Computer Simulation Based Chemical Patent Value

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Abstract

Chemical patent evaluation is a growing concern in industrial and academic research. Patent value conventionally considered a constant. However, the unique characteristics of changing patent value in its life cycle must be considered. This study proposes a simulation model of chemical patent value. Additionally, comparative parameter analyses are conducted to provide detailed information for the proposed model. The analytical results show that drift rate and volatility positively affect patent value. In contrast with the traditional view of patent value as a constant, the proposed model is more realistic for patent evaluation and captures more realistic patent value.

Keywords: *Chemical Patent Value; Computer Simulation; Dynamic*

1.Motivation and Previous Works

Patent valuation is an important issue. Traditional evaluation tools assume that patent value is static, and they do not consider uncertainties. This study addresses the gap in the literature so that managers can properly value their patents. Of the various approaches for evaluating patents, the most intuitive approach is based on management judgment. Although easy to perform, the subjective estimation of the valuator can distort the final value. Therefore, evaluation tools from the finance field have been used for patent valuation. The financial measurements are the most common patent evaluation approaches (Business-Insights 2006). Companies evaluate patents by using the net present value (NPV) approach, which discounts the cash flows generated by patents, and compares it with the costs. The idea of NPV is to compare all expected positive cash flows with negative cash flows to determine whether a patent is profitable. A positive value suggests that a patent is profitable for the owner (Villiger and Bogdan 2005).

Although NPV is the most common approach to patent evaluation, its limitation is its pin-point basis since it assumes that all benefits and costs are certain and as predicted. A common criticism of NPV is that it does not account for uncertainties, so the user must assume that future cash flows are fixed(Villiger and Bogdan 2005). Another evaluation tools is the decision tree analysis which improves NPV analysis

by considering different possible outcomes. Although decision trees enable the user to assess sales revenues uncertainties, patent value is determined mainly by the choice of scenarios and their attributed probability. Questions such as, “How likely is the worst case scenario?” lack a sound theoretical foundation (Villiger and Bogdan 2005).

Since NPV and its expansion tools are generally considered static approaches that do not adequately account for uncertainty, some studies have applied the real options approach to patent valuation. Therefore, the real options approach (Pindyck 1988; Dixit and Pindyck 1994), which aims to evaluate uncertainty, has been applied in R&D evaluation. The real options approach is a valuation method that considers the uncertainty and future growth opportunities associated with an investment. For example, a financial option is a right, but not an obligation, to trade on a real or financial asset at a predetermined exercise price within a predetermined period of time. Myers (1974) first applied option pricing theory to real assets and non-financial investments. He noted that compared to the traditional NPV approach, real options provide a more realistic way to value strategic opportunities and uncertainty. Following Myers, Dixit (1995) used the real options approach to value intangible growth opportunities in investments. Dixit considered uncertainty in the decision making environment. Kulatilaka & Perotti (1998) assessed the value of managerial flexibility with the real options approach while Trigeorgis (1993) used real options theory to evaluate investment projects with uncertain revenues.

For example, Kellogg & Charnes (2000) used a decision tree method for valuing of a biotechnology company based on its R&D. Schwartz (2004) considered an abandon option when valuing patents and patent-protected R&D projects. They concluded that uncertainty is critical for evaluating patents since dynamic characteristics are inherited. Wu and Tseng (2006) used a Real Options approach to study the effects of patent value volatility and time to maturity on patent value. The conclusions of their study were based on the consistent results between the theoretical Real Options model and empirical analysis. That is, patent value increases with time to maturity and patent value volatility. Baudry and Dumont (2006) used the Real Options concept to assess patent renewals strategies with binomial trees. The use of real options to assess uncertainty and patent value in these exploratory studies is still an experimental approach, and no studies have explicitly identified patent life cycle, which is a unique and critical characteristic in patent valuation.

Valuation of chemical patents is very similar to differentiating the characteristics of chemical R&D stages from other industries, *i.e.,* the regulatory scheme governing the overall process. The chemical R&D, or more specifically, the patent licensing

process, involves several predefined stages before a product is launched in the market and begins generating sales revenues.

