Technology and Operations Strategy

A Study of the Relationship among R&D, Patent and Enterprise Value：

An Empirical Research of Smart Grid Industry in Taiwan

Lyn Shen (twdream8@gmail.com)
Graduate Institute of Business Administration
College of Management National Taiwan University

1. Introduction

National Applied Research Laboratories (NAR Labs) in 2015 released “Analysis of Taiwan's Competitiveness in Science and Technology”. The results indicate that in recent years, Taiwan's top three areas in patents with most investment and influential, including the technical impact indicators are electrical machinery, apparatus energy (6,480 cases), semiconductors (6,300 cases) and machine tools (709 cases).

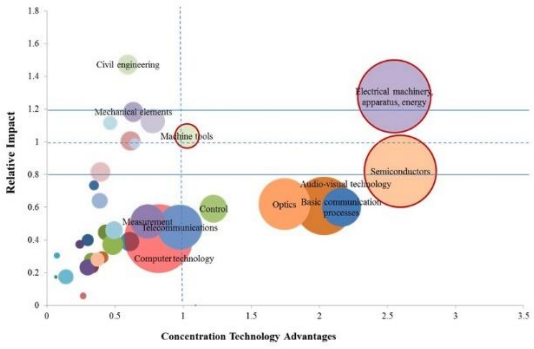


Figure 1 : Relative Impact of Taiwan's Patents in Various Technology Fields Source : NAR Labs

The fields of electrical machinery and apparatus energy is the highest number of patents and the relative influence. The electrical machinery and apparatus energy include many industries, but according to the Chi research, the hot spot patent method, which was tools to predict the next generation of technology.

It was found that in the 2008 and 2009’s hot patents worldwide, the third highest field is UPC324754 "Electricity: Measurement and test / probe". The total number of patents and influence of the patent field: UPC324754 are both increasing while compare the period of 2005-2009 with 2000-2004 by the RTA index in Taiwan.

Measuring, testing and probing electricity is one of the important components of the smart grid. Therefore, the smart grid is an important trend in the world, and there are lots of patents in Taiwan.

The definition of "smart grid" by IEEE refers to the use of digital technology to upgrade the transmission and distribution network, in order to achieve the most optimal operation, and increase the energy market flexibility, then induce a number of the new markets which related to the smart grid.

Smart Grid deployment is imperative, not only in the United States but also around the globe. However, the smart grid is a revolutionary cause of the new communications and control capabilities, energy, generation model and adhere to cross jurisdiction regulatory structure.

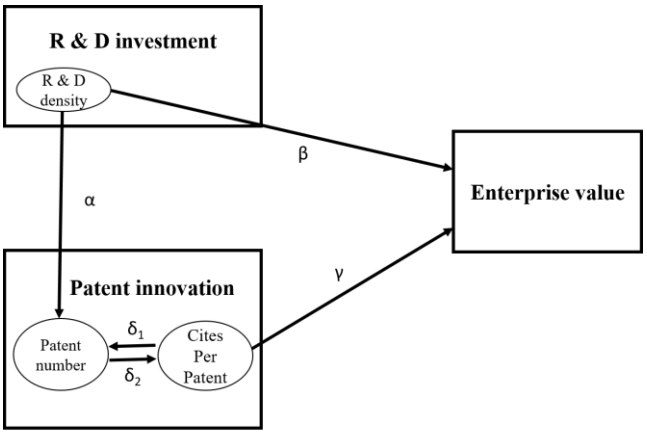
There are six categories be classified in Taiwan Smart Grid Industry: AMI Infrastructure System, Distribution Feeder Automation System, Smart Home and Building System, Micro Grid System, Smart Transmission System and Energy Storage System.

In globalization and increasing hyper competition, companies requiring disruptive innovation and jumping to a new S-curve even more critical in nearly every industry. Matthyssens et al. (2006) stresses the importance of value innovation to create and sustain competitive advantage and to rejuvenate the organization.

In this paper, we will discuss the relationship among the R&D investments in the enterprise, patent innovation, and enterprise value in the rapidly changing environment of the smart energy industry, the relationship, whereby research to help companies understand the value of the patent lies. This paper has the following objectives:

- The influence of enterprise R & D investment on Patent Innovation.
- The influence of patent innovation on enterprise value.
- The impact of R&D investment on enterprise value through patent innovation.

In the past studies, they were more concerning in the relation between patent and company performance, more emphasis in the patent numbers and accounting of enterprise performance of the semiconductor industry. This study is focus on the smart grid industry and has joined with the discussion of patent quality, and is different from the enterprise value.



