http://dx.doi.org/10.5392/IJoC.2013.9.2.038

Patented Knowledge And Its Commercialization

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ABSTRACT

We examine whether the attributes of patented knowledge have any impact on its chances of commercialization. It has been hypothesized that the scope and cumulativeness of patented knowledge would positively affect the likelihood of its commercialization. The hypotheses were tested using patents data on the US biotechnology and pharmaceutical industries. We found support for the prediction that the scope of patented knowledge increases the likelihood of commercialization, but we didn't find support for the cumulativeness aspect. These findings have important implications for firms that develop patentable knowledge, license-out patents, license-in patents from external sources, or debate about patenting strategy.

***Key words**: Patented Knowledge, Commercialization, and Scope of Patents*

1. INTRODUCTION

Patents are an element of knowledge stocks that firms hold and as such affect firm value. Prior theoretical and empirical studies have focused on the relationship between patent characteristics and its impact on patent value and ultimately firm value. Prior studies have demonstrated that patent scope (or breadth) has impact on firm value: [13], [27], [30], [37]; patents receiving more citations are more valuable: [21] and firms with highly cited patents have more market value: [10], [16]; patent scope affects the likelihood of litigation and consequently firm value: [29], [30], [37], among others. Thus, scholars have generally agreed upon that patents with certain characteristics are very valuable and firms with valuable patents would increase firm value and profitability.

But scholars have not paid much attention to the process in which valuable knowledge contributes to increasing firm value and profits. This is where we start. Then, how can valuable patents contribute to increasing firm value and profitability? One is licensing them out to other firms that are willing to develop products out of the patents, and the other is to develop products in-house using the patents. In other words, valuable patents contribute to firm value by becoming building blocks for product developments either in-house or outside of the firm. However, prior studies on patents characteristics and firm value have not paid much attention to the relationship between patents and their commercialization. We know that patented knowledge contributes to firm value by becoming the building blocks of new product development, but we don't know what kinds of patented knowledge have more potential to contribute to new product development and marketing. One notable exception is [36] in that they focused on the impact of patent characteristics on commercialization. But, their study has limitations in that they only focused on the commercialization of patents licensed out by a university. It is this gap that we intend to bridge by explicitly investigate the relationship between patents characteristics and their commercialization.

Regarding patents characteristics, we examine whether the scope and cumulativeness of a patent affect the chances of its commercialization. What we focus on is not whether patented knowledge is commercialized by its holder (i.e., in-house commercialization) or by external developers (i.e., licensed-out commercialization); but whether thepatented knowledge itself is commercialized at all. To test the hypotheses, we use data on the US biotechnology and pharmaceutical patents granted between 1981 and 1999.

We found support for our hypothesis that the scope of a patent would signal the potential values of this patent and thus would draw more potential developers; the scope had positive impact on the likelihood of the patent being commercialized. However, we didn't find support for the hypothesis that patents based on wide-ranging or large number of prior arts would be more easily integrated by external developers and thus would be more commercialized.

Patented knowledge brings profits to firms because this invention leads to new product developments or product improvements that directly affect the sales base of the firm. In this respect, this study wants to make a contribution by examining the link between the characteristics of patented knowledge and the likelihood of commercialization, either in-house or by external partners. Here commercialization refers to the event that a patent is used as a building block for new product development. A patent could be used as a building block for multiple products. In this respect, note that we are

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Manuscript received May. 10, 2013; revised May 31, 2013; accepted Jun 11, 2013

primarily concerned with utility patents that could become building blocks for new products, not process patents that may indirectly affect new product development.

2. THEORY AND HYPOTHESES

2.1 Patenting Invented Knowledge

For a successful commercialization, firms need to have technological experiences such as product knowledge as well as product-market experiences such as marketing: [35]. Securing necessary technological knowledge for new product development is the first step in new product development. Even though product-market experiences are complementary to technological experience in new product development, research shows that important drugs are more likely to reach the market sooner: [12]. This is particularly true in the case of the drug industry due to the long and rigorous FDA approval process: [3]. Thus, once new product innovation is achieved based on newly invented knowledge, we assume that this new product will be launched sooner or later and hereafter focus on the technological side of commercialization. To further narrow down the focus, we look into patented product knowledge.

Once a firm invents a new piece of knowledge that meets novelty, non-obviousness, and industrial application criteria, it should decide whether it would patent the new knowledge or keep it as a trade secret. The upside of patenting the invented knowledge is that the firm has an exclusive right over it for 20 years. The downside is that you need to disclose the knowledge or make it as public knowledge so that anyone can access to it.

