DOES THE MARKET RECOGNISE THE VALUE OF FIRMS' REAL OPTIONS? EVIDENCE FROM EURONEXT

Dissertação de Mestrado em Contabilidade e Finanças

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ABSTRACT

From the real options perspective, the value of a firm comprises two elements: assets already in place and currently generating cash-flows, and real options, corresponding to the capacity for possible future earnings. The concept of real option plays an important role in capital markets as it implies future value that is relevant in predicting the shareholders' expected wealth, should the market efficiency hypothesis hold. Our objective is to analyse if and how the market recognises the value of real options embedded in quoted firms.

As real options are not directly observable, we estimate the proportion of the market value accounted for by real options of a panel of 482 companies listed on Euronext capital markets during the period of 2000-2006 and link this value with variables that have been commonly used as proxies for real options, and that can easily be computed on information withdrawn from firms' publicly available financial information. Evidence found supports our main research hypothesis, that investors (the market) do recognise and value real options within firms when allocating their resources. Results are consistent even after robustness analysis.

We still investigate if the industry factor facilitates the recognition by the market of real options' value for high-tech and R&D based firms, and study the impact of the introduction of the Euro and the IAS on that proportion of firms' value. Results reveal a positive influence of the technology industry factor on the real options' market value and a negative impact of the Euro and the IAS on that value.

Finally, we account for adjustment dynamics of the real options market value through time. Evidence supports the idea that the estimate of real options value is positively influenced by the value of real options recognised in preceding periods of time.

Key-words: real options, assets-in-place, firms' market value, Euronext.

RESUMO

Na perspectiva das opções reais, o valor de uma empresa é composto por dois elementos: os activos já existentes e actualmente a gerarem *cash-flows*, e as opções reais, que correspondem a capacidade para ganhos futuros. O conceito de opção real tem um papel importante nos mercados de capitais, na medida em que implica a existência de valor futuro relevante para prever a riqueza esperada dos accionistas, numa hipótese de eficiência dos mercados. O nosso objectivo é o de analisar se e como é que o mercado reconhece o valor das opções reais presentes nas empresas cotadas.

Como as opções reais não são directamente observáveis, estimamos o valor de mercado relativo às opções reais de 482 empresas listadas nos mercados de capitais da Euronext durante o período de 2000-2006, e relacionamos este valor com variáveis que têm sido frequentemente utilizadas como representativas da sua existência e que podem ser facilmente calculadas com base em informação financeira publicamente disponível. A evidência encontrada confirma a nossa principal hipótese de investigação, de que os investidores (o mercado) reconhecem e valorizam as opções reais existentes nas empresas no momento da afectação dos seus recursos. Os resultados são consistentes, mesmo após a análise de robustez.

Também investigamos se o factor indústria facilita o reconhecimento do valor das opções reais pelo mercado para as empresas tecnológicas ou assentes em I&D, e estudamos o impacto da introdução do Euro e das IAS nessa proporção do valor de mercado das empresas. Os resultados revelam uma influência positiva do factor "indústria tecnológica" no valor de mercado das opções reais, e um impacto negativo do Euro e das IAS nesse mesmo valor.

Finalmente, atendemos às dinâmicas de ajustamento do valor de mercado das opções reais ao longo do tempo. Encontramos evidência de que a estimativa de valor das opções reais é positivamente influenciada pelo reconhecimento do seu valor em períodos anteriores.

Palavras-chave: opções reais, *assets-in-place*, valor de mercado das empresas, Euronext.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AIP	Assets-in-place
aTAX	Adjusted taxes
BLUE	Best linear unbiased estimators
BM	Binomial model
B-S	Black and Scholes model
BVA	Book value of assets
BVD	Book value of debt
BVE	Book value of equity
BVFA	Book value of fixed assets
CAPM	Capital assets pricing model
DCF	Discounted cash-flows
DTA	Decision-tree analysis
EBIT	Earnings before interest and taxes
FCF	Free cash-flow
FD	First differences method
FEM	Fixed effects model
GLS	Generalised least squares method
GMM	Generalised moments method
GOV	Growth options value
IAS	International accounting standards
IOS	Investment opportunity set
MV	Market value
MVE	Market value of equity
NPV	Net present value
OECD	Organisation for economic co-operation and development
OLS	Ordinary least squares
OPT	Option pricing theory
PER	Price earnings ratio
PM	Pooled model
R&D	Research and development
RADR	Risk adjusted discount rate

REM	Random effects model
ROA	Real options analysis
ROG	Real options group
ROT	Real options theory
TD	Time-demeaned method
VAIP	Market value of assets-in-place
WACC	Weighted average cost of capital

1. INTRODUCTION

The growing absence of barriers to free capital circulation has been one of the main factors on the rising development of European capital markets. Nowadays, companies compete not only for markets to their products and services, but also for funds to support their activity, which increases the number of companies listed on securities markets and intensifies the level of competition among them, leading to higher stock prices volatility.

This less predictable behaviour of the market value of companies' stocks, along with the evidence of significant differences between this market value and the related book value have been partially responsible for an increasing debate about the reliability of stock prices and conventional financial models of valuation.

Corporate value creation and competitive position, essential value drivers for a company's stock, are critically determined by corporate resource allocation and by proper evaluation of investment alternatives. Yet, traditional discounted cash-flow (DCF) techniques, focusing almost exclusively upon cash-flows relative to existing resources' value, although developed to help firms to formally evaluate the impact of their decisions on shareholder's wealth, do not adequately address the complexities of the firms' value and competitive strategies.

An increasing number of academics and practicing managers are now convinced that standard approaches to corporate resource allocation[1] and firms' valuation have failed. These failures lie on their inability to properly capture components of managerial flexibility to adapt and revise investment decisions in response to unexpected and uncertain market developments (e.g. Kester, 1984; Paddock *et al*., 1988; Bowman and Hurry, 1993; Dixit and Pindyck, 1994; Trigeorgis, 1996; Kulatilaka and Perotti, 1998; Merton, 1998; Linde *et al*., 2000; Lopes, 2001; Pinto and Pereira, 2005; Alonso *et al*., 2005; Verbeeten, 2006). Management flexibilities may comprehend the opportunities to expansion or the relinquishing of activities, the possibility of putting off investments or bringing them forward in time, or to create synergies and improving resource allocation.

Additionally, conventional DCF techniques assume that all future investment opportunities are self-determining, ignoring the fact that tomorrow's growth is highly

[1] Usually termed as *capital budgeting*.

dependent on today's choices and decisions, so that they do not capture the impact of project interdependencies and competitive interaction.

In this context, the Real Options Approach (ROA) has been complementing the traditional valuation models, as it tries to account for the options that come into existence when firms' active resources and capabilities allow preferential access to future growth opportunities (Bowman and Hurry, 1993).

Building on the concept of *real option*, originally attributable to Myers (1977) when referring to the value of growth opportunities, this new valuation perspective allows for the integration of uncertainty and management flexibility as value sources that cannot be overlooked. As new information turns up and uncertainty about future cash-flows is progressively set on, management is able to decide on the best future actions in order to enhance firms' market value (Pindyck, 1988; Dixit and Pindyck, 1994; Trigeorgis, 1996; Kulatilaka and Perotti, 1998).

Making use of financial options' practical valuation principles and formulations[2] it became possible to generally quantify the value of management's ability to adapt and rework operating and strategic decisions in response to unanticipated market changes.

Firms' value is then made up of contributions from the various components of their resources portfolio. While some physical, monetary and even intangible resources generate value by enabling a company to produce and sell its goods or services in existing markets, other resources, that do not have immediate and measurable payoffs, such as detention of patents, ownership of valuable resources, specific knowledge or market power, are related to investments which are intended to secure and exploit future growth opportunities (Sudarsanam *et al.*, 2006).

Under this perspective, the market value of the firm should be understood as comprising the value of assets already in place and currently generating cash flows[3], and the value of future growth opportunities and management flexibility, best determined as the present

[2] Introduced by Black and Scholes (1973), Merton (1973) and Cox and Ross (1976) and on the basis of Option Pricing Theory (OPT) (reference in Merton, 1998). Option valuation models are presented later in this work.

[3] The value of the *assets in place* (AIP) component is derived from the stream of cash-flows generated over time by allocations of a firm's resources already made, and it equals what the traditional discounted cash-flow models attribute to the company as a whole.

value of the firm's options to make future investments with a positive net present value[4] (Chung and Charoenwong, 1991; Trigeorgis, 1996; Berk *et al*., 1999; Chen *et al*., 2005; Pinto and Pereira, 2005; Alonso *et al*., 2005 and 2006; Sudarsanam *et al*. 2006; Tong and Reuer, 2007).

A few early empirical works suggest that a significant portion of the market value of firms is accounted for growth and flexibility opportunities, that is, the firms' real options to maximize their future value. For example, Kester (1984) estimates that the capitalized value of current cash-flow streams hardly accounts for half of the market value of a large number of companies. In some cases, where firms are characterized by high volatility in demand and important growth opportunities, that fraction is even smaller, representing only 20% of their market value of equity. Pindynk (1988) argues that the fraction of the market value of firms attributable to the value of capital in place should be only one-half or less for firms with reasonable demand volatility, and Triantis (1999) suggests that real options virtually represent all of the value of companies operating in emerging product markets.

The ability to create a valuable portfolio of real options, and to nurture and exercise these options avoiding their fruitless expiration, is important for maximising enterprise value and, thus, shareholders' wealth. However, it is important that investors and equity analysts recognise the value added from increased option value. But is this currently happening?

Under the efficient market hypothesis[5], it is predictable that stock prices reflect available information relative to firms' whose capital is traded in open securities markets, which should include information regarding the real options held by companies.

The immediate consequence of this assumption is that investors are able to comprise in their judgement of a firm's performance, not only the effects of managerial decisions on the amount, time and risk of the expected cash-flows, but also the variables that determine the value of its real option portfolio (Alonso *et al*., 2005).

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[4] Firms can increase their assets and earnings over time without an increase in stock prices if the internal rate of return on projects is the same as the firms' cost of capital.

[5] According to Fama (1970, pp. 383), "the primary role of the capital market is allocation of ownership of economy's capital stock", where prices should "provide accurate signals for resource allocation: that is, a market in which firms can make production-investment decisions, and investors can choose among the securities that represent ownership of firms' activities under the assumption that security prices at any time fully reflect all available information". A market with these characteristics is called an "efficient market", although Fama distinguishes three levels of efficiency – strong, semi-strong and weak.

Nevertheless, there are still not too many studies offering empirical evidence about the effect of real options on stock prices. Apart of the already mentioned estimates from Kester (1984) and Pindyck (1988), Smit (2000) empirically evaluates the option characteristics of growth opportunities, providing evidence in favour of growth options' influence on prices of a sample of US companies. Along with the predictions under real options reasoning, Al-Horani *et al*. (2003) find that the returns of a sample of UK firms were associated with the ratios of research and development expenditures to market value and book-to-market value.

More recently, first analysing a sample of companies listed on the Spanish Stock Exchange, and then testing high-tech companies listed on main OECD stock markets, Alonso *et al*. (2005 and 2006) provide some evidence that stock prices reflect investors' expectations regarding the value of real options. Tong and Reuer (2007) also found evidence on a link between some corporate investments and the growth option value estimated as a proportion of firms' market value.

However, the majority of related empirical contributions have been concentrated on industry-specific analysis like petroleum leases (e.g. Paddock *et al*.,1988) or land transactions (e.g. Quigg, 1993), on the effects that real options have on important variables such as firms' systematic risk (Chung and Charoenwong, 1991) or the expected return on investments (Berk *et al*., 1999), on optimal reallocation decisions (Couto, 2006), or have taken the form of case studies for stock valuation using a contingent claims approach (e.g. Pinto and Pereira, 2005). Moreover, a large number of studies focus on specific investment projects, with the aim of verifying the relevance of embedded options and the suitability of using option pricing models for their valuation (several studies in Trigeorgis, 1999 and in Schwartz and Trigeorgis, 2005).

The aim of this work is to extend current evidence on the market valuation of the firms' real options portfolio, examining the idea that stock prices might reflect investors' expectations concerning the presence of real options, i.e., that stock prices tend to incorporate available information relative to the real options held by companies and their ability to acquire, maintain and exercise them.

To this end, an empirical study is conducted over a balanced panel of 482 companies listed on Euronext stock markets during the period of 2000-2006. It consists on the analysis of the relation between the fraction of firms' market value not accounted for by their assets-in-place, and a series of variables that, in relevant literature, are assumed to reveal the existence and value of embedded real options. Companies' financial information is taken from the Thomson Datastream and SABI financial databases. Markets and interest rates data were obtained through online information provided by Euronext NYSE and National Central Banks.

It is important to notice that there is not one comprehensive way to determine the market value of the real options portfolio held by companies. On one hand, as real options are decisions which have yet to be made, but for whose implementation companies are particularly well resourced, they are the result of accumulated tangible and intangible assets through time, not always adequately recorded in financial statements. On the other hand, real options are affected by factors that are privileged information only managers have access, such as time to expiration, strike price, or the characteristics of the underlying assets (Alonso *et al*., 2005). Consequently, as no direct measure can be accessed, we use an estimate of the value of firms' real options, determined by the difference between the market value of companies and the estimated value of their assets-in-place, as implicitly suggested by Kester (1984).

Furthermore, investors are only able to recognise and incorporate real options value in their analysis if there is enough information publicly offered. The aforementioned real options estimate is then related with several variables, namely asset irreversibility, financial leverage, size and the ratio of the book value of assets to the market value of firms, which have been used as proxies for real options within firms, as they were found to be able to represent available information on the ability of firms to take advantage of the rights to access growth opportunities and make use of them efficiently.

Results are generally consistent with predictions made under a real options reasoning. Asset irreversibility is found positively related with the estimate of the market value of real options, while financial leverage, size and the book-to-market assets ratio have a negative relation with that estimate. These conclusions did stand even after accounting for the robustness of results.

We still found that high-tech and R&D based industries positively influence investors' perception of the existence of real options within firms, and that the recognition of real options value in one period is strongly determined by the fact that this value had been already perceived in former periods of time.

Due to the period of this study, we have also studied the impact of the introduction of the Euro and of the International Accounting Standards (IAS) over the proportion of the market value of firms accounted for by their real options. This impact was found negative in both cases, implying an increase of trust from investors on financial information, where real options are not directly reflected.

This dissertation is organised as follows. Chapter II is based on a literature review, regarding the fundamentals of Real Options Theory. The real options' reasoning is revised and the determinants of option value presented and compared to traditional capital valuation methods. Further attention is given to real options taxonomy and to their pricing methodologies.

Chapter III focus on the problem of estimating the value of the real options portfolio detained by companies. It starts with a theoretical overview of the real options perspective of firm valuation and the association between the existence of real options within a firm and its share value. Then, still on a literature review basis, we present the idea of valuing equity as an option, as well as the theoretical link between the fraction of the firms' market value accounted for by their real options and a series of variables that are able to inform about the existence and the characteristics of those real options. Proxy variables for real options already used in previous studies are presented.

On chapter IV we describe the empirical study. It starts with a description of our research questions, along with some expectations on variable behaviour, supported on literature review. The sample is characterised and several methodological issues revised in order to better explain the models being analysed.

Statistical tests and empirical findings are presented in Chapter V, along with results robustness analysis. Chapter VI concludes, and some possible improvements and suggestions to future research are put forward.

2. FUNDAMENTALS OF THE REAL OPTIONS THEORY

In recent years, managers and academics have been accusing traditional DCF models of hampering the productivity, the competitiveness and the innovation of companies following their precepts. Although widely used, such approaches are regarded for some as short-sighted, not allowing the recognition of sources of value other than cash-flows.

Ignoring strategic aspects of prime importance to the survival of companies in a competitive and uncertain world, conventional methods fail to capture the value of growth and flexibility opportunities embedded in many corporate actions. These opportunities can be seen as a collection of options, enabling management to make or revise decisions at some future time. As with options on financial securities, this management's flexibility to adopt future actions in response to altered future market conditions expands a capital-investment opportunity's value, by improving its upside potential while mitigating possible losses relative to the initial expectations (Trigeorgis, 1996, Linde *et al*., 2000).

By now, several authors (e.g. Kester, 1984; Pindyck, 1988 and 1991; Bowman and Hurry, 1993; Dixit and Pindyck, 1994; Trigeorgis, 1996 and 1999; Kulatilaka and Perotti, 1998; Smit and Trigeorgis, 2004, among many)[6] already agreed that these options need to be not only explicitly considered and valued, but also that their value can be, in some cases, substantial. In fact, according to the real options reasoning, possible investments and acquisitions are frequently undervalued if options involved are not considered.

This chapter provides an overview of the theoretical and empirical background of the Real Options Approach. It begins with the presentation of DCF models' characteristics and limitations, as justification for the growing need of a sound alternative to incorporate both uncertainty and flexibility on the analysis. Then, real options value drivers and taxonomy are described, and reference made to the basics of the Option Pricing Theory (OPT) and related valuation models. The chapter ends reviewing some relevant literature on empirical studies aimed to recognise and value individual real options, as well as multiple and sequential options and their interdependencies.

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[6] Here, reference is made to most known authors that, at early stage, contributed to the development of Real Options Theory. For interesting collections of papers and case studies, see Trigeorgis (1999) and Schwartz and Trigeorgis (2005).

2.1 LIMITATIONS OF TRADITIONAL VALUATION METHODS

Usually firms are seen and valued as going concerns, so that their value reflects an expectation of continued investment aiming growth and shareholders' wealth. Actually, in corporate finance, value creation for the firm's shareholders is the accepted criterion for making investment decisions or selecting business alternatives.

However, as Chung and Charoenwong (1991) draw attention to, it is important to understand that a firm is not a growth firm merely because its assets and earnings are growing over time. To become a growth firm, it should be able to earn returns on its investments which are larger than its cost of capital. The essence of growth is not the expansion by itself, but the existence of profitable investment opportunities, as a firm can increase its assets and earnings through time without an increase in stock price, if the internal rate of return on its projects is the same as the firm's cost of capital.

Towards value creation and continuous growth over time, firms have been given several instruments and techniques in order to evaluate their investment opportunities and to decide future action and strategy.

The question of how a firm should decide whether to invest has been generally answered through the application of standard Discounted Cash-Flows (DCF) techniques. These methodologies are mostly aimed to select investments that, in order to create value, should yield an expected return is excess of the opportunity cost of the invested capital, identified as the expected yield of similar investments with the same level of risk.

In DCF techniques, the two key factors that are accounted for are the time value of money and, to some extent, the risk associated to the uncertainty of the forecasted cash-flows. These two factors are considered when using a risk adjusted discount rate to discount the expected cash-flows (Table 2-1).

A typical discounted cash-flows technique commonly used is the Net Present Value (NPV) analysis (Table 2-1). With NPV a simple rule is applied: firms should take an investment opportunity when its NPV is greater than zero.

A few other approaches have been used in order to evaluate the attractiveness of an investment. For example, while in the NPV perspective the adjustment for risk is made using the abovementioned discount rate (the "risk-adjusted" discount rate), an alternative has been to adjust the cash-flows for the risk and to discount the resulting *certainty-*

equivalent cash-flows at the risk-free rate of interest (Table 2-1). Even though results should be approximately the same, the NPV approach is usually more used in practice because it seems to be easier to estimate the risk-adjusted discount rate than the certainty-equivalent cash-flows (Schwartz and Trigeorgis, 2005).

The *incremental or marginal approach*, also based on the NPV logic, defends that a firm should invest until the value of an incremental unit of capital is just equal to its cost. The main difficulty here is to exactly determine the value of an incremental unit of capital and its corresponding cost (Trigeorgis, 1999).

Other formulation uses the ratio of the capitalized value of the marginal investment to its purchase cost, being that value directly observed if the ownership of the investment can be traded in a secondary market or, if not, determined as the present value of the expected stream of profits. This ratio is usually called as *Tobin's q* (Table 2-1) and, according to this perspective, the investment decision should be positive if the ratio is to be greater than 1. Still under this point of view, an investment should not be undertaken if the level for *q* is less than 1. The optimal rate of expansion or contraction is found by equating the marginal cost of adjustment to its benefit, which will depend on the difference between *q* and 1 (Pindyck, 1988; Dixit and Pindyck, 1994, Chen *et al*. 2007).

In fact, *Tobin's q* measure has been used as a proxy variable for firms' investment opportunities in several empirical studies. For example, Adam and Goyal (2007) empirically prove that, among other possible measures for the investment opportunity set, the *q* measure (highly correlated with the *market-to-book assets ratio*) had the highest information content with respect to investment opportunities. Chen *et al*. (2007) use *Tobin's q* as a proxy for the profitability of new investments, where high-*q* firms are regarded as firms with good investment opportunities, while low-*q* firms are regarded as firms with poor investment opportunities.

All described approaches are essentially equivalent, having as an underlying principle the basic NPV rule and the logic of DCF analysis. However, although fairly simple, the NPV basic principle has at its source a few issues that must be overcome, such as how to estimate the expected stream of cash-flows and, probably the bigger problem, how to determine the discount rate that should be used to compute their present value and that is supposed to represent their risk. This is why they all suffer from the same shortcomings, starting with a high degree of sensitivity to interest rate or to tax policy changes.

Table 2-1 – Traditional valuation techniques

Technique	Description
DCF	In a *DCF* valuation, the project's expected stream of cash-inflows, $E(CF_t)$, over a pre-specified life (*N*), are discounted at a risk-adjusted discount rate *k* to arrive at the project's value, V_0, that is $$V_0 = \sum_{t=1}^{N} \frac{E(CF_t)}{(1+k)^t} \quad [2.1]$$
NPV	*NPV* is the difference between the present value of the expected stream of cash-inflows that the investment will generate, the above V_0 (2.1), and the present value of the stream of expenditures required to invest (cash outflows), I_0, resulting then in net cash flows. NPV is given by the following general expression: $$NPV = \sum_{t=1}^{N} \frac{E(CF_t)}{(1+k)^t} - I_0 \quad [2.2]$$
Certainty-equivalent cash-flows	The *certainty-equivalent* cash-flows are the certain amounts which would have the same value as the uncertain cash-flows. Using certainty-equivalent cash-flows, forecasted cash-flows are adjusted to account for their riskiness and changing riskiness over time. These are then discounted at the risk free rate to account for the time value of money. This method separates the two issues of risk and time, and can help to avoid problems when the risk adjustment varies over time (Brealey and Myers, 1992; Trigeorgis, 1996; Megginson and Smart, 2006).
Tobin's q	*Tobin's q* is defined as the ratio of a firm's market value of assets over the replacement costs of its assets. It is often estimated as the ratio of the firm's assets to the book value of the firm's assets, where the market value of assets equals the book value of assets minus the book value of common equity plus the market value of common equity.

Actually, while variations in the interest rates affect (positively or negatively) the discount rate of the expected cash-flows as well as the level of inflation, changes in tax policies may alter the value of the stream of those cash-flows over a given period of time (Bierman and Smidt, 1993; Damodaran, 2001; Megginson and Smart, 2006). This is particularly important when it comes to apply the NPV decision rule, making it possible to accept or refuse investment opportunities only on the basis of the level of taxation, the projects' financial structure, or the level of risk associated to that specific investment opportunity.

Other important limitations of the DCF techniques (NPV included) have been systematically pointed out, such as placing an over-emphasis on the short term, excluding non-financial benefits from the analysis, having a narrow perspective over the capital investments, and promoting a dysfunctional behaviour generally characterised by a tendency to manipulate results (Adler, 2006).

To better understand traditional valuation methods' limitations it is important to recognise its value drivers as well as the risk determinants that support the idea of the present value of the expected stream of cash-flows.

2.1.1 Value Drivers of NPV

As seen, the NPV rule accepts as firms' value enhancers all investment opportunities that yield an excess return above the opportunity cost of invested capital, that is, a positive NPV. The question that arises at this point is that of how do firms achieve those returns in excess of the opportunity cost of capital. This is why it is relevant to recognise the sources of value creation that determine the application of corporate finance tools such as NPV to value investment projects.

Smit and Trigeorgis (2004) resume value creation underlying sources to, firstly, the attractiveness of the industry in which companies operate, and secondly, to their capability of establishing competitive advantage over rivals. These authors draw attention to the fact that it may be difficult for firms to earn sustained excess returns over the opportunity cost of capital without market imperfections. In the long run, and in a competitive market with no entry or exit barriers and homogeneous products, excess profits due to early investment are surely driven down to zero with new competitors entering the industry and lowering prices. Consequently, an average firm operating in a competitive market would be unable to undertake successive and constantly positive NPV projects.

However, it is possible for a firm to generate excess profits in an aggressive environment as long as it is able to produce any kind of competitive advantage, raising barriers to the entrance of newcomers, or creating some distinctive advantages over the already existing competitors (Bowman and Hurry, 1993).

Under this perspective, it is possible to find important value drivers that may lead to differentiation and, thus, to competitive advantages as sources of consistent positive NPVs, such as (Smit and Trigeorgis, 2004):

- development and introduction of innovative products;
- building up reputation (for quality and integrity), partially dependent on advertising expenditures and marketing skills;
- cost advantages over competition, including property of production technologies, control of important inputs, efficient production facilities, economies of scale and scope, learn from experience or managerial organizational advantages due to decreasing agency costs (see text box bellow);
- employment of firm-specific resources[7] in a context where valuable growth opportunities derive from the control over scarce (intangible) resources.

