Valuation of Intellectual property

The Paper

The presentation was based on a paper entitled *Valuation of intellectual property A real option approach* by Jow-Ran Chang, Department of Quantitative Finance, National Tsing Hua University, Taiwan and Mao-Wei Hung and Feng-Tse Tsai, College of Management, National Taiwan University, Taiwan[1]. It was published in 2005 in the Journal of Intellectual Capital, Vol. 6 No. 3, pp. 339-356.

The goal of the paper is to provide a new approach to evaluate intellectual property (IP). For this purpose, a cautious view of how volatility impacts the economic value of IP's is used. Real option is a useful tool for valuing investments under uncertainty and if it is applied to the valuation of IP with some modifications, it is also widely accepted. However, it is still debatable whether there is a constant rate-of-return. This paper incorporates a sensitivity variable to account for the volatility of the expected rate of return. Thus, rate-of-return can be a constant or increase with volatility.

The findings can be summarized as follows: In the simple model, Vega may be negative when the option is deep in the money. In the general model, the option can be seen as a sequence of options and under the constant rate-of-return shortfall setting. It resembles traditional financial options with positive Vega.

Basics

Intellectual Properties (IP)

The World Intellectual Property Organization describes IP as creations of the mind, such as inventions, literary and artistic works, designs and symbols, names and images used in commerce. Many can be protected by law. The most well-known types are copyrights, patents, trademarks, designs or trade secrets.

[1] Chang, J., Hung, M. and Tsai, F. (2005), "Valuation of intellectual property: A real option approach", *Journal of Intellectual Capital*, Vol. 6 No. 3, pp. 339-356. https://doi.org/10.1108/14691930510611094

The value and importance of IP

IP is important because it brings growth opportunities and competitive edge, hence future cash flow. This is due to the fact that a patent can exclude competitors from a market. Especially high-technology companies spend a lot on research and development and emphasize IP rights and patents. IP is usually inseparable from a firm. It is traded in mergers and acquisitions. Also, it can be transferred in bankruptcy situations. The true value of IP has to be listed in balance sheets.

But the value of IP is hidden or hard to assess. There are some valuation approaches that approximately measure the assets' value, but they usually leave out their latent value. Those approaches include:

- Income approach, cost approach, market approach
- Discount cash flow
- Real option method (ROM)

Real option method (ROM)

A real option is the right, but not the obligation, to undertake certain business initiatives. It is referred to as "real" because it typically references projects involving a tangible asset instead of a financial instrument. ROM are derived from financial options and used toto assess investment-projects.

In contrast to financial options, real options must satisfy certain characteristics:

- Flexibility
- Irreversibility
- infinite life span

Those characteristics make ROM suitable for using them when it comes to IP. Of course, ROM has limitations in practice. Those include:

1. The estimation of volatility is difficult in practice, because IP are not frequently traded.
2. Inexact mapping of assumptions or inputs between option pricing theory and real option application.
3. Patents have "adverse rights" which run counter to "having an option".

Option value versus volatility

There has been a lot of discussion about the relationship of option value and volatility. Most researchers think there is a positive correlation, whereas also a negative relationship has been defended.
In financial options, increasing the volatility will increase the option value. Therefore, sellers of IP try to manipulate the estimation of volatility to be high in order to enhance the option price. Similarly, buyers try to underestimate volatility in order to keep the buying price low. Volatility is also influenced by rate-of-return shortfall.

Main idea

The paper's idea is that the growth rate of demand in real investment projects should not work as in financial assets, which is an assumption other researchers made.
Since real options aren't as frequently tradeable as financial products, this assumption is not viable. Thus, the goals of the authors are to:

- refute some "bad" assumptions of older research
- break myth that higher volatility makes the option price go up, because the upside potential of the price is not restricted, but the downside loss is.