Several factors affect the firm's patenting strategy. First, a firm's patenting strategy varies by sectors in which it operates. For certain sectors that rely on patenting as an effective means of rent appropriation, firms are more likely to patent their invented knowledge: [7], [16]. These sectors include such industries as pharmaceuticals, biotechnology, chemicals, and machinery industries. Second, firms patent their invented knowledge to preempt competition from their rivals or ward off any potential disputes from rival firms: [8], [17], [33], [43]. When firms patent their invented knowledge, they patent new inventions not only for future commercialization, but also for preemption of patent portfolios and/or future protection from any hold-up problems from rival firms. In a similar vein, [5] showed that R&D intensity had no effect on patenting propensity. Thus, when it comes to patenting, a firm's industry and strategic intent may play an important role.

Once a firm intends to patent a newly invented knowledge, it should file an application. In the application, it should specify two important features of a patent in question, among others. First, this firm should present *claims* that this firm purports to be novel, non-obvious, and industrially applicable so that the application deserves to be patented. Second, this firm should also cite *prior arts* or existing patents on which this application is built on. For both claims and prior arts, applicants specify when they file an application. But the authority to finalize claims and prior arts is reserved for the examiner of the application in question. With respect to claims, the examiner's authority makes it clear that applicants cannot just add claims without serious reasons. And regarding prior arts, the examiner makes sure how the application relates to existing patents and in doing so limits the rights granted to the application: [4].

No two patents can have the same claims and prior arts. In this sense we may argue that a patent's claims and prior arts define its identity or unique place in the universe of patents or patented knowledge. Claims represent a window of opportunities that a patent can offer to its holders or licensees, whereas prior arts represent a linking pin that connects this patent with the existing body of patents. As such, we further argue that a patent's claims and prior arts can provide us with an idea about the chances of this patent's commercialization.

2.2 Scope of Patented Knowledge and Commercialization

For any commercialization, the first step is to search for any potential product knowledge that can be used for new product development. And in this process firms trigger search cost. Typically it is more costly to do distant search and learning: [18], [19], [31], [35]. But for public knowledge like patented knowledge, the search cost itself is not significant since all the knowledge can be accessed with ease. Patented knowledge, by definition, receives an exclusive right over it or full protection from any infringements by other parties in exchange for its disclosure to public. So anyone who is interested in a patent can access it by searching for patent database typically run by governments. Thus, we can say that the search cost for public knowledge such as patented knowledge is not a big issue in commercialization.

Since search cost is not a big issue and firms can search for any kinds of patented knowledge with ease, firms may search for certain characteristics that signal the potential value of the patented knowledge in question. We argue that a patent with a broad scope of claims signals that it is more valuable and has a potential to contribute to firm value. This is because claims may represent "the technology or product "space" being protected by the patent": [29]:141 and thus, more claims mean more technology space that the patent holder can exclusively utilize or at least preempt from rival firms.

Research findings show that the breadth of a patent positively affects the value of the patent in question. For example, [27] and [13] assumed, in their search for the optimal breadth of patents, that the breadth positively affects firm profits. Using biotechnology patents data, [30] also found out that the breadth of patent affects the firm valuation in a positive way. In a bit different vein, [29] demonstrated that the breadth of a patent increases the chances of legal disputes over this patent with other firms, which may imply that patent breadth could bring in negative profits to the firm. However, this may also imply that legal disputes intensify because patents with broad scope are typically more valuable and thus invite more legal disputes. With regard to commercialization, [36] found that university patents with broad scope were more commercialized by external developers.

A patent with wide range of scope will have higher chances of being selected for new product development because of its wide range of applications. Not all new product developments will succeed, but other things being equal, the more a patent is used for new product development, the higher the chances that this patent will be commercialized at the end.

Hypothesis 1 *The broader the scope of patented knowledge is, the higher the chances of its commercialization.*

2.3 Cumulativeness of Patented Knowledge and Commercialization

No knowledge can be invented without relying on prior knowledge or prior arts as in patent knowledge. In this sense knowledge advancement is quite cumulative in nature. This is true whether newly invented knowledge is a drastic improvement over the existing body of knowledge or an incremental one. Thus, the existing body of knowledge that serves as the building blocks of newly invented knowledge represents the cumulative nature of any knowledge invention. This is also true in patented knowledge. And if we look into the building blocks of newly invented knowledge, we can trace the genealogy of this new invented knowledge. In the universe of patents, *prior arts* represent the cumulative nature of patented knowledge: [43].

