THE 13th INTERNATIONAL CONFERENCE OF THE SOCIETY FOR GLOBAL BUSINESS & ECONOMIC DEVELOPMENT

Managing the “Intangibles”: Business and Entrepreneurship Perspectives in a Global Context

Università Politecnica delle Marche | Ancona, Italy
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Managing the “Intangibles”: Business and Entrepreneurship Perspectives in a Global Context

Nature and Scope of the Conference

Compared to tangible assets, “intangibles”, or knowledge-based resources, are among the most important determinants of institutions, business and industry performance. Recognizing their role in promoting entrepreneurship, firm performance and socio-economic advancement, several developed countries have recently estimated the economic value of R&D and other forms of innovations, and have integrated them into the measurement of GDP. At the same time, several studies have questioned the net benefits of globalization and the impact of “intangibles” on the level and distribution of income and wealth. These mixed results indicate that the role of intangibles and knowledge resources as a source of equitable development is an open issue and hence of significance for theoretical and empirical research. In this framework, the 13th Conference of the Society for Global Business and Economic Development (SGBED) invites empirical and conceptual research with a focus on the role of the “intangibles” in advancing equitable development in a global business and institutional perspectives.

Topics

• Human Capital Management
• Knowledge Management, Online Education, Higher Education & Executive Training
• Knowledge Transfer within and Across Organizations
• Innovation and knowledge diffusion Role of Information Communication Technologies (ICT), R&D Networks, Technology Clusters, Science Parks, Business Incubators
• Innovation Models: Reverse, Frugal, Incremental & Disruptive
• Managing R&D & Patents & Intellectual Property Rights
• Accounting Standards, Valuation & Reporting of Intangibles
• Transfer Pricing, Taxation Issues of Intangibles
• Marketing of Intangibles: Patents, Designs, Software, Digital Products, Apps
• Brand Management; Brand Equity
• Multi-channel Strategies: Digital Marketing; Customization; Social Media; E-Commerce
• +Managing Global Customer, Supplier and other stakeholder Relationships
• Managing intangibles in the global supply chain and operations management
• Managing intangibles in services businesses
• Financial intangibles
• Entrepreneurship in the Knowledge Economy
• Ethics and Corporate Social Responsibility (CSR), Environmental Protection & Sustainability
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Supporting Peer reviewed Journals for selected papers

- The International Journal of Business and Globalisation – IJBG (ISSN 1753-3627) – Special Issue: “Internationalisation of SME’s, Globalisation and Intangibles Assets”
- The International Journal of Entrepreneurship and Small Business – IJESB (ISSN 1476-1297) – Special Issue: “Entrepreneurship and Intangibles”
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Does the volatility of interest rates affect the value of investment projects?  
A real option investigation

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Does the volatility of interest rates affect the value of investment projects?  
A real option investigation

Abstract

One of the most challenging issues in management is the valuation of strategic investments. Indeed, there are several kinds of projects, for example those concerning brand extension, R&D and IT, that are strongly affected by uncertainty, see e.g. Santos et al. (2014), Kalhagen and Elnegard (2002), Charalamopoulos et al. (2011), Manley and Niquidet (2010), Bernardo et al. (2012) and Baldi and Trigeorgis (2009).

When undertaking projects such as the aforementioned ones, which are characterized by a long-term horizon, a firm has also to face the risk due to the interest rates. In fact, interest rates do not remain constant over time but experience up-and-down movements and volatility that may become significant especially in the long run. In this work, we propose to value investments subject to interest rate risk using a Real Option approach, see, e.g., Schulmerich (2010). In particular, we model interest rates according to a stochastic process of Vasicek type and we calibrate it to the Euribor/Eurirs indexes. Such a process is then integrated in a Black-Scholes framework, which allows us to obtain an explicit formula for valuing various kinds of investment strategies (such as option to defer and option to expand). A numerical application is presented that illustrates the proposed real option approach from the practical point-of-view.