Arojarvi (2001) described these phases in detail and stressed that acquiring a patent is a phased, risky, and highly variable process. In phase 1 (*Discovery),* chemists search for potential new drug candidates from among millions of chemical compounds. In phase 2 (*Pre-clinical),* compounds are preliminarily screened for pharmacological activity and toxicity. In phase 3 (*Investigational New Drug Application (IND)),* FDA approval is sought for further development of promising candidates. In phase 4 (*Clinical trials),* small number, large number, and large-scale trials are conducted. In phase 5 (*New Drug Application (NDA))*, national authorities assess documented evidence of the safety and effectiveness of the drug. In phase 6 (*Post-approval),* additional research is performed to develop extensions of the product.

Successful chemical R&D in each phase increases the potential value of the patent. In early stages of patent licensing, patent values are low because of the risks and uncertainties involved. However, in latter stages such as Phases I-III, the value of a chemical patent grows at an accelerate pace as the potentially huge market revenues protected by the patent are realized.

Another characteristic of the chemical patent is that chemical R&D is patented for about twenty years. Chemical R&D often faces major competition from low-cost generic products after the patent expires. For example, market surveys indicate that, when patent expirations in the U.S begin to peak in the years 2011 and 2012, six of the ten largest products are expected to face competition from low-cost generic alternatives. Products with sales of more than $142 billion are expected to face competition from generic products in major therapeutic products such as cholesterol regulators, antipsychotics and anti-ulcerants. In most cases, by the time a patent has expired, the value of the patent has dropped dramatically. Therefore, most producers abandon the market (Gatyas and Savage 2010).

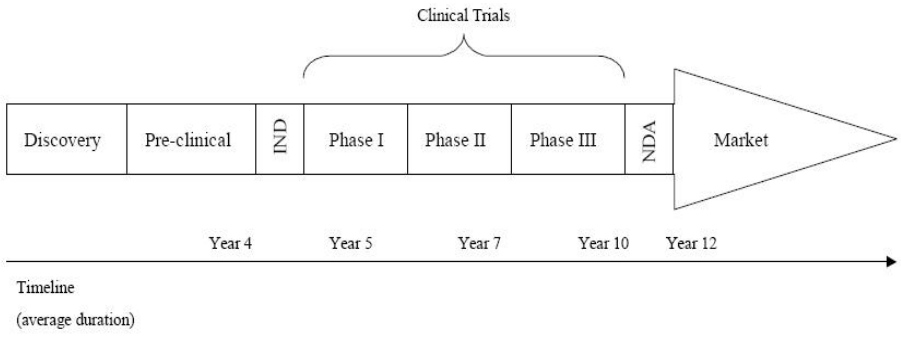

Figure 1. The Phased Chemical R&D Process

Source: Arojarvi (2001)