Related to prior arts, an important cost that firms should consider in selecting patented knowledge for commercialization is transfer cost. Typically transfer cost involves importing knowledge from its owner to its users, and this cost goes up if knowledge is sticky: [18], [19], [40], [42]. This explains why many firms form alliances to facilitate a smooth inflow of novel knowledge. Research findings demonstrate that knowledge is more easily transferred among alliance partners: [14], [28], [34], [38]-[39]; and knowledge spillover is geographically localized: [6], [25], [26].

As can be shown in the above-mentioned research findings, even for public knowledge such as patents, firms should trigger transfer cost when they import knowledge from outside sources. This is because knowledge has both public and private components: [2], [22], [32]. Private knowledge includes firm-specific routines, processes, or trade secrets, whereas public knowledge is not firm-specific but is present in the external environment, in many cases in the form of codified knowledge, notably patents. And private knowledge and public knowledge are complementary to each other in most innovations.

The ability of a firm to assimilate public knowledge is contingent upon this firm's ability to understand the private knowledge within which the public knowledge is embedded: [11], [22]. Even though much attention has been paid disproportionately to the 'tacit' aspect of knowledge, many prior studies have found that firms benefit from public knowledge as evidenced by firms' patent citations: [9], [14], [23], [24], [26]. And tacit knowledge affects firm performance through its indirect effect on learning explicit knowledge: [9].

Prior arts that are used as building blocks for newly patented knowledge may work as an indicator whether newly patented knowledge could be easily assimilated with the internal knowledge base of the firm that did not invent it. If newly patented knowledge is based on the prior arts that are either invented by this firm or used as a building block for this firm's stock of patented knowledge, this firm may find it rather easy to assimilate the newly patented knowledge in its new product development. Thus, the chances of commercialization of this newly patented knowledge may increase. And this possibility may increase as more pieces of prior arts are used as building blocks for this new knowledge or prior arts come from diverse backgrounds. In sum, as patented knowledge is more cumulative, it has more chances of sharing private component with other patents or patents holders, which in turn increases the likelihood of commercialization.

Hypothesis 2 *The more cumulative the patented knowledge is, the higher the chances of its commercialization.*

3. METHODS

3.1 Sample Description

We used data on the US biotechnology and pharmaceutical industries. The total number of observations is 15,034 and the unit of analysis is patent. The data for this study come from three sources: the US patent data: [16], drug information accumulated by *Recombinant Capital*, and *Compustat* data. The US patent data stacked by [16] provide the most extensive information on the utility patents granted by the US Patent and Trademark Office (USPTO) between 1963 and 1999. These data include patent number, patent application year, grant year, assignee information, the number of claims made, main patent class, inventor information, and patent citation information, among others. This study uses the patents that were granted in the classes of biotechnology and pharmaceutical industries between 1981 and 1999.

Drug information was collected from the database accumulated by *Recombinant Capital*. For the brand drugs that are marketed, these dataset include information that links patents and drugs. Specifically the dataset shows which patents are used for a certain brand drug. For some brand drugs, a couple of patents were used for its development, whereas for some others, more than 5 patents were used. Conversely, a patent could be used for multiple drugs. Thus, these dataset only include those patents that were used for brand drugs.

And to include firm-level financial information of the assignees in the data, we used *Compustat* annual firm financial files. We included firm assets and R&D expenses when a certain patent was granted. Because of this inclusion, the total number of observations was reduced to the current level from more than 70,000 patents that were granted between 1981 and 1999.

Patent data, however, have limitations: [4],[42]. First, not all innovations are patentable. The requirements for an innovation to be patentable are that it should be novel, non-obvious, and industrially applicable. Second, patenting itself is a strategic decision that firms choose instead of keeping an innovation as trade secrets. These limitations indicate that there may be many innovations that are either non-patentable or kept secret instead of being patented and disclosed. It is not feasible to quantify the portion of these 'excluded' innovations. However, it is assumed that the impact from the omission of these patents is not that severe. But, of course, this is an empirical question.

In spite of the general limitations of using patent data in knowledge commercialization, we believe that patent information is much more informative, at least, for the biotechnology and pharmaceutical industries. Unlike many other industries where many firms intentionally keep their new innovations as trade secrets, biotechnology and pharmaceutical firms have higher tendencies to patent their newly discovered innovations. In these industries, patent regime has been well implemented that many firms try to patent rather than leave the innovations as trade secrets. For example, for European pharmaceutical firms, sales-weighted patent propensity rate of product innovation was found 79.2%: [7]. So we believe that, for the biotechnology and pharmaceutical industries, these limitations are somewhat alleviated.

