Noh [25] studied data collected from 2007 to 2011, but this study was conducted from 2014 to 2018. It can be interpreted that the effect of university patents on technology transfer performances was insignificant in the past, but it has changed in recent years.

Second, the competency of the university industry–academic cooperation foundation was examined from the perspective of desorptive capacity. Many studies have been conducted on industry–academic cooperation capabilities that contribute to the achievements of the technological commercialisation of universities [60–62]. Those studies approached the issue in terms of the size of the technology transfer organization, the manpower, or the understanding of administrative staff of the industry and market. However, it is difficult to find cases studying the impact of desorptive capacity of the universities from the perspective of outbound open innovation.

Lastly, it was found that the desorptive capacity of the industry–academic cooperation foundation has a moderating effect in the relationship between patent rights and technology license income. For enterprises, studies have demonstrated that desorptive capacity has a moderating effect between R&D investment and corporate performance [53], or between outbound open innovation and corporate performance [54]. Expanding the research subject on the analysis of the moderating effect of desorptive capacity to universities is considered to be of academic significance. This study empirically proved that the higher the desorptive capacity, the greater is the financial compensation, due to the increase in technology transfer fees.

The process of applying internal technology to the outside can be divided into four stages. First, the technologies and markets for which the internal knowledge can be applied are explored. Second, preparations and plans are required to transfer the knowledge. When those preparations are completed, actual contracts will be signed and technology transferred through negotiations with companies. Finally, the transferred technology will be checked to ensure it is working properly. Desorption capacity is required for all of these processes. In the exploration phase, both extensive understanding and analytical ability for technology and market are required. Designing a plan would be easier, if the executives do not object to transferring internal technology to the outside and a positive culture of relocation is formed within the organization. In the technology transfer phase, contracts can be created easily if a tool is set in place to objectively evaluate the value of technology. Negotiation ability with the counterpart is also a key factor. Even after the contract is over, providing technical support can help to maintain a good relationship with the recipient for a long time.

Policy implications can be obtained based on the results of the survey conducted for this paper. The item, whether having a systematic and formal technology transfer process, only received 3.76 points on average on a 7-point Likert scale. In addition, the analysis

results showed that using various technology valuation methods and supporting technical education to demand companies were relatively weak.

To improve the performance of technology transfers, managers such as the university's administrative staff, the head of the industry–academic cooperation foundation and the team leader of the technology transfer organization should strive to strengthen the desorptive capacity of the university as well as ensuring ownership of intellectual property rights. Knowledge of technology and the market should be explored to disseminate intellectual property produced by universities effectively. Technology transfers and follow-up actions through commercialisation should be systematically managed from the planning stage. Then, a much higher level of financial performance is expected even with a similar level of intellectual property rights.

It is reasonable for the government to take the lead in suggesting solutions, rather than solving these items through individual universities. Policymakers must systematise technology transfer processes, develop technology valuation methodologies and disseminate them to universities and companies. Developing educational programmes and supporting the education of those in charge is crucial for improving the desorptive capacity of the organization dedicated to technology commercialisation in universities. It would also be worthwhile to consider providing incentives to universities or professors to create an objective environment where universities can easily transfer their skills to companies.

6. Conclusions

This study attempted to examine the relationship between patents owned by Korean universities and their technology transfer performances. The industry–academic cooperation foundation's ability to transfer information and knowledge outside of the university in outbound open innovation, that is the desorptive capacity and its impact between the university's patent rights and technology transfer performances were also examined. To this end, hypotheses were verified with two models, with the number of patents registered by universities as an independent variable and both the number of licenses and the license income as dependent variables, respectively.

The Korean Council for University Education operates a website called Higher Education in Korea Service that provides essential information about Korean universities. The data related to patents and technology transfer performances for 5 years from 2014 to 2018 were downloaded from the website and used for analysis. In order to verify the first research hypothesis, a regression analysis was performed using valid data from the industry–academic cooperation foundations of 116 universities. It was confirmed that a significant positive effect exists between the number of patents registered and both the number of licenses and license income.

To verify the effect of the desorptive capacity of the second research hypothesis, a questionnaire survey was conducted for the heads or team leaders of the technology transfer departments in industry–academic cooperation foundations. The moderating effect of desorptive capacity was analysed using SEM. The desorptive capacity of the university's industry–academic cooperation foundation showed a significant relationship with the license income. However, it was not significant with the number of licenses. Consequently, desorptive capacity had a moderating effect only on the patent registration and license income.