A new parameter

The authors suggest a parameter γ to model the sensitivity of expected rate of return of the underlying asset to output price volatility. γ may :

- vary under different factors
- be different from industry to industry
- be a constant factor or a linear function of the volatility

Effects of higher volatility

Two kinds of effects are distinguished: Direct effect and indirect effect. The direct effect describes higher volatility leading to higher option price. The indirect effect describes higher volatility leading to a decreasing option price when the rate of return shortfall increases with volatility.

Modeling the relationship between volatility and option value

Three different models to see the relationship between volatility and option value shall be discussed.

Simple model

First, we propose a simple model in valuing an investment project and apply it to evaluate an IP. Suppose the present value of the IP is *V*, and the cash flow generated by IP is *P*. *P* follows the stochastic process as follows:

$$dP = \alpha P dt + \sigma P dz$$

α represents the drift rate of *P*, σ the standard deviation of *P* and *dz* is a wiener process.
Now let *F = F(P)* be the value of the option to invest. Construct a dynamic hedge portfolio $\Phi = F - Fp$, where $Fp = dF / dP$.
The return expected of this portfolio over infinitely short time periods dt is

$$dF - F_p dP - \delta P F_p dt$$

The portfolio is riskless during dt and earns the same risk-free securities, therefore

$$d\Phi = r\Phi dt$$

Hence we get:

$$dF - F_p dP - \delta P F_p dt = r(F - F_p P)dt$$

After some manipulations we arrive at a differential equation:

$$\sigma^2 P^2 F_p P + (r - \delta) P F_p = 0$$

The differential equation is of the Cauchy-Euler type and a solution of the type

$$F(P) = a_1 P^{\beta 1} + a_2 P^{\beta 2}$$

can be found.

Finite period model

Some IPs such as patents have finite lifetime, hence this finite-period-model is suitable for these kinds of IPs.
Again we assume that the cashflow *P* generated by the IP follows the stochastic process:

$$dP = \alpha P dt + \sigma P dz$$

With the Black-Scholes formula we get

$$F(P_0, I, t) = P_0 N(d_1) - Ie^{-rt}N(d_2)$$

$$d1 = \frac{\ln(p_0/i) + [r + (\sigma^2/2)t]}{\sigma\sqrt{t}}$$

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

Now let $P* = Pe^{-(\mu - \alpha)t}$. Again, with the Black-Scholes formula we get:

$$\frac{1}{dt}E(\frac{df}{F}) = \frac{1}{dt}E(\frac{dp}{P}) = \alpha < \mu$$

We set $\delta = \mu - \alpha$. The bigger the dividend rate *δ*, the smaller is the expected rate of return α.
In conclusion a higher dividend rate decreases the option value, very much like in financial options. So we may have a negative relationship between option value *F* and volatility *σ* in some region of *P* if *σ* can enhance *δ*.

General model

We extend the model to a more realistic one. We make the following changes. The project:

1. can be shut down without any cost if *P* is lower than variable cost *c*
2. can be restarted if *P* is above c.
3. produces one unit of output in each period.

Now the project is taken as a set of options and its value V becomes

$$V(P) = \begin{cases} A_1 P^{\beta_1} & P < c \\ A_2 P^{\beta_2} + P/\delta - c/r & P \geq c \end{cases}$$

The option Value F of P is

$$F(P) = \begin{cases} aP^{\beta_1} & P \leq P^* \\ V(P) - I & P > P^* \end{cases}$$

New Idea γ

Now we want to study the impact of volatility on the option price. For this we analyse $dF / d\sigma$. We can now look at the shortfall rate as a function of volatility: $\delta(\sigma) = \mu(\sigma) - \alpha(\sigma)$. The author then defines $\gamma = \alpha'(\sigma)$. This corresponds to the sensitivity of the drift of the output price against volatility.