3.2 Dependent Variable

The dependent variable is an event of commercialization of a patent in question. A patent is commercialized when it is cited as a building block for at least one drug that is approved for by the US Food and Drug Administration (FDA) or already in sale. This variable is a dummy variable where 1 indicates an event of commercialization.

3.3 Independent Variables

3.3.1 Scope of Patented Knowledge: The scope of patented knowledge was measured by counting the number of claims made by the patent in question: [16], [29]. When a patent application is finally granted for patent protection, each patent includes the section 'Claims.' Claims are numbered paragraphs that accurately describe all the unique and essential features of the invention: [4], and the number of claims may indicate the scope or width of the invention: [16]. Thus, whenever a legal dispute erupts, it typically involves around the claims of the invention. As mentioned earlier, even though patent applicants specify the character of claims, the ultimate authority to determine the number or content of claims resides with the examiner of the patent application in question: [4], which renders further validity of this measure in capturing any potential value of patented knowledge in question.

Related to the current measure of patent scope, [30] and [36] measured patent scope as the number of 4-digit International Patent Classification (IPC) subclasses to which a patent is assigned by the examiner. Unfortunately, we could not calculate [30]'s IPC-based measure and compare the result with that of our own measure due to the lack of the information. However, it should be noted that, our measure captures the essence of patent protection since our measure has legal implications on patent protection, whereas [30]'s measure does not.

3.3.2 Cumulativeness of Patented Knowledge: The idea of cumulative patented knowledge is whether the newly patented knowledge is more easily integrated with other knowledge. Ease of integration with other knowledge is critical in that multiple pieces of patented knowledge constitute a new product. Thus a patented knowledge with immense potential for applications may not be used as a building block for new products if it is not easily put together with other important pieces of existing or newly patented knowledge. Cumulative nature of knowledge addresses this concern. Thus, the measure should capture the potential of being integrated with prior and newly patented knowledge.

For the cumulative nature of newly patented knowledge, we used two measures: (1) the number of prior arts cited by the patent in question; and (2) the diversity of prior arts cited by the patent in question. The former measure captures the probability of whether patented knowledge based on more prior knowledge gets more commercialized, whereas the latter captures whether patented knowledge based on diverse prior knowledge gets more commercialized. The diversity measure was constructed as an HHI capturing the diversity of patent classes that each prior art belongs to: [16]. High value means that patented knowledge in question is built on prior arts from many different patent classes.

As mentioned earlier, even though patent applicants specify prior arts, the ultimate authority to determine which prior arts are relevant resides with the examiner of the patent application in question: [4]. This renders further support for the validity of this measure in capturing whether patented knowledge is built on more and diverse prior arts or not.

3.4 Control Variables

To control for any potential impact from patent-level factors, we controlled for several variables. First, to control for the nationality of the inventor and assignee, these two variables were included as dummy variables. Since the data are from the USPTO, it was controlled for any potential advantage on the side of the U.S. inventors and assignees. Thus, U.S. inventors and assignees were coded as 1, whereas other nationalities were coded as 0. And to control for any differences that biotechnology patents may have over pharmaceutical patents, biotechnology patents were coded as 1 and pharmaceutical patents as 0. And to control for any potential impact from inventors: [25], [26], we controlled for the number of inventors. The rationale is that a patent that was developed by more inventors may get more commercialized. And to control for any potential impact of newness of prior arts of patented knowledge, we included mean-year-lag of cited prior arts for each patent. Thus, low value means that cited prior patents are relatively new patents, whereas high value means the opposite. To check for whether patents built on their assignee's own prior knowledge may get more commercialized, we included self-citation ratio that captures the proportion of the cited patents that were granted to the same assignee of the patent in question.

And to control for assignee-level (i.e., firm-level) factors that may affect the outcome, we included firm assets, R&D expenditure, and the number of patents owned by the assignee in question. R&D expenditure directly captures the assignee's capability to invent and patent knowledge, whereas firm assets capture the firm's ability to muster and deploy resources. In the biotechnology and pharmaceutical industries, firms typically patent their inventions: [7]. And the number of patents owned by the assignee firm represents this firm's knowledge stock and its ability to absorb knowledge or absorptive capacity: [9], [34].