1. Introduction

Real options represent a tool for valuing investment projects that offer the managerial flexibility to postpone the decision to invest at a future time, see e.g. Santos et al. (2014), Kalhagen and Elnegard (2002), Charalamopoulos et al. (2011), Manley and Niquidet (2010), Bernardo et al. (2012), and Baldi and Trigeorgis (2009).

As decisions made at a future time depend on market conditions that could be significantly different from the current ones, when valuing investments characterized by a long term horizon it is important to take into account the presence of stochastic interest rates. This topic has raised increasing interest especially in the last years, when, due to the financial crisis, interest rates have become very volatile. The issue of real option pricing under stochastic interest rates has also been considered in Schulmerich (2010), where a numerical approximation method based on a binomial tree is proposed.

In the present work we assume that interest rates evolve according to one of the most popular stochastic interest rate models in finance, namely the Vasicek model. This allows us to price real options by means of an exact analytical formula, so that the use of numerical approximation can be avoided.

Moreover, we calibrate the parameters of the Vasicek model to the Euribor/Eurirs indexes and we analyze the effect of the stochastic interest rates on a benchmark real option problem, see Kumar (1996). Our analysis reveals that the influence of the stochastic interest rates on the investment valuation strongly depends on the correlation between the interest rates themselves and the net present value of the cash inflows, on the time to maturity and on the volatility of the future cash inflows. In particular, the stochastic interest rates can substantially change the real option value when the correlation parameter, the time to maturity and the volatility of the future cash inflows are large.

The paper is organized as follows: In Section 2 the real option pricing models under both constant and Vasicek interest rates are described; in Section 3 an application problem is considered and the effect of the stochastic interest rates is analyzed; in Section 4 some conclusions are drawn and the main future directions of research are outlined.

2. Option pricing under constant and stochastic interest rates

Valuing investment decisions requires us to calculate the expected net present value of the future cash inflows $S_T$, minus the investment cost $C_T$. Therefore, if we take into account the possibility of not running the project if the economic conditions at maturity $T$ are not favorable, we have to compute:
The above expected value can be calculated using the Black-Scholes model (Black and Scholes (1973)), according to which the future cash inflows resulting from the investment to be valued follow the geometric Brownian motion:

\[
E \left[ e^{-\int_{t_0}^{T} r_s \, ds} \max \left( S_T - C_T, 0 \right) \right].
\]

where \( r \) is the (constant) drift and \( \sigma \) is the (constant) volatility of the future cash inflows, respectively, and \( Z_{t,T} \) is a standard Wiener process. In addition, the spot interest rate, which we denote \( r_f \), is assumed to be constant. Moreover, let \( C_T \) be the cost of the investment to be made at a future date \( T \), so that \( \tau = T - t_0 \) represents the so-called time to maturity, \( t_0 \) being the current time. Then, under these assumptions, the expected value (1) is given by the popular Black-Scholes formula:

\[
V_{BS}(\tau, S) = S_{t_0} N(d_1) - C_T e^{-r_T} N(d_2),
\]

where

\[
d_1 = \frac{\ln \left( \frac{S_{t_0}}{C_T} \right) + \left( r_f - \frac{1}{2} \sigma^2 \right) \tau}{\sigma \sqrt{\tau}},
\]

\[
d_2 = d_1 - \sigma \sqrt{\tau}.
\]

Let us observe that in (3) \( e^{-r_T} \) is equal to the price \( P_{BS} \) a bond that pays one Euro at the future time \( T \), i.e. under the assumption of constant interest rates, we have

\[
P_{BS} = e^{-r_f \tau}.
\]

Nevertheless, the dynamics of the interest rates in the last decade suggests that they may experience significant random variations and volatility. Therefore, in order to perform an accurate investment valuation in a world dominated by turbulent financial markets, it is essential to take into account the stochastic dynamics of interest rates, which is done in the present paper. In particular, we assume that the spot interest rate follows a mean-reverting process of Vasicek type:

\[
dr_f = q(m - r_f) dt + \sigma dZ_{t,T},
\]
where \( q \), \( m \) and \( v \) are the so-called speed of mean reversion, long-run mean and instantaneous volatility, respectively (\( q \), \( m \) and \( v \) are assumed to be constant), and \( Z_{2,t} \) is a standard Wiener process having a constant correlation \( \rho \) with \( Z_{1,t} \).