There are several limitations to this study. First, the number of samples used in the analytical model is relatively small for statistical analysis. As there were only 140 industry-academia cooperation foundations, it is almost impossible to solve this problem systematically. Second, the results of the survey conducted to grasp the desorptive capacity could be biased, depending on the subjectivity of the respondents. The reliability and appropriateness of the research model were sufficiently secured from the reliability analysis, but there exist possibilities that the questionnaire can be biased by external factors such as the reputation of the university to which the respondent belongs or the work environment of the industry–academic cooperation organization. Third, this study has temporal limits.

Respondents' judgements on the desorptive capacity of industry–academic cooperation foundations are set in 2018, which is when the survey was conducted. However, those data on patent rights and technology transfer performances were based on the years 2014 to 2018. As the competency of industry–academic cooperation foundations can change significantly over time, the question of whether it is relevant to compare the intellectual property rights accumulated over a certain period of time and the performance of technology transfer based on the judgement of the competency at a certain time may arise. Fourth, this study did not consider the characteristics of each discipline in the university. The effect of patent rights on the number of licenses or license income may differ depending on the academic fields, such as life science, physics and applied engineering. Due to the limitations in data collection, this study could not consider those factors as control variables.

These limitations can be addressed in future studies. In order to ascertain the level of desorptive capacity in a more objective manner, it might be possible to supplement the survey through group discussions and quantitative and objective measurement indicators can be developed. The number of university patents, technology licenses and level of technology transfer income is stored in the database every year. Sensitivity analysis from the data collected over a long period of time might lead to a new result.

Author Contributions: Conceptualization, Y.K. and K.C.; methodology, Y.K.; software, Y.K.; validation, Y.K. and K.C.; formal analysis, Y.K.; investigation, Y.K.; resources, Y.K.; data curation, Y.K.; writing—original draft preparation, Y.K.; writing—review and editing, Y.K. and K.C.; visualization, Y.K.; supervision, K.C.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*; Harvard Business School Press: Boston, MA, USA, 2003.
2. Enkel, E.; Gassmann, O.; Chesbrough, H. Open R&D and open innovation: Exploring the phenomenon. *R D Manag.* **2009**, *39*, 311–316.
3. Gassmann, O.; Enkel, E.; Chesbrough, H. The future of open innovation. *R D Manag.* **2010**, *40*, 213–221. [CrossRef]
4. Cho, E.S. A study on the characteristics and rootedness of open innovation based on the type of companies in Korea. *J. Korean Policy Stud.* **2019**, *19*, 89–113. [CrossRef]
5. Coombs, J.E.; Bierly, P.E., III. Measuring technological capability and performance. *R D Manag.* **2006**, *36*, 421–438. [CrossRef]
6. Bianchi, M.; Chiesa, V.; Frattini, F. Selling technological knowledge: Managing the complexities of technology transactions. *Res. Technol. Manag.* **2011**, *54*, 18–26. [CrossRef]
7. Santoro, G.; Vrontis, D.; Thrassou, A.; Dezi, L. The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity. *Technol. Forecast. Soc. Chang.* **2018**, *136*, 347–354. [CrossRef]
8. Lichtenthaler, U. Outbound open innovation and its effect on firm performance: Examining environmental influences. *R D Manag.* **2009**, *39*, 317–330. [CrossRef]
9. National Research Foundation of Korea. *Industry-Academia Collaboration Manual*; National Research Foundation of Korea: Daejeon, Korea, 2015.
10. National Research Foundation of Korea. *Survey Report on Industry-Academic Cooperation Activities at Universities in 2018*; National Research Foundation of Korea: Daejeon, Korea, 2020.
11. Siegel, D.S.; Waldman, D.A.; Link, A.N. Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. *Res. Policy* **2003**, *32*, 27–48. [CrossRef]
12. Siegel, D.S.; Waldman, D.A.; Atwater, L.E.; Link, A.N. Commercial knowledge transfers from universities to firms: Improving the effectiveness of university–industry collaboration. *J. High Technol. Manag. Res.* **2003**, *14*, 111–133. [CrossRef]
13. Powers, J.B.; McDougall, P.P. University start-up formation and technology licensing with firms that go public: A resource-based view of academic entrepreneurship. *J. Bus. Ventur.* **2005**, *20*, 291–311. [CrossRef]
14. Miller, K.; McAdam, R.; McAdam, M. A systematic literature review of university technology transfer from a quadruple helix perspective: Toward a research agenda. *R D Manag.* **2018**, *48*, 7–24. [CrossRef]

