
Valuation of Patent under Uncertainty: A Real Option Perspective

Authors: **Chun-Yao Tseng**, Tunghai University, Taiwan, cytseng@thu.edu.tw; **Yi-Shan Yeh**, National immigration agency, Taiwan, rubyyeh95@gmail.com

Innovation has become a key to corporate success, so many information electronic companies apply patents to protect their new technology. The application of real option theory (ROT) is suitable for valuing patent, because of the higher degree of uncertainty and operational flexibility connected to the technology innovation and market volatility. The 214 listed firms in Taiwan electronic industry are examined based on analysis of patent and citation dataset comprised of all patents granted by the U.S. Patents of Trademark Office (USPTO). Under market and technology uncertainty factors using option perspective to assess firm's market value. There are three empirical finding : (1) When a company faces market uncertainty, patents are helpful for a company to create value. (2)The companies can't raise market value under technology uncertainty. (3) This study use three indicators to measure patent including quantity indicators (number of patents, priority) and quality indicator (cites per patent). All have a positively impact on firm's value.

Keywords: Patents, Real Option, Uncertainty, Priority Claims, Citation

JEL Classification Numbers: O30, O32, O34

Introduction

In tradition, economist would say that it needs land, labor, capital to start business, but nowadays this kind of condition element has changed, and the most important element of business is knowledge. In 1996, OECD (The Organization for Economic Cooperation and Development) created the term “knowledge economics” and gave it a definition which is an economic style based on acquiring, producing, and utilizing knowledge. As the coming of knowledge economic, evaluating the value of a company can not only depend on the book value of accounting, but also need to take the intangible assets value in consideration, such as patents and trademark. Intangible assets is intangible, deferrable, uncertainty, and hard to value, and the traditional accounting method is not suitable for now a time. Therefore, in this study patent is used to be an estimate indicator to evaluate intangible assets value of a company.

In practice, most companies apply patent right to protect their technology or invention. A company could create greater synthesis effect of economic benefit by applying patent. On the other hand, a company entry a new business or defend its competitor by emerging other companies with patent right of critical technology. Patent is a new product or a new process, many research pointed out that patent has positive influence on corporate value or economic benefits. However, with the view of quality only a few patents have high-quality value (Schankerman and Pakes, 1986). And not every technology or invention with economic value would be applied patent right (Blundell et al., 1999). How to evaluate the value of a new technology and decide which new technology is suitable to apply patent right? To utilize ROT (real option theory) under the consideration of high innovation uncertainty and operating flexibility is a good way. Bloom and Reenen (2001) commanded that high-uncertainty would decrease the influence of new patent on productivity. Moreover, Oriani and Sobrero (2003) used real option which takes uncertainty element, including market uncertainty and technology uncertainty, in consideration to evaluate technology. According to above, this study utilizes patent to estimate corporate value and discusses how patent under uncertain condition influence corporate value.

For patent, most previous research discussed the relationship between patent count and patent value (Griliches, 1981; Pakes, 1985) or investigated the value of patent citation (Trajtenberg, 1990). Griliches (1990)

mentioned that the higher the patent citation the greater the value, and in addition the meaning of patent in technology and in economic is different. While evaluating the value of patent right a company acquired, it is better to take both quantity and quality element into consider (Hall, 1999). Myers (1987) addressed the concept of real option, and this method is used to decide the investment strategy at first. Innovation capital is viewed as an object to decide an investment under uncertainty condition (Bloom and Reenen, 2001). Bloom and Reenen (2001) proved that patent has significant influence on productivity and market value of a company and under high-uncertainty condition patent value is negative related to productivity. Wu and Tseng (2006) also employed ROT to analyze patent value, and the results that the higher volatility increases the patent value is not consist with the previous research.

This study employs the concept of two uncertainty elements, market uncertainty and technology uncertainty, Oriani and Sobrero (2003) commanded, moreover, this study take consideration with priority claims. Patent with priority claims means that this patent is valid in other countries, and this study quantifies priority claims to analyze how it influence corporate value. Besides, this study uses patent count and paten citation which are the indicators of patent to investigate how the patent under uncertainty influences corporate value. Above of all, this study discusses whether the paten under two kinds of uncertainty, market uncertainty and technology uncertainty would influence a corporate value through and utilizes the real option model with uncertainty element to estimate. In detail, this study attempts to investigate: 1. whether patent count, patent citation, and patent priority claims influence a corporate value; 2. under market uncertainty whether patent count, patent citation, and patent priority claims influence a corporate value; 3. under technology uncertainty whether patent count, patent citation, and patent priority claims influence a corporate value.

