

Using Patent Portfolio to Effectively Manage Technical Assets: The Mechanism of Patent Portfolio to Influence Firm Performance

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Abstract: Patent portfolio analysis can be a useful approach to understand technological capabilities. However, little attention has been given to elaborate the mechanism of patent portfolio to firm performance. This paper does an empirical study about how patent portfolio size, patent portfolio diversity and technical scope contribute to firm performance based on panel data of 99 Chinese companies from 2013 to 2017. We incorporate technological opportunity as moderator. Our result indicates that patent portfolio with larger size and broader technical scope can have a positive effect on firm performance, but a more diverse patent portfolio can have a negative effect on firm performance. Technological opportunity has a positive effect on the relationship between technical scope and firm performance; however technological opportunity has a negative effect on the relationship between patent portfolio size, patent portfolio diversity and firm performance.

1 INTRODUCTION

The influence of patent strategy on the competitiveness of knowledge-intensive firms has been a focus of IPR management. As the patenting environment becomes more puzzling, patent portfolio grows to be the basic analysis unit for the formulation and implementation of patent strategy (Parchomovsky and Wagner, 2005). The characteristics and compositions of patent portfolio can influence firm performance (Ceccagnoli, 2009), but the mechanism behind this phenomenon has not yet been elaborated. Therefore, it is of great theoretical and practical significance to make out how patent portfolio influence firm performance.

Parchomovsky and Wagner (2005) have presented a systematic introduction to the concept of patent portfolio as well as its compositions. Then many scholars have explored this subject from different perspectives (Ernst, 1998). The knowledge-based view of the firm stresses that patent portfolio reflects the absorptive capability of knowledge, and influences the effects of knowledge diffusion within the firm (Zhang et al., 2007). The resource-based view demonstrates that patent portfolio enables the

enterprise to acquire complementary resources and exert a beneficial influence on the enterprise's financing ability, alliance ability, and eventually, on enterprise performance. Levitas et al.(2009) and Grimpe et al.(2015) have conducted empirical studies showing that patent portfolio within the enterprise may deliver a positive signal to market. Luo (2017) demonstrated that well-managed patent portfolio bolsters bargaining power of enterprises and gives enterprises an advantage in patent litigation (Arts et al., 2009).

Liu and Li introduced the concept of patent portfolio around 2004, and scholars covered its compositions in greater detail later. Recently, Guo and Chen applied the two-dimensional analysis proposed by Narin and Ernst to measure the effect of patent portfolio in automotive on the improvement of technological innovation ability (Liao, 2014). Kang explored new ways to assess the value of patent portfolio. Generally speaking, patent portfolio has long been the focus for the west scholars, while the empirical studies are far from enough in China.

Based on prior work, we can see some deficiencies of present literature about patent portfolio. Firstly, although some scholars have

founded that patent portfolio diversity negatively influence firm performance based on data of foreign companies, there have been few empirical studies using the data of Chinese firms and other characteristics are ignored. Secondly, the mechanism of how patent portfolio impacts on enterprise performance has never been scrutinized. This paper empirically analyzes how patent portfolio influence enterprise performance by using patent data from 99 Chinese firms belonging to the manufacturing industry of electronic and telecommunications equipment (MIEEE blow). We introduce the technological opportunity as the moderator variable and build a theoretical model to illustrate how patent portfolio size, patent portfolio diversity and technical scope act on enterprise performance.