15. da Silva, V.L.; Kovaleski, J.L.; Pagani, R.N. Technology transfer in the supply chain oriented to industry 4.0: A literature review. *Technol. Anal. Strateg. Manag.* **2019**, *31*, 546–562. [CrossRef]
16. Orazbayeva, B.; Plewa, C.; Davey, T.; Muros, V.G. The future of University-Business Cooperation: Research and practice priorities. *J. Eng. Technol. Manag.* **2019**, *54*, 67–80. [CrossRef]
17. Lee, C.-J.; Choi, J.-I. Factors influencing technology commercialization of universities in Korea: Systematic literature review on domestic research. *J. Korea Technol. Innov. Soc.* **2019**, *22*, 50–84. [CrossRef]
18. Olaya-Escobar, E.S.; Berbegal-Mirabent, J.; Alegre, I. Exploring the relationship between service quality of technology transfer offices and researchers' patenting activity. *Technol. Forecast. Soc. Chang.* **2020**, *157*, 120097. [CrossRef]
19. Rogers, E.M.; Yin, J.; Hoffmann, J. Assessing the effectiveness of technology transfer offices at US research universities. *J. Assoc. Univ. Technol. Manag.* **2000**, *12*, 47–80.
20. Carlsson, B.; Fridh, A.-C. Technology transfer in United States universities. *J. Evol. Econ.* **2002**, *12*, 199–232. [CrossRef]
21. Kim, K.; Hyun, S. Effects of Institutional Environments and Strategic Resources of University TLOs on Technology Commercialization. *J. Small Bus. Innov.* **2006**, *9*, 87–109.
22. Kim, C.-H.; Lee, S.-D. A study on relationships between performance of university-industry cooperation and competency factors of university. *J. Korea Technol. Innov. Soc.* **2007**, *10*, 629–653.
23. Lee, J.-H.; Cho, K.-T.; Lee, S.-S. The intellectual property factors affecting R&D outcome. *J. Digit. Converg.* **2014**, *12*, 203–213.
24. Yoon, Y.; Park, D. The Impact of the University's Capacity for the Industry-Academia Collaboration on the Performance of Technology Commercialization. *J. Soc. Sci.* **2015**, *26*, 157–177. [CrossRef]
25. Noh, S.-Y. The impact on earnings patent technology transfer business performance of the Industry-Academic Cooperation Foundation. *J. Korea Acad.-Ind. Coop. Soc.* **2016**, *17*, 394–399.
26. Thursby, J.G.; Thursby, M.C. Who is selling the ivory tower? Sources of growth in university licensing. *Manag. Sci.* **2002**, *48*, 90–104. [CrossRef]
27. Martinez, C.; Bares, L. The link between technology transfer and international extension of university patents: Evidence from Spain. *Sci. Public Policy* **2018**, *45*, 827–842. [CrossRef]
28. Liu, H.-Y.; Subramanian, A.M.; Hang, C.-C. Marrying the best of both worlds: An integrated framework for matching technology transfer sources and recipients. *IEEE Trans. Eng. Manag.* **2018**, *67*, 70–80. [CrossRef]
29. Cho, D.-W.; Shenkoya, T. Technology transfer: Economic factors that influence transferor and transferee's choice. *Technol. Anal. Strateg. Manag.* **2020**, *32*, 621–633. [CrossRef]
30. Arora, A.; Gambardella, A. Ideas for rent: An overview of markets for technology. *Ind. Corp. Chang.* **2010**, *19*, 775–803. [CrossRef]
31. Durack, K.T. Technology transfer and patents: Implications for the production of scientific knowledge. *Tech. Commun. Q.* **2006**, *15*, 315–328. [CrossRef]
32. Owen-Smith, J.; Powell, W.W. To patent or not: Faculty decisions and institutional success at technology transfer. *J. Technol. Transf.* **2001**, *26*, 99–114. [CrossRef]
33. Drivas, K.; Economidou, C.; Karamanis, D.; Zank, A. Academic patents and technology transfer. *J. Eng. Technol. Manag.* **2016**, *40*, 45–63. [CrossRef]
34. Nah, S.M.; Kim, C.O.; Lee, H. A Comparative Study of the Effect of University Competence on Technology Transfer and Commercialization and start-ups. *J. Korean Inst. Ind. Eng.* **2014**, *40*, 462–476.
35. Cohen, W.M.; Levinthal, D.A. Absorptive capacity: A new perspective on learning and innovation. *Adm. Sci. Q* **1990**, *36*, 128–152. [CrossRef]
36. Min, J.-W.; Vonortas, N.S.; Kim, Y. Commercialization of transferred public technologies. *Technol. Forecast. Soc. Chang.* **2019**, *138*, 10–20. [CrossRef]
37. Garengo, P. How bridging organisations manage technology transfer in SMEs: An empirical investigation. *Technol. Anal. Strateg. Manag.* **2019**, *31*, 477–491. [CrossRef]
38. Zahra, S.A.; George, G. Absorptive capacity: A review, reconceptualization, and extension. *Acad. Manag. Rev.* **2002**, *27*, 185–203. [CrossRef]
39. Lane, P.J.; Koka, B.R.; Pathak, S. The reification of absorptive capacity: A critical review and rejuvenation of the construct. *Acad Manag. Rev.* **2006**, *31*, 833–863. [CrossRef]
40. Lichtenthaler, U.; Lichtenthaler, E. Technology transfer across organizational boundaries: Absorptive capacity and desorptive capacity. *Calif. Manag. Rev.* **2010**, *53*, 154–170. [CrossRef]
41. Müller-Seitz, G. Absorptive and desorptive capacity-related practices at the network level–the case of SEMATECH. *R D Manag.* **2012**, *42*, 90–99. [CrossRef]
42. Hu, Y.; McNamara, P.; McLoughlin, D. Outbound open innovation in bio-pharmaceutical out-licensing. *Technovation* **2015**, *35*, 46–58. [CrossRef]
43. Bianchi, M.; Lejarraga, J. Learning to license technology: The role of experience and workforce's skills in Spanish manufacturing firms. *R D Manag.* **2016**, *46*, 691–705. [CrossRef]
44. Lichtenthaler, U.; Lichtenthaler, E. A capability-based framework for open innovation: Complementing absorptive capacity. *J. Manag. Stud.* **2009**, *46*, 1315–1338. [CrossRef]
45. Fosfuri, A. The licensing dilemma: Understanding the determinants of the rate of technology licensing. *Strateg. Manag. J.* **2006**, *27*, 1141–1158. [CrossRef]