Agency conflicts and costs

The *agency problem* arises from the conflict of interests related to an agency contract under which one or more persons (the principal) engage another person (the agent) to perform some service on their behalf, such as delegating firm's management. As parties to this relationship are utility maximizers, Jensen and Mecking (1976) argued that it is impossible for the principal to align at zero cost the agent's interests to their own, as managers control organizational resources and internal information, and there is a high probability that he will not always act in the best interests of the principal. Agency costs arise in an organization due to conflicts of interest existing among common stockholders, bondholders and managers, because corporate decisions that increase the welfare of one of these groups often reduce the welfare of others. Decreasing agency costs can be obtained through efficient management compensation systems, by reducing transaction costs along the organisation's vertical chain, or by determining the *optimal* ownership structure of the firm (Jensen and Meckling, 1976).

Either exploiting advantages in the market where others are not able to compete, or using firm's unique resource position, the fact is that the expected stream of inflows that are object of NPV valuation are determined by a certain market power difficult to predict and quantify. This is particularly important when there are some determinants, like uncertainty and related volatility of cash-flows, or the level of risk associated to specific investment opportunities that are difficult to determine or kept out of the analysis (Trigeorgis, 1995).

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[7] This source of competitive advantage derives from the "resource-based" view of the firm, where the source of excess profits, rather than found in the companies' external environment, lies in the exploitation of unique internal resources and capabilities (Smit and Trigeorigis, 2004). As an example we have the patents or early-mover advantages.

2.1.2 Risk Determinants

Under uncertainty over future events there is a high probability that perspectives over future market evolution, competitors' actions, and even internal aspects of firms, are not as expected to be. To account for this probability, under traditional analysis based on DCF techniques, the impact of risk is measured by calculating the present value of the expected cash-flows using a discount rate that represents their risk, i.e., the investment projects' opportunity cost levelled with investments with the same degree of risk.

One of the important shortcomings of the NPV rule is its high dependence on the discount rate (level of risk) used on its calculation, especially because the impact of risk on this valuation goes only in one direction: independently of its level, risk tends to depress the value of the investment, so that the higher the risk (*i.e*, the adjusted discounted rate), the lower the projects' NPV (Brealy and Myers, 1992; Damodaran, 2001; Megginson and Smart, 2006).

Consequently, as the same investment opportunity valued at different adjusted rates can be either accepted or refused under the logic of value creation dictated by DCF analysis, it is relevant to define and understand the risk determinants, which is to say, the factors responsible for the volatility of any business results.

On a discussion paper about the role of risk and uncertainty over project evaluation, Micalizzi and Trigeorgis (1999) draw a "map" of risk areas, breaking the risk down into the categories listed on Table 2-2.

Table 2-2 – Risk categories

Risk Areas	Description
Operational and financial risk	Operational risk - Refers to the variability of business results deriving from the operational structure of a firm, revealing the nature of a firm's business activity. The effects that sales variation might have on operating results are the consequence on the weighting of fixed costs, a concept usually termed as *operating leverage*. Financial risk – Divided into the *interest rate risk*, resulting from possible variations of market interest rates, causing unpredictable opportunity costs due to discrepancies between active and passive rates, as well as variations in the prices of financial activities, and the *exchange risk*, which may affect results, value and competitive position of firms. Although different in origin, these two types of financial risk are not independent on their effects over businesses.

Risk Areas	Description
Firm-specific and systematic risk	*Firm-specific risk* –Related to threats specifically identified within the firm's business environment, such as the possible entrance of a new competitors or the failure in a product launch. Under the Markowitz Portfolio Theory, firm-specific risk is seen as a diversifiable risk, which means that investors are able to select particular combinations of investments in order to offset the part of the risk that can be diversified. *Systematic risk* – Present on the economy as a whole, so that all economic agents are affected by its existence. The systematic risk is non-diversifiable, and is usually the bigger proportion of the adjusted discount rate used to compute the present value of expected cash-flows.
Industry risk	*Competitor risk* - Originated by the possibility that strategic choices made by competitors may have consequences on the level of the industry structure, affecting the cost-earnings relation of a certain company. *Technology risk* - Partially related with competitor risk and seen as the combination of factors than cause the firm's loss of competitiveness. This is particularly important on sectors where continuous technological innovation is one of the main characteristics, and also one of the key concerns when it comes to keep "alive" growth and value creation opportunities.
Market-demand risk	Associated to the volatility of business and, in most cases, crosses over other categories of risk. It is essentially due to the volatility in consumer needs and preferences, underlying the importance of managerial flexibility to adapt and revise strategies through time.
Country risk	It stems from the commercial and industrial relationship between firms and governments of countries where investment opportunities are being taken into account. Country risk is often evaluated through the analysis of economic, financial, fiscal and social variables of targeted countries such as, inflation rates, exchange rates or tax policies, in order to define the level of attractiveness and the risk profile of a certain economy.

Source: Miccalizzi and Trigeorgis, 1999; pp. 2

As traditional valuation models based on DCF analysis are highly dependent on the discount rate used to calculate the present value of expected cash-flows, the appropriate opportunity cost of capital is usually established so that it represents the expected yield of similar investments with the same level of risk.

Since a well-diversified investor can eliminate the unsystematic component of risk, the only relevant risk for which a premium in terms of a higher return is demanded is the systematic risk.

The Capital Asset Pricing Model (CAPM)[8] has been used as a relatively suitable instrument through which it is possible to determine the project's systematic risk (Trigeorgis, 1996). CAPM is a model for pricing individual assets (securities), which attempts to determine the theoretically appropriate required rate of return that must be earned to compensate for their systematic risk. The model's basic assumption is that, in equilibrium, an individual security is priced to reflect its contribution to market or systematic risk (Smith, 1990; Trigeorgis, 1996; Damodaran, 2001).

The simplest form of the CAPM

The simplest form of the CAPM yields the following expression for the equilibrium expected returns, $E(R_i)$, on asset i

$$E(R_i) = R_f + \beta_{im} \cdot [E(R_m) - R_f] \quad [2.3]$$

where R_f is the risk-free rate of interest, $E(R_m)$ is the expected return on the market portfolio of all assets, β_{im} (the beta coefficient) represents the sensitivity of the asset to market returns, or a measure of systematic risk of asset i, and is given by the expression

$$\beta_{im} = \frac{cov(R_i, R_m)}{var(R_m)} \quad [2.4]$$

with $cov(R_i, R_m)$ the covariance between the return on asset i and the market return, and $var(R_m)$ the variance (volatility) of the market return. Additionally, the factor $[E(R_m)-R_f]$ is interpreted as the market or risk premium.

In theory, according to this model, an asset is correctly priced when its observed price is the same as the value calculated using the CAPM derived discount rate. If observed prices are higher or lower than the CAPM valuation, the asset is said to be over or undervalued, respectively (Damodaran, 2001).

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[8] The CAPM was introduced by Treynor, Sharpe and Litner in the early 1960s. These authors independently developed a positive theory of the determination of assets prices, built on the earlier work of Markowitz on diversification and portfolio theory. Although consistent with the logic that investors require a higher return for holding a more risky asset, the CAPM has been widely studied, tested, and often subjected to criticisms, especially in what it refers to its basics assumptions (reference in Smith, 1990).

Since β reflects the asset's sensitivity to non-diversifiable risk, by definition, the market as a whole has a β of one[9]. Betas exceeding one signify more than average riskiness. As the CAPM returns the asset's appropriate required return or discount rate, this is, the rate at which future cash-flows produced by the asset should be discounted given that asset's relative riskiness, the higher the β, the higher the rate cash-flows will be discounted at, decreasing their present value and approximating the NPV measure to zero.

Apart from some practical issues arising when using CAPM to determine the cash-flows' opportunity cost, it is also relevant to understand how it affects the value of future possible investments. Although each cash-flow is discounted at the appropriate discount rate estimated as the rate of return on a traded asset with identical risk characteristics, criticisms arise when only a single risk-adjusted discount rate is used for the whole stream of cash-flows, reflecting not uncertainty but only time preferences (Teisberg, 1995).

In fact, the appropriate cost of capital is not fixed as presumed by traditional DCF approaches. Risks may vary over time and place, through the different stages of an investment's life, and even across the various components of the cash-flows (e.g., costs may have different risks than revenues). The use of a constant discount rate, k, implicitly assumes that the relevant total risk increases at a constant rate through time, or that uncertainty inherent on future events is resolved each period at the same pace as it comes up (Trigeorgis, 1995 and 1996).

To overcome this problem, a deeper understanding of uncertainty is needed, in order to truly incorporate changes in risk under different possible future conditions, as well as the decisions that managers can make to deal with that risk and increase the value of a project or strategy and, consequently, the firm's value and shareholders' wealth.

2.1.3 Uncertainty, Irreversibility and Timing for Investment

Uncertainty

The aforementioned difficulties inherent to the determination of the expected stream of cash-flows associated to investment opportunities, as well as to the assessment of its corresponding risk-adjusted discount rate (RADR), both determinant to the application of the NPV rule and traditional DCF approaches, are important limitations of these models.

[9] Stock market indices are frequently used as local proxies for the market having, in this case, a beta of one.

Nevertheless, a few other relevant shortcomings of traditional valuation methods can be pointed out, especially when observing important characteristics of most investment decisions.

Investment is economically defined as the act of incurring in immediate cost in the expectation of future rewards. Future rewards are uncertain, which makes *uncertainty* one of the major characteristics of investment decisions (Dixit and Pindyck, 1994).

Uncertainty is generally seen as the gap between the information currently available and the information required to make a decision. A condition of uncertainty exists in resource allocation decisions because investing involves uncertain outcomes that, in the long run, are important to firms' survival and about which complete information is unavailable (Verbeeten, 2006). In fact, the presence of uncertainty over future events caused a need for rethinking the way investment decisions are supported, since the best that can be done is to evaluate the probability of alternative outcomes, that might mean a greater or a smaller profit than predicted, or even a possible loss.

Through the lifetime of an investment's project, as new information is known, a natural reassessment of investors' expectations of cash-flows occurs. Considering the existence of this managerial flexibility, it is also important to consider changes in the nature of risk (the opportunity cost of cash-flows), which automatically invalidates the use of a constant discount rate (Trigeorgis, 1996).

Despite some assets show a quite stable β over time, in general this measure may be very difficult to determine accurately. Apart from statistical measurement difficulties, evidence shows that a project's real β depends on its life, the growth rate, the pattern and the characteristics of individual components of expected cash-flows, the procedure by which investors revise their expectations, and the relationship between forecasted errors for the cash-flows and those for the market return (Myers and Turnbull, 1977[10]). Thus, as Trigeorgis (1996) points out, since the project's β is used to obtain its cost of capital, and NPV is determined with the β of a security with the same level of risk as the project, then both project and security should be matched on all the above factors, making a generalised RADR form of NPV with different discount rates in various periods more appropriate than the more widely used single cost of capital approach.

[10] Reference in Trigeorgis (1996).

Uncertainty has also been having an impact on the sophistication of capital budgeting practices and evaluation methodologies. Verbeeten (2006) empirically studied the impact of uncertainty on the choice of valuation methods, concluding that uncertainty causes the need for more sophisticated techniques, especially when financial uncertainties increase (social, market and input uncertainties did not reveal such a pressure for using more complex procedures). Moreover, the author also concludes that instead of substituting methodologies, firms prefer to use multiple tools simultaneously to evaluate investment opportunities.

Other approaches have been proposed to overcome the shortcomings of static NPV model and to more firmly incorporate uncertainty on the analysis. Dynamic versions of DCF methods started to consider uncertain cash-flows more carefully. Instead of assuming a predetermined decision path and a single (expected) scenario of future cash-flows, they require all important future uncertainties and possible contingent decisions to be laid out.

One of these approaches is *Sensitivity Analysis*, useful in identifying the crucial variables that contribute the most to the riskiness of the investment. It starts with a "most likely" scenario with estimates of the key variables upon which NPV is calculated. Then, while keeping all variables equal to the base-case, each variable is changed in a percentage below and above the "most likely" scenario, giving an idea of NPV sensitivity to misestimates on a given risky variable.

Even so, Sensitivity Analysis has limitations. It considers the effect of only one error in a key variable at a time, and examines the effect of each variable in isolation, not accounting for variable interdependencies (Trigeorgis, 1996 and 2005; Megginson and Smart, 2006).

To cope with these limitations, a methodology able to consider the impact of several possible combinations of variables was necessary. Under this perspective, *Monte Carlo Simulation* tries to arrive at output probability distributions or to a risk profile of cash-flows. Simulation is then able to handle with complex decision problems under uncertainty, with a large number of input variables and their possible interdependencies.

Although more complete, simulation analysis is a quite complex method and, as traditional methods, also stumbles on the problem of the determination of the appropriate discount rate as it depends upon an outcome probability of NPV distribution. The problem of not considering the management flexibility is also still present. Based on a predetermined strategy that offers quite symmetric probability distributions, the model cannot handle possible asymmetries introduced by changes in strategy (Trigeorgis, 2005).

Another approach that tries to account for uncertainty along with the possibility of different management decisions on a later period is the *Decision-Tree Analysis* (DTA). This method structures the decision problem hierarchically by considering all possible alternatives for management action, depending on future contingencies and sequential investment decisions. A decision-tree is a visual representation of the sequential choices that managers face over time with regard to a particular investment.

As Myers (1977, pp.146) early called attention to, "investment is discretionary. The amount invested depends on the net present value of opportunities as they arise in the future". This means that a part of the value of a firm is necessarily due to the possibility of keeping the option to make further investments on probable favourable terms. Kester (1984, pp.155) also defended that while some important investments allow for straightforward evaluation using ordinary DCF techniques, others "are but the first link in a long chain of subsequent investment decisions".

Under DTA, management is forced to consider both the implied operating strategy, and the interdependencies between the initial and the subsequent decisions (Teisberg, 1995). As Trigeorgis (1996) refers, although in DTA the only thing that is needed is to make the current decision, management should realize that the current choice will definitely determine (and is determined by) the feasibility and attractiveness of future events and possible later decisions.

Though decision trees are useful tools for sharpening strategic thinking, they have a serious flaw. For many investments, risk changes as one moves from one point in the decision-tree to another. Analysts have no obvious way to make adjustments to the discount rate to reflect these risk changes, making it very difficult to know whether the final NPV obtained from this method is the correct one.

Additionally, DTA has a practical limitation arising from the difficulty in determining the probabilities for each branch of the tree. In this case, firms must have a great deal of experience to define reliable estimates, making of this task "more an art than a science" (Megginson and Smart, 2006).

Irreversibility

A second important characteristic of investment is that it is partially or, in some cases, completely irreversible. This means that the initial cost of investment is, at least to some extent, sunk[11] (Dixit and Pindyck, 1994).

Several authors (Pindyck, 1988, 1991 and 2005; Dixit and Pindyck; 1994; Kulatilaka and Perotti, 1998; Linde *et al*., 2000) draw attention to the fact that *irreversibility* has serious implications for the understanding of investment behaviour, not only individually, but also in aggregate terms.

It has been argued that irreversibility turns investments sensitive to several forms of risk, such as the uncertainty over future product prices and operating costs, over future interest rates, and over the cost and the moment for investment itself. Consequently, this key feature of the investment decision has also implications at the level of macroeconomic policies. In this case, rather than tax incentives and actions towards interest rates, stability and credibility are much more able to stimulate investment.

There are a variety of possible reasons that explain investment expenditures to be irreversible, and thus sunk costs. On one hand, there is the fact that the capital might be firm or industry specific. This specificity means that the capital cannot be used by different firms or different industries in a productive way. Firm specific investments are, for example, marketing and advertising expenditures. An example of industry specific investments is the acquisition of particular equipment only used in the production activity of a certain industry. In this last case, the expenditure may not be completely sunk as the equipment can still be sold to firms in the same line of business.

On the other hand, irreversibility can also be caused by government regulations and institutional arrangements (Pindyck, 1991). This is particularly relevant where the law that regulates labour (contracting, training and, above all, firing employees) or fiscal policies is stricter.

Finally, even when investments are not firm or industry specific, they might be partially irreversible when re-saling values are bellow their purchase cost, which normally occurs with office equipment and vehicles.

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[11] Sunk costs are costs that have already been incurred and which cannot be recovered, even if the firm should go out of business (Pindyck, 1991 and 2005).

Timing for investment

A third characteristic of investment decisions that undermines the logic of the traditional valuation methods, and highly related to uncertainty and irreversibility, is the capacity to, under uncertain conditions, delay irreversible investment expenditure in order to get more information about future events (Dixit and Pindyck, 1994). Although complete certainty is never possible to obtain, firms have the possibility to choose the *timing for investing*.

The ability to delay investments is valuable and opposed to the "now or never" preposition assumed by the NPV decision rule (Dixit and Pindyck, 1994; Trigeorgis, 1995, Linde *et al*., 2000, Damodaran, 2001a). However, a rational investor will only delay the investment until the value of this delay pays off its costs. Costs of delay essentially exist due to the risk of entry by other firms and foregone cash-flows that, in a competitive environment, makes it almost imperative to undertake a pre-emptive action.

It is also important to recognise that when investment is total or partially irreversible, and future demand or cost conditions are quite uncertain, an investment expenditure involves taking the opportunity, i.e., exercising the option, to productively invest at any time in the future, giving up the possibility of waiting for new information that might affect the desirability or timing of the expenditure. This option value to delay is than lost, so that it should be included as a cost of the investment – an opportunity cost (Pindyck, 1988).

Under this perspective, if choices were to invest today or never invest, there would be no opportunity to wait and, consequently, no opportunity cost of exercising that option, so that the NPV rule would apply. But if the opportunity to wait exists and investing is partially or totally irreversible, the standard NPV rule is no longer valid.

The appropriate decision rule would now depend on the capacity of the value of a unit of capital to exceed the purchase and installation costs by an equal to the value of keeping the firm's option to invest these resources elsewhere or later in time (Pindyck, 1988). Yet, as mentioned above, there are situations in which a firm cannot wait to invest. As Pindyck (1991) reminds, the less time there is to delay and the greater the cost of delaying, the less will irreversibility affect the investment decision.

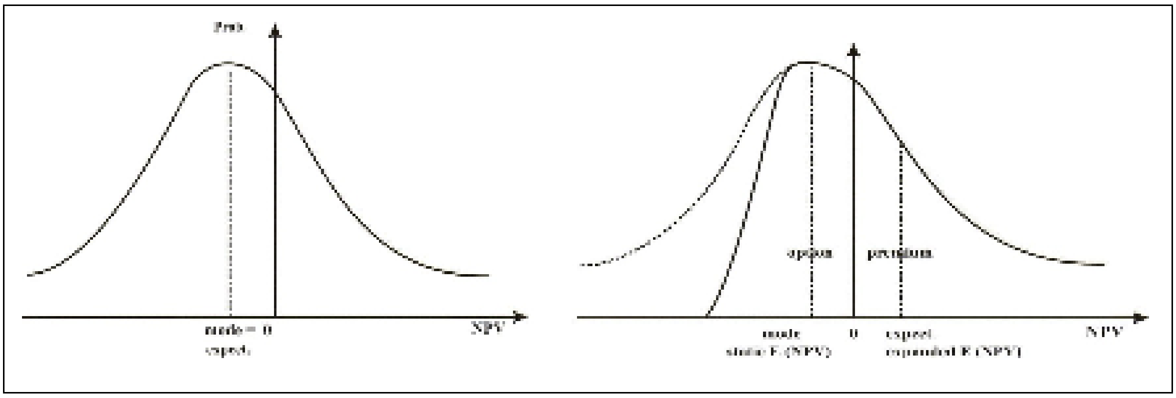
A growing body of research has been showing that the ability to delay irreversible investment expenditures can profoundly affect the decision to invest. Several authors have been stressing that some of the most important aspects of many investments are, in fact, the timing of the investment and the flexibility involved (Kester, 1984, Dixit and Pindyck, 1994; Trigeorgis, 1996; Amram and Kulatilaka, 1999; Linde *et al*., 2000; Herath and Bremser, 2005; Schwartz and Trigeorgis, 2005; Antoshin, 2007; among others). Not only is the investment opportunity itself important, but more so, how managers decide to exploit these opportunities most effectively to increase shareholder value.

Although several criticisms can be made to traditional valuation methods, the basic inadequacy of NPV or other DCF approaches seems to be the fact that they ignore, or do not properly capture, management's flexibility to adapt and revise later decisions.

Traditional NPV makes implicit assumptions concerning an expected scenario of cash-flows over a pre-specified life, presuming management's commitment to an operating strategy, and treating investment projects as independent investment opportunities. However, there is a high probability that, in a world of uncertainty and competitive interaction, cash-flows differ from what it was originally expected. This makes it possible for management to revise the operating strategy as new information arrives and uncertainty about future cash-flows is resolved (Trigeorgis, 1995, 1996 and 1999).

This is particularly important because management's flexibility to adapt to new realities introduces an asymmetry or skewness in the probability distribution of NPV (Fig.2-1), expanding the investment opportunity's value, as it improves its upside potential and limits downside losses relative to management's initial expectations (Trigeorgis, 1996).

Figure 2-1 – Managerial flexibility as source of asymmetry in the probability distribution of NPV



Source: Trigeorgis, 1996, pp. 123

A new decision rule has then been proposed, the *expanded NPV*:

Expanded NPV = Static (Passive) NPV + *Option Premium*

Expanded NPV aims to reflect both components of the value of an opportunity: the traditional (also called static or passive) NPV of direct cash-flows, and a premium for the flexibility available to management as an option to change in some way the initial operating strategy. Thus, the *option premium* represents the value of operating and strategic options from active management and interaction effects of competition, synergy, and interproject dependence (Trigeorgis, 1996).

The decision approach for investments using the expanded NPV includes now both uncertainty and the flexibility for different actions as that uncertainty is progressively diminishing. Under this logic, one can see uncertainty as a factor that creates opportunities rather than decreasing their value (one of the negative consequences of the standard NPV). Managers should than welcome uncertainty instead of fearing it, as increased uncertainty can lead to a higher asset value if managers identify and use their options to flexibly respond to unfolding events (Linde *et al*., 2000).

The possibility to conceptualize and quantify the managerial options to increase the project value has been one of the main motivations for using an options-based approach to capital budgeting and to firm's valuation.

In fact, the Real Options Approach (ROA) highlights the combined importance of uncertainty and managerial discretion, as well as it presents a dynamic view of firm's investment and organizational governance decisions. Additionally, scholars believe in real options to become a normative theory, able to bridge corporate finance and strategy, by injecting strategic reality into capital budgeting models, while also bringing the discipline of financial markets into strategic thinking.

2.2 INVESTMENTS AS SOURCE OF CORPORATE REAL OPTIONS

Both theoretical analysis and empirical evidence have been leading to the conclusion that standard NPV does not properly evaluate the strategic impact of investment decisions, mainly because it cannot take into account the interaction between present alternatives and future opportunities for investment, treating them as independent realities that firms face through time. When firms decide to, for example, launch a new product in a new market, invest in research and development (R&D), or acquire patents or copyrights, the results of these investments are difficult to measure in terms of cash-flows directly connected with the project and, quite often, their value is linked to future opportunities.

As Kester (1984, pp.153) mentions “companies can reduce the guesswork of investment analysis by clearly linking current capital budgeting decisions with strategic opportunities”. In fact, for the above described types of investment activities, although costs are relatively known, benefits are highly uncertain; however, even if NPV is negative, firms may decide to proceed with the investment if managers estimate that the value of future opportunities justifies the initial cost.

As noted before, the discretionary asymmetric nature of various projects and their dependence on future events, that are uncertain at the time of the initial decision, makes their operating flexibility and intrinsic strategic value impossible to be properly captured by traditional DCF techniques. However, these important aspects are appropriately analysed if we think of investment opportunities as collections of options on real assets (real options), that can be optimally exercised over time (Trigeorgis, 1996).

Real Options Approach (ROA) seeks to value investment projects considering that firms are valued as going concerns that make capital investments to create and exploit investment opportunities, but also assuming that firms have various courses of action which, in turn, are intertwined with the broader concept of managerial flexibility.

In contrast to traditional views, ROT maintains that firms can engage uncertainty and benefit by investing in options to respond to uncertain futures and by managing investments in a sequential fashion as uncertainty is resolved (Dixit and Pindyck, 1994).

This way of thinking has two key assumptions: on one hand, investment decisions are characterised by growth concerns and uncertainty about future events and, on the other hand, decision makers can benefit from managerial flexibility to adapt strategies to uncertain developments (Micalizzi and Trigeorgis, 1999). Acquisition of rights and patents, entering new markets, joint ventures, and launching of new products, are all examples of highly risky and uncertain projects, where the degree of managerial flexibility becomes a necessary competitive instrument in achieving the goal of value creation.