Literature review

Indicators of Patent

There have different meanings about in economics and in technology, in this study it focuses on economics meaning of patent. What is special for patent

is about its high potential value and it could reflect the efficiency of management on its value, therefore, patent is usually used to estimate the ability of innovation and invention of a company. Griliches (1990) thought that patent could be an indicator to presented output and input of invention while there has less information about innovation. Now patent indicators most utilized are ipIQ patent indicators addressed by CHI Research. It estimates patent quality objectively by quantifying patent information, and then evaluates technology ability of a company. There are ipIQ patent indicators:

Number of Patents- total patent a company owns in a particular period, and is used to estimate the technology activity level which the company works on.

Patent Growth 1 Year (%) - the growth percentage which compares with the previous year, and the result presents the changes of technology activities.

Citation- the count number one paten cited by the later patents and the higher the citation the more important the technology the paten present is.

Current Impact Index (CII) - the ratio that one patent citation compares with total paten citation that the sum of all patents a company has. The greater the CII is the more important and the more superior the technology is.

Technology Strength- patent number multiplies by current impact index. It estimates the power of the patent cluster on particular technology.

Technology Cycle Time (TCT) - it presents the mean of the gap of the cited patents and all patents. It could estimate the time gap between current patent technology and previous patent.

Science Linkage- the count number which science papers or references (not patent reference) patent cites, it could estimate the connection between patent and science, and for example, while one patent cites a lot of science papers or references, it might mean that the technology of a company has tightly connection with basic science.

Science Strength- patent number multiplies by science linkage, and it estimates the level a company utilized basic science on it patent cluster.

This study not only employs ipIQ patent indicators to estimate, but also uses patent priority claims to evaluate patent. Patent priority claims established by Paris Convention Rule 4 based on territoriality the patent

protection system of most countries follow. The reason why patent priority claims set up is to avoid inventors losing their own right that they could not apply patent right to each patent office at the same time and could claim their right in several countries through international rule or agreement between national. Usually, patent priority claims are applied previous to patent application approval 6 to 12 months. Also, patent priority claims is considered in this study, and this study employs real option to investigate how patent priority claims influence corporate value.

Patent and Corporate Value

Previous research about how patent influences corporate value is most from Griliches (1981) who used Tobin's Q to present corporate value. Griliches (1981) commanded that evaluate output of research and development and patent value with market value, but there has different view of this suggestion. Toivanen et al (2002) investigated the connection between innovation and market value of 877 companies in British during 1989 to 1995, and the empirical result showed that expenditure of research and development was significant positive relative to market value, however, patent counts was not. Hall et al. (2005) discussed whether Tobin's Q value was related to ratio of R&D and assets, ratio of patent and R&D, and patent citation per patent, the research was found that each ratio had significant influence on corporate value, especially that per patent citation could gain corporate value up to 3%.

Generally, while estimate the connection between patent and corporate value, it would often compare with expenditure of research and development. Gambardella and Torrisi (2000) utilized top 500 chemistry and electronic companies of North American, European, and Japan to be research objects and found out that patent number had greater influence on market value than expenditure of research and development. There had a research found out patent was positive related to market value, and furthermore where paten granted from also had different influence on market value, for example, patent granted from U.S. had greater influence on corporate value than patent granted from Taiwan or China (Tseng, C.Y., 2003). According to above, this study adopts the investigate method of Hall et al. (2005) to discuss the relationship between patent and corporate value and in this study it focuses on the value of patent granted from U.S.