Control variable : Company size, debt ratio, revenue growth rate

2. Literature Review

2.1 Relationship between R & D investment and enterprise value：

Cohen and Levinthal (1990) defined absorption capacity as a firm's ability to recognize the value of new information, assimilate it, and apply it to commercial

ends. The absorptive capacity is cumulative, while the companies invest more in R&D, it's easier to accumulate it in the next one.

Griliches (1981) found a significant relationship is found between the market value of the firm and its intangible capital. Artz, K. W., et al. (2010) suggested that patenting and product innovation have different effects depending on the performance metric examined. Sohn, D. W(2010) showed R&D investment is the most significant factor affecting patenting.

Hagedoorm and Cloodt (2003) pointed that the performance of the organization patent can reflect the capability of R & D, and it can also affect the performance of the enterprise. R & D expenditures can be used to analysis enterprise value and non- comparison and subjective characteristics (David and Lev, 2002), as mentioned above, much of the literature reviews support investment in research and development to the enterprise operating performance have positive effects, and that the amount plays an important role.

Hypothesis 1 (H-1): R&D investment is positively associated with enterprise value.

2.2 The relationship between patent innovation and enterprise value：

The resource-based view (RBV) is the basis for a company to lie in the application of valuable tangible or intangible resources to improve the competitive advantage. (Wernerfelt, 1984)

Peteraf (1993) analyzed that the essence of parsimonious model of resources and firm performance is superior resources, ex post limits to competition, imperfect resource mobility, and ex ante limits to competition.

R&D investment can improve productivity and create company value (Hirschey, 1982; Hirschey and Weygandt, 1985; Chauvin and Hirschey, 1993; Lev and Sougiannis, 1996; Hall, 1999).

Griliches and Mairesse (1984) analyzed that in high-technology industries, R&D investment have value relevance. Lev and Sougiannis (1996), and Hall (1999) show that R&D activities is positively associated with current equity value and future company value. Bloom, N., et al. (2002) showed that patents have an economically and statistically significant impact on firm-level productivity and market value.

Technological capabilities and Market-interface capabilities is the critical component of the core

competence. Therefore, core competence is divided into technology core competence, marketing core competence (ET al.1995 Gallon). Patel and Pavitt (1977) argued that technology is one of the sources of the main advantage of the manufacturers, the patent citation can measure inimitable (Markman et al., 2004), and the quality of patent on behalf of, and with company profits have positive correlation (Hall et al., 2001).

Hypothesis 2 (H-2): Patents are positively associated with enterprise value.

2.3 The relationship between R & D investment and enterprise value through patent innovation：

Bound, J. et al.(1984) found that much larger output of patents per R&D dollar for the small firms, with a decreasing propensity to patent with size of R&D programs throughout the sample. Pakes(1985) showed that the total value of patent rights and the relationship between changes in it and changes in the quantity of patents. Scherer (1965) analyzed that the patent approval number and corporate performance in sales growth has a positive relationship

A successful business needs to respond to the changes in the environment, to take a different approach (Miller, 1988). Spital & Bickford (1992) study found that the rapid change of technology environment. Successful business investment in R & D funds ratio is usually higher than the average, and in a dynamic environment, the ability of technological innovation is the key to success.Hall et al. (2002) provided R&D intensity is related to patent measures, and the innovation of new product introduction is related to the operating performance. Schoenecker and Swanson(2002) found limited evidence that aspects of firm technological capability quality are related to firm performance.

Hypothesis 3 (H-3): **The relationship between R&D and enterprise value is related to the influence of patent.**

3. Method

3.1 Data Collection and Sampling

3.1.1 Data Sampling：The Standard Industrial Classification (SIC) is a system for classifying industries by a four-digit code, it is used by government agencies to classify industry areas. However, there is not yet a category exclusively for smart grid and companies that engage in smart grid spread across many categories.

In order to adopt more accurate sample, the sampling of this study

will use listed companies of Taiwan Smart Grid Industry Association (TSGIA), which was officially established in 2010 for the purpose of facilitating the development of the smart grid industry in Taiwan.

In addition, TSGIA is also the officially recognized organization of standardization. TSGIA has 40 publicly traded companies as group member, which are from smart grid industry sectors in Taiwan, including system, component, material, and chemical suppliers, as well as government or private research institutions, consultancies and etc.

3.1.2 Data Collection：

3.1.2.1 Patents data source：The data comes from United States Patent and Trademark Office (USPTO) online patent database. Search Sample companies' number of patents, patent citations from 2010 to 2015 year.

3.1.2.2 Enterprise value data source：The firms' public financial reports from the Taiwan Economic Journal (TEJ) database, including R&D costs, technology introduction, the total assets, the number of employees, staff productivity.