To obtain the estimates for the hypothesis testing, logistic regression analysis was used. In addition, assignee-specific fixed- and random-effects estimations were also conducted to see whether there are any systematic differences from regular logistic regression analysis. And to make sure that the results are robust, some additional analyses were also conducted.

4. RESULTS

The descriptive statistics and correlation coefficients are shown in Table 1. Out of 15,034 patents in the current data, only 239 patents were actually used for developing new drugs that are sold in the US, which is about 1.6 %

Table 1. Descriptive Statistics and Correlation Coefficients.

	Variables	Mean	Std Dev	1	2	3	4	5	6
1	Knowledge Commercialization	0.02	0.13						
2	Biotechnology (=1)	0.20	0.40	-0.06 *					
3	U.S. Inventor (=1)	0.89	0.31	-0.02 *	0.00				
4	U.S. Assignee (=1)	0.95	0.23	-0.03 *	-0.03 *	0.63 *			
5	Self-citation Ratio	0.27	0.35	0.03 *	-0.07 *	0.05 *	0.05 *		
6	Mean-year-lag of Citations Made	8.77	5.76	0.01	-0.10 *	0.01	-0.01	-0.27 *	
7	Number of Inventors	2.65	1.62	0.03 *	0.03 *	-0.06 *	-0.05 *	-0.02	0.02
8	ln(Number of Patents for the Assignee)	4.88	1.57	0.03 *	-0.11 *	0.06 *	0.12 *	0.18 *	-0.01 *
9	ln(Firm Assets)	8.39	1.53	-0.02 *	-0.06 *	-0.03 *	0.00	-0.01	0.04 *
10	ln(R&D Expenditure)	5.73	1.49	-0.02 *	-0.05 *	-0.04 *	-0.01	0.00	0.01
11	Knowledge Scope (Number of Claims)	14.60	12.70	0.03 *	0.00	0.05 *	0.03 *	-0.05 *	-0.01
12	Knowledge Cumulativeness (Number of Citations Made)	6.97	7.96	0.03 *	-0.09 *	0.08 *	0.06 *	-0.05 *	0.18 *
13	Knowledge Cumulativeness (Diversity of Citations Made)	0.34	0.27	0.02 *	-0.09 *	0.06 *	0.05 *	-0.12 *	0.22 *

	Variables	7	8	9	10	11	12
8	ln(Number of Patents for the Assignee)	0.18 *					
9	ln(Firm Assets)	0.09 *	0.51 *				
10	ln(R&D Expenditure)	0.13 *	0.62 *	0.91 *			
11	Knowledge Scope (Number of Claims)	0.06 *	-0.04 *	-0.03 *	-0.02 *		
12	Knowledge Cumulativeness (Number of Citations Made)	0.09 *	0.00	-0.02 *	-0.07 *	0.09 *	
13	Knowledge Cumulativeness (Diversity of Citations Made)	0.02 *	-0.03 *	-0.02 *	-0.04 *	0.06 *	0.39 *

[a] *N*=15,034

Table 2. Results of Logistic Regression Analysis

Independent Variables		Model 1	Model 2	Model 3
Intercept		-2.88 **	-3.16 **	-3.26 **
		(0.47)	(0.47)	(0.48)
Biotechnology (=1)		-3.41 **	-3.40 **	-3.36 **
		(0.71)	(0.71)	(0.71)
U.S. Inventor (=1)		-0.01	-0.03	-0.06
		(0.28)	(0.28)	(0.28)
U.S. Assignee (=1)		-1.16 **	-1.17 **	-1.21 **
		(0.33)	(0.33)	(0.33)
Self-citation Ratio		0.48 *	0.51 **	0.54 **
		(0.19)	(0.20)	(0.20)
Mean-year-lag of Citations Made		0.01	0.01	0.01
		(0.01)	(0.01)	(0.01)
Number of Inventors		0.07 +	0.06	0.06
		(0.04)	(0.04)	(0.04)
ln(Number of Patents for the Assignee)		0.28 **	0.29 **	0.29 **
		(0.07)	(0.07)	(0.07)
ln(Firm Assets)		-0.10	-0.08	-0.10
		(0.11)	(0.11)	(0.11)
ln(R&D Expenditure)		-0.21 +	-0.23 *	-0.20 +
		(0.12)	(0.11)	(0.12)
Knowledge Scope (Number of Claims)	H1 (+)		0.01 **	0.01 **
			(0.00)	(0.00)
Knowledge Cumulativeness (Number of Citations Made)	H2 (+)			0.01
				(0.01)
Knowledge Cumulativeness (Diversity of Citations Made)	H2 (+)			0.27
				(0.28)
Log likelihood		-1128.94	-1123.25	-1121.68
Pseudo-R^2		0.0799	0.0845	0.0858
LR χ^2		195.99 **	207.36 **	210.51 **
d LR ?^{2}			11.37 **	3.15