Uncertainty

The reaction between environment and organization is very close, and each organization has to make decision and operate under the whole environment. About environment uncertainty, it could be classified into three types: 1. probability that cannot know what happen in the future (Duncan, 1972), and this kind of probability that corporate could not expect accurately. 2. Information without cause-effect which means that it cannot have any clear information about the results caused by any decision (Duncan, 1972). 3. Results which cannot be anticipated, it is that corporate know nothing about any reaction and results. Therefore, it would increase the impact, un-known reaction, or both under environment uncertainty, and then corporate would face more and higher risk of uncertainty. Dwyer and Welsh (1985) estimated uncertainty with 27 environment element and had two common factors, heterogeneity which means there has higher uncertainty degree in the market and volatility presents the change degrees of environment.

From the buyers, Heide and Weiss (1995) thought that there had several types of uncertainty in the technology market; one of them is from heterogeneous and volatility of technology. Besides, while the buyers facing the change speed of technology is faster, the uncertainty degree would increase, and the buyers would take new suppliers into consider, in the other words, the cooperating activity would be less since technology uncertainty decreases. In high-tech industry, there are two kinds of uncertainty, market uncertainty and technology uncertainty. In this study, it employs this concept of uncertainty of high-tech industry to estimate Taiwan electronic industry, and focuses in the uncertainty of industry environment to investigate.

Real Option

Black and Scholes (1973) proposed Black-Scholes Model and are employed as evaluating method in finance. In finance, option is a kind of design of virtual investment, and option means an executing right not an obligation. Real option purposed by Myers (1987) from Sloan School, he commanded that profit produced by an investment comes from the utility of assets and the

choice of future investing, and that is what so called “real”. Real option theory extends the use of financial option and is employed on un-financial product. The main different point of these two kinds of option is that the information needed for financial option to make decision is more available than real option. There has open information for underlying asset. The other different point of these two options is that the executing right of financial option is very clearly and could link to the object, premium and strike price. Comparing with traditional financial analysis, real option emphasizes on non-financial effect behinds innovation, such as development opportunity of future market, add-value produced from technology ability increasing, and competitiveness.

Black-Scholes Model is (Fischer and Scholes, 1973) adopted to evaluate value of call option and put option. Black-Scholes Model has several hypotheses:

The changes of strike price consist with Geometric Brownian Motion (GBM), and expect performance (μ) and volatility of stock price (σ) which is constant are not changing with executing period.

Before expiration date, there has no constant dividend yield.

Stock price consists with lognormal distributions.

Volatility of risk free rate and stocks return rates is constant.

Stock price is a continual change value.

European option only can be execute on expiration date.

And its function is as follow:

$$C = SN(d_1) - Ke^{-rT}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

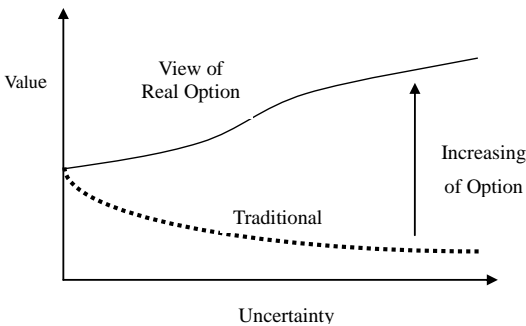
$$d_2 = d_1 - \sigma\sqrt{T}$$

Where C = market value of call option; S = current value of underlying asset; K = strike price of put option; r = risk free rate; σ = standard deviation of stock return rate; T = time period of expiration date from now; N(.) = accumulation normal distribution.

The one element of evaluating option value which most consists with this study is volatility. This study use the concept of Black-Scholes Model to estimate volatility and adopts real option model to estimate

uncertainty. The purpose of innovation is to provide an opportunity for corporate to create future benefit. In theory, all the invention investment decisions could be treated as option strategy. No matter how giant the risk needs to take, where the economic profit is there has meaning of innovation and invention. The investment of research and development of a corporate is equal to buying an option of future opportunity, and the decision of investment depends on whether the cost is reasonable. In recently, real option theory is extended to adopt on evaluating other assets or deicing manage strategy (Anderson, 2000). According to above, while evaluating option of corporate strategy, the main element depends on what kind of uncertainty the corporate facing, especially important in uncertainty of external and internal.