Based on the geometric Brownian motion (2) and the Vasicek process (6), the expected value (1) can be determined using the closed-form solution as obtained in Rabinovitch (1989):

\[
V_{RAB}(\tau,S_{t_0},r_{t_0}) = S_{t_0} N(D_1) - C_T P_{RAB}(\tau,r_{t_0}) N(D_2),
\]

(7)

where

\[
D_1 = \frac{\ln \left( \frac{S_{t_0}}{C_T P_{RAB}(\tau,r_{t_0})} \right) + \frac{\vartheta}{2}}{\sqrt{\vartheta}},
\]

\[
D_2 = D_1 - \sqrt{\vartheta},
\]

(8)

\[
\vartheta = \sigma^2 \tau + \left( \tau - 2B + \frac{(1-e^{-2q\tau})}{2q} \right) \left( \frac{v}{q} \right)^2 - 2\rho \sigma (\tau - B)v,
\]

and \( P_{RAB}(\tau,r_{t_0}) \) is the price at time \( t_0 \) of a bond that pays one Euro at time \( T \) computed based on the stochastic process (6). The value of \( P_{RAB}(\tau,r_{t_0}) \) has been obtained by Vasicek (1977):

\[
P_{RAB}(\tau,r_{t_0}) = Ae^{-Br_{t_0}},
\]

(9)

where

\[
B = 1 - e^{-q\tau},
\]

\[
A = e^{k(B - \tau) - \frac{v^2}{4q}},
\]

and \( A \) is the market price of risk. For the sake of simplicity, following a common approach, in the present work we set \( \lambda = 0 \). It is worth noting that formula (7) differs from the Black-Scholes one as the term \( \vartheta \) takes into account not only the volatility of the future cash inflows, but also the volatility of the interest rate and its covariance with the future cash inflows (compare (4) and (8)).

3. Effect of the interest rate volatility: An empirical analysis
In this section we consider an application problem and we examine the differences between the case of constant interest rates (formula (3)) and the case of stochastic interest rates (formula (7)). To perform an accurate analysis of the effect of the stochastic interest rates, the parameters of the Vasicek model are calibrated to real market data. Specifically, we have considered the Euribor/Eurirs indexes in a time period ranging from one month to thirty years, and we have obtained:

\[ r_0 = 0.0013, \quad q = 0.41, \quad m = 0.0094, \quad v = 0.0123. \]  

(8)

In order to compare the project valuation obtained using the Black-Scholes formula with that obtained using the Rabinovitch formula, we impose that (5) and (9) yield the same bond value. By doing that the interest rate to be used in the Black-Scholes formula is obtained as

\[ r_f = -\frac{\ln(P_{RAB}(\tau, r_0))}{\tau}, \]

where \( P_{RAB}(\tau, r_0) \) is the bond price calculated according to (9).

The real option parameters are taken from Kumar (1996):

\[ S_0 = 20000, \quad C_T = 15000, \quad \tau = 5, \quad \sigma = 0.4. \]  

(9)
Figure 1 shows the real option price for different values of the correlation coefficient. We note that for values of $\rho$ that are small in magnitude (say, approximately, $-0.1 < \rho < 0.1$) there is not any significant difference between the Black-Scholes formula and the Rabinovitch formula. Instead, for values of $\rho$ that are negative and large in magnitude (say, approximately, $\rho < -0.75$), the Black Scholes formula significantly underprices the real option, i.e. $V_\text{BS} < V_\text{RAB}$, whereas for values of $\rho$ that are positive and large in magnitude (say, approximately, $\rho \geq 0.75$) the Black Scholes formula significantly overprices the real option, i.e. $V_\text{BS} > V_\text{RAB}$.