Recent advances in finance and strategy have suggested that ROT potentially offers a powerful valuation tool as well as a systematic strategy framework to evaluate and structure resource investments under uncertainty, and that successful use of real options can lead to benefits of downside risk reduction and upside potential enhancement (Bowman and Hurry, 1993; Trigeorgis, 1996, Amram and Kulatilaka, 1999).

2.2.1 Origins and Development of Real Options Theory

Real Options Theory begins by drawing an analogy between real options and financial options. A financial option is a derivative security whose value is derived from the worth and characteristics of another financial security, the underlying asset. By definition, a financial option gives its holder the right, but not the obligation, to buy (call option) or sell (put option) the underlying asset at a specified price (i.e, the exercise price), on or before a given date (i.e, the expiration or maturity date).

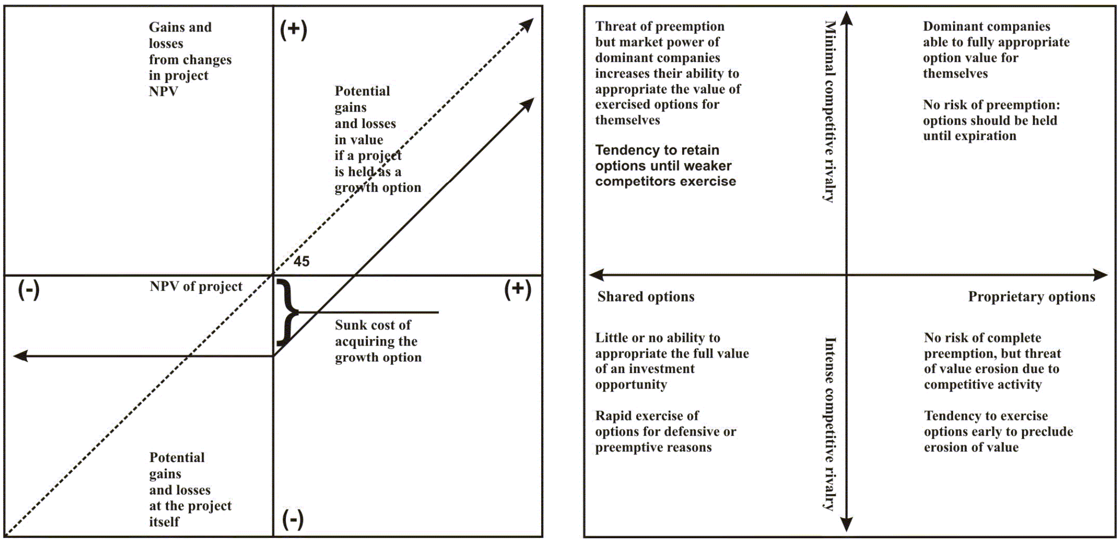
The notion of *real option* was first developed by Myers' (1977) idea that one can view firms' discretionary investment opportunities as a call option on real assets, in much the same way as a financial call option provides decision rights on financial assets. By way of comparison, a real option's underlying asset is the gross project value of expected operating cash-flows, its exercise price is the investment required to obtain this underlying asset, and the time to maturity is the period of time during which the decision-maker can defer the investment before the opportunity expires (Myers, 1977; Kester, 1984; Dixit and Pindyck, 1995; Trigeorgis, 1996). Formally stated, real options are investments in real assets, as opposed to financial assets, which confer the firm the right but not the obligation to undertake actions in the future (Trigeorgis, 1996; Amram and Kulatilaka, 1999).

Initial interest in real options began to emerge in the early 1980s, when management researchers started to express dissatisfaction with traditional financial techniques to resource allocation and strategic decision making. As mentioned, these techniques make it hard to account for follow-on investment opportunities or to capture managers' flexibility in adapting their decisions to evolving market and technological uncertainty.

This view was shared by financial economists such as Myers (1977) and Kester (1984). When analysing a specific aspect of the agency costs of debt, the underinvestment problem, Myers (1977) demonstrated that with fixed claims in the firm's capital structure, stockholders can have incentives to reject positive NPV projects. In fact, the author explains that part of the value of a firm should be accounted for by the present value of options to make further investments in more favourable terms, since the firm is not obliged to undertake all of its future investment opportunities, and that this value will depend on the rule for deciding when to exercise the existing options.

Kester (1984) also refers that opportunities to invest are worth more than the project's NPV, explaining that their value depends directly on the length of time that the project can be deferred, on the project's risk, on the level of the interest rates and on the exclusiveness of the owner's right to exercise the option. So, the longer the project can be deferred the more valuable a growth option will be, as the time that the decision maker has to examine the course of future events is higher. The value of a growth option also increases with risk due to an asymmetry between potential upside gains and downside losses as an option matures (Fig.2-2). Although high interest rates translate into higher discount rates and lower present values of future cash-flows, they also imply a lower present value for future capital necessary to exercise the option.

Figure 2-2 – The asymmetry between upside gains and downside losses in option ownership[12] and the timing for the commitment of capital



Source: Kester, 1984; pp.159

When it comes to the exclusivity of the owner's right to exercise the option, the more exclusive, the more valuable is the option to its owner, once shared options[13] can be exercised by any other firms that equally owns (or shares) its rights.

The decision of when to exercise a growth option has equally been one of the concerns of the real options approach. Again, by means of analogy, a financial option that is said to be *in the money* is an option that, if exercised today, would yield a positive net payoff[14]. On a real options' perspective, although the same basic rule applies, this decision will often

[12] As the NPV of project declines below zero, the value of the growth option stops falling and goes flat.

[13] Shared real options are described in more detail on section 2.2.2.

[14] An option is said to be *out of the money* if exercising it today yields a negative payoff.

depend on a comparative analysis of the advantages and disadvantages of that exercise (Kester, 1984; Bowman and Hurry, 1993; Trigeorgis, 1995).

Generally, because the option to invest is worth more than the NPV of the underlying project, companies should wait until the last possible moment to commit funds, preserving the option's premium and, simultaneously, protecting the firm from costly mistakes. A firm can delay the competitive process of investing to grow (but still preserve and create value) when there exist barriers to entry arising, for example, from economies of scale, product differentiation, brand loyalty or patents. However, under specific circumstances, firms may eventually decide to exercise its growth options earlier than necessary. This may occur when competitors have access to the same option and rivalry in the industry is intense, when the project's NPV is high enough, or when there exist low levels of interest rates and risk (Myers, 1977; Kester, 1984; Chung and Charoenwong, 1991; Trigeorgis, 1996; Damodaran, 2001a).

In the field of finance and economics, the real options literature has been having an analytical focus, employing real option analysis to evaluate firms' investments under uncertainty and to model the optimal conditions for undertaking such investments.

Since Myers' (1977) and Kester's (1984) work, a considerable amount of research started to be developed. Research has focused largely on the evaluation of investments in natural resources (Titman, 1985; Paddock *et al*., 1988; Quigg, 1993), studied the relationship between the options to alter operating scale and the value of the firm (McDonald and Siegel, 1985; Pindyck, 1988), analysed the optimal timing of specific investments (McDonald and Siegel, 1986; Berk *et al*., 1999; Pereira and Armada, 2003), discussed several possible real options firms can explore (Pitkethly, 1997; Amram and Kulatilaka, 1999; Lopes, 2001; Chen *et al*. 2005; Couto, 2006; Dempster, 2006), considered the value of flexibility in capital budgeting (Kulatilaka, 1993; Trigeorgis, 1996; Linde *et al*., 2000; Verbeeten, 2006; Antoshin, 2007; Kort *et al*., 2007) or studied the effects that real options have on important variables such as firms' systematic risk (Chung and Charoenwong, 1991), diversification discount (Bernardo *et al*. 2000), sunk costs (Pindyck, 1991 and 2005), and performance measurement (Herath and Bremsen, 2005).

More recently there has been some concern with the implications of the real options approach for the Theory of the Firm (Foss, 1998; Roemer, 2004), and the agency costs' problem (Myers, 2000; Mauer and Sarkar, 2005; Mondher, 2005), as well as a tendency for several authors to empirically analyse firms' value and stock returns under a real options' perspective (Kellog and Charnes, 2000; Liu, 2000; Schwartz and Moon, 2000; Buckley *et al*. 2002; Alonso *et al*., 2005; Pinto and Pereira, 2005; Li, 2006; Clark *et al*., 2007; Liu and Chang, 2007).

On a more aggregate basis, Pindyck (1991) reviewed the literature on the investment under uncertainty, Dixit and Pindyck (1994) provided an extensive discussion on the theoretical advances of the theory, Trigeorgis (1996) presents a literature review on the real options approach and its relevant applications and Copeland and Antikarov (2002) focus on the real options analysis as a new paradigm for capital budgeting. This research dynamics has also been responsible for several collections on real options articles, such as Trigeorgis (1995), Trigeorgis (1999), and Schwartz and Trigeorgis (2005).

However, compared to the large amount of theoretical work, there have been relatively few large-scale empirical studies, as pointed out by Schwartz and Trigeorgis (2005) and Couto (2006). This fact is partially explained by Philippe (2005) that, when analysing empirical studies conducted on real options, highlights the common adversities encountered when real options models are empirically tested, namely:

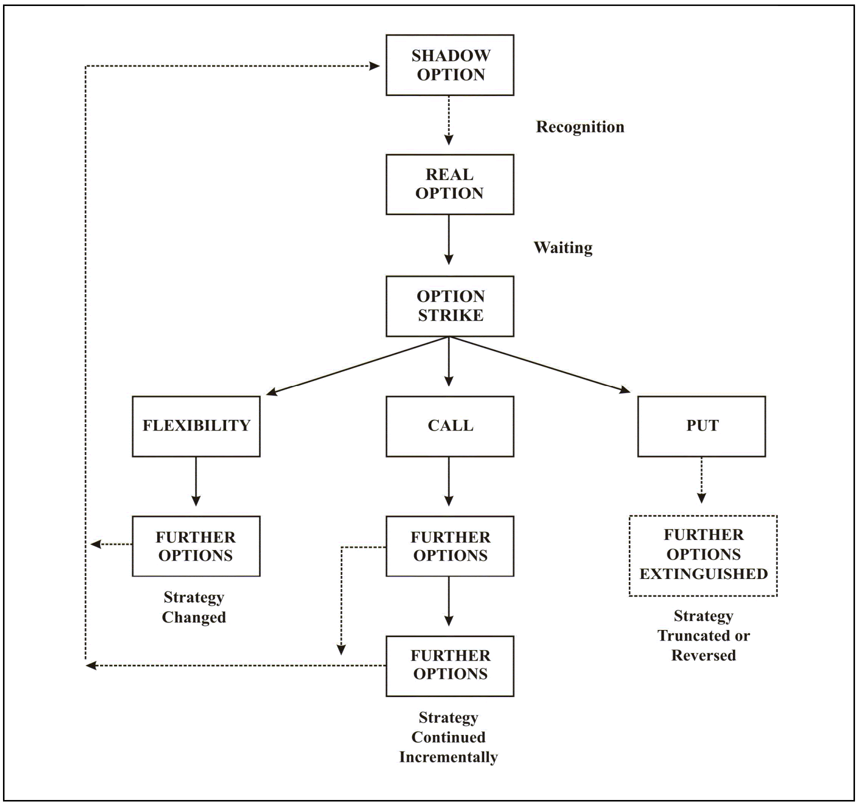
- the difficulty in gathering the massive quantity of information necessary to value real options;
- the fact that real options are difficult to value with the same tools used to value financial options, so that it is important to find evidence of the existence of real options in market data, which may become a hard task since real assets (real options' underlying assets) are usually not traded;
- the complexity to empirically test assets value and their correspondent options, as their intrinsic value is hardly measurable.

Developments relating real options to strategy are also noteworthy. On one hand, research has paid attention to the competitive environment surrounding firms' investments and strategic aspects of real options, which have important implications for competitive strategy (Caballero and Pindyck, 1996; Kulatilaka and Perotti, 1998; Smit and Trigeorgis, 2004). On the other hand, research has also used ROT to analyse investments in building strategic resources, such as R&D, or other corporate development and strategic activities, such as acquisitions, diversification, or even information disclosure (Triantis, 1999; Chen *et al.*, 2005; Dempster, 2006; Sudarsanam *et al*., 2006).

Although the extensive work already in place, the development of ROT in strategic management is mainly based on Bowman and Hurry's (1993) work to develop an options based theory perspective of strategic management. They proposed options as a strategy heuristic for understanding sequential resource commitments under uncertainty.

Central to their theory development is the notion that option lens "offer an economic logic for the behavioural process of incremental resource investment", as the authors defend that "options come into existence when existing resources and capabilities allow preferential access to future opportunities"(Bowman and Hurry, 1993; pp.762). Their perception is that organisations exist as the result of a set of resources and a process of strategic choice, where the opportunities can only be taken when decision makers recognize them in the first place. When that option is struck, this action results in a new set of resources that will, in turn, yield new options for future exercise. Strategies are then produced by the sequential striking of these options, that the authors call the *option chain* (Fig. 2-3).

Figure 2-3 – The option chain



Source: Bowman and Hurry, 1993, pp.764

Despite the specific option at stake in a given moment, the option chain describes the importance of shadow options recognition for effective real options come into existence.

Once recognised, real options are only exercised in response to two types of market strike signals – the *opportunity arrival signal* which indicates that the opportunity for profitable strike exists but there is still an incentive to wait as the organization continues to learn and a later decision might be even better, and the *expiration signal*, indicating that the closing of the opportunity is imminent and delaying the decision will not bring further value to that option (Bowman and Hurry, 1993).

As a theory of investment, ROT does not speak directly to managerial and organizational capabilities required for options implementation, although it places a high demand on these capabilities for options execution. Tong and Reuer (2007) have recently called attention to the need for more research in order to help specifying the theory's boundaries and enhance its managerial relevance. In fact, most of the existing research is conceptual in nature, describing various opportunities and challenges facing firms implementing real options and, while specific topics may vary, research has been emphasizing the importance of managerial and organizational dimensions during the stages of options' creation, identification, evaluation, maintenance and exercise.

Bowman and Hurry (1993) point out the difficulty that managers might have in recognising valuable options in firms' investments as they have their own cognitive limitations and behavioural biases, or may face difficulties in evaluating complex cues from multiple sources of uncertainty. Moreover, even recognising the embedded options, organizations may not have the appropriate structures or supportive systems in place, leading managers to deviate from optimal decision criteria (Trigeorgis, 1996).

In addition, there is still the problem of managers not to use the correct information to access real options' value due to the lack of suitable proxies (Adam and Goyal, 2007), or simply not follow the optimal exercise policies due to incentive problems and agency conflicts (Mauer and Sarkar, 2005; Paggaza *et al*., 2006).

Nevertheless, from several authors' point of view, ROT has been providing a set of analytical tools and heuristics to evaluate and deal with uncertainty:

1) ROT emphasizes dynamic efficiency gains by providing new rules for resource investments and suggesting that real options shift firms' investment thresholds away from the NPV>0 criterion. This new insight determines that a firm may use a reduced investment threshold and decide to invest with a negative NPV if the embedded growth options are seen as sufficiently valuable. By contrast, a firm may

use an elevated investment threshold and decide not to invest in a positive NPV project, if deferral options are sufficiently valuable and associated opportunity cost of investing in the current period significant (Pindyck, 1988; Dixit and Pindyck, 1994; Trigeorgis, 1996).

2) Using the analogy with financial options, ROT posits an asymmetric payoff structure for investments reducing downside risk while permitting access to upside opportunities. Asymmetry in performance outcomes is due to the discretionary decision rights that options create, translated into the right to select an outcome in the future only if it is favourable. ROT suggests that the greater the level of uncertainty, the higher the potential payoff to the option holder, given that the initial investment is limited and downside losses contained (Bowman and Hurry, 1993; Trigeorgis, 1996). In addition, maintaining flexibility under uncertainty has option value, which can account for a substantial proportion of many investments (Kester, 1984; Pindyck, 1991; Triantis, 1999; Sudarsanam *et al.*, 2006).
3) ROT has shed some new light into firms' resource allocation processes and strategic decisions, by bringing the discipline of financial markets into qualitative strategic planning tools, and by incorporating strategic realities into traditional capital budgeting models that do not explicitly account for the value of flexibility and managerial discretion (Trigeorgis, 1996; Amran and Kulatilaka, 1999; Smit and Trigeorgis, 2004; Verbeeten, 2006; Reuer and Tong, 2007).

2.2.2 Real Options Taxonomy

Through time and research a taxonomy of real options has been developed, derived from models designed to support the investment decision process (e.g. Myers, 1977; Kester, 1984; McDonald and Siegel, 1986; Paddock *et al.*, 1988; Pindyck, 1988; Quigg, 1993; Kulatilaka and Perotti, 1998; Lopes, 2001; Pereira and Armada, 2003; Couto, 2006; Dempster, 2006).

Gathering a significant amount of relevant literature, Trigeorgis (1995) proposed a classification of common real options that has been quite generally accepted by the literature that came behind. According to the author, firms may have the possibility to engage in options to defer, time-to-build options, options to expand, options to contract, options to shut down and restart operations, options to abandon, options to switch use, growth options and option interactions (Table 2-3).

Table 2-3 – Real options taxonomy

Taxonomy	Description
Option to defer	The *option to defer* captures the value of waiting to invest until more information is acquired. By delaying an investment, valuable information may be gained as uncertainty due to economic conditions unfolds and more knowledge becomes available. This option represents a call option on the cash-inflows of a project with the investment cost as the strike price. In these cases, an early investment implies sacrificing the value of the option to wait and, thus, an opportunity cost.
Time-to-build option	The *time-to-build option* describes the option embedded in a large number of investment projects to be developed through stages. The staging of capital investments over time creates the possibility to stop investment on an intermediate phase, should the conditions are no longer favourable for the firm. Each stage can be viewed as an option on the value of subsequent stages, taking the form of compound options.
Option to expand	The *option to expand* occurs when market variables are more favourable than initial predictions and managers may have the flexibility to speed up or expand an investment beyond original plans. It is similar to a call option on the additional part of an investment project, and it can be of strategic importance as it may enable firms to capitalize on future growth opportunities.
Option to contract	The *option to contract* is available to management when market conditions turn out to be weaker than originally expected. A firm can shrink or downsize a project as an alternative to the first predicted scenario as new information is obtained. This flexibility to mitigate a loss is analogous to a put option.
Option to switch use	The *option to switch use* of inputs or outputs corresponds to the possibility to change from current inputs/outputs to cheaper inputs or more profitable outputs. Firms must be willing to pay a flexibility premium over the cost of rigid alternatives that confer less (or none) operating choices.
Abandonment option	*Abandonment options* can be understood as put options representing the possibility to permanently abandon a project, in exchange for its salvage value. These options represent an opportunity to moderate losses when companies have no longer conditions to keep a competitive position in the market. However, one needs to fully account for all the costs involved in the exercise of this option, once it may lead to the loss or erosion of valuable expertise and important organizational capabilities that can still be applied in alternative ways.
Growth options	Many investments can be seen as a path for future opportunities with strategic importance. Their value comes more from the growth opportunities they create than from their direct expected cash-flows. Expansion will be carried out only if market conditions turn out to be favourable.

Taxonomy	Description
Option to shut down and restart operations	An *option to shut down and restart operations* may be available on those situations where companies are unable to generate cash revenues sufficiently high to cover variable operating costs, and the costs of switching between the operating and the idle modes are relatively small. Thus, it might be better to temporarily not operate and, if prices rise up, restart operations. Operations in each year are seen as a call option to acquire future revenues, paying the variable costs of production as the exercise price.
Interacting options	Some investments frequently involve a combination of several real options. The value of multiple interacting options may be complex, once their combined value frequently differs from the sum of their separate values. This occurs because some options embedded in one investment may shape the value of other options of the same project, affecting the overall value of the option combination.

Source: Adapted from Trigeorgis, 1995; pp.99-105.

Seeing investments as source of corporate real options drove some authors to propose an option-based project classification, standing on the project's deferability, competition and compoundness (Micalizzi and Trigeorgis, 1999; Smit and Trigeorgis, 2004; Schwartz and Trigeorgis, 2005), in order to help management to focus on both strategic and flexibility value of investment decisions (Fig. 2-4).

The first fundamental question to be addressed is the degree of exclusivity to expropriate the value of a real option. Here we may have:

- *Proprietary real option* provided by exclusive rights to its owner on the benefits created by the investment. Proprietary options may result from license or patent protection, high barriers to entry, or a unique knowledge that cannot be duplicated;
- *Shared real options* that involve non-exclusive rights, shared by many competitors in some industry. These may occur, for example, when the opportunity to introduce a new product is not protected by possible replications, or the opportunity to enter a new market has no significant barriers to competitive entry.

A second relevant issue regards the distinction between simple and compound options:

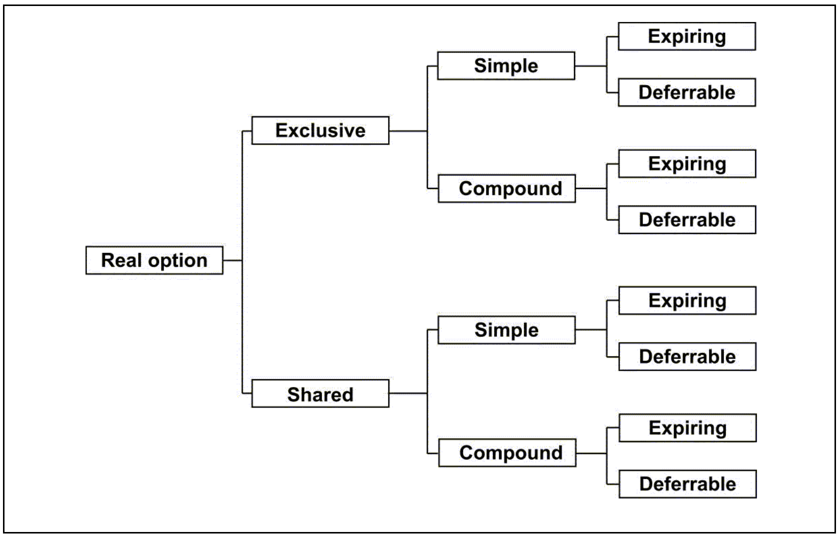
- *Simple options* require a relatively simpler analysis, as they realise their benefits through an expected stream of operating cash-flows;

- *Compound options* derive from multi-stage projects and can be seen as a result of a sequence of interrelated investment opportunities. As we have options on options, their value is always more difficult to determine.

Lastly, it is also significant to analyse the duration and expiration of an investment opportunity. It is useful to distinguish between:

- *Expiring real options* diminish the decision-making capacity as well as the value of that particular investment option as they are immediately exercisable. These situations are usually found in highly competitive situations, where the value of waiting is overtaken by competitive considerations;
- *Deferrable real options* are those with the possibility to postpone the decision to their exercise. The degree to which an option is deferrable depends on whether the option itself is shared or exclusive.

Figure 2-4 – Project classification based on the characteristics of real options



Source: Smit and Trigeorgis, 2004; pp.15

Although project classification under real options perspective and real options taxonomy have been well accepted and replicated by the research community, some recent case studies are worth to be mentioned as they contribute to widen the scope of real options categorization to specific cases that might be found in several real life projects.

When studying an acquisition contract of a spanish plant by a portuguese company, Lopes (2001) realised some peculiar characteristics on the process. The buying company guaranteed that a significant part of its production would be bought by the acquired firm at a pre-determined price.

The author develops the idea that this investment opportunity, which includes a guarantee, does not only alters the business risk, but is also difficult to measure under traditional valuation methods. It can thus be seen as an investment opportunity that includes a put option on the current value of the project, with exercise price equal to the cash-flows calculated for the prices and quantities of the contract, and which the author called an *option of production placement partially guaranteed*.

Also on a case study, Couto (2006) develops a model using Real Options Analysis where, in an uncertain environment, the optimal relocation of economic units is investigated along with the right moment to adopt new locations. This new approach to the problem of investment relocation values the management flexibility embedded in projects (*real options on the relocation process*) that, if ignored, can give rise to significant sub-evaluation and decision-making errors.

A completely different subject is the one treated by Dempster (2006) when introducing a theory of corporate announcements based on the concept of *announcement options*. According to the author, this option is an important contribution to bridge the corporate disclosure literature and the theories of signalling.

Dempster (2006) provides a framework for valuing announcements and their optimal timing, which is particularly important for quoted companies as they need to capture investors' attention but still have to cope with granting valuable information to competitors. The option to announce, or not announce, is a particularly powerful strategic decision because it influences investors' perceptions and expectations about the present value of future expected growth, affecting precisely the intangible component of value which is so difficult to assess and evaluate.

2.3 REAL OPTIONS VALUATION

Option Pricing Theory (OPT) and subsequent models were developed to cope with specific characteristics of particular assets. In general, the value of any asset is usually addressed by the present value of the expected cash-flows on that asset. However, with options, the present value of the expected cash-flows understates their true value since they have two important and specific characteristics that must be accounted for: they derive from the values of other assets, and the cash-flows on the assets are contingent on the occurrence of specific events (Trigeorgis, 1996; Merton, 1998; Damodaran, 2001a).