2 LITERATURE AND CONCEPTUAL DEVELOPMENT

2.1 Patent Portfolio and Firm Performance

Patent portfolio theory explains the phenomenon of “the patent paradox” (Parchomovsky and Wagner, 2005). The concept of patent portfolio is derived from technology portfolio (Ernst, 1998). Parchomovsky and Wagner (2005) provided a definitional basis of distinct-but-related patents. The Patent Corporation Treaty (PCT) interprets the patent portfolio as a collection of patents owned by a single entity and the patents may be related or unrelated. Based on the prior work (Ernst, 1998; Lin et al., 2006), this paper focuses on the patent portfolio at the firm level, and defines the patent portfolio of year i as the aggregation of patents applied by the enterprise from year $i-4$ to year $i-1$. A well-designed Patent portfolio can be process-oriented, problem-oriented or product-oriented. Such patent portfolios pay attention to the whole efficacy, and the patents within the portfolio may be complementary or alternative so as to form the superiority in the intense market competition. The patents applied for have increased progressively as enterprises grow, and we call this “organically accumulated patent portfolio”. The industrial characteristics and the market competition structures may decide the critical quantity. The organically accumulated patent portfolio can't provide effective protection due to the weak correlation among patents, and it is easier to be imitated or even outstripped by competitors.

The quantity of individual component patents involved indicates the size of patent portfolio (PPS below). Researches pointed out that all the benefits of a patent portfolio are broadly proportional to the size (Parchomovsky and Wagner, 2005). Some advantages generated by a greater amount of patents will be sketched below. Firstly, larger numbers of patents can enhance the overall technological value of the portfolio. High-value patents grow increasingly difficult to obtain and more patents may makes up for the quality defect. Patent portfolio is more valuable than the simple sum of individual patents. Secondly, more patents with adjacent claims may expand the scope of protection and enhance its defensive capability. Complementary patents for the core patent can bolsters bargaining power of enterprises (Luo et al., 2017). Steensma suggested that a well-crafted patent portfolio is more likely to prevent competitors so as to gain a quasi monopolistic position in market. Thirdly, more patents contribute to attract external resources. Turanay et al. (2016) conducted an empirical study showing that investors regard the patent application activity in knowledge-intensive industry as positive signal of technical superiority, which will heighten the stock price and market value. Levitas and Mcfadyen (2009) also demonstrated that positive signal of patenting can stabilize shareholders' confidence, improve financing capacity and reduce the cost of holding excessive liquidity during R&D activities. Based on these analyses, the following hypothesis is proposed:

H1a The patent portfolio size is positively related to firm performance.

A well-crafted patent portfolio should seek a balance between size and diversity. Turanay measured patent portfolio diversity (PPD below) as the distribution of patents across different categories of technology (Turanay et al., 2016). Patent portfolio is a constructed array of related-but-distinct individual patents. Diversity may show the complex relationship among these patents. Some technical characteristics leading to lower diversity of patent portfolio will be sketched below. Technologies will be compatible when the latter technology is from changes to former critique. Secondly, it is easier to expand from one technology field to another if different technology fields are adjacent to each other. In other words, the knowledge base between the adjacent technology fields is similar. Patent portfolios with lower diversity are usually accompanied by overlapping authority. The capability based view of firm strategy suggests that firms should concentrate on technology fields

they can do best. Patent portfolios with higher diversity usually incorporate discrete patents. These technologies are less correlated and enterprises may implement diversified strategies. The distribution of patents for Chinese enterprises is extremely uneven and only a few giant corporations own a large number of patents. Lin et al. (2006) stated that enterprises without massive technical stock should focus on the core technology field so as to generate synergies. Grimpe and Hussinger (2015) also demonstrated that highly correlated or overlapped patents can generate more value. Based on these analyses, the following hypothesis is proposed:

H1b The patent portfolio diversity is negatively related to firm performance.

Fabry and Ernst used the number of IPC classes in patent applications to represent the technical scope of the patent portfolio. Technical scope focuses on getting a number of core technologies in the core technology field. In the case that the patent portfolio diversity is determined, broader technical scope can provide more sufficient protection for products. The protection of mature technology strengthens the existing technical capacity of the enterprise, and the protection of undeveloped technology is beneficial for enterprises to acquire the first-mover advantage. Grimpe and Hussinger (2015) believe that the first-mover advantage generated by the patent portfolio can guarantee the freedom of research and development and help to extracting as much value as possible. Based on these analyses, the following hypothesis is proposed:

H1c The technical scope of the patent portfolio is positively related to firm performance.