3.2Variable index model：

3.2.1 R&D model： The R&D investment is usually measured by the current R&D expenses. Much of the literature is used to reduce the current operating income, and to eliminate the heteroscedasticity ,called R & D density, defined as follows (Sougiannis ,1994 ; Lev and Sougiannis,1996 ; Huang and Liu, 2005)：

R&D intensity = R & D expenses / Net current revenue

3.2.2 Patent innovation index：

3.2.2.1 The index model of Patent quantity：Number of Patent (PN) is the granted numbers on the patent owner in a particular period of time, in the patent classification project. Arundel & Kabla (1998) and Cloodt & argued (2003) that the number of patents can be used as a measure of the number of R & D output in high-tech industry. CHI Research (ipIQ) first proposed the method of the quality and quantity of the patent, and the evaluation index is described as follows:

Number of patent approval = The United States Patent Office approved patent number from 2010 to 2015.

$PN^{i}_{j,k}=\sum_{k} PN^{i}_{j,k}$

i: The patent owner.

j: The technical field.

k: A specific time.

$PN^{i}_{j,k}$: The approved patent number of the company in the technical field and specific time.

3.2.2.2 The index model of Patent Quality：Hall et al. (2001) argued that the patent quality can be found through the number of patent citations. Many studies have also found that patent citations have a positive impact on financial performance. (Ernst, 1995; Hagedoorn and Cloodt, 2003; Markman et al,2004)

Thus, the number of patent citations are as a measure of the quality of R&D output in this paper. Cites per patent (CPP) is the number of patents cited by other companies to assess the quality of the patent in the past five years. The higher the number of references, the more advanced technology, and more influence on the industrial technology and the future development.

CPP_y (Cites Per Patent) = The number of times for a company which patents (during y-1 and y-6) was cited in year y / The number of patents (during y-1 and y-6) for a company in year y

3.3 The index model of Enterprise value：Many studies adopt the accounting evaluation model of corporate earnings, but may underestimate the value of the enterprise。Griliches(1981) suggested that the value of the enterprise is formed by the construction of tangible and intangible assets. Ohlson (1995) deduced the stock evaluation model based on the accounting information by dividend discount method(DDM), net surplus and linear Information Dynamics Model (LIM). Ohlson model has different results for different life cycle enterprises, so this study is a Ohlson model to consider the life cycle of the enterprise.

$P_{it}=\beta_{i0}+\beta_1 D_1+\beta_2 D_2+\beta_3 bv_t+\beta_4 X^a_{it}+\beta_5 D_1 bv_{it}+\beta_6 D_2 bv_{it}+\beta_7 D_1 Xait+\beta_8 D_2 X^a_{it}$

i : Individual companies

P t : market price in phase t

X t : Abnormal earnings per share

Xat : Abnormal earnings per share

phase t

Growth stage: D_1=1 and D_2=0

Maturity stage: D_1=0 and D_2=1

Decline stage: D_1=0 and D_2=0

4. The expected result

According to the literature review, the three assumptions should be established, then can strengthen the original literature, but also for the future researchers. There are a number of assumptions that may not be established. In the other situation, if not all the hypotheses are established, then it will need for further investigation in company strategy, research efficiency, government policies, competitors, trade barriers, time-lag effect between R&D investment, patent, and other factors.

4.1 Condition 1:

Hypothesis 1: R&D investment is positively associated with enterprise value. (True)

Hypothesis 2: Patents are positively associated with enterprise value. (True)

Hypothesis 3: The relationship between R&D and enterprise value is related to the influence of patent. (True)

4.2 Condition 2:

Hypothesis 1: R&D investment is positively associated with enterprise value. (False)

Hypothesis 2: Patents are positively associated with enterprise value. (True)

Hypothesis 3: The relationship between R&D and enterprise value is related to the influence of patent. (True)

Conclusion is not consistent with the literature review.Need for further investigation in company strategy, research efficiency, time-lag effect between R&D investment and patent, and etc.

4.3 Condition 3:

Hypothesis 1: R&D investment is positively associated with enterprise value. (True)

Hypothesis 2: Patents are positively associated with enterprise value. (False)

Hypothesis 3: The relationship between R&D and enterprise value is related to the influence of patent. (True)

Conclusion is not consistent with the literature review. Need for further investigation in government policies, competitors, trade barriers and etc.

Most patent and performance of previous studies in Taiwan, focusing on the semiconductor industry and enterprise performance, this study aimed at the emerging smart grid industry enterprise value. Furthermore, because governments are in effect of solar energy and smart grid industry. Therefore, there are many variables will affect the results, it is worth further observation and discussion.

Reference

Alavi, M. & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. MIS Quarterly, 25(1), 107-136.

Artz, K. W., Norman, P. M., Hatfield, D. E., & Cardinal, L. B. (2010). A longitudinal study of the impact of R&D, patents, and product innovation on firm performance. Journal of Product Innovation Management, 27(5), 725-740.