The theory behind option-pricing was primarily developed for use in pricing financial options. The most influential development in terms of impact on finance practice was the key paper on the valuation of options on financial assets published by Black and Scholes in 1973, coinciding with the opening of the Chicago Board Options Exchange and a great expansion in the trading of such options on common stocks.

However, new financial products and markets designs, improved computer and telecommunications technology, and advances in the theory of finance, led to dramatic and rapid changes in the structure of global financial markets and institutions. Consequently, the influence of OPT on finance practice rapidly overcame financial options and derivative securities boundaries, to be applied to evaluate price risk in a wide range of both financial and non-financial applications. Option-pricing models started to play a significant role in supporting the creation of financial products, the design of new financial institutions, decision-making by management, and formulation of public policy on the financial system. Option-like structures were soon seen to be lurking everywhere and an explosion of research in applying option-pricing occurred (Merton, 1998).

Many of the option-pricing applications that followed do not involve financial instruments, but the called real options. The most developed area for real option application is investment decisions by firms. Nevertheless, real option analysis has also been applied to a wide variety of situations, as described previously. The common element for using option-pricing is the same with financial options: the future is uncertain and, in an uncertain environment, having the flexibility to decide what to do after some uncertainty is resolved has value. As Merton (1998, pp.339) highlights "option-pricing theory provides the means for assessing that value".

2.3.1 Option Pricing Theory Methods

The two basic methods for valuing options and other derivatives are the Binomial Model (BM), a discrete time period analysis with a relationship to the principle of risk-neutral valuation, and the Black-Scholes Model (B-S), usually applied on continuous time option valuation.

In both cases, if pricing formulas are to be obtained, including a distributional assumption concerning stock price movements, it is important to adopt a set of basic assumptions (Trigeorgis, 1996). Typically, the standard option valuation relies on the subsequent hypothesis:

1. Markets for stocks, bonds, and options, are frictionless and allow for continuous trading. This assumption means that there are no transaction costs or taxes, no restrictions on short sales, all shares of all securities are infinitely divisible and borrowing and lending (at the same rate) have no restrictions;
2. The risk-free interest rate is constant over the life of the option (or known over time);
3. The underlying asset pays no dividends over the life of the option (an assumption that is later removed);
4. The distributional assumption concerning the stock price process is that stock prices (*S*) follow a stochastic diffusion Wiener process[15] of the form,

$$\frac{dS}{S} = \alpha \cdot dt + \sigma . dz \qquad [2.5]$$

where α is the instantaneous (total) expected return on the stock, σ is the instantaneous standard deviation of stock returns (assumed constant), and dz is the differential of a standard Wiener process with mean 0 and variance dt. In the discrete-time case (the BM) this diffusion process is replaced by a multiplicative binomial process over successive periods which, in the limit, as the trading interval gets smaller, becomes equivalent to the log-normal distribution underlying the process in equation (2.5).

The Binomial Option Pricing Model developed by Cox, Ross and Rubinstein in 1979, enabled the development of a simple and almost intuitive method for valuing options (Trigeorgis, 1996; Ferreira, 2005) as it uses a discrete-time sequential logic of the varying price over time of the underlying asset. The BM uses an iterative procedure, allowing for the specification of points in time, during the time span between the valuation date and the options' expiration date, providing a mathematical valuation of the option at each point of the specified time (for more details see Appendix A.2).

The Black-Scholes formula is the most common method to value financial options and, rather than an alternative to the previous model, is one of its limiting cases, once it explicitly assumes that the price process is continuous and that there are no jumps in the asset's prices. The model relates the price of an option to five inputs: time to expiration; strike price; value of the option's underlying asset; implied volatility of the underlying asset; and the risk-free rate (more detailed explanation is presented on Appendix A.3).

[15] The Wiener process (or Brownian motion) is briefly explained in Appendix A.1.

2.3.2 Determinants of Real Options Value

Characterising a firm's growth opportunities and managerial flexibility as real options provides, as mentioned, a different perspective from which to examine how management can augment shareholder value.

By understanding the drivers of option value and using insights gained from financial option pricing, the possibility to value enhance strategic and operating decisions increases. Furthermore, the value added from these decisions can be quantified through the abovementioned option pricing techniques, and thus appropriately reflected in the company's share price[16], and in the compensation of managers who make those decisions (Triantis, 1999; Chen *et al*., 2005).

In this sense, the firms' investment opportunities are equivalent to perpetual call options and, therefore, the decision to invest is equivalent to deciding when to exercise those options. The investment decision can then be viewed as a problem of option valuation (Dixit and Pindyck, 1994).

The value of an option is determined by a number of variables relating to the underlying asset and financial markets (Trigeorgis, 1996; Triantis, 1999; Linde *et al*., 2000; Damodaran, 2001a; Buckley *et al*. 2002; Copeland and Antikarov, 2002; Couto, 2006; Antoshin, 2007). With financial options it has been shown that changes in the key value drivers in the B-S formula impact the value of call and put options (resumed in Table 2-4):

Table 2-4 - Value driver movements and option premium effects

Variables	Call option	Put option	Description
Underlying asset's value	+	-	As options are assets that derive value from an underlying asset, changes in its value affect the value of the options on that asset. Since calls provide the right to buy the underlying asset at a fixed price, an increase in the value of the asset will increase the value of the calls. Puts, on the other hand, become less valuable as the value of the asset increases.
Exercise (strike) price	-	+	In the case of calls, where the holder acquires the right to buy at a fixed price, the value of the call will decline as the strike price increases. In the case of puts, where the holder has the right to sell at a fixed price, the value will increase as the strike price increases.

[16] Under the assumption of market efficiency.

Variables	Call option	Put option	Description
Time to expiration	+	+(-)	A longer time to maturity always has a positive effect on a call option value. First, it reduces the present value of the exercise price on maturity if the option ends up in-the-money. Second, a longer time horizon gives potentially higher intrinsic values on maturity since the volatility of the underlying asset grows with the square root of time. For European put options, however, the effects of a longer time to maturity cannot definitely be determined, but for short-term puts it is usually positive. Concerning long-term options there are influences that may have contradicting effects as the positive effect of the increased volatility may be compensated by the fact that one receives the exercise price only at maturity. Especially for American put options, a longer time period has a positive effect on the value of the option because gives the right to receive the exercise price at any time prior to maturity.
Volatility of underlying asset's value	+	+	The higher the variance in the value of the underlying asset, the greater the value of the option (both calls and puts). While it may seem a paradox that an increase in a risk measure (variance) should increase value, the fact is that options are different from other securities since their buyers can never lose more than the price paid for them, and still have the potential to earn significant returns from large price movements.
Interest rate	+	-	Together with the time to maturity of the option, these variables determine the time value of money on the exercise price. A higher risk-free interest rate will have a positive effect on a call option because the exercise price will only have to be paid at the maturity date, if paid at all, and making it possible to invest the money somewhere else gaining at least the risk-free rate for the time period left to maturity. For put options, a higher interest rate has a negative impact, since it decreases the present value of the money received by the sale of the underlying asset in the future.
Dividend payout rate	-	+	The value of the underlying asset can be expected to decrease if dividend payments are made on the asset during the life of the option. Consequently, the value of a call on the asset is a decreasing function of the size of the expected dividend payments because options do not participate on the dividends. Inversely, the value of a put is an increasing function of those dividend payments.

* The plus sign indicates that the value of the option changes in the same direction as the value of the relevant variable does, as the minus sign indicates exactly the opposite.

Source: Linde *et al.*, 2000; pp. 26

Applying these ideas to the real options scenario should suggest some messages for managers in their creation and defending of real options within the firm, since the value drivers of a real options are similar to those with respect to financial options (Table 2-5):

- The exercise price in a financial option is similar to the amount of capital expenditure required to be committed under an investment opportunity. Although this value may not be constant or known in the beginning of a project, in practice it is not considered unreasonable to assume it to be certain (Trigeorgis, 1996);
- The stock price under a financial option is comparable to the present value of cash-inflows resulting from committing to a real option. These expected cash-flows can be estimated by prognosis or by using a simulation model (Linde *et al*., 2000);
- The time that a financial option has to expire is comparable to the amount of time for which a particular real option commitment can be profitably deferred;
- Volatility of stock returns in a financial option is similar to the volatility of potential project inflows, i.e., the variability of the return of the underlying asset. There are a few different approaches that can be used to determine this volatility (Amram and Kulatilaka, 1999; Linde *et al*., 2000). One possible way is to take an educated guess since assets with higher hurdle rates (and a higher than average systematic risk) are also likely to have higher volatilities. This means that one can look at the returns on broad-based stock indexes and, building up from there, adjust for higher σ that individual companies usually have relating to the market, or even higher σ that individual projects have relating to the company as a whole. Another way to estimate volatility is to use historical data on investment returns in the same or related industries. As it is not always possible, volatility can also be estimated using Monte Carlo simulation techniques based on the projection that can be made on the probability distribution of the project returns;
- Since the exercise price can be deferred, risk-free rates come into play. With financial options the exercise price is fixed and not subject to risk. With real options, the amount of capital expenditure to be committed is usually uncertain. To meet the requirements of option pricing models, we think of capital expenditures to be paid in terms of certainty-equivalents, enabling risk-free rate to be used.

However, one must take into account that with financial options the naturally evolving value of some underlying variables, such as stock price, is the process by which the option holder becomes better informed over time. In contrast, with a real option, it must often be applied a conscious, and usually costly effort to resolve uncertainty. This can mean that the way in which information is acquired and managed can have a significant effect on the value of the option to the firm.

Table 2-5 - Comparison between financial options and real options key variables

Financial option (call option)	Variable (B&S model)	Real option (project)
Exercise price	*X*	Expenditure required to acquire the assets
Stock price	*S*	Present value of the operating assets to be acquired
Time to expiration	*t*	Lengh of time decision may be profitably deferred
Variance of stock returns	σ^2	Riskiness of the underlying operating assets
Risk-free rate of return	*r*	Time value of money*

* Usually the affinity with the B&S formulation is achieved if the expenditures involved in acquiring the assets under the real option are converted into certainty equivalent terms and a risk-free rate is then applied to *X*.

Source: Adapted from Trigeorigis, 1996; pp.125

Triantis (1999) suggests that, to increase the amount of information available for future decisions, a firm should try to lengthen the maturity of its options, speed up the rate of acquiring information, or increase the precision of its estimation process, in order to optimally exercise the option or even transform its nature.

In the same line of thought, Buckley *et al*. (2002) go a step forward and enumerate a series of actions managers can take into account when enhancing real options value. Hence, the major practical points for managers to bear in mind are:

- Increasing the present value of the expected inflows (*S*) – this can be done, for example, by focusing upon price, volume and costs; building customer switching costs; sourcing almost exclusively from the lowest cost producer; creating sequential opportunities; attempting to control key resources; taking pre-emptive positions and creating entry costs; or arranging exclusive distribution channels and raw materials supply contracts.
- Reducing the present value of expected outflows either alone or in partnership (*PV* of *X*) – the authors suggest practical measures such as lowering capital costs, exploring economies of scale or scope, or even outsourcing.
- Increasing management's ability to respond to uncertainty in potential product markets as it would enhance the value of flexibility and, in real options, this seems to be a good measure for the σ variable – some possible ways of achieving it are taking pre-emptive low-cost positions or outsourcing.
- Extending real options maturity (*t*) – it can be done with obtaining exclusive raw materials supply contracts, creating exclusive distribution channels, building switching costs, controlling key resources, or seeking for alliances.

Despite the importance of recognising real options' value drivers in order to best manage these important assets, it is still difficult to identify real options with real value, which is the first step to effectively manage them. In fact, the real options approach to investments and their valuation is only now spreading outside academia and becoming a common, but not yet standard technique in practice.

Damodaran (2001a) defends that some key tests should be made to determine when real options are indeed valuable. The author reminds that despite the argument that investments have valuable strategic or expansion options embedded in them, there is still the danger that this argument might be used to justify poor investments. Thus, while not all investments have intrinsic options, it is also true that not all options, even if existing, have true value. To assess whether an investment creates valuable options that need to be considered, Damodaran (2001a; pp.51) believes that three questions need to be answered affirmatively:

1. "Is the first investment a pre-requisite for the later investment/expansion? If not, how necessary is the first investment for the later investment/expansion?"
2. "Does the firm have an exclusive right to the later investment/expansion? If not, does the initial investment provide the firm with significant competitive advantages on subsequent investments?"
3. "How sustainable are the competitive advantages?"[17]

Another important feature of a firm's investments in real options that needs to be highlighted is the "portfolio" aspect. The typical application of ROA is focused on maximising the value of a particular investment, which is not necessarily consistent with shareholder value maximization, as the project may negatively impact other projects or future opportunities and, by these means, negate any value that it would create on its own.

To maximise total shareholder wealth rather than simply the value of a single real option, firms have to engage in portfolio optimisation exercises, taking firm's constraints into

[17] The sustainability of competitive advantage is a function of two forces. On one hand, the *nature of the competition* that must take into account the fact that, other things remaining equal, competitive advantages fade much more quickly in sectors with aggressive competitors. On the other hand, the nature of the competitive advantage, determining that if the resource controlled by the firm is finite and scarce, the competitive advantage is likely to be sustainable for longer periods. If the competitive advantage comes from being the first mover in a market then it will soon be challenged. The most direct way of reflecting this in the value of the option is in its life (Damodaran, 2001a).

account, including the financial ones (Triantis, 1999). Myers (1977) early pointed out that a highly levered firm may not be optimally exercising its growth options if the exercise price must be entirely paid by the shareholders while the benefits are to be shared with the bondholders. This underinvestment problem illustrates the importance of designing a firm's financing strategy to be consistent with extracting the maximum value out of a firm's portfolio of real options.

2.4 LIMITATIONS OF THE REAL OPTIONS PERSPECTIVE

Although the similarity to financial options has been extremely fruitful in enhancing our understanding and providing analytical tools to improve valuation techniques, several authors remind that the analogy between real and financial options may be incomplete and, sometimes, even ignore some important differences between the two (Dixit and Pindyck, 1994; Trigeorgis, 1996; Merton, 1998; Amram and Kulatilaka, 1999; Teisberg, 1999; Linde *et al*. 2000; Damodaran, 2001a; Copeland and Antikarov, 2004; Mondher, 2005; Couto, 2006).

One of the main differences derive from the fact that, in many cases, real options being valued are not financially traded assets in organized financial markets, at minimal costs. Although some real options may be traded, it occurs mostly in imperfect markets and at substantial costs (Trigeorgis, 1996). The practical consequence is that one can rarely make use of observable prices or find assets that fit the replicating portfolio logic under the OPT. Furthermore, it becomes almost impossible to assess a proper discount rate, as the risk neutral perspective hardly can be applied (Dixit and Pindyck, 1994)[18].

Another problem arises when relating to the estimation of the volatility of the underlying asset. Even when its price can be reasonably determined, we still must take into account that real options are usually long-term options and that the variance is unlikely to remain constant over extended periods of time (a basic assumption of the option pricing models), making it difficult to estimate in the first place (Dixit and Pindyck, 1994; Damodaran, 2001a).

[18] For some practical solutions for this problem see Dixit and Pindyck (1994) and Copeland and Antikarov (2004).

There are some modified versions of the OPT allowing for changing variances however, as Damodaran (2001a) highlights, these versions require that the process by which variance changes is explicitly modelled, thus augmenting the complexity of the evaluation.

Also important is the need to recognise that financial options are well-specified contracts with a clear owner and a defined payoff, all features that are rarely present in real options (Trigeorgis, 1996; Zingales, 2000). In fact, many real-world options are not clearly allocated to one owner (proprietary versus shared options) so that their holders have one more problem to deal with: the competition.

In addition, real options' payoff is usually highly dependent upon the way the option is exercised, becoming endogenously determined rather that exogenously specified as with financial options. Still, this exercise is not always instantaneous as assumed by the option pricing models. It may require actions that do not happen in one single moment in time (like, for example, building a plant) with direct implications on the true life of the real option (often less than its stated life).

Trigeorgis (1996) has also referred that, with real options, across-time interdependencies and option compoundness are most likely to exist. As seen, some real options lead to further discretionary investment opportunities becoming more complicated to analyse. Difficulties start when trying to identify all options involved, and continue with finding a model that fits a particular problem.

Complications are even higher when several options are present at the same time. The highest probability is that they suffer from multiple interactions, changing the value of the project as well as the critical boundaries at which exercising each option becomes optimal. This problem requires further attention as shared compound real options come into existence.

Beyond the limitations that result from the practical differences between financial and real options, one major problem frequently pointed out to ROA is that it is seen as a relatively complex analysis when compared to the more traditional valuation methods. Yet, Amram and Kulatilaka (1999), and more recently Schwartz and Trigeorgis (2005), believe that the discussion has been too focused on the mathematical tools needed for evaluation, putting aside the power of the basic idea. For these authors, the Real Options Approach has value, not so much by the conclusions resulting from the B-S model (or another), but much more on the understanding that there is a need to alter management's perspective of investment, imposing a clear thought on the risk and complexity of strategic decisions.

This perspective might mean that, despite the criticisms that can be made to the Real Option Analysis and to the use of option pricing techniques to value real options, there is a strong conviction that this analysis can lead to better decisions that the ones emanating from traditional valuation techniques, even because, as research evolves and markets grow, models are becoming more sophisticated (not necessarily meaning more complex) and information available more robust.

Throughout this chapter we have tried to synthesize the main reasons underlying the Real Options Analysis development, starting with the limitations of the traditional valuation methods, going through the basics of the Real Options Theory and presenting determinants for the real options valuation as well as its limitations.

On the next chapter we intend to analyse a different context of the same subject, viewing real options as a component or stock prices of quoted firms, trying to understand how much of their value is perceived by the financial markets in general, and by investors in particular, heading towards the specific problem analysed on this work.

3. Real Options as Component of Firms' Market Value

In dynamic and uncertain environments it is important to be flexible and adapt strategically over time in order to capitalize on favourable future investment opportunities, limit losses from adverse market developments, and respond appropriately to competitive moves.

Nowadays, it is already widely accepted that corporate decisions should be made consistent with maximisation of shareholders' wealth. So, a value based management has been emphasised as a correct approach to the development of value based metrics and quantitative tools to help firms to formally evaluate the impact of their decisions on shareholder value.

However, academics and managers, started to feel that these metrics fail to capture the true value of long-term investments as they leave behind some of their strategic value that cannot be easily quantified. The consequence is that, while the intangible benefits are recognised and appreciated, they are not properly compared against the costs associated with strategic investment decisions, which is particularly troubling given that a considerable fraction of shareholder's value rests on the outcome of key corporate strategic decisions (Busby and Pitts, 1997; Howell and Jagle, 1997; Triantis, 1999).

As now firms are also increasingly competing in capital markets in order to raise funds to finance their activity, thinking of future investment opportunities and management flexibility in terms of real options may provide, as discussed before, a substantial progress in modern corporate resource allocation and risk/uncertainty management. But real options reasoning goes a step further, enabling perceptions of strategic position in the industry that, eventually, end up reflected in the firms' market value, should markets be, at least at some degree, efficient.

Financial theory posits that capital markets convey through stock prices their expectation of the firms' future performance, as the efficient market hypothesis states that stock prices fully reflect all publicly available information and are unbiased indicators of firm value (Fama, 1970). Although the debate over the extent of market efficiency continues, this efficiency hypothesis has been surviving the criticisms suffered through the past three decades (e.g. Fama, 1991). Overall, the extant body of research seems to indicate that capital markets are efficient due to the efficiency of most individual stocks (Markovitch *et* *al*., 2005). Thus, to the extent that stock prices reflect future (expected) cash-flows, they can serve a vital economic function by providing feedback when they change in response to firm's actions.

Under a market efficiency hypothesis, one could then expect that stock prices incorporate all firm-related available information that, over time, is acquired by investors. Change in the investors' information set may be associated either with investors becoming aware of managerial actions as they are revealed to the public, or with the arrival of other information about performance of past strategies. In both cases, new information allows investors to update their expectation of the firms' future cash-flows (Markovitch *et al*., 2005). This logic leads to the conclusion that a change in investors' information set may affect stock prices.

Several authors have been defending the idea that real options represent a considerable part of a company's market value (Myers, 1977; Kester, 1984; Pindyck, 1988; Chung and Charoenwong, 1991; Quigg, 1993; Trigeorgis, 1996; Berk *et al*. 1999; Triantis, 1999; Kellog and Charnes, 2000; Liu, 2000; Smit, 2000; Schwartz and Moon, 2000; Buckley *et al*. 2002; Al-Horani *et al*., 2003; Tong and Reyer, 2004 and 2007; Alonso *et al*., 2005 and 2006; Chen *et al*., 2005; Pinto and Pereira, 2005; Li, 2006; Sudarsanam *et al.*, 2006; Clark *et al*., 2007, Liu and Chang, 2007).

This conviction, already supported with some empirical evidence, opened the door to a new line of research that tries to value firms under a real options perspective, identify the component of the stock prices related to firms' real options, as well as understand how real options affect the perceptions that actual and potential investors have about the value, growth potential, and competitive position of quoted companies.

The fundamental question raised on this research study is that if real options' value is perceived and prized by the market. Do investors recognise their existence (and future growth opportunities) when allocating their capital? If investors perceive the existence of real options, how do they identify and value them? What we do know for sure is that, quite often, the market's value of firms is different from their book value, usually associated to the value of the assets in place and, thus, unable to express the intangible value that derives from the real options existence.

Throughout this chapter we briefly analyse the idea of firms' valuation using ROA, and the association between the existence of real options within a firm and its equity/share value. We follow on reviewing the literature that, in different ways, has been trying to present real options as a component of the firms' value as an introduction to the empirical work described ahead.

3.1 FIRMS' VALUATION WITH REAL OPTIONS

From classical corporate finance texts (e.g. Brealey and Myers, 1992; Damodaran, 2001) one can think of the value of a firm in a number of different ways. On the one hand, there is the firm's fundamental value, seen as an accurate representation of its equity and debt relative to its physical and human capital. On the other hand, we also have the firm's market value, which is how the external market place currently values all the firm's assets, equity and debt. Corporate finance tells us that, in perfectly efficient markets, fundamental and market values should be equivalent. However, this is often not the case, and it is precisely this divergence that has been generating an increased discussion through the recent past.

Dempster (2006) shows that a firm's market value can be driven by investor's expectations and their current hopes and fears, as much as by any fundamental analysis[19]. This evidence was particularly prevalent in periods of high uncertainty. The question raised here is how do firms' real options integrate those expectations.

When the term *real option* first appeared with Myers (1977), the main focus was the effect of a firm's financing strategy on its investments decisions. Myers pointed out that a highly levered firm might not optimally exercise its growth options (also described as an *Investment Opportunity Set* – IOS) if the exercise price must be entirely paid by the shareholders, while the benefits are mutual to bondholders. This "underinvestment" or "debt overhang" problem, which has been mentioned previously in this work, is quite important when analysing the best financing strategy to cope with the aim of revealing the maximum value of a set of real options.

Following developments on ROA focused mainly on its role on capital budgeting, in the clear sense of a rational allocation of resources, as well as on the valuation of specific real options. Interactions between capital budgeting under a growth option perspective with long range planning and strategic decisions were the next step. Because investment

[19] This is the basic premise of *Behavioural Finance* (for an introduction see Schleifer, 1999).

decisions today can create the basis for the investment decisions tomorrow, capital allocations made at any time started to be seen as vital steps in the ultimate achievement of strategic objectives (Kester, 1984).

By this time, we should take notice that real options' evaluation methods are no longer merely academic techniques. Its basic notions are already many times considered at the moment of decision, even if only implicitly. Some empirical studies revealed that executives not only value real options (even if subjectively) but also would like to dominate the knowledge to implement ROA techniques (Busby and Pitts, 1997; Howell and Jagle, 1997; Verbeeten, 2006).

Only more recently real options perspective is used to understand how firms are valued by markets and how their existence and effective management are perceived by outsiders, namely investors. Nevertheless, linking real options approach with the value of a firm is not a new idea.

Back in 1977, Myers defended that organizational investments have two sides: on one hand, they provide current returns on cash-flow and, on the other hand, open up options. Once firms are valued as going concerns, the immediate consequence of that logic is that the firms' market value should include those options. Therefore, the value of any firm should be the sum of earnings generated by investments in place (also seen as the value of installed capacity or the value of the firm's options to utilize, or not, some or all of its capacity over time), plus the option of strategic choices (or the value of the firms' options to add more capacity later). Still according to Myers, the fundamental difference between these two parts of the market value of a firm is that the value of growth opportunities depends, at least in part, of the future discretionary investments, while the value of assets already in place does not.

This idea is later reinforced by Kester (1984) when mentioning that once the strategic benefits of investments as valuable options to future growth are understood by all involved, it becomes clear that such investments add value to the company's equity, just as projects that yield immediate cash-flows do, being the only difference the fact that value comes initially in the form of real option rather than in the form of cash-inflows.

Although managers presumably try to focus on increasing firm value without worrying too much about the daily variations in the market price of the firm's shares, they know that, in the end, the market value may be relevant for the firm's activities. Thus, it is important that not only managers, but also equity analysts and investors, recognise the value added from increased option value (Triantis, 1999), and that managers are able to develop an efficient policy on voluntary disclosure (namely of real options) and market signalling (Chen *et al*., 2005).

