Valuation of a Startup Business with Pending Patent Using Real Options

by

J. Barry Lin* and Anthony F. Herbst**

*Department of Finance
University of South Florida
5700 North Tamiami Trail
Sarasota, Florida 34243
Tel: (941) 359-4395
Email: lin@sar.usf.edu

**Department of Economics & Finance
College of Business Administration
University of Texas at El Paso
El Paso, TX 79968
Tel: (915) 747-5245
E-mail: aherbst1@elp.rr.com

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Abstract

The uncertainty over whether a patent application will succeed makes the valuation of a new business based on a yet unpatented technology difficult. This paper applies a real option model to the valuation of a business in the process of applying for patent. Optimal exercise of an embedded growth option is illustrated through a numerical example. It is demonstrated that the resolution of uncertainty — and correctly valuing an optimally exercised growth option — is critical in the valuation of such projects. We also highlight an important difference between the asset value-evolution type of uncertainty for the real options, and the business risk type of uncertainty for the patent application.

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1. Introduction

New high-tech companies often start with pending patents on their core technology. Whether the company successfully obtains the patent often determines its future success or even its survival. The uncertainty about issuance of the patent makes the valuation of such startup businesses difficult, especially when the patent is associated with expected high growth. The modeling of patent uncertainty, together with a growth real option is often challenging. This paper uses a real option model as a framework to correctly evaluate a startup business with pending patent and associated growth real option. We illustrate the optimal exercise of a growth real option given the (uncertain) outcomes of the patent application. We use a straightforward numerical example to demonstrate the resolution of uncertainty, the optimal exercise of real options, and the contingent-claim valuation of the project.

2. Literature Review

Black and Scholes (1973) recognize the default option held by the equity holders of a corporation. The same concept applied in the field of capital budgeting, treating a project owner as having the flexibility of changing the modes of operation, default and abandonment among them, has spawned a large body of research into real options in the last decade. Trigeorgis (1993, 1996) gives a comprehensive review of the real option literature.

These studies include analyses of operating flexibility in a wide variety of business activities: natural resource industry (Brennan and Schwartz 1985, Kemna 1993), leasing

(Copeland and Weston 1982, McConnell and Schallheim 1983), flexible production (Kulatilaka 1988, Kulatilaka and Trigeorgis 1993), research and development (Kolbe, Morris, and Treisburg 1991), strategic acquisition (Smith and Triantis 1993), foreign investment (Baldwin 1987, Kogut and Kulatilaka 1993), shipping (Bjerksund and Ekern 1993), government subsidies (Mason and Baldwin 1988), and regulation (Treisburg 1993), among others. Amram and Kulatilaka (1999) give a variety of real option applications in many diverse areas.

The valuation of real options may be analyzed by *Contingent Claim Analysis* (CCA), where the value of a contingent claim is derived by finding the value of an equivalent portfolio of traded assets, a so-called *tracking portfolio* (Cox, Ross, and Rubinstein 1979). Conceptually, contingent claim analysis (CCA) is very similar to decision-tree analysis, with the critical difference being use of the risk-neutral probabilities and consequently the risk-free rate. Varian (1987) gives a detailed illustration of the theoretical foundation and application of CCA.

3. A Startup Business with a Patent Application

Suppose UniPat is a startup company that has a novel Internet application. The company has a patent pending on its technological development. The company's patent attorney estimates that it will take at minimum a year for the U.S. patent office to issue the patent. There is a probability of $\boldsymbol{q} = 0.5$ that the patent will be issued, and $(1 - \boldsymbol{q}) = 0.5$ that the patent office will refuse the patent because the patent examiner believes it is obvious, or a search reveals the technology has already been patented by others.

The management of UniPat wants to launch their Internet operation immediately when the patent is issued. To be ready to act then, they must invest $\boldsymbol{I_0}$ = \$4 million now for programming, computer and network hardware, and marketing materials. If the patent is not issued, or is delayed, they will launch the application anyway after a year. But the consequences of not having a patent will be that competitors can duplicate their application, and UniPat's earnings will be much lower than with the patent protection.