The value of option is based on external element not option itself. While the more the uncertainty element is, the higher the value of real option (Dixit & Pindyck, 1995; Anderson, 2000). According to previous research about real option, it is classified uncertainty into two types, market uncertainty and technology uncertainty. Adner and Levinthal (2004) commanded that real option provides an estimation of uncertainty in the future, and it could help management to make a suitable action under uncertainty. Since management could control investment plan and utility it effectively, the uncertainty would increase assets value a corporate had (Figure 1).



Source: Amram and Kulatilaka (1999)

Figure 1: Comparison of Traditional View and Real Option View

Early research combined research and development and real option, research and development is viewed as option of growth and provided future

investment opportunity or flexibility to let management to make a decision, give up, defer, and redesign program, to fit new technology (Childs and Triantis, 1999; Huchzermeier and Loch, 2001). Duncan (1972) thought environment uncertainty would influence the innovation decision of an organization; however, environment has dynamic action which would change with time and contains a lot of uncertainty factors. Therefore, environment uncertainty is also an important factor of organization operation and performance. Moriaty and Kosnik (1989) addressed two uncertainty elements in high-technology industry, market uncertainty and technology uncertainty. Value of real option would be much higher since corporate facing more uncertainty elements, and the value of time period would also be higher. Corporate gives up the profit of time value and executing right, while executing the investment. Under high uncertainty, corporate usually defers to execute the investment plan until the suitable timing (McGrath, 1997). This study take uncertainty element into consideration to consist with the real circumstances in high-tech industry.

Methodology

The purpose of this study is to investigate whether patent would influence corporate value under uncertainty, and the research framework of this study as Figure 2. This study utilizes three indicators to estimate patent, including patent number, patent citation, and patent priority claims. Patent number is the most common patent indicator to be used, and in this study it focus on patents which is granted from U.S. by Taiwan electronic industry, moreover, this study adopts qualified indicator (patent citation) to discuss patent value and to estimate the level of technology activities what corporate works on. And patent citation could show out how important or critical the technology which granted by the corporate is. Through international agreement, patent priority claims provide patent applicant claim patent right of his own patent in member countries to avoid losing patent value under the patent protection system of territoriality.

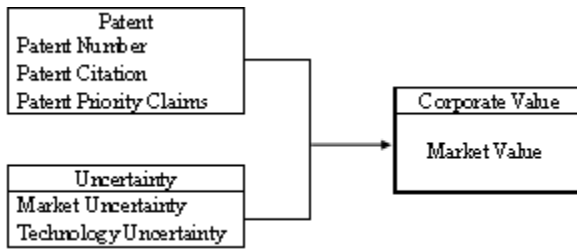


Figure 2: Research Framework

This study also employs real option model to estimate how patent value influences corporate value under different uncertainty. Based on the real option model with uncertainty elements purposed by Oriani and Sobrero (2003), and this study classify uncertainty into two types, market uncertainty and technology uncertainty. Previous research found out that under uncertainty circumstances there has deferring effect on investment, and it causes the cautionary effect to let management have more information and make correct decision. Generally, management can not anticipate the volatility level of market, and only option in the money has executing benefit, therefore, the higher the volatility level the higher the option value is. Similarly, while corporate facing more and higher uncertainty, the underlying assets of real option is higher. According to above, this study constructs hypotheses as follow:

H1a: patent number is positive related to corporate value under market uncertainty.

H1b: patent number is positive related to corporate value under technology uncertainty.

H2a: patent citation is positive related to corporate value under technology uncertainty.

H2b: patent citation is positive related to corporate value under market uncertainty

H3a: patent priority claims is positive related to corporate value under technology uncertainty.

H3b: patent priority claims is positive related to corporate value under market uncertainty

Differ from previous research used general regression analysis, this study adopts the concept of production function to explain patent asset and

corporate performance, and this is so called total factor productivity method. Besides, this study employs market value model addressed by Griliches (1981) to solve the time-deferred problem caused by total factor productivity method and constructs the empirical model:

$$\ln V/A = \ln b + \ln(1 + \gamma_1 \text{Pat}/A + \theta_i * U_i) + e \quad (1)$$

$$\ln V/A = \ln b + \ln(1 + \gamma_2 \text{Cit}/A + \theta_i * U_i) + e \quad (2)$$

$$\ln V/A = \ln b + \ln(1 + \gamma_3 \text{Pri}/A + \theta_i * U_i) + e \quad (3)$$

Where V/A presents market value of a corporate, and V/A value is comes from average stock price of current year divides by average outstanding shares of current year. Pat is the patent number granted from USPTO. Cit means citation count that patent granted from USPTO is cited by other later patent. Pri presents total number of patent that claims patent priority. U_i means uncertainty, and this study classifies it into two types, market uncertainty (U_1) and technology uncertainty (U_2). U_1 is estimated by the volatility of per market index on individual stock price, and U_2 is estimated by Science Linkage.