This valuation implies new criteria for efficient resource allocation with implications on strategy planning and financing decisions; as seen before, to the immediate and foreseeable cost-benefit value, one must add the option value. Resource investments that are able to maximize both components are most likely to deliver higher market value. Differences in the investment behaviour of firms under identical circumstances may then be caused, not by differences in the cost of capital or cost structure, but because their cost-benefit judgements do, or do not, implicitly value options (Bowman and Hurry, 1993).

This valuation approach is also consistent with the increasingly accepted idea that real options represent a part of a company's value (Kester, 1984; Chung and Charoenwong, 1991; Berk *et al*., 1999; Trigeorgis, 1999; Kellogg and Charnes, 2000; Damodaran, 2001a; Buckley *et al*., 2002; Ramezani, 2003; Alonso *et al*., 2005; Chen *et al*., 2005; Pinto e Pereira, 2005; Dempster, 2006; Li, 2006; Sudarsanam *et al*., 2006; Antoshin, 2007; Tong and Reuer, 2007) and that the more volatile is demand the larger is this fraction (Pindyck, 1991; Smit and Trigeorgis, 2005; Kort *et al*., 2007). Virtually, in the cases of companies operating in emerging product markets, all of their value is accounted for by the real options' component (Triantis, 1999).

This logic comes from the knowledge that uncertainty, beyond increasing the value of a firm's investment opportunities, also decreases the amount of actual investing that the firm will need. The result is that when a firm's market or economic environment is uncertain, the stock market value of the firm can go up, even though the firm does less investing and, perhaps, produces less (Paddock *et al*., 1988; Pindyck, 1991). Some exceptions are found when subdividing uncertainty in economy-wide and firm-specific types of uncertainty (Antoshin, 2007), or when the projects' life is short and low levels of uncertainty exist (Gryglewicz *et al*., 2008), but the base case still applies to the majority of companies.

Firms' managerial resources, reputation, market position, scale, IT expertise, brand name recognition, patents, financial resources, access to low cost inputs, investments in R&D, foreseeable product or geographical expansion, asset's flexibility, and other sources of competitive advantage, enable them to productively undertake investments and several strategic decisions that other firms cannot assume. This means that the source of excess profits should not be expected from external environment, but rather from the exploitation of unique internal resources and capabilities that confer competitive advantage over the costs of these resources and sustain the real source for value creation (Kulatilaka and Perotti, 1998; Smit and Trigeorgis, 2004; Li, 2006).

Also important is to notice that not all stocks generate the same growth potential, being most common that the so called growth stocks like biotech, pharmaceutical or information technology stocks yield higher price-earnings and market-to-book ratios due, precisely, to the intangible and strategic value of their growth opportunities. Smit and Trigeorgis (2005) provide evidence that industries with higher volatility and risk (whether it is market, firm-specific, or total risk) tend to have more valuable growth opportunities and a higher proportion of the present value of growth opportunities (PVGO) to price on average higher than other industries. The same idea had been already defended by Triantis (1999) or Buckley *et al*. (2002), and more recently by Clark *et al*. (2007).

The pointed reasons for this are:

- Firstly, the fact that those industries involve more expected technological changes and competitive moves. And, as so, as time goes by and new realities are formed, managers must be better prepared to learn, adapt, revise or completely alter their initial investment decisions. Under the logical belief that efficient markets and rational investors appropriately reward with higher market valuations those firms better able to cope with change, this higher underlying volatility is translated into higher (simple) option value;
- Secondly, growth firms, like leading firms in information technology or consumer electronics, also tend to have a bigger proportion of compound options (options on options), which amplifies their option value and, in turn, are most likely translated into higher market valuations that, from the perspective of standard DCF valuation methods, may appear excessive.

One of the areas where some empirical work has been developed in order to provide evidence that the option-pricing theory has more than descriptive value is, precisely, on the valuation of firms under a real options perspective and using option pricing techniques.

To name some of the first related studies focusing on firms' valuation we have the one presented by Paddock et al. (1988) and the study of Quigg (1993) (see Table 3-1).

Despite these studies, it was not before the beginning of the 21st century that several empirical works appeared, most of them focusing mainly on technology and telecommunications companies (Kellog and Charnes, 2000; Schwartz and Moon, 2000; Buckley *et al*., 2002; Pinto and Pereira, 2005, Liu and Chang, 2007) . This was probably caused by the skyrocketing valuations of these companies against all the traditional premises of firms' valuation. Real options valuation methods were then applied to assess the value of companies on an attempt to illustrate how those methods can be used for financial analysis (more details available on Table 3-1).

Also worth to mention is the development of a tool for market valuation and security analysis by the *Real Options Group* (ROG)[20] – the *Real Options Security Analysis* (ROSA™) (see Table 3-1).

Another current line of research has been the attempt to evaluate the impact of the existence of real options on the firms' value and, particularly, their financial performance. This kind of analysis becomes harder to develop once, typically, real options within firms are not directly observable, forcing researchers and analysts to rely on proxy variables to measure this reality.

In fact, it has already been demonstrated that evaluation paradigms have been changing (Verbeeten, 2006), especially after the crash in technology stock prices in 2000 (Clark *et al*., 2007). New evaluation techniques tend to include measures that reflect growth options that, because are not directly observable, are usually represented by suitable proxies. Clark *et al*. (2007) find that recognised proxies for future cash-flows are generally insignificant and almost with no explanatory power over the period of 1994-1999 and, during the period of 2000-2003, those proxies raise the explanatory power of evaluation models by 10%, suggesting a change on evaluation criteria. Under this perspective, we may also refer

[20] The Real Options Group (ROG) was formed by some pioneers in real options thinking and practice, with the aim of applying their knowledge and expertise to creating value in uncertain business environments. At the heart of ROV's approach is a sequential management process named at Strategic Real Options Valuation (S-ROV), that is the basis of the management consulting services offered, and that focus on internal value creation, such as project design and valuation, capital allocation and product portfolio management, and corporate strategy and valuation. For more detail, the ROG website may be consulted at http://www.rogroup.com.

the works of Smit (2000), Al-Horani et al. (2003), Ramenzani (2003), Carson (2005), File and Kwak (2006) and Tong and Reuer (2007) (see Table 3-1).

Table 3-1– Some real options valuation studies

Authors	Study description
Paddock *et al*. (1988)	Developed an option-based model that valued offshore petroleum leases as a function of the market price of oil. Although their main objective was to determine the fairness of oil prices by comparing the results of their model and the markets' valuation or the valuations done with regard to discounted cash-flow techniques, the fact was that their study needed a previous valuation of the companies' assets.
Quigg (1993)	On a large scale study aiming to test empirical predictions of real option-pricing models, the author uses a model that incorporates the option to wait to invest in the valuation of urban land, and provides evidence that the market prices reflect an option premium for optimal development that, based on her estimations, represents a mean of 6% of the land value.
Kellog and Charnes (2000)	Used real options perspective to value a biotechnology company, assuming that the same company could be understood as a portfolio of projects.
Schwartz and Moon (2000)	Apply ROT and capital budgeting techniques to the problem of valuing an internet company. They formulate a continuous-time model, based on assumptions about expected growth rate of revenues and on expectations about the continuously changing cost structure of this kind of companies as new information becomes available, and conclude that, given high enough growth rates of revenue, the value of internet stocks may be rational.
Smit (2000)	Empirically evaluates the option characteristics of growth stocks and provides evidence in favour of growth option influence on prices of a sample of US companies during the period of 1988-1998.
Buckley *et al*. (2002)	Use the example of Netscape to show how ROA might be applied to value a growth stock. The authors argue that real options valuation is not a revolutionary new technique that challenges DCF methods, but more a refinement that complements traditional valuation models that, in appropriate circumstances, namely highly volatile contexts, can be logically used. Nevertheless, real options valuation techniques are proved to augment the value of the firm compared to more traditional valuations.
Al-Horani *et al*. (2003)	Find that the returns of a sample of UK firms could be directly associated with ratios of R&D expenditures to market value and to book-to-market value.

Authors	Study description
Ramezani (2003)	Using a sample of 3.000 firms, considers how the existence of real options affects financial measures of firms' performance. He finds that financial ratios seem to reflect the value of firms' real options, and that performance measures for firms with valuable real options are significant higher.
Carson (2005)	Identifies appropriate proxies for the investment opportunity set (IOS) of certain companies, examining the correlation between the various proxies and an observable measure of the IOS.
Pinto and Pereira (2005)	Explore and apply ROA and modern capital budgeting techniques to the problem of a technology-based dividend-paying company's valuation under uncertainty, incorporating in their model some features aimed at pricing non-stock equity claims. Their work had the innovative premise of the introduction of dividends and analysis of the effects of financial distress/bankruptcy and golden shares' control.
File and Kwak (2006)	Examine the relationship between the level of investment opportunity sets and managers' accounting choices in Japanese firms, providing information on earnings management practices and their practical results in terms of growth opportunities creation.
Liu and Chang (2007)	Extended the valuation model developed by Schwartz and Moon (2000) in order to express a more realistic jump-diffusion model for the evolution of revenues, and to deal with problems of valuing options with early exercise features. The authors apply the model to the valuation of an illustrated company, concluding that the presence of random jumps decrease the firm's value or stock price. However, authors notice that, for the non-equity claims, their early exercise raises the equity value of the firm earlier on time.
Tong and Reuer (2007)	Estimate the components of firm value accounted for by growth options, which are then used to derive a measure of firms' growth option value. And to identify several types of internal and external corporate development activities that are commonly viewed as conferring firms discretionary future investment opportunities, to empirically investigate if they effectively contribute to firms' growth option value.
ROG – ROSA™	ROSA™ is a market data-base statistical methodology used to advise on stock selection or portfolio management, and to identify companies whose growth potential is properly priced (or not) by the market. According to the ROG, this tool uses market data on option-related variables (such as firm-specific and market volatility, index of managerial flexibility or asymmetry of returns, the degree of R&D, among others) to determine a firms' growth potential and the percentage of eventual mispricing.

Additionally, assuming that a firm that uses real options thinking and models take an active risk management view, Herath and Bremsen (2005) develop an integrated performance measurement system for strategy implementation, incorporating real options under the category of R&D investments, and apply it to a pharmaceutical company in order to evaluate the impact of these specific real options on firms' performance.

A similar framework is developed by Sudarsanam *et al*. (2006), but based on a typology of intellectual capital derived from the influence upon the various valuation parameters of real options, aimed at identifying its impact over the corporate value.

The results of a study of Australian firms over the period of 1998-2000 reveals that firms with high growth potential (real options) and executive share option plans are associated with better firm performance (Hutchinson and Gul, 2006). More, the authors conclude that it is the combination of both high growth opportunities and high levels of options detained by companies that is associated with higher financial performance.

Alonso *et al*. (2005 and 2006) also attempt to provide sustainable evidence that the recognition of the existence of real options affects the value of the firms on the capital markets, as stock markets tend to reflect expectations of investors regarding the efficient identification and management of those options. The authors analyse a first sample of companies listed on the Spanish Stock Exchange (Alonso *et al*., 2005), and then do the same testing on high-tech companies listed on main OECD stock markets, where real options are expected to represent a significant part of the firms' value (Alonso *et al*., 2006). Both studies provide evidence consistent with the basic assumption that real options do have an influence on market prices of companies.

More recently, attention has been driven to specific problems, such as knowledge-based organizations evaluation supported on real option valuation techniques (Wu *et al*., 2008), or the development of a real options framework to analyse the behaviour of stock returns in mergers and acquisitions (Hackbarth and Morellec, 2008).

Recent research has then been providing some empirical evidence on the growing importance of real options within the firms' valuation, not only on the managers perspective when considering real options' value on their financial and strategic decisions, but also by outsiders to companies, who increasingly realise the real options existence, as well as their influence on firms' capacity to grow and create value.

3.2 VALUING EQUITY AS AN OPTION

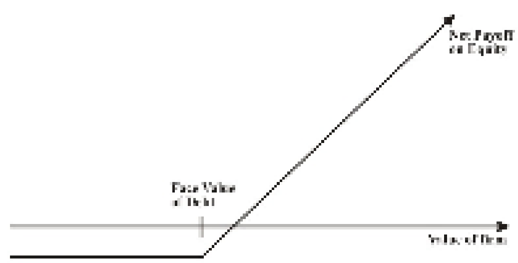
Traditionally, the value of equity is obtained by subtracting the value of debt from the firm value which is, in turn, determined by estimating cash-flows over a long time horizon and discounting them back at a discount rate that reflects their riskiness.

Several authors argue that DCF models understate the value of equity (e.g. Myers, 1977; Pindyck, 1991; Dixit and Pindyck, 1994; Berk *et al.*, 1999; Linde *et al.*, 2000; Schwartz and Trigeorgis, 2005), especially if firms have high financial leverage or negative operating income (Myers, 2000; Damodaran, 2001a; Mondher, 2005).

Equity in a firm may be interpreted as a residual claim, meaning that equity holders have a claim on all the cash-flows left over after financial claimholders (such as over debt or preferred stock) have been satisfied. The same principle applies if a firm is eventually liquidated: equity investors receive what is left in the firm after all outstanding debt and other financial claims are paid off. As the principle of limited liability protects equity investors in publicly traded firms, even if the value of the firm is less than the value of the outstanding debt, they cannot lose more than their initial investment (Trigeorgis, 1996; Triantis, 1999; Copeland and Antikarov, 2002).

Thus, equity can be viewed as a call option on a firm, where exercising the option requires the firm to be liquidated, and the face value of the debt (corresponding to the exercise price) paid off (fig.3-1).

Figure 3-1 – Payoff on equity as option on a firm



The basics of options valuation tell us that the payoffs on a call option with a strike price of K, on an asset with a current value of S, are as follows:

$$\text{Payoff on exercise} = \begin{cases} S - K, & S > K \\ 0, & S \leq K \end{cases}. \qquad [3.1]$$

Source: Damodaran, 2001a, pp.58

Being V the liquidation value of a firm, and D the face value of its outstanding debt and other external claims, the payoffs to equity investors can be understood as:

$$\text{Payoff to equity on liquidation} = \begin{cases} V - D, & V > D \\ 0, & V \leq D \end{cases}. \qquad [3.2]$$

The use of OPT to value equity (as a call option), namely the B-S model, is the next step[21]. However, as described on Table 3-2, it should be noticed that some compromises have to be made to use this model in valuation, as we need to obtain the option pricing inputs (Damodaran, 2001a).

Table 3-2 – Description of option pricing inputs for valuing equity

Option pricing inputs	Description
Value of the firm (V)	It may be obtained estimating the market values of the assets of the firm, either by using the market prices of these assets, or by discounting the expected cash-flows at the weighted average cost of capital (WACC). Nonetheless, it should be taken into account that if the firm's value is being estimated using a discounted cash-flow model, then only assets in place are being considered. The result is that the estimated firm's value is less than the total firm's value, which includes expected future investments (Kester, 1984; Chung and Charoenwong, 1991; Chung and Kim, 1997; Kulatilaka and Perotti, 1998; Damodaran, 2001a; Copeland and Antikarov, 2002; Arnold and Crack, 2004; Pinto e Pereira, 2005; Dempster, 2006).
Variance in the firm value (σ)	It can be directly obtained if both firm's stocks and bonds are traded in market place. When bonds are not traded we can use an estimate of the value of similarly rated bonds. Both methods become less accurate in periods when stock and bond prices suffer from higher volatility. So, an alternative way is to use the average variance in firm value for other firms in the same sector (Berk *et al*., 1999; Damodaran, 2001a; Buckley *et al*., 2002; Arnold and Crack, 2004; Alonso *et al*., 2005; Clark *et al*., 2007).
Maturity of debt (t)	This task may become complicated as most firms have more than one debt issue and much of the debt has periodic compromises. As known, the option pricing models only allow one input for the time to expiration, demanding that multiple debt issues and coupon payments are compressed into one single measure. Multiple issues have to be converted into one equivalent zero-coupon debt, which is possible by estimating the duration of each debt issue and calculating a weighted average of the duration of the different issues (Damodaran, 2001a). The result may then be used as a measure of the time to expiration of the option.

[21] For some practical examples see Damodaran (2001a) and Copeland and Antikarov (2002).

Viewing equity as a call option implies to understand firms' equity with value, even if the value of the firm falls below the face value of the outstanding debt. This means that, although the firm may be seen as not attractive to investors or analysts, its equity is not worthless. Just as deep-out-of-the-money traded financial options have value because of the possibility that the value of the underlying asset may increase above the strike price in the remaining life of the option, equity has value because the time premium on the option (i.e., the time until all debt matures and comes due), and the possibility that the value of the assets may increase above the face value of all debts before they come due.

3.3 MARKET IDENTIFICATION AND VALUATION OF REAL OPTIONS

3.3.1 Real Options' Market Value

Viewing firms' opportunities to grow and to be flexible as real options provides a new framework for examining corporate decisions. As mentioned earlier in this work, ROA and its tools are believed to be useful when comparing alternative strategies from the perspective of shareholders' value maximization.

Triantis (1999; pp.55) refers that "if managers' incentives are appropriately aligned, they will actively create real options, take steps to enhance the value of existing options through controlling key value drivers and transforming the nature of the options, and select the appropriate time to exercise the options". Nevertheless, while firms' managers may be confident that their actions increase the fundamental value of companies, it is not given that the market value of firms' shares does reflect this reality. This particular concern is expressed by Bowman and Hurry (1993), who remind that the option-value of the firm's total value relates to shadow options (still awaiting for recognition), and to latent assets (identified as opportunities), both not easily discerned by the market, since the majority of the variables affecting the value of real options are not directly observable.

Aware of these limitations, one can anticipate that the market value of any firm's real options will only reflect investors' expectations if these are to be based in publicly available information. Therefore, data contained in financial statements must be able to reveal information concerning the existence and the capacity to efficiently exercise real options within those companies (Alonso *et al.*, 2005). Under a market efficiency hypothesis, this information, once accessible, will be sooner or later reflected on stock market prices, converting real options in a component of firms' market value.

According to Myers (1977), under a real options approach, the value of a firm consists of two elements: assets-in-place (AIP) and future investment options (real options). AIP refer to particular allocations of a firm's resources that already have been made. The value of this component can be derived from the stream of cash-flows generated over time (Chung and Charoenwong, 1991; Kester, 1984; Chung and Kim, 1997; Merton, 1998; Kellogg and Charnes, 2000; Linde *et al*, 2000; Damodaran, 2001a; Ramezani, 2003; Alonso *et al*., 2005; Adler, 2006; Tong and Reuer, 2007).

To describe the second element, the future investment options, Myers (1977) introduces the term *Investment Opportunity Set* (IOS). To the author, this is a portfolio of real options detained by companies, and a reference on the extent to which a firm's value depends on its future discretionary expenditures. Examples of discretionary investments include investments in new projects, expenditures on advertising, marketing, product development, and R&D. Under this perspective, the IOS represents rights due to companies in order to decide the allocation of resources that, to some extent, may affect future cash-flows (Kallapur and Trombley, 1999; Carson 2005).

Several authors that followed argue that the IOS plays an important role in corporate finance, and that the mix of assets-in-place and investment opportunities may affect firms' capital structure, the maturity and covenant structure of their debt contracts, firms' dividend policies, their compensation contracts and their accounting policies (Foss, 1998; Berk *et al*., 1999; Myers, 2000; Roemer, 2004; Mauer and Sarkar, 2005; File and Kwak, 2006; Neves and Pindado, 2006).

If Myers' (1977) standpoint on real options is correct and market efficiency exists, then a firm's market value should reflect both the present value of future cash-flows to be generated by its current resource allocation, and the value derived from future resource allocation opportunities. As Alonso *et al*. (2005; pp.1675) conclude, "this implies that in judging decisions undertaken by managers, investors consider not only the effects of managerial decisions on the amount, time and risk of a firm's expected cash-flows, but also on the variables that determine the value of its real option portfolio".

However, it should be taken into account the fact that the nature and composition of the real options portfolio (or IOS) is determined by tangible and, especially, intangible assets that firms accumulate during their overall existence, and that are not adequately recorded in financial statements (Sudarsanam *et al*., 2006). As a consequence, quantifying this component of a firm's market value becomes a quite complex task and its value ends up being estimated by indirect means (Bernardo *et al*., 2000; Buckley *et al*., 2002; Tong and Reuer, 2007; Alonso *et al*., 2005 and 2006; Adam and Goyal, 2007; Chen *et al*., 2007).

This estimation of real options' market value has been introduced by Kester (1984) building on Myers' (1977) logic of firms' value components. According to the author, "the importance of growth options can be recognized by looking at the difference between the total market value of a company's equity and the capitalized value of its current earnings stream" (Kester, 1984; pp. 154). In other words, as the market value of a firm's real options can be defined as the difference between its total market value and the value of its assets-in-place, firm's real options value can be estimated by subtracting the present value of its expected cash-flows to equity (under a no-growth assumption) from the market value of equity.

In practice, Kester (1984) measures the proportion of firm's value attributable to growth options, or the firm's growth option value (GOV) as follows:

$$\mathrm{GOV} = \frac{\mathrm{V_{GO}}}{\mathrm{V}} = \frac{\mathrm{V} - \mathrm{V_{AIP}}}{\mathrm{V}} \qquad [3.3]$$

where,

V = firm's total value

V_{GO} = value of future growth opportunities

V_{AIP} = value of assets-in-place currently generating cash-flows

The empirical study conducted and presented here also follows Kester's logic on the real options' market value estimation.

3.3.2 Proxies for Real Options

Given the discretionary nature of investment opportunities, these are regarded and valued as *real options*. As reviewed throughout the present work, these options are valuable sources of competitive advantages, and are often associated with the possibility to add more value to the firm in general, and to its shareholders, in particular.

Despite market efficiency theory predicts that the total market value of a firm will reflect available information, including that one relating to its real options portfolio, the fact is that most of the time, investment opportunities and the flexibility to undertake them are unobservable by outsiders. Consequently, the proposition that firms' market valuations reflect the value of real options becomes not directly testable, forcing empirical researchers to rely on proxy variables to measure the existence and value of firms' investment opportunities, i.e., the real options value (Tong and Reuer, 2004; Philippe, 2005; Alonso *et al*., 2006; Adam and Goyal, 2007).

In this context, several authors have been trying to relate some strategic, operational and financial decisions undertaken by companies, with the establishment and existence of real options, as well as on their influence on real options' value. The aim is no longer to evaluate specific (real) options available to firms in different uncertain scenarios, but to find measures that outsiders can identify as alternative evidence that real options exist, are being managed, and can be, in some future time, exercised in order to create value. In Table 3-3 we refer to some of these measures and describe related empirical evidence.

Table 3-3 – Possible measures as representative of real options existence within firms

Measure	Relation with real options
International investment	Kogut (1985) is among the first authors to formally conceptualize and empirically test real options in strategic management, suggesting that *international investment* confers valuable growth options to multinational corporations, and that initial investment in a foreign country often carries a large option value, since this investment can unlock opportunities for future expansion. The author emphasizes that multinational corporations hold high levels of operating flexibility, allowed by the possibility to shift value chain processes across geographically dispersed activities as uncertain environmental conditions evolve, granting the corporations with a portfolio of important switching options.
R&D	A frequent proxy for growth real options held by firms is the level of *research and development expenditures* (R&D) (see, for example, Chung and Charoenwong, 1991; Bernardo *et al*., 2000; Smit, 2000; Tong and Reuer, 2004; Carson, 2005; Herath and Bremsen, 2005; Alonso *et al*., 2006; Adam and Goyal, 2007). The reason for this comes from the fact that the primary result of R&D projects is not cash-flow, but the knowledge and learning necessary for investing in future expansion projects. In most cases, a positive relationship was found between R&D activities, usually measured by the level of corresponding expenditures, and the portion of the firms' value due to growth options.

Measure	Relation with real options
Intellectual property rights value	Along with R&D expenditures it is possible to find in financial literature some other proxies for real options with intangible characteristics, such as *intellectual property rights value*, i.e., patents (Pitkethly, 1997), or the measure *(Assets - Property, Plant & Equipment)/Assets* (Bernado *et al.*, 2000). However, as a result of tests performed, these were found to be highly correlated with the R&D variable, and thus with no increasing explanatory power.
Geographical and business diversification	*Geographical diversification*, along with *business diversification* were studied by Bernardo *et al*. (2000), under a broader analysis of the diversification discount problem[22]. This phenomenon can be partially explained by real options, as authors believe that the market value of single-segment firms include the value of real options to diversify and expand in other segments, whereas multi-segment diversified firms may have exhausted their options to diversify and expand. The same variables are used as proxies for real options by Alonso *et al*. (2005), who find a significant and positive correlation between the market value of real options and the *business diversification* indicator, although no significant correlation could be found to the *geographical diversification* variable.
Investments in joint ventures and acquisitions	Kogut (1991), and more recently Tong and Reuer (2004), empirically positively related *investments in joint ventures* with growth option value, while concluding that *investments in acquisitions*, due to the extinguishing of expanding alternatives, are negatively related to growth options' value within firms. The same results are generally obtained by Hackbarth and Morellec (2008) when developing a real options framework to analyze the behaviour of stock returns in mergers and acquisitions.
Corporate debt	*Corporate debt* is often referred as a main determinant of a firm's ability to manage its options in an efficient way (Kallapur and Trombley, 1999; Alonso *et al*., 2005; Mauer and Sarkar, 2005; Chen *et al*., 2007). This comes from the fact that *corporate debt* might discourage the efficient exercise of options to invest before the liquidation date of debt (Myers, 1977) which, in turn, is explained by agency problems arising from the divergence of interests induced by asymmetric distribution of costs and benefits of exercising real options. It has been demonstrating a negative relation with the market value of real options of firms.