[a] + p<.1, * p<.05, ** p<.01
N =15,034

For the patents that were granted during this period, they cited, on average, 7 prior arts as building blocks. And they claimed about 14.6 claims for protection from any potential infringements by others. The correlation coefficients do not show any irregularities that need a special attention other than the coefficient between *ln* (Firm Assets) and *ln* (R&D Expenditure), which is 0.91. This indicates that R&D expenses are high for big firms, which is not surprising from the fact that big biotechnology and pharmaceutical firms undertake large

scale new product developments. To check out whether this high correlation affects the outcome, we analyzed the same data excluding either *ln* (Firm Assets) or *ln* (R&D Expenditure) from the equation. The results did not show any notable differences for other variables in the equation except that the coefficient of the included variable is a bit higher in magnitude. So both variables are included in the equation.

The results of logistic regression are presented in Table 2. Model 1 is a baseline model that includes control variables only. Among the control variables, the coefficients of biotechnology, US assignee, self-citation ratio, *ln* (Number of patents for the assignee) and *ln* (R&D Expenditure) turned out to be statistically significant.

The coefficient of biotechnology implies that when the patent is a biotechnology patent, the odds of the commercialization of this patent decreases by a multiplicative factor of 0.03 (i.e., *exp* (-3.41)), compared with pharmaceutical patents in the data. However, the mean-year-lag of citations made and the number of inventors did not show any statistically significant outcomes. Grant years were also included in the analyses as dummy variables. The coefficients are not reported to conserve space.

Table 3. Results of Assignee-specific Fixed- Effects Estimation

Independent Variables		Model 1	Model 2	Model 3
Biotechnology (=1)		−2. 97 **	−2. 95 **	−2. 94 **
		(0. 72)	(0. 72)	(0. 72)
U.S. Inventor (=1)		−0. 09	−0. 14	−0. 14
		(0. 30)	(0. 30)	(0. 30)
U.S. Assignee (=1)		0. 54	0. 55	0. 54
		(4. 39)	(4. 32)	(4. 58)
Self-citation Ratio		0. 28	0. 31	0. 33
		(0. 22)	(0. 22)	(0. 22)
Mean-year-lag of Citations Made		0. 01	0. 01	0. 01
		(0. 01)	(0. 01)	(0. 01)
Number of Inventors		0. 04	0. 03	0. 03
		(0. 04)	(0. 04)	(0. 04)
ln(Number of Patents for the Assignee)		0. 06	0. 02	0. 02
		(0. 28)	(0. 28)	(0. 28)
ln(Firm Assets)		0. 31	0. 32	0. 31
		(0. 26)	(0. 26)	(0. 26)
ln(R&D Expenditure)		0. 12	0. 08	0. 08
		(0. 26)	(0. 26)	(0. 26)
Knowledge Scope (Number of Claims)	**H1 (+)**		0. 01 **	0. 01 **
			(0. 00)	(0. 00)
Knowledge Cumulativeness (Number of Citations Made)	**H2 (+)**			0. 00
				(0. 01)
Knowledge Cumulativeness (Diversity of Citations Made)	**H2 (+)**			0. 40
				(0. 30)
Log likelihood		-939.372	-934.79	-933.866
LR χ^2		84.9 **	94.07 **	95.91 **
dLR χ^2			9.17 **	1.84

[a] + p<.1, * p<.05, ** p<.01
N=10,310

The positive sign of the variable self-citation ratio implies that patents built upon their assignee's prior arts get more commercialized. And the coefficient of *ln* (Number of patents for the assignee) indicates that patents held by firms with more knowledge stock will be more commercialized. Even though it is not reported here, additional analyses show that patents with higher level of self-citation ratio and *ln* (Number of patents for the assignee) are more commercialized by the patent-holder than by outside firms. And the negative coefficient of *ln* (R&D Expenditures) indicates that patents granted to firms with higher R&D expenditures get less commercialized. This may be due to the fact that firms with big R&D spending may get more patents, but since the likelihood of drug approval is quite low, the actual probability of a patent to be commercialized by big firms may end up lower than that of smaller firms.