This study adopts Taiwan electronic industry which has higher expenditure of research and development, and finally this study selects 214 electronic companies from 1997 to 2006 year to investigate. About information of patent is mainly come from USPTO. Based on these data, this study constructs panel data to analyze. Panel Data Analysis could construct and test more complicated models than purely crosses-section or time-series data. If using traditional method OLS (Ordinary Least Square) to estimate, it might lead to heterogeneity bias. Therefore, this study draws on pooled regression to do analysis and use fixed effect model and random effect model to avoid heterogeneity bias.

Empirical Result

This study adopts 214 Taiwan electronic companies to be the investigating objects, and period of these data is crosses form 1997 to 2006 year. The basic descriptive statistics of the data this study collects shows as Table 1. From Table 1, it could find out that granted patent of Taiwan electronic industry is increasing, and it could also know that more and more corporate apply patent to protect its own technology and gain it market value of corporate.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Market value	239414.99	712838.82	4139.71	7440742.1
Patent Number	90.07	406.56	1	3841
Patent Citation	340.49	1875.38	0	19509
Patent Priority Claims	42.98	224.09	0	3060
Beta	1.00	0.29	-0.26	2
Science Linkage	28.91	168.55	0	2191

From Table 2, the count of patent priority claims from 2005 to 2006 year decreasing dramatically decreases might be the cause of the time gap between application date and the date claims priority. There has a great changing of patent citation, and it might be the reason that it needs 3 to 5 years to react. According to the result, it could know that under market uncertainty patent number, patent citation, and patent priority claims are all significant positive related to market value of corporate (Table 3). Under market uncertainty, patent, patent citation, and patent priority claims have positive influence on corporate value, and this means patent value a company have is good for the company under some kind suitable level of uncertainty. This result consists with the hypotheses, H1a, H2a, and H3a, this study addresses.

Table 2: Statistical Result of Taiwan Electronic Industry from 1997 to 2006

Year	Patent Number	Growth (%)	Patent Citation	Growth (%)	Patent Priority Claims	Growth (%)
1997	452	40.87%	5937	-8.24%	253	70.17%
1998	763	68.81%	8730	47.04%	563	122.53%
1999	1158	51.77%	10013	14.70%	733	30.20%
2000	1899	63.99%	13040	30.23%	597	-18.55%
2001	2237	17.80%	12298	-5.69%	852	42.71%
2002	2098	-6.21%	8591	-30.14%	1319	54.81%
2003	2246	7.05%	6801	-20.84%	1453	10.16%
2004	2755	22.66%	4817	-29.17%	1699	16.93%
2005	2380	-13.61%	2170	-54.95%	942	-44.56%
2006	3288	38.15%	468	-78.43%	393	-58.28%
Total	19276		72865		8804	

Table 3 : Result of Patent and Corporate Value under Market Uncertainty

Variable	H1a	H2a	H3a
Patent	0.027*** (0.01)		
Citation		0.0188** (0.0083)	
Priority Claims			0.0458*** (0.0122)
Market Uncertainty	1.043*** (0.0427)	1.0436*** (0.0428)	1.0385*** (0.0426)
Constant	2.4062*** (0.2021)	2.4562*** (0.2018)	2.4784*** (0.2013)
R-square	0.73	0.7296	0.7312

Note: 1. * Denotes statistical significant at 0.1 level; **Denotes statistical significant at 0.05 level; and*** Denotes statistical significant at 0.01 level.
2. The value in parenthesis is standard error.