[22] The diversification discount is a documented empirical result that shows that the market value of diversified firms operating in several business segments appear to be less than the sum of the market values of single segment firms operating in corresponding businesses (Bernardo *et al*., 2000).

Measure	Relation with real options
Financial leverage	*Financial leverage* is also seen as a good source of information on a company's capacity for raising funds for the acquisition, maintenance and exercise of its real options, whether through additional borrowing, or by profit retention. It also has been found negatively related with the market value of real options (Alonso *et al*., 2005 and 2006; Mauer and Sarkar, 2005).
Asset irreversibility	*Asset irreversibility* is believed to affect the value of options, as the opportunity cost associated to the exercise of a growth option increases with the level of irreversibility of the assets, augmenting the value of postponing the commitment of resources. This variable has been found positively correlated with the value of real options (Chung and Charoenwong, 1991; Berk *et al*., 1999; Triantis, 1999; Linde *et al*., 2000; Alonso *et al*., 2005).
Operational flexibility	*Operational flexibility* intends to represent a situation where companies hold operating options, i.e., the capacity to modify the scale of operations and to substitute factors and products (Kulatilaka, 1993; Linde *et al*., 2000; Alonso *et al*., 2005). As mentioned by Myers (1977), the successive exercise of these rights reduces the impact of changes in demand, product prices, and costs of inputs on firms' operating profits, reducing the volatility of their gross profit, while increasing the correlation between sales and operating costs.
Operating leverage	Under the real options reasoning, it is possible to admit that the value of a firm's real options should increase with its *operating leverage*, once the more the fixed costs exceed the variable ones, the greater the sensitivity of the firm's gross profit to changes in the markets of factors and products. The result is a decrease on the value of the assets-in-place (AIP), while the utility and value of flexibility options becomes higher (Alonso *et al*., 2005). Additionally, greater operating leverage will imply greater risk of the assets that underlie growth options and, consequently, a greater proportion of the total value of a company accounted for by these options (Kulatilaka and Perotti, 1998; Micalizzi and Trigeorgis, 1999; Alonso *et al*.,2005).

Along with the abovementioned measures, let us also refer some price-based proxies for real options:

1º) Kallapur and Trombley (1999) identified a series of empirical price-based proxies for the Investment Opportunity Set (IOS), recognized as the real options portfolio, relying on the idea that the growth prospects of a firm are, at least partially, impounded in stock prices. Thus, the greater the growth prospects of a firm, the higher its market value. One pointed measure of growth opportunities is the *ratio* *of book value of assets to total market value of the firm*. The higher this ratio, the higher is believed to be the ratio of AIP to the market value of a firm, and the smaller the ratio of investment opportunities to firm value. Despite a few potential weaknesses found in literature (Smith and Watts, 1992), this ratio is commonly used due to a higher correlation with future growth than other similar measures, such as *Tobin's q* (Kallapur and Trombley, 1999; Adam and Goyal, 2007).

2º) The *ratio of the market value of equity to book value of equity* (Chung and Charoenwong, 1991; Carson, 2005; Adam and Goyal, 2007), has also been used as a price-based proxy for investment opportunity, where the difference between the market value and the book value of equity represents a higher value of real options to the firm. However, this ratio depends on the extent to which the firm's return on its existing assets and expected future investments exceed its required rate of return on equity (File and Kwak, 2006), and stays behind on explanatory information about the IOS when compared to the previous measure (Adam and Goyal, 2007).

3º) The *earnings-price ratio* is a third commonly used price-based measure of real options (Chung and Charoenwong, 1991; Carson, 2005; Hutchinson and Gul, 2006; Adam and Goyal, 2007). Although Chung and Charoenwong (1991) showed that the larger the E/P ratio, the larger the proportion of equity value attributable to earnings generated from AIP relative to growth opportunities, Kallapur and Trombley (1999) found that this measure did not exhibit any consistent association with subsequent growth, indicating that this might not be a valid proxy for real options, and Adam and Goyal (2007) demonstrated that there are other variables with better performance, such as the market to book assets ratio mentioned above.

In addition, effective holding and exercising capacity of real options can too be reflected in the risk of returns (*stock* β). Since an option's risk is greater than its underlying asset's risk, an increase in the risk of stocks will be associated with an increase in the fraction of value accounted for by options to invest, keeping the remaining variables constant (Chung and Charoenwong, 1991; Berk *et al*., 1999; Alonso *et al*., 2006).

Smit (2000) still accounts for another effect that real options have on return distribution, reminding that option-defined discretionary decisions allow managers to increase profits while limiting losses. The result is that the existence of the real options portfolio tends to shift the probability distribution of stock returns to the right (see, fig 2-1) and, thus, the proportion of the market value of a firm due to real options will increase on the skewness of its returns. Several authors introduced the *skewness of returns* of firms as a proxy for real options, using the standard deviation of stock returns, and finding a general positive and significant relation with the proportion of market value of firms not due to AIP (Smith and Watts, 1992; Kulatilaka and Perotti, 1998; Bernardo *et al*., 2000; Smit, 2000; Alonso *et al*., 2006; File and Kwak, 2006; Gryglewicz *et al*., 2008).

Finally, also representing a firm's possibilities of raising funds in order to acquire and exercise options is the variable of *firm's size* (Berk *et al*., 1999; Carson, 2005; Alonso *et al*., 2005; Beck *et al*., 2006; File and Kwak, 2006; Adam and Goyal, 2007; Clark *et al*., 2007). The use of this proxy comes from the perception that larger firms are not only better prepared to obtain additional funding, but are also committed in different markets and business activities, accumulating knowledge and expertise, and thus, naturally breeding growth options.

Even though positive relations were found between the market value of real options and the *firms' size*, Bernardo *et al*. (2000) call attention to the need to distinguish *size* from *age*. If a close relation is assumed between firms' size and their age, than firms' dimension can be considered a proxy for the situation where, as firms grow, a process of substituting their options to expand with AIP is followed and, consequently, a negative relation is expected to exist with the market value of their real options.

Although several proxies for real options can be found in empirical literature, related studies had to cope with the difficulty on gathering the necessary amount of information for large scale analysis. Despite the compulsory information disclosure that quoted companies are obliged to, the access to financial databases is still a problem for some researchers. Even when access is granted, it is sometimes difficult to find enough detailed information to include a large number of proxies in the analysis, especially in the case of less developed financial markets.

On the following chapters we describe our empirical study aimed at looking for evidence on the possible recognition of real options within firms by the market, namely investors. For the purpose, some of the abovementioned proxy variables for real options are used.

4. RESEARCH DESIGN AND METHODOLOGY

As stated when revising the literature, several studies have been conducted to sustain the conviction that real options represent an important part of firms' market value, as well as attention has been given to understand how this value is perceived and prized by the market.

Although some empirical facts tend to support the idea that, not only the market value of firms incorporate a proportion dedicated to their real options, but also that real options' value is indeed perceived as valuable by the market, evidence is mixed when it comes to the intensity of this relationship and to the kind of available information (variables) used as representative of real options' existence within firms.

In this context, we will try to provide further evidence on the real options' component of companies' market value, focusing on the investor's understanding of their existence, and on the premise that they value these options when the decision to invest (allocate resources) is made. To this end, we intend to explore the relationship between the proportion of firm's market value attributable to real options and a set of variables that may inform investors about the existence and the characteristics of the real options portfolio held by these firms. In this way, we aim to provide an empirically answer to our general research question: does the market recognize the value of firms' real options?

Throughout this chapter we will pose our research hypothesis, describe data and sample selection, and proceed with the definition of the methodology used, along with the model and its variables.

4.1 RESEARCH HYPOTHESIS

According to some authors, starting with Myers in 1977, the market value of the firm comprises two basic elements: the value of assets already in place and currently generating cash-flows, and the value of its real options portfolio, able to create future value, and so, already valuable at the present time. As exposed throughout the literature review, the market value of real options cannot be directly determined. So, as suggested by Kester (1984) and used in several studies that came ahead, we may understand this value as an estimate given by the difference between the market value of a firm and the value of its assets-in-place (e.g. Chung and Charoenwong, 1991; Linde *et al*., 2000; Alonso *et al*. 2005; Sudarsanam *et al*., 2005; Tong and Reuer, 2007).

Academics have also been trying to find suitable proxies for the real options' component of the firm's value and, quite often, a significant positive or negative relationship has been found, depending on the proxy that was being analysed (as previously referred to in section 3.3.2 of this work).

Exploring the relation between the abovementioned estimate of real options and some of its empirical tested proxies may shed some light over our main research question, as it can provide an indicator of whether the market (investors) recognises the implicit value of real options within firms. In fact, under the assumption of the efficient markets principle, once investors recognise the existence of real options, they will reflect this knowledge on the price of stocks, driving the total market value of firms away from the simple component of the value of assets-in-place and, thus, granting a higher proportion of that market value to real options.

Our first research hypothesis can then be put forward as follows:

> H_1: *Investors recognise real options value within a firm when deciding to allocate resources.*

The literature review widely supports the idea that real options are a component of firms' value. Nevertheless, only a few empirical studies attempt to relate proxies for firms' real options with an estimate of their value in order to access how important are real options to the firm's market value (e.g. Smit, 2000; Buckley *et al*., 2002; Al-Horani *et al*., 2003; Alonso *et al*., 2005 and 2006; Chen et *al*., 2007; Tong and Reuer, 2007). Moreover, conducted studies were either geographically restricted, studying only one country and its financial market, or industry-specific, focusing essentially on high-tech companies, or even on a single firm, with characteristics of case-studies.

In general, evidence found in prior studies tend to support H_1; however, a more widespread analysis may be necessary to confirm these results, namely through the inclusion of more countries (markets) and several economic activities.

To test this hypothesis we consider a model (extensively described ahead) that relates an estimate of real options value mostly under Kester's (1984) perspective, with several proxies of real options[23] found in relevant literature.

The global significance of the model should be able to confirm, or not, H_1. Even expecting an overall significance of the model and, consequently, the empirical confirmation of this first research hypothesis, we understand that, due to the proxies chosen in this study, the specific markets analysed, and the fact that there is still not an extensive body of knowledge on this matter, findings might deviate from expectations.

In order to identify possible reasons for the fact that investors may, or may not, perceive real options existence and value, a set of sub-hypothesis is formulated, each of them related to the choice of particular proxy variables for real options (the independent variables of the model).

Even though several possible proxy variables could be used, under the impossibility to use them altogether[24], it was made an effort to choose proxies that satisfied some conditions. Thus, depending on available data, proxies used should be:

- Representative of both operational and financial aspects of a firm's situation;
- Simple to construct and easy to understand;
- Able to represent the capacity of management to identify, maintain and optimally exercise real options;
- Not directly correlated among each others.

The result was the choice of four proxy variables for real options, all of them used in prior empirical research: *asset irreversibility*, *financial leverage*, *size* and the *ratio of book-value of assets to total market value of firm*. Therefore, we are able to formulate the corresponding sub-hypotheses, according to empirical findings described on chapter 3.

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[23] In some of the empirical studies these proxies were related to the firms' Investment Opportunities Set (IOS), also identified with the Real Options Portfolio.

[24] Even if a high number of explanatory variables tend to increase the coefficient of determination (R^2) of the model along with its explanatory power, the use of all the proxy variables found in relevant literature, and described in section 3.3.2, is not possible, justifiable, or desirable for several reasons. First, most of these proxies are highly correlated, making it difficult to isolate each variable's marginal effect on dependent variable and, certainly, leading to additional and unnecessary estimation problems. Second, to compose a model of this nature with a high number of proxy variables it would be necessary a large amount of data, difficult to deal with all at once. Third, even when financial databases exist and its access is granted, we still have to deal with the inexistence of data for some firms/variables during the whole period of the analysis.

The first sub-hypothesis is an operational-related hypothesis, and it is posted as:

H_{1a}: Asset irreversibility is positively related with the market value of real options.

Asset irreversibility can be used as a proxy for real options existence as it affects the value of options to invest through the impact on the opportunity cost that is present when exercising options that can be postponed. Pindyck (1991 and 2005) dedicated some particular attention to these opportunity costs, explaining that, assuming that commitment of resources can be deferred, there is an optimal moment for investment (exercising the option) which happens when the underlying value exceeds the sum of the value to exercise the option plus the present value of exercising the same option at a later moment in time. When a high degree of asset irreversibility exists, the more likely to a company to postpone the optimal date for exercising its growth options, as it implies a greater value for deferrable options (a higher opportunity cost) and, thus, a higher proportion of the total market value related to its options when compared to the fraction of assets-in-place component.

Alonso *et al*. (2005) still highlight the fact that this kind of investments constitute, themselves, mechanisms for the identification and acquisition of new growth options, often characterised by a highly irreversibility nature. Furthermore, the value of these growth options is generally positively dependent on their exclusivity which, in turn, depends on the specificity of the assets supporting them.

A second sub-hypothesis, related to the financial aspect of firms, is formulated as:

H_{1b}: Financial leverage is negatively related with the market value of real options.

Financial leverage has been used as a proxy for real options' existence as it is believed to represent a source of information on the capacity of a firm to raise funds for the acquisition, maintenance and exercise of real options (Mauer and Sarkar, 2005; Alonso *et al*., 2006; Chen *et al*., 2007). Corporate financial leverage increases the probability of the appearance of under-investment problems due to agency conflicts and financial restrictions. These problems arise from the divergence of interests of equity and debtholders, induced by the asymmetric distribution of costs and benefits among them when executing firms' real options (Myers, 1977 and 2000; Zingales, 2000). So, we expect that an increase in financial leverage will be associated with a decrease in the proportion of total market value accounted for by options to invest.

Consistent with the prior use of the variable *size* as a source of information regarding the company's possibilities for raising funds in order to acquire and manage real options (Chen and Charoenwong, 1991; Berk *et al*., 1999; Carson, 2005; Alonso *et al*., 2006; Adam and Goyal, 2007), our third sub-hypothesis is aimed at the issue of firms' dimension and reveals the expected positive relationship between size and the market value of real options.

> H_{1c}: *Firms' size is positively related with the market value of real options.*

Expectations are made under the assumption that larger firms are better prepared to obtain funding to finance their options, as well as simultaneously committed in different markets and activities, which favours the accumulation of knowledge and expertise, two important sources of real options.

Nevertheless, it should be mentioned that the former positive relation is not so clear at all times, as one can understand size as a manifestation of the logical evolution of a firm's portfolio investments. As so, Alonso *et al*. (2005) and Bernardo *et al*. (2005) predict and test a possible negative relationship between options relevance and firms' size, justified by the fact that size can be a sign of the actual situation of a company that grows as a process of sequential substitution of its options to invest in assets-in-place, with a correspondent decrease on the proportion of total market value accounted for real options.

Finally, the fourth sub-hypothesis is a market related one, and it is specified as follows:

> H_{1d}: *The ratio of book value of assets to total market value of firm is negatively related to the market value of real options.*

This sub-hypothesis relies on the idea earlier empirically presented by Kallapur and Trombley (1999) that the growth prospects of a firm are partially, if not totally, impounded in stock prices, meaning that the greater the growth prospects, the higher the market value, raising the possibility to measure growth opportunities with the firms' *ratio of the book value of assets to total market value*.

Although Smith and Watts (1992), and more recently File and Kwak (2006), found some potential weaknesses related to this ratio, Adam and Goyal (2007) conclude that, among other price-based proxies for real options, this ratio has a higher correlation with future growth. The higher is this ratio, the higher is then believed to be the ratio of assets-in-place to the market value of firms and, consequently, the smaller the ratio of investment opportunities to firms' total value (Kallapur and Trombley, 1999; Carson, 2005; Hutchinson and Gul, 2006; Adam and Goyal, 2007).

After testing H_1 and its subsequent sub-hypotheses (H_{1a}, H_{1b}, H_{1c} and H_{1d}) that describe a possible relationship between an estimate of the proportion of firms' total market value dedicated to real options and a set of proxy variables for real options, we are able to realise how important these options are to the market and how much do they contribute to companies' market value. Noteworthy is the fact that the necessary data can be found in quoted firms' financial information (balance sheets and income statements) and thus publicly available to investors at all time.

As the present study is conducted on a sample of companies listed on Euronext NYSE over the period of 2000-2006, we intend to analyse the impact of two specific events that may have affected the way that investors reflect their perception of existent real options within firms on their market value: first, the introduction of the Euro as the official currency of the Eurozone[25] in 2002 and, second, the obligation of quoted/publicly traded companies to apply International Accounting Standards (IAS) to their consolidated accounts starting on 2005[26].

Both events are expected to have reinforced market efficiency, not only as facilitators for comparisons among quoted companies, but also because they should be able to promote market transparency. This leads us to pose our two related research hypothesis:

H_2: The introduction of the Euro has impact on the way that investors perceive and value the existence of real options within firms.

H_3: The application of the IAS affects the way that investors perceive and value the existence of real options within firms.

[25] The Euro is the official currency in 16 of the 27 member states of the European Union. These 16 states (Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia and Spain) are known collectively as the Eurozone. The euro was introduced to world financial markets as an accounting currency on January of 1999, replacing the former European Currency Unit (ECU) on January of 2002.

[26] The European Parliament and of the Council, on 19 July 2002, approved the Regulation (CE) No 1606/2002, on the application of international accounting standards (IAS), stating in its article 4 that "for each financial year starting on or after 1 January 2005, companies governed by the law of a member state shell prepare their consolidated accounts in conformity with IAS".

Although no record was found concerning the testing of these hypotheses in similar studies, we believe that these aspects are worth to be analysed, as they are important steps to european financial markets harmonization, development and, consequently, increased efficiency.

In fact, recent empirical evidence indicates that the effects of the Euro on european equity markets do exist on issues such as dynamic interactions among different stock markets (Westermann, 2004), degree of market integration (Askari and Chatterjee, 2005), portfolio diversification (Kashefi, 2006; Moerman, 2008) or european financial market dependence (Bartram *et al*., 2007). Additionally, it is also possible to find recent studies reporting important effects of the use of IAS on european stock markets (e.g., Floros, 2008; Miihkinen, 2008; Callao *et al*., 2009), where evidence provided supports the general idea that investors perceive the benefits of harmonized accounting standards as out weighting the costs of its implementation.

Apart from the effects of the introduction of the Euro and the IAS, we also would like to analyse the differences that might exist on the market's perception and valuation of real options among different industries, especially when it comes to the distinction between technological-related activities and other economic activities.

Smit and Trigeorgis (2004) highlight that not all stocks generate the same earnings stream or have the same growth potential. In fact, growth stocks (especially high-tech companies) typically yield high price-earnings and market-to-book ratios due to the intangible and strategic value of their growth opportunities. Earlier, Triantis (1999) also defended that, in the case of some companies operating in emerging product markets, all of their value could be virtually composed on real options value. The base argument was that these companies have positioned themselves to potentially exercise profitable growth options in the future by investing in several sources of competitive advantage (e.g., R&D, IT expertise, brand name recognition) and, simultaneously, maintaining the ability to revise their investment and operating decisions over time, as uncertainty is resolved (Kellog and Charnes, 2000; Liu, 2000).

In empirical terms, Alonso *et al*. (2006) confirm the expectation that technological firms exhibit a larger proportion of their market value derived from real option when compared to that observed in companies in other industries.

A testable hypothesis under this context, in its alternate form, is:

H_4: There is a positive influence of the industry factor on the market value of real options detained by high-tech and R&D based companies.

Rejection of the null hypothesis associated with H_4 is consistent with expectations on a positive relationship between the market value of real options and the fact that companies belong to technological industries.

Finally, we still analyse the possibility of adjustment dynamics to our model (Marques, 2000), in order to understand how, and if, the recognition on the value of real options by the market in one period affects the value recognition of firms' real options on the next period. The research hypothesis comes as follows:

H_5: The market value of real options in one period has impact on the way that investors perceive and value the existence of real options within firms on the next period.

When considering this hypothesis we work under the assumption that investors decide to affect resources based on future positive expectations, in order to maximize their return (Howell and Jagle, 1997).

If the market recognises the value of existing real options in one period, it is most probable that, on the next period, that value will affect the proportion of the market value of firms corresponding to their real options at the moment and, consequently, firms' market value (Zingales, 2000; File and Kwak, 2006; Clark *et al.*, 2007). According to this, we expect a statistically significant coefficient for the lagged variable.

4.2 SAMPLE DESCRIPTION

After the identification of the research purposes, it is necessary to define the data that must be collected and the sample selection criteria.

Related studies were conducted either focusing on one single stock market (one country) or over specific industries. Our intention is to analyse the Euronext financial market that comprises several European stock exchanges[27], of different dimensions and degrees of maturity.

Data is drawn from the financial statements of firms listed on Euronext Lisbon, Euronext Paris, Euronext Brussels and Euronext Amsterdam, between the years 2000 and 2006, available at *Thomson Datastream* financial database. As *Datastream* lacks on information for the Portuguese market, we still obtained information on *SABI* database and, in some particular cases, directly from the online publicly available information of the companies. Although *Datastream* has information on interest rates for several periods, operations and markets, we complemented data with online information of the respective central banks.

The choice of the period of 2000-2006 is due to several reasons:

- Firstly, the year 2000 is the year of the Euronext foundation and, at the end of 2006, the same Euronext suffered an important modification in its structure and dimension with the entrance on the NYSE. This last event was deliberately left out of the analysis, in order to avoid eventual disturbances on the time-series;
- Secondly, based on prior empirical evidence, proxies for investment/growth opportunities are expected to have more explanatory power after the year 2000 than on previous periods, suggesting a change on evaluation criteria by the market, possibly explained by the crash in technological stock prices (Clark *et al*., 2007);
- Thirdly, as argued by several authors through time, any empirical study involving real options effects, whether on investment decisions, or directly on firms' value, should consider a relatively long period of time, so that those effects have enough time to be felt or perceived (e.g., Dixit and Pindyck, 1994; Trigeorgis, 1996; Kulatilaka and Perotti, 1998; Linde *et al*., 2000; Damodaran, 2001a; Buckley *et al*., 2002; Alonso *et al*., 2005; Clark *et al*., 2007). The period of seven years considered on the present study is also aimed at accounting for this fact.

From a global universe of approximately 1.070 companies quoted on Euronext stock markets during the period of 2000-2006, financial data was first collected on 974

[27] The Euronext was formed on September of 2000 as a result of the merger of the stock exchanges from Paris, Brussels and Amsterdam. In 2002, BVLP (Bolsa de Valores de Lisboa e Porto) and LIFFE (London International Financial Futures and Options Exchange) joined the group and, at the end of 2006, the Euronext was widened with the entrance of the NYSE (New York Stock Exchange), adopting the designation of NYSE Euronext (NYX). The NYSE Euronext provides a single market for its cash products, including shares, bonds, exchange-traded funds, investment funds, certificates, warrants and ETVehicles, being the first pan-atlantic financial market and one of the largest stock markets in the world.

companies. As financial institutions have different accounting categories and rules, these were then excluded from the universe, to improve the homogeneity of the sample, consequently reduced to 794 companies. We also excluded firms not satisfying the following criteria:

1. Available income statement and balance sheet items necessary to compute the variables (dependent and independent) of the model, for the whole period of 2000-2006, in order to obtain a balanced panel;
2. Showing monthly stock returns data for the period under analysis, as continuous returns are required to estimate stock betas when these are not directly available at financial databases (which is the case of most of the companies quoted on Euronext Lisbon);
3. Having a positive estimate of real options market value in, at least, one year of the whole period under analysis.

The final sample includes 482 non-financial companies from the several Euronext stock markets (Paris, Amsterdam, Brussels and Lisbon). The combination of these 482 companies with the seven years analysed provides a balanced panel with a total of 3.374 firm-year observations.

These companies account for just about 60% of non-financial companies listed on Euronext during the period of the study, and approximately 69% of the sample are firms listed on Euronext Paris, while Euronext Lisbon listed companies represent slightly more than 6% of the companies on our sample (table 4-1).

Table 4-1 – Sample description by market

Euronext Stock Market	Nr. firms	% on sample	Nr. observations
Euronext Paris	329	68,3%	2.303
Euronext Amsterdam	69	14,3%	483
Euronext Brussels	53	11,0%	371
Euronext Lisbon	31	6,4%	217
Total	**482**	**100,0%**	**3.374**

On the following tables (4-2 and 4-3) a general description of the companies on the sample is offered in order to better contextualize the study.

Referring to their nature, firms belong to 9 industries categorized according to the ICB Industry Classification[28]. Table 4-2 shows the different weighting of the various businesses relative to the number of the listed companies, highlighting the large contribution of activities such as Industrials, Consumer Goods, Consumer Services and, to some extent, Technology.