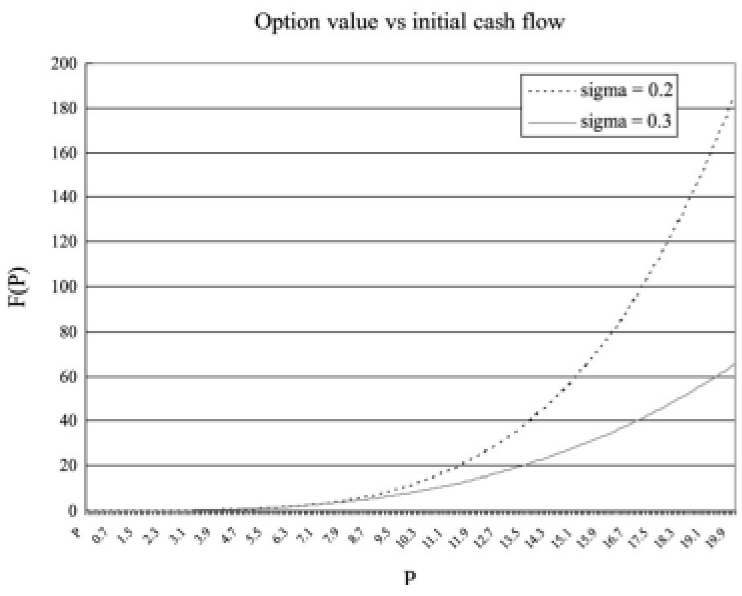
With some calculations we fi nd a restriction for *γ*:

$$\gamma < \lambda\rho v_m + (r - c/\sigma)$$

δ increases with σ and enlarges the critical value *P*.* Then, the option becomes less valuable. But a larger volatility δ generates a higher probability for cashflow to overstride the critical value *P**. The options becomes more valuable.

Numerical Analysis

We compare the simple and general model only for the Case 2:



Simple model,
Case 2
rate of return shortfall increases with the same velocity as drift rate of P

Figure 5.
$P = 20, I = 100, r = 0.05,$
$\lambda = 0.3, \rho = 0.8, \gamma = 0$

General model
Case 2
rate of return shortfall increases with the same velocity as drift rate of P

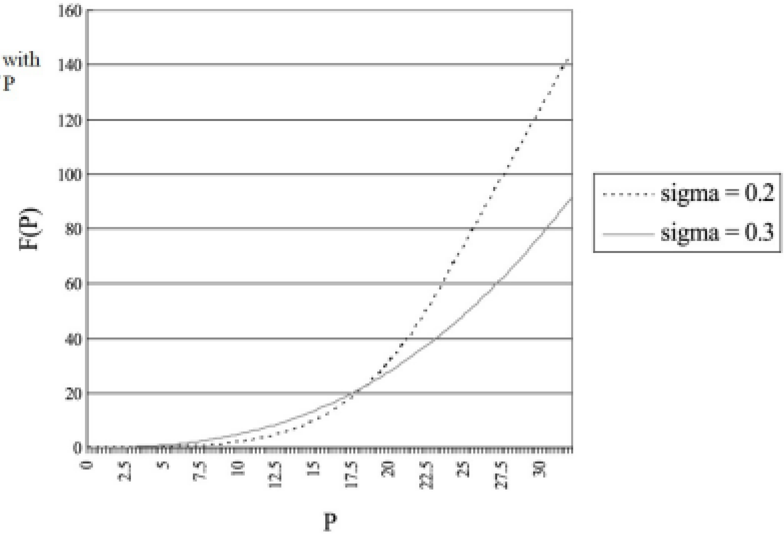


Figure 8.
$P = 20, I = 100, r = 0.05,$
$\lambda = 0.3, \rho = 0.8, \gamma = 0,$
$c = 5$

Summary

Simple model

In the simple model, the correlation between volatility and option price can be negative when the option is deep-in-the-money. If the rate-of-return shortfall increases with volatility, the option value has also a negative relation with volatility, even in out-of-the-money situations.

General Model

In the general model, with constant rate-of-return shortfall the option behaves like a financial option with a positive relation to volatility. If the rate-of-return shortfall changes with volatility, it can be that volatility has a negative impact on the option price in certain ranges.

Discussion

The first point of the discussion was about the applicability of the presented models. It was confirmed that they are for example applicable to artistic work.