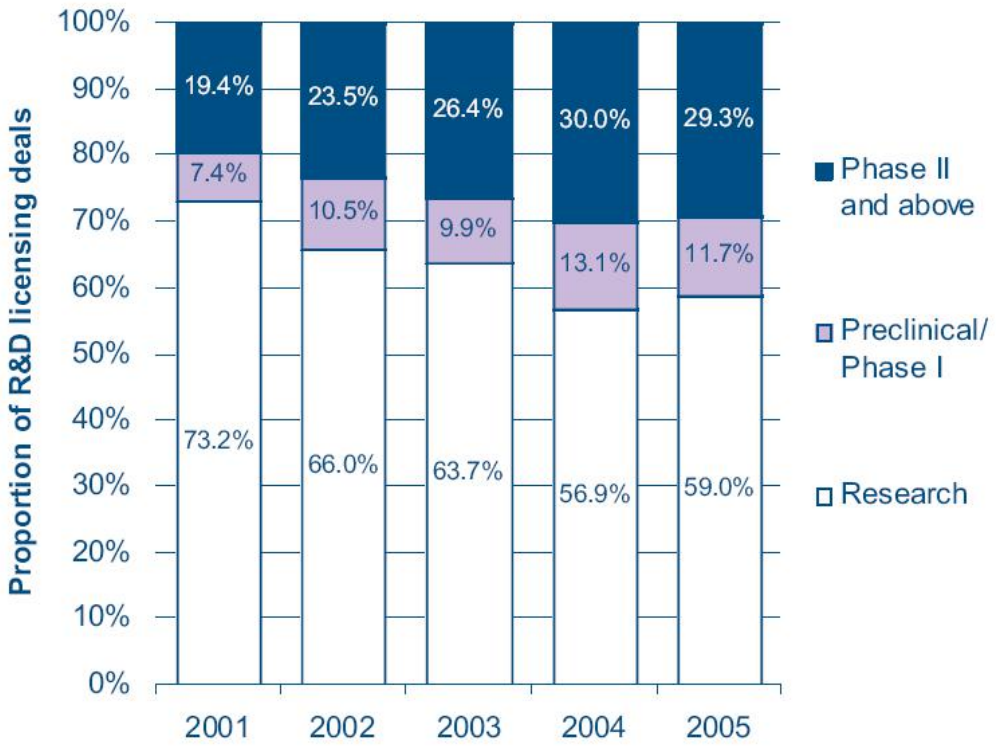

Figure 2 Stage in which Chemical R&D are Patented During 2001-2005

(Source: Business Insight 2006)

The patent valuation must link to the phased chemical R&D process Previously, chemical R&D was patented during pre-clinical trials (Gambardella 1995). However, market surveys reveal significant increases in late-stage deals between 2001 and 2005. In recent year, biotech R&D licensing deals for biotech R&D licensing deals, the proportion of agreements signed in phase II or later has grown from less than 20% in 2001 to almost 30% in 2005. Licensing agreements in later stages, particularly in phase II, appear to be driving growth in licensing activity over the past five years (Business-Insights 2006).

Although existing approaches do not consider patent life cycle, some studies have addressed the issue. For example, Myers and Howe (Myers and Howe 1997) performed an exploratory study of the importance of life cycle in evaluating patents. They proposed a simulation-based model of investments in chemical R&D programs, which considered cost uncertainty during different phases of drug R&D. They documented the importance of product life cycle, *i.e.* pre-clinical, phase I, II and III clinical trials, and FDA filing, before the launch of a new drug. In a risk analysis of the phased process, the author found that most projects are abandoned in Phase 1.

Risk then gradually diminishes over time until the final phase is reached. Similarly, Villiger and Bogdan (2005) argued that, since patent value may change during the life of the R&D project, users must adjust cash flows according to the probability of success in different phases of R&D.

Unfortunately, the patent life cycle is difficult to evaluate by traditional discounted cash flow analysis. In contrast to tangible assets such as plants and machines in which value is determined by market costs, patent values are uncertain and unforeseeable. Inherent uncertainties in patent values result from the risk that patents may fail at any developmental stage. Therefore, cash flows are also uncertain and unforeseeable. Additionally, when justifying a patent acquisition, firms must consider the unique S shape curve life cycle. Traditional methods do not account for these patent characteristics, even though the important value drivers for patents are contingent on such unknown future states.

1. Patent Value Process

Based on Schwartz and Moon (2000) and Dias (2001)'s as well as Wu et al (2011)'s development in financial mathematics, we model the patent life cycle as a stochastic process.

The Model

Assume that the patent value V follows the standard Brownian motion according to Dixit and Pindyck (1994):

$$\frac{dV_t}{V_t} = \alpha_t dt + \sigma_1 dz_1 \tag{1}$$

Where

$\frac{dV_t}{V_t}$: the change in patent value

α_t: slope of the patent value

Dz: increment of the Brownian motion.

$$\frac{d\alpha_t}{\alpha_t} = \eta(\overline{\alpha} - \alpha)_t dt + \sigma_2 dz_2 \tag{2}$$

Where

η: decay rate

$$E[V(T)] = e^{-\eta T}V(0) + (1 - e^{-\eta T})\alpha \tag{3}$$

$$Var[V(T)] = \frac{\sigma^2}{2\eta} + (1 - e^{-2\eta T}) \tag{4}$$

$$\rho_{dz_1 dz_2} = 0 \tag{5}$$

where Eq. (3) shows the expected patent value and Eq. (4) shows the variance in patent value. Equation (5) indicates that the variance in Eqs. (1) Equation (2) are not correlated, and are generated from different Normal Probability Distributions *N(0,1)*.

2. Analysis of Results

Figure 3 shows the patent value obtained by Monte Carlo simulation. The value pattern follows the life cycle noted in (Arojarvi 2001) as shown in Fig. 3. Patent value reflects two patterns of uncertainties: 1) the major pattern is life cycle uncertainty, which determines the outline of the value curve, and 2) the uncertainties along the curve. Figure 4 shows that patent value fluctuates throughout the life cycle in the proposed model, which describes the potential value of the patent before market launch, *i.e.,* the discovery phase, the pre-clinical phase, the IND phase, Phase I, Phase II, and Phase III. The patent value reaches a stable level of market sales after the market launch during Years 5-20. Since the patent value drops dramatically when the patent expires, the entire value of the patent can be realized by discounting the entire 20 years of the patent lifetime.