Table 4-2 – Sample description by industry

Industry	Euronext Paris	Euronext Amsterdam	Euronext Brussels	Euronext Lisbon	Firms by industry	
					Nr.	%
Oil & Gas	1	3	0	0	4	0,83%
Basic Materials	12	1	4	4	21	4,36%
Industrials	114	24	18	9	165	34,23%
Consumer Goods	76	15	12	4	107	22,20%
Health Care	20	2	5	0	27	5,60%
Consumer Services	61	10	11	9	91	18,88%
Telecommunications	5	1	0	2	8	1,66%
Utilities	14	1	0	0	15	3,11%
Technology	26	12	3	3	44	9,13%
Nr. firms by market	**329**	**69**	**53**	**31**	**482**	100,00%

Although there is a high degree of heterogeneity with respect to the average size of firms in the sample (see Table 4-3), these can be regarded as of medium-to-large size within the context of the four countries that are represented on the study (France, Netherlands, Belgium and Portugal).

As expected, in spite of no direct information is evidenced on tables, Euronext Paris is the securities' market where the largest firms in the sample are traded. On the contrary, Euronext Lisbon is where a higher proportion of smaller companies offer their stocks. Euronext Amsterdam and Euronext Brussels are quite similar among each other, not only when it comes to the average dimension of quoted firms, but also on the number of firms that are traded on those financial markets.

[28] Euronext sector indexes are actually based on the new ICB (Industry Classification Benchmark) classification, launched in January 2005 by the FTSE Group and Dow Jones Indexes, and effective on Euronext markets on January 2006. ICB classification is originally decomposed in four levels – Industry, Supersector, Sector and Sub-sector –, although only levels 1 and 3 are formally included in Euronext indexes composition (except for Euronext Lisbon, where decomposition is made only by level 1). For more detail, see Appendix B.

Table 4-3 – Descriptive statistics by industry

	Total Assets*		Net Sales*		Market Value*	
Industry	**Mean**	**Var.coef.**	**Mean**	**Var.coef.**	**Mean**	**Var.coef.**
Oil & Gas	37.663,41	1,743	47.853,35	1,813	47.205,26	1,716
Basic Materials	1.427,31	1,419	1.438,58	1,380	5.758,32	2,700
Industrials	2.661,06	3,881	1.541,29	3,107	15.062,78	4,448
Consumer Goods	3.520,82	3,184	3.161,27	3,052	16.362,74	4,098
Health Care	1.702,34	5,718	716,10	4,220	8.593,36	2,833
Consumer Services	2.571,87	2,475	2.892,04	3,169	39.506,81	6,575
Telecommunications	18.514,70	1,867	7.493,38	1,894	74.103,67	2,694
Utilities	12.737,96	2,996	5.129,20	2,570	47.141,55	1,892
Technology	270,55	2,790	270,26	2,673	108.215,07	7,538

* Values in millions of €

It is also interesting to realize that technological companies are, in general, the companies that report the smallest average on total assets and net sales values but, at the same time, are also the ones that exhibit the highest average market value. This is particularly relevant when comparing Technology industry with other industries represented in the sample, such as Oil and Gas, Telecommunications and Utilities (Table 4-3).

4.3 Model Specification

Given the pooled time-series and cross-sectional nature of our information, panel data techniques were employed to test the purposed research hypothesis.

The panel data approach has several advantages when compared to the cross-section or time-series approaches individually considered. One of the advantages is the possibility to control for individual heterogeneity, as panel data analysis suggests the existence of different characteristics among individuals. These characteristics, that can be constant or variable through time, are hardly recognised in time-series and cross-sectional assessments, leading to biased results (Baltagi, 1995; Marques, 2000). Additionally, panel data provide an increased number of observations, raising the degrees of freedom, reducing (or eliminating) the problem of multicollinearity, and improving econometric estimates (Wooldridge, 2007). Finally, panel data facilitates the introduction of adjustment dynamics, providing the opportunity to consider more complex and realistic models (Marques, 2000).

Panel data analysis may be conducted using three types of models. The simplest, and also more restrictive, is the aggregated *Pooled Model* (PM), which assumes that both the intercept value and the slope coefficients are common to all individuals (firms) and, consequently, no heterogeneity exists among them. An alternative to the PM is the *Fixed Effects Model* (FEM), where heterogeneity among individuals is introduced on the constant part of the model (it is considered to be a fixed heterogeneity), in order to capture differences that do not change over time (e.g. dimension, location, industry). The third possible panel data model is the *Random Effects Model* (REM), where differences among individuals are considered to be random and, consequently, only captured in the error term, a stochastic variable with probabilistic properties (Gujarati, 2003).

Throughout this study, we use the common techniques for estimating models with panel data: the *Ordinary Least Squares* method (OLS) for the *pooled model*, the method of the *First Differences* (FD) and the *Time-Demeaned* method (TM) for the *fixed effects model*[29], and the *Generalised Least Squares* method (GLS) for the *random effects model*. At each regression, the adequate tests are performed to decide which method/model produces the best (more efficient) estimators.

When adjusting the model to introduce adjustment dynamics (necessary to test H_5), the abovementioned methods generate biased estimators, partially induced by the endogenous nature of the lagged dependent variable. Although several solutions exist, after accommodating the problem of endogenous variables, we use the *Generalised Moments Method* (GMM) to estimate the dynamic models, as it can be easily applied to our data, producing the necessary efficient estimators (Wooldridge, 2007).

Regressions and all the necessary tests are performed using *Gretl* econometric software.

4.3.1 Methodology to Test Hypothesis 1

When examining the hypothesis that investors recognise real options value within firms when deciding to allocate funds (H_1), proxies of the real options existence within firms are related to an estimate of the market value of the firms' attributable to those real options.

[29] In the case of the fixed effects model, there is still one more possible estimation method – the *Least Squares Dummy Variables* method (LSDV) – consisting on the introduction of a dummy variable for each individual of the sample which, for the present study, is not admissible due to the large number of companies in the study. An alternative is to apply LSDV with dummies for each country.

The mathematical specification of the model is as follows:

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO_{it} + \mu_{it} \quad [4.1]$$

where,

ROV_{it}	=	estimate of the proportion of the market's value of the firm *i* accounted for by its real options on period *t*
$ASSI_{it}$	=	degree of asset irreversibility of firm *i* on period *t*
$FLEV_{it}$	=	level of financial leverage of firm *i* on period *t*
$SIZE_{it}$	=	size of firm *i* on period *t*
$RATIO_{it}$	=	ratio of the book value of assets to total market value of firm *i* on period *t*

and *i* represents each company (i=1, 2, …, 482), *t* represents the year (t=1, 2, …, 7), α and β_j (j=1, 2, …,4) represent the parameters of the model that we want to estimate, and μ_{it} is the error term.

To test sub-hypotheses H_{1a}, H_{1b}, H_{1c} and H_{1d} the same model is used. In fact, these sub-hypothesis relate to the sign and statistical significance of each of the proxies for real options used, i.e., the model's independent variables.

4.3.1.1 Dependent variable

To define our dependent variable (*ROV*), we start looking at Myers (1977) seminal idea that firms' discretionary future investment opportunities are "growth options", and that a firm's value can be decomposed into the value of its assets-in-place and the value of future growth opportunities, as described earlier in this work.

Studies that followed, tried to empirically estimate the firms' value of growth real options. One important example, also mentioned earlier, is Kester's (1984) proposal to measure it by the difference between total market value and the capitalized value of the firms' current earnings stream (assets-in-place), discounted at 15%, 20%, or 25% (see equation 3.3).

Our approach to estimating the real options value within firms, which we detail bellow, is generally consistent with that of Kester's (1984), although it represents several improvements over his, especially when referring to the determination of the *current earnings* component and the use of universal discount rates across firms.

Thus, following the basic premises of the work of Tong and Reuer (2004 and 2007), Alonso *et al*. (2005 and 2006) and File and Kwak (2006), the dependent variable of our model (ROV), that represents an estimate of the proportion of the market value of a firm accounted for by its real options, is given by the following general expression:

$$ROV_{it}=\frac{MV_{it}\text{-}VAIP_{it}}{MV_{it}} \quad [4.\ 2]$$

with,

ROV_{it}	=	estimate of the proportion of the market's value of the firm *i* accounted for by its real options on period *t*
MV_{it}	=	market value of firm *i* on period *t*
$VAIP_{it}$	=	value of assets in place of firm *i* on period *t*

The market value of firms (MV_{it}) is given by,

$$MV_{it} = MVE_{it} - BVE_{it} + BVA_{it} \quad [4.3]$$

where

MVE_{it}	=	market value of equity of firm *i* on period *t*
BVE_{it}	=	book value of equity of firm *i* on period *t*
BVA_{it}	=	book value of assets of firm *i* on period *t*

The other component of ROV_{it}, the value of a firm's assets-in-place (AIP_{it}), is estimated as a perpetuity on the value of the firm's current free cash-flows (FCF_{AIP}), discounted at its cost of capital (K_{AIP}):

$$VAIP_{it} = \frac{FCF_{AIP\,it}}{K_{AIP\,it}} \quad [4.4]$$

with,

FCF_{AIPit}	=	free cash-flow generated by assets-in-place of firm *i* on period *t*
K_{AIPit}	=	cost of capital of firm *i* on period *t*

Conceptually, free cash-flows represent the cash that a company is able to generate after laying out the money required to maintain or expand its assets base. Although it can be computed in several ways, we follow the logic of free cash-flow determination used by Alonso *et al.*, (2006)[30] and Chen *et al.* (2007). To approximate the measure of the free

[30] The measure of free cash-flow used by the authors is the result of the incorporation of referees' suggestions (see Alonso *et al.*, 2006).

cash-flow generated by assets-in-place, it is then assumed that replacement investments in current assets are equivalent to accounting depreciation, so that FCF_{AIPit} is obtained by subtracting adjusted tax payments from firm's current earnings before interest and tax (EBIT), as it follows:

$$FCF_{AIP_{it}} = EBIT_{it} - aTax_{it} \qquad [4.5]$$

with,

$EBIT_{it}$	=	current earnings before interest and tax of firm *i* on period *t*
$aTax_{it}$	=	adjusted tax payments of firm *i* on period *t*

One of the main differences between the estimate of real options market value performed by Kester (1984) and the one that is adopted in this study is related to the discount rate used to determine $VAIP_{it}$ (4.4). K_{AIP} should be able to summarize the average systematic risk of a firm's existing assets, leaving behind the risk associated to its real options[31], which does not happen when using the observed unlevered beta of a company (Chung and Kim, 1997; Berk *et al.*, 1999; Linde *et al.*, 2000; Tong and Reuer, 2004; Alonso *et al.*, 2006). Since abovementioned betas are impossible to estimate, we need to use a proxy to approximate K_{AIP} measure. Thus, we estimate the firm-specific cost of capital using the CAPM measure:

$$K_{AIP_{it}} = R_{f_t} + \beta_{u_{it}} \times (R_{M_t} - R_{f_t}) \qquad [4.6]$$

where,

K_{AIPit}	=	cost of capital of firm *i* on period *t*
Rf_t	=	risk free rate on period *t*
R_{Mt}	=	risk of the market portfolio on period *t*
β_{uit}	=	firm-specific beta used as a proxy of assets of firm *i* on period *t*

The risk free rate (R_f) is, for all companies in the study, the average of the returns on long-term treasury bonds from each one of the countries involved, as these returns were quite similar during the whole period of analysis. Market returns (R_M) are country specific and

[31] As demonstrated by Chung and Kim (1997) the unlevered beta of a company is affected by the greater risk of its real options, resulting on an excessively high capital cost for estimating the company's assets-in-place, individually considered. Although this is the base idea in our calculations, Arnold and Crack (2004) call attention to the fact that, when valuing real options, the critical issue is much more the correct estimation of volatility than of choice of the discount rate.

on a yearly basis[32]. The proxy for firm-specific beta of assets (β_u) was directly collected from the *Datastream* financial database[33]. Along with the values of β_u, also the data referring to the parameters *MV*, *MVE*, *BVE*, *BVA*, *EBIT*, *Tax Payments (aTax)* are directly collected on *Datastream* (and *SABI*, in the case of some Portuguese companies).

4.3.1.2 Independent Variables

Independent variables of the model are proxies for real options, used and empirically tested in prior studies. The reasons for the choice of these particular variables were already put forward, along with the expectations on their behavior. Our concern at this point is to describe the way these variables are determined.

Nevertheless, it is worth to remember that it is the sign and significance of each of the corresponding coefficients that enable us to accept (or reject) sub-hypotheses H_{1a}, H_{1b}, H_{1c} and H_{1d}. *Datastream* and *SABI* provide the necessary elements to compute the independent variables of the model.

Asset irreversibility (*ASSI*) is a measure that gives us the relative weight of fixed assets (assets with dominant irreversible characteristics) on the total assets of companies. It is then determined by the expression:

$$ASSI_{it} = \frac{BVFA_{it}}{BVA_{it}} \qquad [4.7]$$

where,

$BVFA_{it}$ = book-value of fixed assets of firm *i* on period *t*

BVA_{it} = book-value of total assets of firm *i* on period *t*

The variable of *financial leverage* (*FLEV*) is intended to represent the capacity of a company to access new funds for real option optimal exercise. The higher the value of

[32] Both R_f and R_M were directly withdrawn from *Datastream*, although values were in general confirmed on the online information of annual reports from the correspondent Central Banks.

[33] As several computing options are available at *Datastream*, we chose the measure resulting from the use of the previous five-year monthly stock returns and returns of the market portfolio, taking into account the effect of financial leverage and taxes as well as the firms' equity's beta (also available at *Datastream*). Results are expected to prevail even when K_{AIP} is approximated using the arithmetic average of capital costs for sample companies, as demonstrated by Alonso *et al.* (2006). In some cases, mostly for the companies quoted on Euronext Lisbon, it was necessary to determine this value by the usual means.

FLEV the fewer additional debt the firm is able to obtain. Financial leverage is given by the ratio:

$$FLEV_{it} = \frac{BVD_{it}}{BVA_{it}} \quad [4.8]$$

where,

BVD_{it}	=	book-value of debt of firm *i* on period *t*
BVA_{it}	=	book-value of total assets of firm *i* on period *t*

To account for the *size* (*SIZE*) of the sample companies it is used a measure on the basis of the natural logarithm of assets book value: *log* (BVA_{it}).

Finally, the *ratio of the book value of assets to total market value of firms* (*RATIO*) is given by the simple expression:

$$RATIO_{it} = \frac{BVA_{it}}{MV_{it}} \quad [4.9]$$

where the necessary inputs are as known.

Table 4-4 reports some general descriptive statistics on the variables included on the research model, as specified on the methodology to test H_1 and its sub-hypothesis. Statistical information is sorted by year, and refers to the full sample of the 482 firms.

To avoid extreme variances on real options' value estimates, after accommodating our sample to all pre-defined selection criteria presented on the previous section of this work, we still excluded observations recording extreme values for the variable *ROV*[34].

Generally, data confirms the predictable relevance of that portion of market value not due to assets-in-place (*ROV*) in the several industries that are represented on the sample. However, it is possible to observe a large dispersion of values among companies, with some estimates being negative. It is also possible to notice that the values recorded do not describe any particular tendency over time, most probably because information is provided on aggregate terms.

[34] Extreme values were considered to be those that exceed the mean of the full sample plus three times its standard deviation.

Table 4-4 – Descriptive statistics on dependent and independent variables

		Dependent variable	Independent variables			
		ROV	*ASSI*	*FLEV*	*SIZE*	*RATIO*
2000	Mean	0,6784	0,3967	0,6452	2,0959	0,5516
	S.d.	1,2810	0,2307	0,2361	1,1273	0,5462
	Var. coef.	1,8882	0,5816	0,3660	0,5379	0,9902
	Max	8,7584	0,9683	2,8374	5,1138	4,6916
	Min	-6,6547	0,0079	0,0285	-1,2248	0,0000
2001	Mean	0,8078	0,4018	0,6473	2,1336	0,5980
	S.d.	1,7912	0,2272	0,2345	1,1291	0,5630
	Var. coef.	2,2174	0,5655	0,3622	0,5292	0,9416
	Max	13,7073	0,9933	2,0933	5,1313	5,5133
	Min	-12,8910	0,0019	0,0366	-1,2248	0,0000
2002	Mean	0,9656	0,4059	0,6690	2,1200	0,5868
	S.d.	2,2297	0,2245	0,4157	1,1351	0,5794
	Var. coef.	2,3092	0,5530	0,6214	0,5354	0,9873
	Max	14,4606	0,9419	7,3825	5,1625	6,8926
	Min	-6,0478	0,0000	0,0289	-1,4368	0,0000
2003	Mean	0,5509	0,4074	0,6916	2,1083	0,5695
	S.d.	2,3034	0,2247	0,6793	1,1334	0,5868
	Var. coef.	4,1814	0,5515	0,9823	0,5376	1,0305
	Max	14,4284	0,9975	11,8812	5,1670	7,7506
	Min	-12,2463	0,0000	0,0358	-1,5464	0,0000
2004	Mean	0,1938	0,4066	0,6393	2,1426	0,5426
	S.d.	2,3300	0,2245	0,2242	1,1041	0,4812
	Var. coef.	12,0255	0,5522	0,3508	0,5153	0,8868
	Max	12,0216	0,9981	2,2808	5,1714	2,7675
	Min	-12,8472	0,0130	0,0278	-0,2803	0,0000
2005	Mean	0,1129	0,4192	0,6212	2,2115	0,5422
	S.d.	2,3486	0,2245	0,2464	1,0982	0,5038
	Var. coef.	20,7953	0,5355	0,3967	0,4966	0,9292
	Max	15,7985	0,9977	2,3616	5,2637	3,5033
	Min	-12,7807	0,0098	0,0536	-0,2803	0,0000
2006	Mean	0,2629	0,4266	0,6100	2,2815	0,5397
	S.d.	1,6645	0,2210	0,2596	1,0725	0,5085
	Var. coef.	6,3319	0,5181	0,4256	0,4701	0,9423
	Max	14,1994	0,9976	3,8138	5,2478	3,7098
	Min	-7,6699	0,0104	0,0546	-0,2803	0,0000

4.3.2 Methodology to Test Hypotheses 2 and 3

In order to understand how does the introduction of the Euro and the IAS impacts on the global understanding that investors have about the existence of real options within firms, we test H_2 and H_3 by introducing two additional *dummy* variables in the model given at [4.1]. Each of these dummies is aimed at analysing the significance of those phenomena.

The new expression for the model to be estimated is:

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \beta_5 du_{02} + \beta_6 du_{05} + \mu_{it} \quad [4.10]$$

where all the variables have the same interpretation as in [4.1] and

du_{02}	=	dummy variable that takes the value 1 after 2002 and 0 the years before
du_{05}	=	dummy variable that takes the value 1 after 2005 and 0 the years before

At this stage, different and additional procedures are taken in order to better evaluate the individual effect of each event. Thus, firstly, two additional regressions are conducted for the whole period of 2000-2006, using only one dummy at the time (one regression to analyse the impact of Euro introduction, with du_{02}, and another to study the impact of the use of IAS, with du_{05}).

Secondly, we provide the results for the real options proxies' coefficients obtained from separate regressions referred to:

- The pre and post Euro period – 2000-2001 and 2002-2006, respectively;
- The pre and post IAS period – 2000-2004 and 2005-2006, respectively.

We will reject H_2 if coefficient for du_{02} is not statistically significant or if coefficients for the independent variables do not differ considerably from the pre to the post Euro period analysis. The same logic is applied to H_3, which will be rejected if coefficient for du_{05} is not statistically significant, or if coefficients of the remaining variables from the pre and post IAS period are alike.

4.3.3 Methodology to Test Hypothesis 4

When reviewing the literature, it is possible to find several studies that have empirically concluded, or have relied on the premise, that companies in high-tech industry, along with R&D based firms (for example, pharmaceuticals) are believed to enclose a higher proportion of real (growth) options value to their total market value than more conservative industries (Triantis, 1999; Smit and Trigeorgis, 2004; Pindyck, 2005, Pinto and Pereira, 2005; Alonso *et al.*, 2006, Clark *et al.*, 2007).

Our intention when testing H_4 is to observe whether the fact of belonging to these activities decisively contributes to the markets' perception of real options value.

To test this research hypothesis we employ two complementary methodologies. On one hand, we introduce a *dummy* variable on the original model, intended to reveal high-tech companies of the sample (du_{gs}). This dummy will assume the value of 1 for companies with ICB codes of 4000/4570 (healthcare industry / pharmaceutical and biotechnology sector) and 9000 (technology industry) and 0 for companies in all other industries represented on the sample.

The expression of the model to estimate comes:

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \beta_7 du_{gs} + \mu_{it} \qquad [4.11]$$

The sign and the statistic relevance of du_{gs} (β_7) will enable us to accept or reject H_4.

On the other hand, we divide our sample into two separate data panels. Panel A is composed by firms that previously assumed the value of 1 for the dummy du_{gs}. Panel B is composed by all other firms of the sample. Regressions are made on model [4.1] for each panel, and a comparative analysis to coefficients and global model significance is made.

4.3.4 Methodology to Test Hypothesis 5

The most common nature of economic relations is dynamic and one of the advantages of panel data is, as mentioned, the possibility to include adjustment dynamics to the analysis.

To test H_5, where we intend to analyse if the market value of real options within firms in one period is relevant for the perception that investors have on real options market value for the subsequent periods, it is necessary to introduce in the model, as an explanatory variable, a lagged dependent variable. The following regression model is estimated:

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \beta_8 ROV_{it-1} + \mu_{it} \qquad [4.12]$$

where all the variables have the same interpretation as in [4.1] and ROV_{it-1} is the one period lagged dependent variable.

This dynamic panel data specification cannot be estimated by the usual methods on FEM and REM models as these reveal biased and inefficient estimators. The estimation method most commonly applied to dynamic equations with panel data and a lagged dependent variable is GMM (*Generalised Method of Moments*), using a set of instrumental variables to solve the problem of endogeneity of the regressors (Marques, 2000).

The sign and statistical significance of β_8, as well as the global significance of the model [4.12] should provide enough information to accept or reject H_5. In other words, we should be able to provide some evidence on the adjustment dynamics of the real options market value from one period to the next.

This chapter was aimed at describing the research hypothesis of this study, the sample and the methodology used to achieve our purposes, namely the models to be regressed, the construction of dependent and independent variables and the estimation methods. On the next chapter we report and discuss our findings, by comparison to the previous expectations.

5. Empirical Results

At this stage we explore and discuss the outcomes of the several panel data analysis. We start this section by providing empirical evidence on whether investors recognize real options' value within firms when allocating resources, and thus answering to our first research hypothesis (*H_1*) and its subsequent sub-hypotheses.

Secondly, we investigate whether the introduction of the Euro and the IAS have any impact on the way that investors' perceive real options existence and value (*H_2* and *H_3*, respectively), as both events are believed to augment market transparency and facilitate comparisons among companies.

Thirdly, we intend to find out if the proportion of the market value of firms dedicated to their real options is more easily identified within the context of high-tech companies (*H_4*).

Finally, we end up by examining the adjustment dynamics on the proportion of firms market value accounted for by their real options through time (*H_5*), which is done by studying the relationship between the one-period lagged value of real options estimate and its present assessment.

5.1 Investors Perception on Real options Value

The first model to be tested was the model from equation [4.1]. With this model we aim at understanding if investors identify and attribute some value to real options that may exist in quoted firms. When posing our research hypothesis *H_1*, we referred that this recognition takes place if the market (investors) is able to relate financial evidence directly obtained from companies' public financial statements with the possibility of firms having the capacity to identify, obtain, maintain and optimally exercise their real options.

To this end, as explained earlier in this work, we study the relationship between four proxies of real options already used and empirically tested in prior studies (*asset irreversibility*, *financial leverage*, *size* and *ratio of book-value of assets to total market value*) and an estimate of the options' value, approximated by indirect means (as stated in section 4.3).

Table 5-1 reports the corresponding regression results for the total sample of 482 companies listed on Euronext stock market during the period of 2000-2006. Four different sets of coefficients were obtained, as four different methods were applied – the OLS method for the *Pooled Model* (PM), the First Differences (FD) and the Time-Demeaned (TD) methods for the *Fixed Effects Model* (FEM) and the GLS method for the *Random Effects Model* (REM).

The application of different methods must be made in order to achieve efficient and unbiased regressors. Then, through the appropriate tests, we are able to identify which coefficients should be analysed.

To choose between the PM and the FEM (to pool or not to pool) we must submit results of the FEM regression to a Test F[35]. As a decision criterion, we should reject the null hypothesis, that stands for the homogeneity among individuals in the sample (PM), and opt for the FEM if $F_{stat} > F_{(N-1,TN-N-k)}$, with N being the number of individuals (firms), T the number of periods analyzed, and k the number of independent variables (Wooldridge, 2007). As in this case F(481, 2888) = 3,5455 with a p-value < 0,05 (see Table 5-1) we conclude on the existence of heterogeneity among individuals and reject the null hypothesis.