Dr. Mekler introduced us to the example of a DaVinci picture that was sold for 450 Mio $. An associated question would be: “How do we value a DaVinci which has not been found before?”. This means that we associate a cash flow with a piece of art. Hence attributing a cash flow has been done in the most unexpected situations.

Buying and ownership of artwork can be seen as an option in a certain sense. The person has the option to sell/trade it.

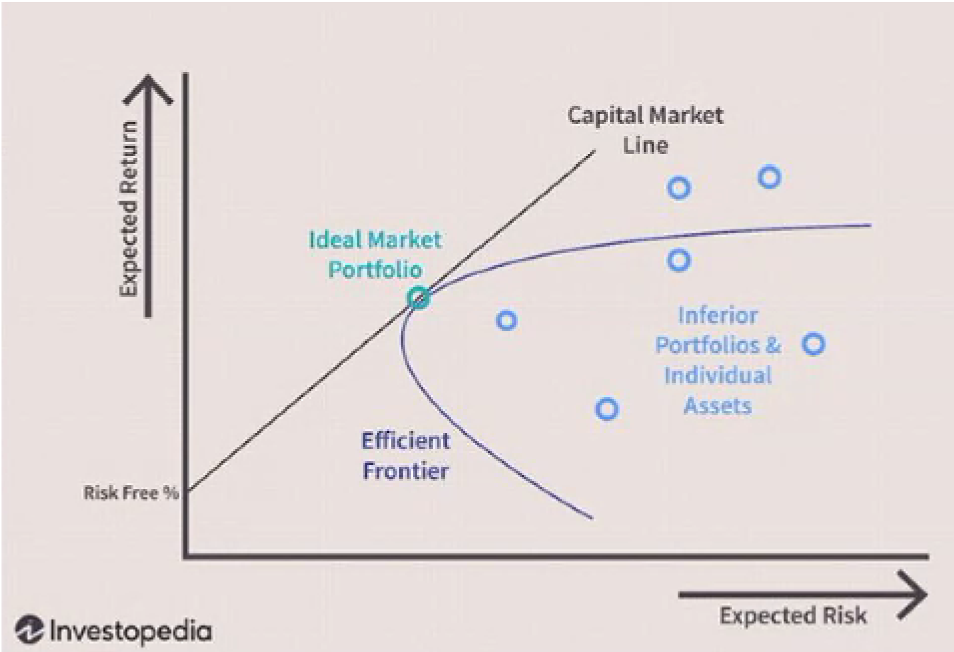
The paper is from 2005, but can still be adapted to more recent problems and situations.

Financial options have limited life spans. Flexibility means you can wait before selling the option. But since financial options have limited spans, you cannot wait too much there. Therefore, they are less flexible.

Traditionally, option traders were convinced that higher volatility leads to a higher price. This comes from the thought that for an option on asset with higher volatility, the person wants to be rewarded with a higher price. But the observation in real world is that this is only true for certain types of options, not for all.

Vega	Theta	Delta	Gamma
Measures Impact of a Change in Volatility	Measures Impact of a Change in Time Remaining	Measures Impact of a Change in the Price of Underlying	Measures the Rate of Change of Delta

Having a patent is like a fence around an IP. Even if that fence would not exist, there is still a value in IP, which can in theory be infinite. Modelling this is really hard. One possibility is to model it as a sequence of finite options which are stacked one upon the other. This sequence mimics the real world option.
Another issue is the value of waiting. Selling or buying are irreversible options. You cannot buy it twice. Uncertainty is bigger in the future than in the present. This leads to higher volatility which may make it worth waiting.



This relationship works well for financial options (higher volatility leads to higher price), but not necessarily for other kinds of options (for example real options).

Feedback

The presentation was well-structured and understandable. The concepts that were presented were rather complex. The mathematics behind the concepts was on a level where I assume the audience could follow. The complexity comes also from the fact that there were a lot of technical terms from the financial sector involved. In a certain sense this is not always easy to understand but it really makes this seminar something special. It gives the opportunity to acquire knowledge outside of mathematics and to see how mathematical reasoning and models can be helpful.