46. Lichtenthaler, U. The drivers of technology licensing: An industry comparison. *Calif. Manag. Rev.* **2007**, *49*, 67–89. [CrossRef]
47. Rivette, K.G.; Kline, D. *Rembrandts in the Attic: Unlocking the Hidden Value of Patents*; Harvard Business Press: Boston, MA, USA, 2000.
48. Chesbrough, H.; Vanhaverbeke, W.; West, J. *Open Innovation: Researching a New Paradigm*; Oxford University Press: New York, NY, USA, 2006.
49. Maresch, D.; Fink, M.; Harms, R. When patents matter: The impact of competition and patent age on the performance contribution of intellectual property rights protection. *Technovation* **2016**, *57*, 14–20. [CrossRef]
50. Ziegler, N.; Ruether, F.; Bader, M.A.; Gassmann, O. Creating value through external intellectual property commercialization: A desorptive capacity view. *J. Technol. Transf.* **2013**, *38*, 930–949. [CrossRef]
51. Bravo, M.I.R.; Ruiz-Moreno, A.; Montes, F.J.L. Examining desorptive capacity in supply chains: The role of organizational ambidexterity. *Int. J. Oper. Prod. Manag.* **2018**, *38*, 534–553. [CrossRef]
52. Yoo, S. Development of an Instrument to Measure Desorptive Capacity. Master's Thesis, SungKyunKwan University, Suwon, Korea, February 2012.
53. Kim, H.; Kim, Y.; Cho, K. The effect of research and development investment and desorptive capacity on firm performance. *Asian J. Technol. Innov.* **2014**, *22*, 252–267. [CrossRef]
54. Choi, J. Identifying the moderating effect of desorptive capacity in the relationship between open innovation and firm performance. Master's Thesis, SungKyunKwan University, Suwon, Korea, February 2017.
55. Hatcher, L. *Advanced Statistics in Research: Reading, Understanding, and Writing up Data Analysis Results*; ShadowFinch Media, LLC: Saginaw, MI, USA, 2013.
56. Baron, R.M.; Kenny, D.A. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* **1986**, *51*, 1173–1182. [CrossRef]
57. Ping, R.A., Jr. Estimating latent variable interactions and quadratics: The state of this art. *J. Manag.* **1996**, *22*, 163–183. [CrossRef]
58. Kline, R.B. *Principles and Practice of Structural Equation Modeling*, 4th ed.; Guilford publications: New York, NY, USA, 2015.
59. Jang, S.; Shin, Y.; Jung, H. Relationship between R&D investment, technology management capability, and firm performance. *Korean J. Bus. Adm.* **2009**, *38*, 105–132.
60. Powers, J.B. Commercializing academic research: Resource effects on performance of university technology transfer. *J. Higher Educ.* **2003**, *74*, 26–50. [CrossRef]
61. Di Gregorio, D.; Shane, S. Why do some universities generate more start-ups than others? *Res. Policy* **2003**, *32*, 209–227. [CrossRef]
62. Park, G.; Kim, B.; Cho, H. A study on the determinants of the successful outcome of technological innovation and technology transfer in Korean Universities. *J. Ind. Prop.* **2011**, *35*, 149–198.