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# Valuation of the China internet company under a real option approach☆

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**Abstract** The objective of the paper is description, application and verification of the real option methodology in financial decision-making of the internet company in China. There is the real option methodology described. Subsequently financial characterisation of internet Baidu company is given. Crucial part consists in calculation of the company value under several scenarios and real option alternatives. We conclude that generalised real option methodology is suitable method of valuation of the internet company under China economical conditions.
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## Introduction

Valuation of the company is very important problem in financial decision making. One of the well developed methodologies is a real option approach. The internet industry and Chinese market is full of uncertainty and flexibility. The objective of the paper is description, application and verification of the real option methodology in financial decision-making of the internet company Baidu in China.

## Valuation procedure of an American real option

The generalised principle of valuation is called the martingale principle see e.g. (Luenberger, 1998). The principle is being defined so that a value has to be equal to the expected future value, implying the random process is without trend. In the case of the risk neutral approach this category is ratio of random value and risk-free asset, so after rearranging

$$V_t = e^{-r \cdot dt} \cdot \widehat{E}(V_{t+dt}), \tag{2.1}$$

here $V_t$ is value, $r$ is risk-free rate, $dt$ is time interval, $\widehat{E}(V_{t+dt})$ is risk neutral expected value. We can gain the same result for complete market under replication valuation strategy or arbitrage principle.

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One of the basic approaches of derivatives valuation under complete market is replication strategy; see e.g. (Smith and Nau, 1995, p. 795; Amram et al., 1999; Barnett, 2005; Boer, 2002; Brandao and Dyer, 2005; Carlsson and Fuller, 2003; Chevalie-Roignant and Trigeorgis, 2011; Cox et al., 1979; Čulík, 2004, 2006, 2008, 2010; Damodaran, 2001; Dixit and Pindyck, 1994; Dluhošová, 2004; Driouchi et al., 2012; Guthrie, 2009; Junyan Guo, 2015; Muzzioli and Torricelli, 2004; Shockley, 2007; Smit and Trigeorgis, 2004; Triantis, 2001; Trigeorgis and Schwartz, 2001; Viebig et al., 2008; Yoshida, 2002, 2003; Zmeškal, 1999, 2001, 2005, 2006, 2008, 2010a,b, 2011, 2012). Having derived the replication strategy, we suppose a compact (effective) market, asset-bearing the incomes (dividends, coupons, etc.) proportional to an asset price. The replication strategy is based on creation a portfolio from underlying asset $S$ and risk-free asset $B$ so, for every situation the derivative value is to be replicated; it means a derivative value equals a portfolio value.

Portfolio value in appraising a moment $t$ is $\Pi_t \equiv a \cdot S_t + B_t = f_t$; portfolio value in a moment $t + dt$ for growing price is $\Pi_{t+dt} \equiv a \cdot S^u_{t+dt} + B_t \cdot e^{r \cdot dt} = f^u_{t+dt}$; the portfolio value in a moment for declining price, $\Pi_{t+dt} \equiv a \cdot S^d_{t+dt} + B_t \cdot e^{r \cdot dt} = f^d_{t+dt}$; where $\Pi_t$ is portfolio value, $S$ is underlying asset value, $a$ is a amount of underlying asset, $B$ is risk-free asset value, $f$ is derivative value, $r$ is continuous risk-free rate, $u$ ($d$) are indexes of growth (fall) of underlying asset, $S^u_{t+dt}$, $S^d_{t+dt}$ are their prices in up-movements (down-movements).