2.2 The Moderating Effect of Technological Opportunity

Klevorick et al. (1995) demonstrated that “technological opportunity” (TO below) refers to differences in the set of possibilities for technological advance that exist within technologies and industries at different points in time. Patel and Pavitt (1997) analyzed firm-specific differences in technological opportunity from two perspectives: the annual applications in patent class *i* and the distribution of the annual patent application of the enterprise. We try to understand how enterprises seize technological opportunities from two perspectives. Firstly, the enterprise pursues the development opportunities of the whole industry and applies for more patents as this industry develops rapidly. Secondly, based on the understanding and

expectation of technology development, enterprises implementing the offensive strategy start market arrangements in advance so as to gain more personal opportunities. In any case, enterprises will have a larger patent portfolio size but higher uncertainty may accompany with this process, because they are more likely to outpace or misjudge market trends in reacting to the crisis. Manufacturers in the vertical value chain increasingly rely on the organizations in upstream enterprises, which in turn makes it more difficult for downstream enterprises to access high-value patents. Therefore they apply for more low-value patents and we call this as “passive technological opportunity”. Passive technological opportunity indicates the downstream enterprises gradually lose control of the advanced technologies, which may impede their profitability. Based on the above analysis, the following hypothesis is proposed:

H2a Technological opportunity negatively moderates the relationship between patent portfolio size and firm performance.

Based on the analysis above, the technological opportunities that enterprises may fight for include two types: the development opportunities of the whole industry and the opportunities of individuals. From the perspective of dynamic capabilities, the individual firms experience technical evolution during development. All companies face equal industry opportunities but different individual opportunities. Due to the high uncertainty of R&D activities, enterprises may involve different technical fields or low-correlation technical categories within the same technical field when accessing technological opportunities, which will increase patent portfolio diversity gradually. Involving in different technical fields helps to capture potential opportunities. Enterprises getting more various opportunities sometimes have to scatter limited resources in different business, which may make coordination even more difficult and raise the cost of knowledge transfer. Based on the capability view, dispersed resource may fail companies to form the lasting competitiveness, which will result in more sunk costs. Based on these analyses, the following hypothesis is proposed:

H2b Technological opportunity negatively moderates the relationship between patent portfolio diversity and firm performance.

The more technological opportunities, the faster the industry develops and the more dramatically technologies change, and enterprises broaden technical scope to adjust to such changes. Getting

more individual opportunities contributes to the comprehension of existing or potential technologies, which leads to broader technical scope involved in business. Also, more opportunities contribute to capturing complementary resources and improving competitiveness. What we should emphasize here is that technological opportunity may generate positive moderating effect between technical scope and firm performance yet negative moderating effect between patent portfolio diversity and firm performance. It is not a contradiction. Wagner demonstrated that the primary role of patent portfolio diversity is to avoid risks such as technical risks, market risks and legal risks. Surely patent portfolio diversity also helps to obtain complementary resources, but only if the risks are successfully avoided can complementary resources create more benefits. The investment of subsequent R&D resources may transform into sunk costs when diversity-oriented strategy fails to avoid risks. While technical scope focuses on further strengthening property so as to gain competitive advantage. Based on these analyses, the following hypothesis is proposed:

H2c Technological opportunity positively moderates the relationship between the technical scope of patent portfolio and firm performance.

3 RESEARCH DESIGN

3.1 Sample Firms and Data

Based on standard classification of industries in China, this paper selects 121 enterprises belonging to MIEEE listed in Shanghai or Shenzhen. We finally confirm 99 enterprises with valid data after excluding ST shares, *ST shares or enterprises without patents. Patent data and documents in this paper come from IncoPat database which has collected more than 100 million patents from 112 countries or regions and updates the data four times a week.

We only focus on patents for invention or utility. We finally get the data of patent portfolio from 2013 to 2017 for each firm. The data of firm performance in this paper is derived from the Wind database.