About technology uncertainty, it could know that patent number, patent citation, and patent priority claims have no significant influence on corporate performance under technology uncertainty (Table 4). The result shows that patent has positive but not significant influence on corporate performance whether patent number, patent citation, or patent priority claims. The result about technology uncertainty does not support the hypotheses, H1b, H2b, and H3b, this study addresses.

Table 4: Result of Patent and Corporate Value under Technology Uncertainty

Variable	H1b	H2b	H3b
Patent	0.0491*** (0.0117)		
Citation		0.0389*** (0.0098)	
Priority Claims			0.075*** (0.0143)
Technology Uncertainty	0.0179 (0.0189)	0.0167 (0.019)	0.0299 (0.0187)
Constant.	3.4439*** (0.2325)	3.5366*** (0.2316)	3.5635*** (0.2308)
R-square	0.6262	0.6257	0.6285

Note: 1. * Denotes statistical significant at 0.1 level; **Denotes statistical significant at 0.05 level; and*** Denotes statistical significant at 0.01 level.

2. The value in parenthesis is standard errors.

According to the empirical results, this study finds out that patent number, patent citation, and patent priority claims have positive influence on corporate performance, but only under the circumstances of market uncertainty it is significant positive related to corporate performance. And that means put their effort into innovation or research and development and apply patent right for their own technology, product, or process is good for corporate performance. Besides, it is a great chance for companies while they facing market uncertainty.

Conclusion

There are three main hypotheses in this study, and they are patent number is positive related to corporate value under market uncertainty (H1a) and technology uncertainty (H1b); patent citation is positive related to corporate value under market uncertainty (H2a) and technology uncertainty (H2b); patent priority claims is positive related to corporate value under market uncertainty (H3a) and technology uncertainty (H3b). Table 5 is the summary of the empirical results. This study finds out that patent number, patent citation, and patent priority claims are significant positive to corporate performance under uncertainty circumstance, and it might be caused by the patent protecting system of territoriality. Under territoriality patent protecting system, in order to protects the right of patent, corporate would apply patent application in several countries, and this behaviors not only keeps the executing right of the particular technology, product, or process, but gains the value of corporate. So patent number, patent citation, and patent priority claims really indeed bring benefit to corporate owns patent.

Table 5: Summary of Empirical Result

	Hypotheses	Empirical Result
H1a	Patent number is positive related to corporate value under market uncertainty	Supported
H1b	Patent number is positive related to corporate value under technology uncertainty	Not supported
H2a	Patent citation is positive related to corporate value under market uncertainty	Supported
H2b	Patent citation is positive related to corporate value under technology uncertainty	Not supported
H3a	Patent priority claims is positive related to corporate value under market uncertainty	Supported
H3b	Patent priority claims is positive related to corporate value under technology uncertainty	Not supported

Under market uncertainty, patent number, patent citation, and patent priority claims are significant positive to corporate performance, and it believes that it could bring benefit to corporate under some kind level of market uncertainty. As to technology uncertainty, the empirical results do not support the hypotheses that patent number, patent citation, and patent priority claims are significant positive to corporate performance. From this, it appears that it needs to think more carefully while making decision of investment and technology strategy. Not every kind of uncertainty could bring benefit for corporate, only under the circumstance of market uncertainty could benefit corporate performance. Market technology uncertainty could create more profit for corporate, and it means this real option (investment) could be executed.

This study estimates patent value with three indicators; quantify indicators (patent number, patent priority claims) and qualify indicator (patent citation), and these all have significant positive influence on corporate performance. It might enhance the willing of apply patent application to protect unique technology, product, or process and gain the corporate value. Also, it could bring greater benefit for corporate who claims patent priority because of the territoriality patent protecting system (Barney, 2001).

In practice, this study suggests that each corporate should think more about patent application. Although there has some limitation and cost for applying patent right, patent right could increase market value of

corporate and also protect unique technology a company owns and invent. Furthermore, it could know more information and learn more technology knowledge from open information of granted patent. Territoriality is the common patent protecting system now. However, with the globalization trade the protecting system is more completely, and it brings more and more positive effects for a company not only in economic but in technology. Every company would face some kind of different uncertainty, but for Taiwan electronic industry market uncertainty is more important than others, and the volatility of market technology has good effects for it.

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