Model 2 introduces the variable to test Hypothesis 1 which posits that when patented knowledge has wide range of scope, it has higher chances of commercialization. The coefficient is positive and statistically significant. This indicates that when a patent can secure one more claim for protection, the chances of its commercialization increases by a factor 1.014 (i.e., *exp*(.014)).Thus, Hypothesis 1 is supported.

Model 3 introduces two new variables to test Hypothesis 2 which posits that the more patented knowledge is cumulative of prior knowledge base, the higher the chances of commercialization. The coefficients of the number of citations made and the diversity of citations made are not statistically significant. Thus, Hypothesis 2 is not supported.

To check out whether the results are quite sensitive to the estimation methods, a couple of additional analyses were conducted. First, we obtained assignee-specific fixed-effects estimates to see whether unobservable time-invariant assignee-specific characteristics cause any significant differences from the logistic regression results. The results of assignee-specific fixed-effects estimation are presented in Table 3. Note that the number of total observations used in the analysis was substantially reduced to 10,310. This is due to the omission of the observations of assignees that are all positive or negative with regard to a commercialization event. The coefficients for the main variables are quite similar to the results of the logistic regression.

Second, we also obtained assignee-specific random-effects estimates to see any systematic differences. Since patents of the same firm may share certain characteristics, we used assignee-specific random-effects estimation that lets the patents of the same firm correlate with one another. The results are presented in Table 4. The coefficients of this estimation are similar to those of the logistic estimation and we could not find any systematic differences. But the likelihood-ratio test of the ρ is statistically significant, which implies that the panel-level variance component is important and the assignee-specific random-effects estimator is different from the pooled estimator (i.e., logit). And the Hausman test showed that random-effects estimation results are not systematically different from those of fixed-effects estimation.

Table 4. Results of Assignee-specific Random-Effects Estimation.

Independent Variables		Model 1	Model 2	Model 3
Intercept		−3.69 **	−3.96 **	−4.06 **
		(0.89)	(0.88)	(0.88)
Biotechnology (=1)		−3.27 **	−3.27 **	−3.26 **
		(0.72)	(0.72)	(0.72)
U.S. Inventor (=1)		−0.09	−0.14	−0.14
		(0.29)	(0.29)	(0.30)
U.S. Assignee (=1)		−1.65 **	−1.66 **	−1.68 **
		(0.55)	(0.55)	(0.55)
Self-citation Ratio		0.26	0.28	0.30
		(0.22)	(0.22)	(0.22)
Mean-year-lag of Citations Made		0.01	0.01	0.01
		(0.01)	(0.01)	(0.01)
Number of Inventors		0.05	0.03	0.03
		(0.04)	(0.04)	(0.04)
ln(Number of Patents for the Assignee)		0.12	0.12	0.13
		(0.12)	(0.12)	(0.12)
ln(Firm Assets)		−0.21	−0.18	−0.18
		(0.15)	(0.15)	(0.15)
ln(R&D Expenditure)		0.24	0.21	0.22
		(0.17)	(0.17)	(0.17)
Knowledge Scope (Number of Claims)	**H1 (+)**		0.02 **	0.02 **
			(0.00)	(0.00)
Knowledge Cumulativeness (Number of Citations Made)	**H2 (+)**			0.00
				(0.01)
Knowledge Cumulativeness (Diversity of Citations Made)	**H2 (+)**			0.31
				(0.29)
σ_v		1.14	1.12	1.12
ρ		0.28	0.28	0.28
Log likelihood		-1087.9	-1081.98	-1081.43
Wald χ^2		63.64 **	77.02 **	77.73 **

[a] + p<.1, * p<.05, ** p<.01
N=15,034

To further test whether the main variables of interest exhibit any differences between in-house commercialization and licensed-out commercialization, group-mean t-test was conducted on the number of claims, the number of citations made, and the diversity of citations made. The results are mixed. For the variables ‘the number of claims’ and ‘diversity of citations made’, we could not find any statistically significant differences between in-house and licensed-out commercialization. However, for the variable ‘the number of citations made’, we found a statistically significant difference between the two types of commercialization: licensed-out commercialization, on average, has cited 10 prior citations whereas in-house commercialization 8 citations (p<.05). This indicates that for licensed-out commercialization, prior arts may play a bigger role, which is not surprising since integration is more problematic for licensed-out commercialization.