This fact has the following economic explanation: if $\rho$ is negative and large in magnitude then to the higher values of $S_r$ (those that are bigger than $C_r$ and hence concur to determine the option value, see (1)) correspond lower interest rates and therefore the present value of the investment tends to be higher.

Let us now vary the time to maturity. The results obtained are reported in Figure 2. Again, as experienced before, for values of $\rho$ that are small in magnitude there is not any significant difference between the Black Scholes formula
and the Rabinovitch formula. Instead, for values of $\rho$ that are negative and large in magnitude we have $V_{BS} < V_{RAB}$ and the relative difference increases as $\tau$ increases, whereas for values of $\rho$ that are positive and large in magnitude we have $V_{BS} > V_{RAB}$ and the relative difference decreases as $\tau$ increases. However, we can see that the differences between $V_{BS}$ and $V_{RAB}$ are appreciable only for times to maturity larger than approximately four years (we are assuming that the relative difference between $V_{RAB}$ and $V_{BS}$ is appreciable only if it is greater than 2% in magnitude).

Let us conclude the sensitivity analysis by varying the volatility of the future cash inflows. This is an important aspect as $\sigma$ is a characteristic parameter of any project and it is not easy to determine.

**FIGURE 2. GAP IN THE VALUE OF THE REAL OPTION BETWEEN THE BLACK-SCHOLES FORMULA AND THE RABINOVITCH FORMULA AS A FUNCTION OF THE TIME TO MATURITY.**
As we can observe by comparison of Figure 3, Figure 4 and Figure 5, the qualitative shape of the curves obtained does not significantly depend on the time to maturity. On the contrary, the time to maturity can significantly affect the value of the relative difference between $V_{BS}$ and $V_{RAB}$. In particular, if $\tau = 1$ and $|\rho| = 1$ the relative difference between $V_{BS}$ and $V_{RAB}$ has a maximum equal to approximately 0.005 and a minimum equal to approximately $-0.005$, whereas if $\tau = 15$ and $|\rho| = 1$ the relative difference between $V_{BS}$ and $V_{RAB}$ has a maximum equal to approximately 0.06 and a minimum equal to approximately $-0.06$.

However, the relative difference between $V_{BS}$ and $V_{RAB}$ are significant, i.e. greater than 2% in magnitude, only for values of $\tau$, $\rho$ and $\sigma$ which are large in magnitude, say $\tau \geq 5$, $\rho \leq -0.75$ or $\rho \geq 0.75$ and $\sigma \geq 0.15$.

**FIGURE 3. GAP IN THE VALUE OF THE REAL OPTION BETWEEN THE BLACK-SCHOLES FORMULA AND THE RABINOVITCH FORMULA AS A FUNCTION OF THE VOLATILITY OF THE FUTURE CASH INFLOWS, $\tau = 1$.**
FIGURE 4. GAP IN THE VALUE OF THE REAL OPTION BETWEEN THE BLACK-SCHOLES FORMULA AND
THE RABINOVITCH FORMULA AS A FUNCTION OF THE VOLATILITY OF THE FUTURE CASH INFLOWS,
\( \tau = 5 \).
4. Conclusions

In this paper, we propose a real option approach which also takes into account the uncertainty due to the interest rates.

In particular, by employing the popular Vasicek model, which allows us to use the closed-form solution obtained by Rabinovitch (1989), we investigate the effect of the interest rate volatility on the valuation of investment projects. This analysis is done by considering an application case related to the problem described in Kumar (1996). The results obtained reveal that the stochastic interest rates can substantially affect the project valuation when the correlation between the stochastic interest rates themselves and the net present values of the cash inflows, the time to maturity and the volatility of the future cash inflows are large.

These findings indicate that a deeper analysis of the effect of the interest rate volatility on the value of strategic investments is worth to be done. In particular, it could be interesting to investigate how stochastic interest rates impact the valuation of projects different from the one considered in this paper. This will be the subject of a future work.
References