By solution of three equations for variables $a$, $B$, $f_t$, we can get a general formula for derivative price,

$$f_t = e^{-r \cdot dt} \cdot \left\{ f^u_{t+dt} \cdot \left[ \frac{e^{r \cdot dt} \cdot S_t - S^d_{t+dt}}{S^u_{t+dt} - S^d_{t+dt}} \right] + f^d_{t+dt} \cdot \left[ \frac{S^u_{t+dt} - e^{r \cdot dt} \cdot S_t}{S^u_{t+dt} - S^d_{t+dt}} \right] \right\}. \tag{2.2}$$

The derivative price is determined as a present value of expected value in a following period. This is the general formula for European derivative price valuation by the replication strategy, which should be written as follows,

$$f_t = e^{-r \cdot dt} \cdot [f^u_{t+dt} \cdot (\widehat{p}) + f^d_{t+dt} \cdot (1 - \widehat{p})], \quad \text{or}$$
$$f_t = e^{-r \cdot dt} \cdot \widehat{E}(f_{t+dt}). \tag{2.3}$$

In the case of the American derivative type, formula is following,

$$f_t = \max\{g_t; e^{-r \cdot dt} \cdot [f^u_{t+dt} \cdot (\widehat{p}) + f^d_{t+dt} \cdot (1 - \widehat{p})]\}, \quad \text{or}$$
$$f_t = \max[g_t; e^{-r \cdot dt} \cdot \widehat{E}(f_{t+dt})] \tag{2.4}$$

where $g_t$ is payoff value.

Symbol $\widehat{p}$ implies the risk-neutral probability of up-movement and $\widehat{E}(f_{t+dt})$ is the risk-neutral expected value,

$$\widehat{p} = \frac{e^{r \cdot dt} \cdot S_t - S^d_{t+dt}}{S^u_{t+dt} - S^d_{t+dt}}, \tag{2.5}$$

This probability can be considered neither a market growth nor a subjective probability. Due to (2.3) the derivative price is equal to the present value of risk-neutral expected value of subsequent period, which coincides with generalised martingale principle, see (2.1).

We can express the underlying asset price, under the proportional continuous income $c$, due to Geometric Brown's process as follows,

$$S^u_{t+dt} = S_t \cdot U; \quad S^d_{t+dt} = S_t \cdot D, \quad \text{where}$$
$$U = e^{\sigma \cdot \sqrt{dt}}, \quad D = e^{-\sigma \cdot \sqrt{dt}}, \quad (1 + C)^{-1} = e^{-c \cdot \sqrt{dt}}, \tag{2.6}$$

then after substitution to (2.5) and after re-arranging we get particular risk-neutral probability formula

$$\widehat{p} = \frac{((1 + R)/(1 + C)) - D}{U - D}.$$

This formula can be generalised substituting $(1 + R)/(1 + C) = G$ as follows $\widehat{p} = (G - D)/(U - D)$.

There exist several type of financial option. One of them is financial (debt) real option with payoff function,

$$g = \max(A - D; 0), \tag{2.7}$$

where $A$ is asset value, $D$ is debt value.

The option to expand can be used as an American option, which allowed expanding project at any time during the project's life, payoff function is as follows,

$$g = \max(A \cdot x - INV_{\exp}; 0), \tag{2.8}$$

where $x$ is the scale of possibility, $INV_{\exp}$ is investment (CAPEX) of expansion.

The option to contract can be used like American option, with following payoff,

$$g = \max(INV_{con} - A \cdot y; 0), \tag{2.9}$$

here $INV_{con}$ deinvestment, $y$ is percentage of contraction.

Another type of option is multiple option combining several types of the option. If we combine expansion and contraction options, we get this payoff function,

$$g = \max(A \cdot x - INV_{\exp}; INV_{con} - A \cdot y; 0) \tag{2.10}$$

## Characterisation of internet Baidu Inc. company

Over the past twenty years, the internet has truly transformed China. There are more than 600 million internet users in China, which indicate almost a half of Chinese are living with internet. In this huge market, Baidu occupies more than 75% revenue share in the internet search market, and 30% market share in online advertising area until 2013. At the same time, it has approximately 753,000 active online marketing customers. Its online marketing customers not only be individuals, but also consist of small and medium enterprises (SMEs) throughout China, large domestic companies and Chinese divisions or subsidiaries of large, multinational companies.

Baidu is founded in 2000, at beginning it was an internet search engine website. And then with the development of technology and expansion of market scale, Baidu extended its service from simple search to mobile and cloud, location based services, consumer products and international operations. Its products include web pages, news, images, multimedia files, music, movies and it is also the first one in

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