3.2 Independent Variables

We choose to use a 4-year time window to reasonably reflect the actual attributes of the patent portfolio. The quantity of individual component patents involved indicates the size of patent portfolio

(Parchomovsky and Wagner, 2005), and the formula for this index is:

$$PPS = \sum_{t-1}^{t-4} n_i$$

i =focal firm; n_{ik} = number of patents owned by focal firm i .

We measure patent portfolio diversity or the degree to which a firm built a diversified repertoire of patent portfolio in the technological categories defined by the International Patent Treaty. Turanay et al. (2016) used the inverse of non-biased Herfindahl Index (HHI) by Hall to measure PPD, and the formula for Turanay's index is:

$$PPD_i = 1 - \left[\frac{N_i * HHI_i - 1}{N_i - 1} \right]$$

$$HHI_i = \sum_{k=1}^K \left[\frac{N_{ik}}{N_i} \right]^2$$

Where, i =focal firm; k =patent classes; N_{ik} = number of patents in class k by focal firm i ; and N_i = total number of patents in all classes by focal firm i . The value of patent portfolio diversities ranges between 0 and 1, and a bigger value indicates higher diversity.

Fabry and Ernst used the number of IPC classes in patent applications to represent the technical scope of the patent portfolio.

3.3 Dependent Variables

Previous literature identified three categories of firm performance: innovation performance, market performance and financial performance. Lin selected return on assets (ROAs) as a measure for firm performance (Ceccagnoli, 2009; Lin et al., 2006). ROA indicates the entity's capacity to build value. Besides, we choose revenue of major activities (RMAs) to measure the current state of operation.

3.4 Moderator Variable

Klevorick et al. (1995) demonstrated that technological opportunity refers to differences in the set of possibilities for technological advance that exist within technologies and industries at different points in time. The formula for Turanay's index is:

$$TO_{it-1} = \sum_{j=1}^J \left(patents_{jt-1} * P_{jit-1} \right)$$

i =focal firm; $Patent_{jt-1}$ =number of patents in class j applied for by all entities in year $t-1$; P_{jit-1} =the percentage of patents in class j applied for by firm i in year $t-1$. The bigger value of patent portfolio

Table 1. Regression models for patent portfolio and firm performance measures.

	Model 1A	Model 1B	Model 2A	Model 2B
	RMA		ROA	
PPS	0.0688** (2.98)	0.180*** (5.48)	-0.000288 (-1.61)	-0.000333 (-1.29)
PPD	-3.665+ (-1.94)	-3.245 (-1.57)	-0.0439** (-3.00)	-0.0610*** (-3.76)
TS	7.393*** (6.19)	5.777*** (4.27)	0.0146 (1.58)	0.0230* (2.17)
TO	1.045 (1.36)	0.120 (0.15)	0.0183** (3.08)	0.0134* (2.06)
age	-34.20*** (-4.10)	-31.83*** (-3.87)	-0.462*** (-7.16)	-0.478*** (-7.39)
lnem	561.0*** (12.07)	553.6*** (12.05)	-0.939** (-2.61)	-0.913* (-2.53)
TO * PPS		-0.00457*** (-4.65)		0.00000298 (0.04)
TO * PPD		-0.0239 (-0.82)		-0.000410+ (-1.79)
TO * TS		0.103*** (4.05)		-0.000137 (-0.69)
_cons	-3713.5*** (-7.22)	-3676.7*** (-7.23)	21.01*** (5.28)	21.09*** (5.27)
Adj R ²	0.6447	0.6583	0.2111	0.2171
F-value	74.18***	63.17***	11.8***	9.95***
N	485	485	485	485

t statistics in parentheses; + p<0.1 * p<0.05 ** p<0.01 *** p<0.001

diversity indicates that the firm may catch more technological opportunities in the process of development.

3.5 Control Variables

Based on the prior art, we use the natural logarithm of the number of employees (lnem blow) as a control variable for firm size effects and use Stata 15.0 to set the dummy variable for company nature effects. At the same time enterprise age is also a control variable in this study.

4 RESULTS

We adopted hierarchical regression analysis methods for analyzing such panel data by using Stata 15.0 software and centralized the independent variables and moderator variables. All four Models are highly significant (p-value < 0.001 for each Model) as shown in the TABLE 1.