The required initial investment of $4 million is to be raised from venture capitalists.

The critical uncertainty for UniPat is the patent application. This uncertainty is expected to be resolved in one year. Depending on the patent application's outcome, the firm evolves either into an Internet business with some degree of monopolistic market power (Case 1) or into an Internet firm in a highly competitive market (Case 2). See Figures 1 and 2 for the evolution of firm value in the 2 cases.

Hired by a consortium of venture capitalists for the valuation of UniPat, BarrTony Consulting estimated risk-neutral probabilities for the 2 cases. In case 1, if the patent is granted, the risk-neutral probabilities are: $p = 0.4$ and $(1 - p) = 0.6$. If the patent is denied, in Case 2, the risk-neutral probabilities are: $p = 0.76$ and $(1 - p) = 0.24$[1].

BarrTony Consulting's analyses also suggest that the firm will have two real options. In year 2, the firm can sell the firm for salvage value of $V_{S,2} = \$5$ million. In year 3, the firm can expand operation by 80% by investing an additional amount $I_3 = \$2$ millions.

[1] To simplify our discussion, risk-neutral probabilities are assumed to have been estimated before the formal analysis and valuation of the startup business. Risk-neutral probabilities are functions of the volatility of the underlying traded tracking portfolio. See Varian (1987) for more details on risk-neutral probabilities.

Insert

Figures 1 and 2: Evolution of Firm Value here.

4. Iterative Valuation Process:

Given that the venture capitalists will sell their holding after 3 years, the iterative analysis starts in firm values in year 3.

Case 1:

Consider Case 1, wherein the firm gets the patent. At **t = 3**, the firm will exercise the expansion option if the investment increases firm value. Otherwise, the firm will forego the expansion real option and stay with base operation. With the real option, firm value[2] at **t = 3** for each state of economy will be $\boldsymbol{V'_3} = \text{Max}(\boldsymbol{V_3}, [(1 + 80\%)*\boldsymbol{V_3} - \boldsymbol{I_3}])$, or:

$$\begin{aligned} \boldsymbol{V'_{3UU}} &= \text{Max}(15{,}312{,}500,\ 1.8*15{,}312{,}500 - 2{,}000{,}000) \\ &= \text{Max}(15{,}312{,}500,\ 25{,}562{,}500) \\ &= 25{,}562{,}500 \end{aligned}$$

The expansion real option is exercised in this state of economy.

[2] Since it will be clear from the context that we are working with currency values, the dollar sign, $, will be omitted in this section.

$\boldsymbol{V'_{3UD}}$ = Max(5,250,000, 1.8*5,250,000 – 2,000,000)

= Max(5,250,000, 7,450,000)

= 7,450,000

The expansion real option is exercised in this state of economy.

$\boldsymbol{V'_{3DD}}$ = Max(1,800,000, 1.8*1,800,000 – 2,000,000)

= Max(1,800,000, 1,240,000)

= 1,800,000

The expansion real option is not exercised in this state of economy.

From $\boldsymbol{V'_{3UU}}$ and $\boldsymbol{V'_{3UD}}$, we can derive $\boldsymbol{V'_{2U}}$ by applying the risk neutral probabilities:

$\boldsymbol{V'_{2U}}$ = $[\boldsymbol{p}^* \boldsymbol{V'_{3UU}} + (\boldsymbol{1-p})^* \boldsymbol{V'_{3UD}}]/(1 + \boldsymbol{r_f})$

= [0.4*25,562,500 + 0.6*7,450,000]/(1 + 6%)

= 13,863,208

Similarly, from $\boldsymbol{V'_{3UD}}$ and $\boldsymbol{V'_{3DD}}$, we can derive $\boldsymbol{V'_{2D}}$ by applying the risk neutral probabilities:

$\boldsymbol{V'_{2D}}$ = $[\boldsymbol{p}^* \boldsymbol{V'_{3UD}} + (\boldsymbol{1-p})^* \boldsymbol{V'_{3DD}}]/(1 + \boldsymbol{r_f})$

= [0.4*7,450,000 + 0.6*1,800,000]/(1 + 6%)

$= 3{,}830{,}189$

At this point, the firm's management will consider the salvage real option. At **t = 2**, the firm will exercise the salvage real option if it increases firm value. Otherwise, the firm will forego the salvage real option and stay with base operation. With the real option, firm value at **t = 2** for each state of economy will be $V'_2 = \text{Max}(V_2, 5{,}000{,}000)$, or:

$$V'_{2U} = \text{Max}(13{,}863{,}208, 5{,}000{,}000)$$

$$= 13{,}863{,}208$$

The salvage real option is not exercised in this state of economy.

$$V'_{2D} = \text{Max}(3{,}830{,}189, 5{,}000{,}000)$$

$$= 5{,}000{,}000$$

The salvage real option is exercised in this state of economy.

Finally, from V'_{2U} and V'_{2D}, we can derive V'_1 by applying the risk neutral probabilities:

$$V'_1 = [p^* V'_{2U} + (1 - p)^* V'_{2D}]/(1 + r_f)$$

$$= [0.4*13{,}863{,}208 + 0.6*5{,}000{,}000]/(1 + 6\%)$$

$$= 8{,}061{,}588$$

Case 2:

In Case 2, the firm is denied the patent. At **t = 2**, the firm will exercise the salvage real option if it increases firm value. Otherwise, the firm will forego the salvage real option and stay with base operation. With the real option, firm value at **t = 2** for each state of economy will be V''_2 = Max(V_2, 5,000,000), or:

V''_{2U} = Max(5,500,000, 5,000,000)

= 5,500,000

The salvage real option is not exercised in this state of economy.

V''_{2D} = Max(4,500,000, 5,000,000)

= 5,000,000

The salvage real option is exercised in this state of economy.

Again, from V''_{2U} and V''_{2D}, we can derive V''_1 by applying the risk neutral probabilities:

V''_1 = [p* V''_{2U} + ($1 - p$)* V''_{2D}]/(1 + r_f)

= [0.76*5,500,000 + 0.24*5,000,000]/(1 + 6%)

= 5,075,472

5. Present Value of the Project and Patent Uncertainty:

At time 0, there is a 50:50 probability that the firm will receive the patent it has applied for or have it rejected by the patent office after 1 year. Note that the uncertainty in the patent application is distinct and different from the asset value evolution type of uncertainty in the conventional binomial pricing model. While asset-value-evolution type of uncertainty can be hedged by a tracking portfolio (which is the basis of contingent claim valuation), the patent uncertainty cannot. The patent uncertainty is treated as business risk and accounted for by a risk-adjusted discount rate.

The time 0 valuation approach follows conventional net present value, where the probabilities are NOT the risk-neutral probabilities driven by asset value evolution but are instead the traditional decision-tree type of probabilities. We have:

$$
\begin{aligned}
\boldsymbol{NPV_0} &= [\boldsymbol{E_0}(\boldsymbol{V_0})/(1 + \boldsymbol{K})] - \boldsymbol{I_0} \\
&= [(0.5^* \, \boldsymbol{V'_1} + 0.5^* \, \boldsymbol{V''_1})/(1 + 20\%)] - \boldsymbol{I_0} \\
&= [(0.5^*8{,}061{,}588 + 0.5^*5{,}075{,}472)/(1 + 20\%)] - 4{,}000{,}000 \\
&= 5{,}473{,}775 - 4{,}000{,}000 \\
&= 1{,}473{,}775
\end{aligned}
$$

With a positive NPV greater than a million dollars, the venture capitalists should proceed with their investment in the new venture.