Barney, J. B., & Baysinger, B. (1990). The organization of schumpeterian innovation. Strategic Management in High Technology Firms, 19(2), 3-14.

Bloom, N., & Van Reenen, J. (2002). Patents, real options and firm performance. The Economic Journal, 112(478), C97-C116.>

Bound, J., Cummins, C., Griliches, Z., Hall, B. H., & Jaffe, A. B. (1982). "Who Does R&D and Who Patents?" R&D, Patents and Productivity, edited by Zvi Griliches. Chicago: Univeristy of Chicago Press.

Breaking the industry recipe. Industrial Marketing Management, 35(6), 751-761.

Brown, J. S., & Duguid, P. (2001). Knowledge and organization: A social-practice perspective. Organization Science, 12(2), 198-213.

Cohen, W.N., Levinthal, D.A. (1990) Absorptive Capability: A New Perspective on Learning and Innovation. Administrative Science Quarterly, 35, 1128-1152.

Gallon, Mark, R., Stillman, M., H., & David, C. 1995. Putting core competency thinking to pratice. Technology Management, May-June: p20-28.

Hall, H. B., A. Jaffe, and M. Trajtenberg. 2001. Market value and patent citations: a first look. Working Paper, University if California.

Hall, L. A., & Bagchi-Sen, S. (2002). A study of R&D, innovation, and business performance in the Canadian biotechnology industry. Technovation, 22(4), 231-244.

Henderson, R. & Cockburn, I. (1994). Measuring competence? Exploiting firm effects in pharmaceutical markets research. Strategic Management Journal, 15, 63-84.

James A. Ohlson, “Earnings, Book Values, and Dividends

in Equity Valuation", Contemporary Accounting Research, Vol. 11 No. 2, pp. 661-687, 1995.

Leonard-Barton, D. 1995. Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation.

management, Strategic Management Journal, 18(7), 509□533.

Mansfield, Edwin, (1984), R&D and Innovation: Some Empirical Findings, p. 127-154 in , R&D, Patents, and Productivity, National Bureau of Economic Research, Inc,

March, J., Simon, H.A. (1958) Organizations. John Wiley, New York.

Markman, G. D., M. I. Espina, and P. H. Phan. 2004. Patent as surrogates for inimitable and non-substitutable resources. Journal of Management. 30(4): 529-544.

Matthyssens, P., Vandenbempt, K., Berghman, L., (2006) Value innovation in business markets:

Ohlson, J. A., "Earning, book value, and dividends in equity valuation", Contemporary Accounting Research, Vol.11 No.2, pp. 661-687, 1995.

Patel, P., & Pavitt, K. 1997. The technological competencies of the world's largest firms: Complex and path-dependent, but not much variety. Research Policy, 26(2): p141-156.

Peteraf, M.A. (1993) The Cornerstones of Competitive advantage: a Resource-based View. Strategic Management Journal, 14(3), 179-192.

Peteraf, M. A. (1993). The cornerstones of competitive advantage: A resource - based view. Strategic management journal, 14(3), 179-191.

Schankerman, Mark and Ariel Pakes.(1986) "Estimates of the Value of Patent Rightsin European Countries During the Post-1950 Period," Economic Journal, Vol. 96, (December 1986)

Scherer, F. M. (1965). Corporate inventive output, profits, and growth. The Journal of Political Economy, 290-297.

Scherer, F. M. (1965). Firm size, market structure, opportunity, and the output of patented inventions. The American Economic Review, 55(5), 1097-1125.

Schoenecker, T., & Swanson, L. (2002). Indicators of firm technological capability: validity and performance implications. Engineering

Management, IEEE Transactions on, 49(1), 36-44.

Schumpeter, J. A. (1942). Capitalism, socialism and democracy, NY: Harper.

Schumpeter, J. A. (1942). Capitalism, socialism, and democracy, New York, NY: Harper.

Sohn, D. W., Hur, W., & Kim, H. J. (2010). Effects of R&D and patents on the financial performance of Korean venture firms. Asian Journal of Technology Innovation, 18(2), 169-185.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic

Wernerfelt, B. (1984). A resource-based view of the firm. Strategic management journal, 5(2), 171-180.

Wiig, K.M. (1997) Knowledge management: Where did it come from and where will it go? Expert Systems with Applications, 14(5), 67-78.

Zahra, S.A., George, G. (2003) The Net-Enabled Business Innovation Cycle and the Evolution of Dynamic Capabilities. Information System Research, 13(2), 147-150.

Zvi Griliches, Market value, R&D, and patents, Economics Letters, Volume 7, Issue 2, 1981, Pages 183-187, ISSN 0165-1765,