Model 1A and Model 1B include RMA as dependent variable, and Model 2A and Model 2B include ROA as dependent variable. RMA and ROA represent measures of short-term firm performance. However, Model A does not consider the interaction effects between patent portfolio size, patent portfolio diversity, technical scope, and technological opportunity. Models with interaction terms strengthen the explanatory power according to the adjusted R² values. These three attributes have different impacts on RMA and ROA as shown in Models 1A and 2A, because RMA indicates a truer picture of an enterprise's short-term condition, while ROA represents its capability to create high value. Patent portfolio size and technical scope generate significant positive effect on RMA, but not for ROA. The coefficient of technical scope in Model 2B is 0.0230 when considering the interaction effects, which is positive and significant. Those results suggest that patent portfolio size and technical scope positively impact on firm performance. Thus, hypothesis 1a and hypothesis 1c are true. However, larger patent portfolio size does

not mean a greater ability to create higher value. Enterprises should pay attention to the quality of patents. The coefficients of patent portfolio diversity in Models 1A and 2A are -3.665 (t-value = -1.94) and -0.0439 (t-value = -3.00), respectively, both of which are significant. Those results support hypothesis 1c and indicate that more diversified technologies can't form the superiority in the intense market competition.

The coefficients of technological opportunity in Model 1B and Model 2B are 0.120 and 0.0134 respectively, only the latter is significant, which indicates that catching technological opportunities may help to create high value by leveraging the existing asset base. The coefficients of enterprise age in Model A2 and Model B2 are -31.83 and -0.478 respectively and both are significant, which indicates that enterprises in MIEEE may get undesirable performance with age. Perhaps the old companies with rigid system and institutions lead to lower administrative efficiency. The coefficients of $\ln em$ in Model A2 and Model B2 are 553.6 and -0.913 and both are significant. The former is positive while the latter is negative, which indicates that more employees can create more revenue but may reduce the ability to create high value.

The coefficient of the interaction term $TO*PPS$ is negative and significant in Model 1B; however it is almost equal to 0 in Model 2B. This result supports hypothesis 2a, which means that Chinese enterprises in MIEEE might have caught a number of passive technological opportunities but missed the high-value patents. The coefficients of the interaction term $TO*PPD$ are negative and significant in Model 1B and in Model 2B, though only the latter is significant. This result indicates that more technological opportunities are accompanied by higher uncertainty, and a mass of R&D resources may turn out to be the sunk costs when technological opportunities lure into the wrong direction. The coefficient of the interaction term $TO*TS$ is positive and significant in Model 1B; however it is almost equal to 0 in Model 2B. This result supports hypothesis 2c, which means that enterprises should patent more in the core technology field.

The empirical results of this paper indicate that patent portfolio size has positive impacts on firm performance; however, large blocks of non-core patents can't create high value. Patent portfolio diversity has negative impacts on firm performance, and diversified technical strategies accompany with high risks. The technical scope of the patent portfolio positively affects firm performance, thus, enterprises should concentrate its limited R&D resources on a specific technology and even within

the core technology field so as to strengthen the property.

5 CONCLUSIONS AND IMPLICATION

Passive technological opportunity will negatively moderate the relationship between patent portfolio size and firm performance. Enterprises should cultivate independent R&D capacity in order to possess advanced technologies. Technological opportunity will negatively moderate the relationship between patent portfolio diversity and firm performance. Thus, enterprises may need to develop the ability to accurately identify the valuable opportunities. Technological opportunity positively moderates the relationship between the technical scope of patent portfolio and firm performance. Enterprises had better broaden technical scope within the core technology field.

This study notes some limitations in investigating the mechanism of patent portfolio to firm performance. We neglected the small and medium enterprises; however they are an important part of the market. We didn't measure other attributes of the patent portfolio such as its total value due to the availability of the related data. This paper lays the groundwork for future research on patent portfolio and firm performance.

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