6. Conclusions

Real options provide a way of looking at capital investments and other corporate investment decisions that offers insights that traditional DCF methods cannot. Whether or not adopting a real options approach will provide a clear numerical signal to adopt or reject a particular project is not as important as the fact that engaging in the exercise of framing the problem in real option terms, and focusing management attention on the framed problem will facilitate better decision making. This paper provides an illustration in the case of a startup new business with pending patent. The real option modeling process provides a straightforward methodology for modeling embedded operational flexibility. It is also a clear way to handle the two types of uncertainty involved in this particular situation.

The numerical solution method used to solve a particular real option problem is not nearly as important as careful framing of the problem and attention to including only the truly relevant sources of uncertainty and key decision variables. The binomial model is flexible and can handle various types of real options. In truly complex real option evaluation involving uncertainty, computer simulation (Monte Carlo method) may be required.

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Figure 1: UniPat

Stage 1, Technology Development

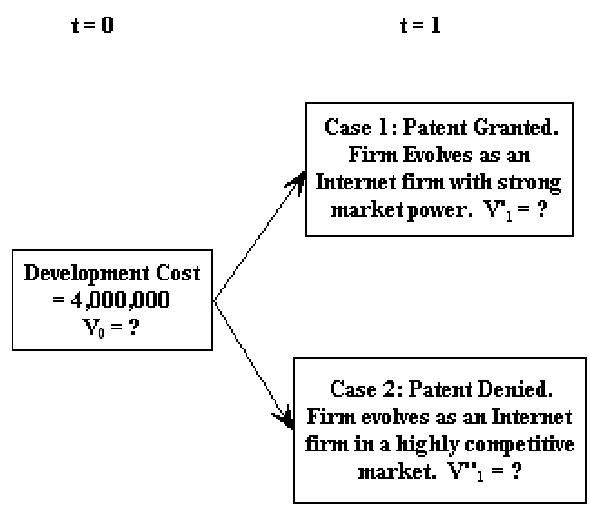
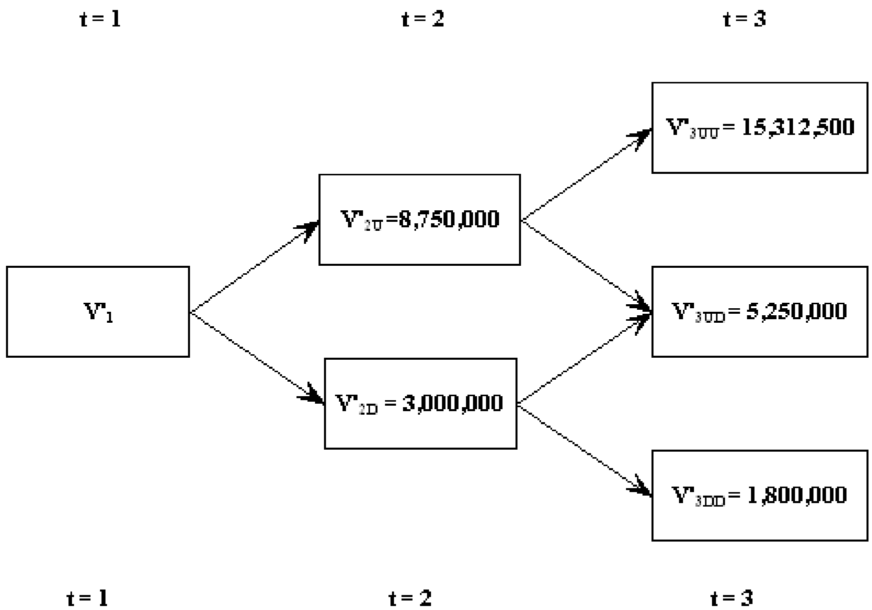


Figure 2: UniPat

Stage 2, Commercial Operation

Case 1: Patent Granted. Firm evolves as an Internet firm with strong market power.



Stage 2, Commercial Operation

Case 2: Patent Denied. Firm evolves as an Internet firm in a highly competitive market.