5. CONCLUSIONS AND DISCUSSION

We have examined whether the characteristics of patented knowledge can affect its commercialization. The results demonstrate that the scope of patented knowledge, measured by the number of claims, has a positive impact on commercialization. However, we didn’t find support for the positive relationship between the cumulativeness of patented knowledge – measured by the number and diversity of prior arts – and commercialization.

We believe this study makes important contributions to the literature on knowledge in general and on patents in particular. First, by investigating the relationship between patented knowledge characteristics and commercialization, our study bridges the missing link between patented knowledge characteristics and firm valuation: [13], [27], [30], [37]. The results demonstrated that patents with broad scope make positive contributions to firm value because they have higher chances of commercialization. And group-mean t-test results also demonstrate that this positive relationship holds both for in-house and licensed-out commercialization. Our study expands [36] in that they only focused on licensed-out commercialization of patents developed by a university.

Second, by measuring the scope of patented knowledge by the number of claims, our study expands the tools of measuring patented knowledge. The measure "claims," probably one of the most important items in any patent, was underutilized in patent-related studies: [16], [29]. Typical studies on patent data have used patent citations disproportionately: [10], [14], [15], [20]-[22]. This study sheds new light on the use of claims in patent-related research.

And our study also provides some implications for patenting strategy. Patenting itself is a strategic decision that is affected by the sector the firm belongs to: [7], [29], [30] and by the firm's incentive to preempt competition from rivals: [8], [17], [33], [43]. According to our results, when the intellectual property regime is in place as in the biotechnology and pharmaceutical industries, firms may be better off patenting their invented knowledge if this knowledge is sufficiently broad in scope. In other words, if the knowledge is more commercializable, then patent it. However, firms should also be aware of [29]'s finding that patents with broad scope invite more patent litigation.

For small biotechnology firms that specialize in developing commercializable knowledge and license it out or sell it off to large drug companies, our results suggest these firms may be better off developing new knowledge that is broad in scope. Firms that produce commercializable knowledge have more chances of rent appropriation at a later stage. Rent appropriation from your own invented knowledge takes several forms. You may develop products on your own, which is very unlikely for small biotechnology firms; or you may license the knowledge to other firms so that you get upfront lump-sum payment and royalties; or you may simply sell the knowledge to other firms and get lump-sum payment in return. Whatever the intentions, focusing on the knowledge characteristics leading to higher commercialization is critical, especially for small firms that work as a research lab.

Regarding the hypothesized impact of the cumulativeness of the patent on its commercialization prospect, we didn't find support. This result may be due to a couple of possibilities. One possibility is that the measures we used may also represent the originality or pioneering nature of the patented invention. Some of prior studies argue that lack of prior arts indicates that the patented invention is a groundbreaking one: [5], [36]. According to these studies, groundbreaking patents get more commercialized. And the diversity measure we used was also used to capture the originality of the patented invention: [16]. According to [16], patents that are built upon prior arts from narrow patent classes are original. Thus, these two measures may also represent the opposite (i.e., negative) impact on commercialization.

The other possibility is that, for patents, the impact of the private component on commercialization may not be as significant as we originally thought. The role of private component is that this aspect of knowledge helps integrating knowledge. Patents, especially utility patents that we have used for hypothesis testing, represent an extreme form of codified knowledge. And since patents are granted to give the holder an exclusive right over them, the level of codification of the invention should be high. This high level of codification may make the role of private component less relevant in commercialization.

Finally, our study has a couple of limitations. First, we used data on the biotechnology and pharmaceutical industries, which poses a certain limit on generalizing the findings. These industries are unique in the sense that patenting is an effective means of rent appropriation, which is why biotechnology and pharmaceutical firms patent their invention far more than the firms in other industries: [37]. Thus, for those industries where patents are not critical for rent appropriation, the findings may not be applicable. Second, our data only included the patents developed by firms, but not those patents that were developed by universities. For example, university patents differ from corporate patents in that the former are more basic compared to the latter: [41], which may have certain impact on commercialization. In this respect, [36] complements our findings.

Despite these limitations, this paper shows that certain characteristics of patented knowledge positively affect the chances of commercialization. It has been hypothesized and tested that the scope and cumulativeness of patented knowledge positively affect the likelihood of commercialization of this patent. The results support the prediction that the scope of patented knowledge increases the likelihood of commercialization of this patent. These findings have important implications for firms that develop patentable knowledge, license-out patents, license-in patents from external sources, or debate about patenting strategy.

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