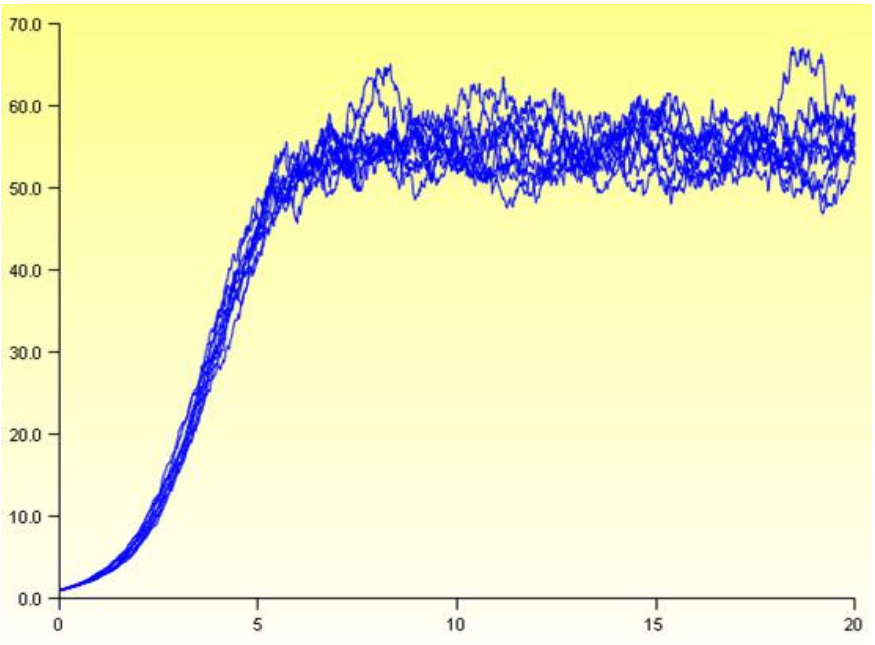

Figure 3 The Patent Value by Simulation

In contrast with the traditional view that patent value is a constant and static concept, the proposed model normatively incorporates the life cycle and uncertainties into patent valuation. Based on simulation, a range of possible patent values under uncertainties can be useful for negotiating patent licenses. To observe the effect of a parameter by Monte Carlo simulation, a specific time slot Δt=150 is selected, and different simulation times are applied (see Table 1). The mean value of the patent at time slot Δt=150 is $18.7 million with a standard deviation of 2.7. The standard deviation gradually decreases, and the mean value converges to a fixed value as simulation time is increased.

The next step is summarizing the comparative statistical analysis to explore how each parameter affects patent value. Table 2 shows that volatility (σ) is positively related to patent value. The potential value of the patent increases and σ increases since growth opportunities constitute a substantial component of overall patent value.

The effect of changes in reversion rate (η) are then examined for effects on patent value. Given the same setting, growth rate correlates positively with profitability. The results show that the higher the value of α, the more valuable the patent.

3.Conclusions & Managerial Implications

This study demonstrates the stochastic modeling in patent evaluation. Chemical manufacturers can use this model to quantify patent value. Unlike the NPV approach, the proposed model considers uncertainties and provides a more reasonable and realistic patent value curve.

Table 1 The Influence of Simulations Loops on Standard Deviation Converge

Simulation Loops	**100**	**1,000**	**10,000**	**20,000**
Mean Value	18.7	17.7	16.4	16.2
Standard Deviation	2.7	0.8	0.7	0.6

Table 2 Parameter Impact on Patent Value

Parameter	**Change**	**Patent Value**	**Impactions**
Volatility (σ)	+	+	Increase the upper bound and decrease the lower bound (increase the band)
Reversion Rate (η)	+	-	Increase the time of reaching a long term equilibrium
Drift Rate (α)	+	+	Increase both upper and lower bound

The limitation of the proposed model is that, as in other evaluation approaches, some parameters inevitably require estimation. Nevertheless, practitioners can use industry survey data or rely on their own expertise for parameter estimation and adjust the model to the specific case to obtain a realistic revenue curve. Notably, the goal was to develop an evaluation framework rather than to estimate patent value. The proposed model can serve as a prototype for analyzing patent values.

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