To decide among the PM and the REM a Breusch-Pagan[36] test is required. This test defines the LM statistic and PM is rejected if LM > χ_1 (Wooldridge, 2007). Results on Breusch-Pagan test reveal a statistic LM = 686,62 with a p-value < 0,05 (see Table 5-1), leading us to choose the REM where random heterogeneity among firms is admitted.

The Hausman test[37] is the last step on the process of choosing the best panel data regression model, and it is intended to help on deciding whether FEM or REM should be adopted. Once heterogeneity is admitted, it is important to understand if this heterogeneity has a fixed or random nature. The Hausman test allows us to reject the null hypothesis of random effects when the statistic H > χ_i^2 (Wooldridge, 2007).

In this case, our statistic H = 20,924 with p-value < 0,05, does not allow the rejection of the REM. Therefore, we conclude that, in our model, heterogeneity among firms is not observable but rather random. REM coefficients obtained from the GLS method are the most efficient and consistent ones, so that our discussion is focused on the values presented on the last column of Table 5-1.

[35] Test F to fixed effects model is described on Appendix C.1.

[36] Breusch-Pagan test is described on Appendix C.2.

[37] Hausman test is described on Appendix C.3.

Worth to be mentioned is the fact that, although the use of panel data analysis provides a number of considerable advantages over purely cross-sectional or time-series data, we still need to account for some potential problems arising from pooling data across time when it comes to obtaining BLUE (best linear unbiased estimators) estimators.

Firstly, we looked at the problem of multicollinearity, representing correlation among independent variables. Even if less probable in panel data analysis, it should be investigated. The maximum VIF value for the variables in all of the models was 2.8, well below the rule-of-thumb threshold value of 10 that is indicative of multicollinearity problems (Gujarati, 2003).

Secondly, several steps were taken to test and control for autocorrelation problems. The econometric software used conducts Durbin-Watson tests automatically for the pooled and the fixed effects models. In most of the cases, our results did not produce statistics falling into the autocorrelation or inconclusive regions. Wherever this problem existed, we followed the procedure of Cochrane-Orcutt (also available with Gretl) to eliminate autocorrelation of errors (Wooldridge, 2007).

Thirdly, we needed to address for the problem of heteroscedasticity. The use of the GLS method for REM solves this difficulty automatically (Wooldridge, 2007). When PM or FEM are the final choice in terms of results for analysis, we should report all results with significance levels based on robust standard errors (Gujarati, 2003).

When looking at the information on Table 5-1 we can see that results are generally consistent with predictions, in accordance to the idea empirically defended by several authors that real options value is an important component of firms' total market value (e.g. Triantis, 1999; Smit, 2000; Buckley *et al.*, 2002; Al-Horani *et al.*, 2003; Alonso *et al.*, 2005 and 2006; Chen et *al.*, 2007; Tong and Reuer, 2004 and 2007).

In fact, the overall model is globally significant[38] as the joint significance test of the model rejects the null hypothesis in favour of the alternative one, where all coefficients are different from zero.

Based on our empirical outcomes, we may conclude that the market recognizes the value of real options within firms when allocating resources, as it includes this value on the total market value of firms according to information withdrawn from their financial statements.

[38] More detailed information on the results of the GLS method can be found on Appendix D, where complete outputs from Gretl are provided.

In other words, investors associate some specific characteristics of firms to the capacity of their managers to identify, create, obtain, manage and optimally exercise real options, valuing this capacity when deciding to invest, which ends up reflected on the total market value of firms. These conclusions support the research hypothesis H_1.

Table 5-1 – General results for H_1, H_{1a}, H_{1b}, H_{1c} and H_{1d}

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO_{it} + \mu_{it}$$

Coefficient	Pooled OLS	FEM FD	FEM TD	REM GLS
Constant	0,8821	-0,0875	-0,0168 *	0,7508
ASSI	-0,0196 *	1,1691	1,3783	0,3402
FLEV	-0,6353	-0,5806	-0,7958	-0,6867
SIZE	-0,1766	0,0394 *	0,0433 *	-0,1727
RATIO	-0,6961	-1,8140	-1,1398	-0,7975
N	482	482	482	482
Adjusted R^2	0,0690	0,0378	0,3172	0,1746
F-stat	63,5175 [0,0000]	29,3611 [0,0000]	4,2305 [0,0000]	---
θ	---	---	0	0,4668
Test F (481, 2888)	---	---	3,5455 [0,0000]	---
Breush-Pagan test	---	---	---	686,62 [0,0000]
Hausman test	---	---	---	20,924 [0,0003]

Notes: OLS is Ordinary Least Squares, FD is First Differences, TD is Time-Demeaned, FEM is Fixed Effects Model, GLS is Generalised Least Squares and REM is Random Effects Model.
(*) indicates that the estimated coefficient is not statistically significant at a maximum of 10% significance level.
Numbers in brackets are p-values for tests performed.
F-stat is used to test the joint significance of the model.

The adjusted R^2 of the model is 0,17461, meaning that the independent variables explain approximately 17,5% of the dependent variable behavior. Even if not too high, this measure only indicates that more proxies for real options value could be included on the model, as they might be able to increase its explanatory power.

When observing the results of the study disaggregated by market (Table 5-2) it is possible to see that, in general, our primarily conclusions remain unchanged. For each of the individually considered Euronext securities markets (Paris, Amsterdam, Brussels and Lisbon), after performing all the necessary tests, GLS regression outcomes reveal that, in all cases, the model shows a global statistical significance.

Consequently, we are able to conclude that the market value of real options is perceived and valued by investors who apply resources in markets of different dimensions and degrees of maturity, even if belonging to the same global financial market. Hence, H_1 still stands when data is disaggregated in one panel per country.

Table 5-2 - Results for H_1, H_{1a}, H_{1b}, H_{1c} and H_{1d} disaggregated by market

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO_{it} + \mu_{it}$$

Coefficient	Pooled OLS	FEM FD	FEM TD	REM GLS
EURONEXT PARIS				
Constant	0,8556	-0,0632 *	0,8341	0,8177
ASSI	0,0102 *	1,2022	1,4031	0,3979
FLEV	0,5179	-0,3727	-0,4951	-0,5080
SIZE	-0,1311	0,3003 *	-0,1323 *	-0,1152
RATIO	-0,6980	-1,9031	-1,6458	-0,9585
N	329	329	329	329
Adjusted R^2	0,0717	0,0531	0,3599	0,1622
F-est. (p-value)	45,4619 [0,0000]	28,6560 [0,0000]	4,8980 [0,0000]	---
θ	---	---	0	0,5043
Test F (328, 1970)	---	---	4,1538 [0,0000]	---
Breush-Pagan test	---	---	---	608,92 [0,0000]
Hausman test	---	---	---	31,845 [0,0000]
EURONEXT AMSTERDAM				
Constant	0,8384	-0,0687 *	-1,7205 *	0,2072 *
ASSI	0,4079 *	-1,2681 *	0,0534 *	0,5303
FLEV	-1,8739	2,6018	3,2492	2,6846
SIZE	-0,5475	0,1797 *	-0,2774 *	-0,6232
RATIO	-0,5126	-1,3523 *	1,5310	-0,0391 *
N	69	69	69	69
Adjusted R^2	0,0753	0,0380	0,3530	0,1785
F-est. (p-value)	10,8093 [0,0000]	5,0771 [0,0005]	4,6530 [0,0000]	---
θ	---	---	0	0,49491
Test F (68, 410)	---	---	4,0179 [0,0000]	---
Breush-Pagan test	---	---	---	107,04 [0,0000]
Hausman test	---	---	---	14,044 [0,0072]
EURONEXT BRUSSELS				
Constant	0,2029 *	-0,0686 *	-7,1698	-1,0387 *
ASSI	-0,6825 *	4,5373	1,8272 *	-0,2234
FLEV	-1,4774	-8,9014	-7,1563	-2,7512
SIZE	-0,0429 *	0,2561 *	0,5517 *	-0,0187 *
RATIO	-0,6924	0,7766 *	0,7180 *	-0,4935
N	53	53	53	53
Adjusted R^2	0,0488	0,0903	0,2528	0,1989
F-est. (p-value)	5,7419 [0,0002]	8,8666 [0,0000]	3,2348 [0,0000]	---
θ	---	---	0	0,3588
Test F (52, 314)	---	---	2,9214 [0,0000]	---
Breush-Pagan test	---	---	---	22,201 [0,0000]
Hausman test	---	---	---	28,828 [0,0000]
EURONEXT LISBON				
Constant	-0,5796 *	-0,2192 *	-1,9263 *	-1,3119 *
ASSI	0,4966 *	8,1855	6,2877	1,4199
FLEV	-4,0069	-10,9230	-5,5911	-4,2501
SIZE	-0,5423	-3,8976	-2,3947	-0,6351
RATIO	-1,1311	-2,6982	0,6754 *	-0,8544 *
N	31	31	31	31
Adjusted R^2	0,1903	0,2398	0,3345	0,1877
F-est. (p-value)	13,6911 [0,0000]	15,5880 [0,0000]	4,1939 [0,0000]	---
θ	---	---	0	0,3079
Test F (30,182)	---	---	2,53187 [0,0000]	---
Breush-Pagan test	---	---	---	5,8434 [0,0156]
Hausman test	---	---	---	19,273 [0,0007]

(*) indicates that the estimated coefficient is not statistically significant at a maximum of 10% significance level.

In all cases we have an adjusted R^2 greater than 0,16 (values span from 0,16224 in Euronext Paris to 0,19888 in Euronext Brussels), which is also consistent with results for the whole set of companies in the sample. The four proxies used in the study are, in general, responsible for explaining approximately 18% of the market value of real options behaviour. Considering the high number of possible proxies for real options reviewed earlier in this work, this is believed to be a good end result.

To discuss sub-hypotheses H_{1a}, H_{1b}, H_{1c} and H_{1d} we need to examine each of the regression coefficients in more detail.

The real options proxy of *asset irreversibility* (*ASSI*) is an operational indicator of firms' situation, and represents an indirect measure of the probability of a company to postpone the optimal moment for exercising options. This is due to higher opportunity costs usually associated with higher levels of asset irreversibility, leading to a greater value of deferrable options.

The strong positive and statistically significant value of *ASSI* coefficient supports H_{1a}, which stated that asset irreversibility is positively related with the market value of real options. These results are consistent with empirical evidence from prior related studies (Chung and Charoenwong, 1991; Berk *et al*., 1999; Triantis, 1999; Linde *et al*., 2000; Alonso *et al*., 2005; File and Kwak, 2006). In fact, according to our findings, a positive marginal variation on ASSI implies a positive variation on *ROV*, in the proportion of 0,3402 for our selected sample, all the other variables remaining unchanged (Table 5-1).

Results from disaggregated analysis also reveal a positive sign and a high degree of significance of the irreversibility coefficients, confirming its influence in postponing a firm's investment and, therefore, "its explanatory power regarding the weight of growth options not yet exercised in a firm's total assets" (Alonso *et al*. 2005; pp.1683).

The exception comes from Euronext Brussels, where the negative sign of the coefficient ($\hat{\beta}_1$) shows that irreversibility of assets seems to have been contributing to the diminishing value of real options within firms quoted in that financial market. As the GLS coefficients for the REM are consistent, convergent and efficient, and the *ASSI* coefficient is statistically significant, we believe that its sign must be a consequence of specific characteristics of the set of 53 companies included on the Euronext Brussels panel.

Bearing in mind the particular case of Euronext Brussels, we may conclude that H_{1a} is supported by our empirical results.

The variable of *financial leverage* (*FLEV*) is a financial ratio of firms and it has been used as a proxy for real options' existence because it is aimed at representing firms' capacity for raising additional funds in order to exercise their real options. As explained before, increases in financial leverage are believed to decrease the proportion of total market value accounted for by real options within firms, due to a higher probability of under-investment as a result of agency conflicts and financial restrictions (Myers, 1977 and 2000).

The negative sign of *FLEV* coefficient, along with its statistical significance, supports H_{1b} and is also consistent with results obtained on previous studies (Smit and Watts, 1992; Mauer and Sarkar, 2005; Alonso *et al*., 2005 and 2006; Li, 2006; Pagaza *et al*. 2006), although in some cases, the low statistical significance for this variable did not help authors to confirm their predictions, which was the case of Alonso *et al*. (2005). According to our data analysis, when *FLEV* suffers a marginal positive variation, the value of *ROV* varies negatively, on the proportion of 0,6867, assuming all the other variables unchanged. This is a contrary, but stronger impact on dependent variable than the one occurring with *ASSI* (Table 5-1).

Referring to regression results provided on Table 5-2, it is possible to realise that, when studying each of the Euronext financial markets individually, we still find support for H_{1b}. Appart from Euronext Amsterdam, all other data panels report a negative and significant coefficient of *FLEV*. This statistical behaviour suggests the negative influence of debt on a firm's ability to manage efficiently its real options as a result of the under-investment problem.

These logical expectations find no evidence on the particular case of the Dutch stock exchange, where the only negative sign for the *FLEV* coefficient is revealed on the *pooled model*. However, OLS estimators for PM are biased and inefficient and, consequently, neglected in favour of the GLS estimators. The positive (and statistically significant) relation between the *financial leverage* variable and the estimates of real options value suggests that, for this set of companies, financial constraints due to high debt levels do not directly imply under-investment.

Research sub-hypothesis H_{1c} states that the firms' size is positively related with the market value of real options, under the assumption that larger firms are better prepared to deal with their real options, not only due to more capacity for additional funding, but also because of an expected accumulation of knowledge, expertise and diversification of markets and activities. Empirical support for this idea is found in Chen and Charoenwong (1991), Busby and Pitts (1997), Berk *et al*. (1999), Carson (2005), Alonso *et al*. (2006), File and Kwak (2006), Verbeeten (2006), Adam and Goyal (2007).

However, when examining our regression outputs, we find no support for H_{1c}, neither for the Euronext securities market considered as a whole (Table 5-1), nor for the disaggregated analysis by country/market (Table 5-2). In fact, in all cases, real options ratios are negatively and significantly related to *size*, suggesting that the most of the total market value of larger firms derives from the ability of its assets-in-place to generate cash-flows, while for smaller firms this market value comes essentially from future opportunities.

Although results confirm *size* as a good proxy variable for real options existence, it represents a situation where firms' size is the consequence of a growth process characterised by substituting growth options with assets-in-place. Nevertheless, our results still find accordance in some few empirical studies, where a negative relation between dimension and real options value has been found (Bernardo *et al*., 2000; Alonso *et al*., 2005; Beck *et al*., 2006).

Overall, our empirical outcomes reveal that a marginal variation on *SIZE* is responsible for a negative deviation on *ROV* on the proportion of 0,1727, *ceteris paribus*.

Finally, results on our variable *RATIO* reveal, as expected, a strong negative correlation between the *ratio of book value of assets to total market value of firm* and the market value of real options detained by quoted firms. Justification for this variable behaviour drives from the assumption of market efficiency, where stock prices reflect the growth prospects of firms. Hence, the smaller this ratio, the higher is the measure of real options value within firms.

As we can observe on Table 5-1, results from the global model are supportive to $H_{1d,}$ also in accordance to previous studies, where this ratio was frequently used as a proxy for the investment opportunities' set and the same relation was found (Kallapur and Trombley, 1999; Carson, 2005; Hutchinson and Gul, 2006; Adam and Goyal, 2007). When focusing on disaggregate panel regressions, results equally reveal a negative correlation for all markets (Table 5-2), even if not always statistically significant.

Taken as a whole, findings provide strong evidence that the proportion of market value not due to assets-in-place responds to changes in the independent variables as predicted by the real options approach, suggesting that this portion of a firms' market value is linked to investors' expectations regarding the real options value detained by companies.

Concluding, we find empirical support for our research hypothesis H_1 and its subsequent sub-hypotheses H_{1a}, H_{1b} and H_{1d}, in both aggregated and disaggregated analysis, even if for some individually considered stock markets not all variables were consistently found significant (Table 5-11).

We did not find support for sub-hypothesis H_{1c}, once the sign of the coefficient of the variable *SIZE* is contrary to expected. Nevertheless, *SIZE* is still seen as a proxy for real options value, even if its increasing behaviour represents for investors, not a better capacity to create, manage and exercise options, but rather a natural growth process of substituting existing real options by assets-in-place.

Table 5-11 provides a summary of our empirical results concerning the research hypotheses studied in this section.

5.2 EURO AND IAS INFLUENCE ON THE REAL OPTIONS' VALUE PERCEPTION

The second and third research hypotheses (H_2 and H_3) are concerned with the effects over the proportion of firms' market value dedicated to real options of two particular events that occurred during the period of analysis: the introduction of the Euro as the official currency of the Eurozone, and the obligation of firms to apply IAS to their consolidated accounts, in 2002 and 2005, respectively.

Both events are expected to promote market transparency and facilitate comparisons among firms, which most certainly affects market's perception on the real situation of publicly traded firms in Euronext and, consequently, the way investors value firms and their embedded real options.

The model expressed in equation [4.10], where two dummy variables (du_{02} and du_{05}) are added to the model studied on the previous section, is intended to test H_2 and H_3. On Table 5-3 we report the results of the testing. We provide evidence for the whole sample and, once more, for each of the Euronext securities' markets considered individually, aiming at facilitating the analysis of particular outcomes.

As before, different panel data regression methods were used and adequate tests performed. These tests led us to accept, at all times, the hypothesis of the REM and its GLS estimators. For this reason, outcomes in Table 5-3 only refer to the GLS regression results.

Table 5-3 – Results for H_2 and H_3 for both aggregated and disaggregated analysis

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \beta_5 du_{02} + \beta_6 du_{05} + \mu_{it}$$

Coefficient	Euronext full sample	Euronext Paris	Euronext Amsterdam	Euronext Brussels	Euronext Lisbon
Constant	0,9408	0,9196	0,6083 *	-0,2294 *	-0,9574
ASSI	0,4092	0,4527	0,6407	-0,1546	1,4158
FLEV	-0,6541	-0,4883	2,5069	-2,2088	-4,6112
SIZE	-0,1378	-0,0823 *	-0,5923	0,0131 *	-0,5982
RATIO	-0,8568 *	-0,9955	-0,0950 *	-0,5974	-1,0793 *
du_{02}	-0,1876	-0,0986 *	-0,3292 *	-0,3846 *	-0,6985
du_{05}	-0,3681	-0,3018	-0,4024	-0,7414	-0,1018 *
N	482	329	69	53	31
Adjusted R^2	0,1890	0,1720	0,1923	0,20646	0,19745
Breush-Pagan test	713,50 [0.0000]	623,03 [0,0000]	111,13 [0,0000]	24,813 [0,0000]	6,963 [0,0083]
Hausman test	41,706 [0,0000]	41,230 [0,0000]	11,878 [0,0447]	22,704 [0,0000]	18,3887 [0,0053]

(*) indicates that the estimated coefficient is not statistically significant at a maximum of 10% significance level.
du_{02} is a dummy variable for the impact of the introduction of Euro that assumes the value 0 from 2000 to 2001, and the value 1 from 2002 to 2006.
du_{05} is a dummy variable for the impact of the introduction of IAS that assumes the value 0 from 2000 to 2004, and the value 1 from 2005 to 2006.
Numbers in brackets are p-values for tests performed.

When regression is conducted over the full sample (482 companies from the four different markets) we realise that the coefficients of the main explanatory variables remain unchanged when compared to the previous model. With reference to the dummy variable du_{02}, results lead us to conclude on the effective impact of the introduction of the Euro over the proportion of the market value of firms committed to real options, as the estimated coefficient ($\hat{\beta}_5$) has a strong negative statistical significance. Thus, based on this outcome, we find support for research hypothesis H_2. Additionally, we also find support for H_3 as the coefficient of du_{05} ($\hat{\beta}_6$) is statistically significant as well, meaning that introducing the obligation of applying IAS to consolidated accounts has an effective impact over ROV.

The negative sign of both estimators indicates that, first with Euro, and then with the IAS, investors attribute more proportional value to the component of assets-in-place (those assets that are currently generating cash-flows, or are already expected to do so) than to the real options component of the market value of firms. This is actually not surprising, since a common currency and harmonised accountancy rules increase the trust on financial information, where real options are not directly reported.

The adjusted R^2 continues to be quite low (0,1890); however, we should be keeping in mind that the model is relating an estimate of real options market value with a few chosen proxies for these real options.

Comparing results for the full sample and those that are evidenced for disaggregated analysis, although we may find a minority of variables not statistically significant, overall the conclusions are the same for the testing of H_2 and H_3 in each of the individual stock markets. The coefficients of both dummies are negative at a significant level, especially for *du05*, representing the impact of the introduction of the IAS (Table 5-4).

Even though, it is worth to highlight some interesting details. It is in Euronext Lisbon where we find, simultaneously, the highest impact of the introduction of the common currency Euro (-0,6985) and the minimum impact of the IAS application (-0,1018; but not statistically significant). Euronext Paris experiments the less impact of the Euro introduction (-0,1876; but not statistically significant) and Euronext Brussels suffers the uppermost effect of IAS over *ROV* (-0,7414).

In order to consolidate our results, we performed additional tests to H_2 and H_3. Firstly, we tested each of the research hypotheses separately. To this end, we introduced a dummy variable at the time, to account for both the statistical significance and sign of corresponding regressors.

Results are reported on Table 5-4 and found consistent with previous outcomes. Research hypotheses H_2 and H_3 continue to find support in our empirical evidence. The impact of the two events that are being studied is negative on the value of the real options component of firms' market value, most probably due to an increased awareness and trust of investors on the true value of assets-in-place of quoted companies.

Secondly, to determine whether there has been a fundamental change on the perception of real options value by the market, we use a technique similar to the one performed by Clark *et al*. (2007) to study the market valuation of technology stocks before and after the crash. We divide the total analysis period into two sub-periods for each event, with a breakpoint corresponding to the year's specific occurrence. The idea is to fit the equations separately for each sub-period, and see whether there are significant differences in the estimated coefficients.

Table 5-4 – Results for H_2 and H_3 when dummies are introduced separately

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \boldsymbol{\beta_5 du_{02}} + \mu_{it}$$
$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \boldsymbol{\beta_6 du_{05}} + \mu_{it}$$

Coefficient	Euronext (full sample)	
	(only du_{02})	(only du_{05})
Constant	0,9583	0,8390
ASSI	0,3824	0,3941
FLEV	-0,6885	-0,6462
SIZE	-0,1626	-0,1377
RATIO	-0,8158	-0,8562
du02	-0,3325	---
du05	---	-0,4431
N	482	482
Adjusted R^2	0,1821	0,1842
Breush-Pagan test	699,88 [0,0000]	709,81 [0,0000]
Hausman test	27,182 [0,0000]	40,228 [0,0000]

All estimated coefficient are statistically significant.
du02 is a dummy variable for the impact of the introduction of Euro that assumes the value 0 from 2000 to 2001, and the value 1 from 2002 to 2006.
du05 is a dummy variable for the impact of the introduction of IAS that assumes the value 0 from 2000 to 2004, and the value 1 from 2005 to 2006.
Numbers in brackets are p-values for tests performed.

Table 5-5 reports achieved results for the several sub-periods. To test the impact of the Euro introduction (*H_2*) we have regression outcomes for the sub-periods of 2000-2001 (pre 2002) and 2002-2006 (pos 2002). To assess the effect of the IAS implementation (*H_3*) we tested the sub-period 2000-2004 (pre 2005) and the sub-period 2005-2006 (pos 2005).

In the case of *H_2*, for the sub-period 2000-2001 the reported results are no better than those on the whole sample period. We have more non-significant variables and less explanatory power of the model. The results for the sub-period 2002-2006 are slightly better, where all variables showing statistical significance, while R^2 is a little higher than both of the sub-period 2000-2001 and of the whole period analysis.

A comparison of the coefficients from the two sub-periods shows that most of them differ in magnitude, even though the signs remain unchanged. We may then conclude that the introduction of the Euro in 2002, as the official currency of the countries in the study, represents a change on the way that investors price the proportion of the market value of firms accounted for by real options. However, the maintenance on the coefficient signs is one more evidence that independent variables of the model are effective proxies of real options.

The same method was applied to re-test research hypothesis H_3. Results for the sub-period 2000-2004, that represents the period before the use of IAS, demonstrate a somewhat weaker explanatory power that the ones for the whole period. We can observe improvements on the adjusted R^2 for the sub-period of 2005-2005, when the application of the IAS is already a reality.

Table 5-5 – Results for H_2 and H_3 introducing sub-periods of analysis

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \mu_{it}$$

Coefficient	Introduction of Euro (H_2)		Introduction of IAS (H_3)	
	pre 2002(1)	pos 2002(2)	pre 2005(3)	pos 2005(4)
Constant	0,5557	0,8456	1,0032	-0,0330 *
ASSI	0,2068 *	0,1734	0,2503	0,3773
FLEV	-0,9307	-0,6219	-0,4171	-1,9333
SIZE	-0,1403	-0,1695	-0,1642	-0,2008
RATIO	-0,3477	-0,9499	-0,6806	-1,2527
N	482	482	482	482
Adjusted R^2	0,1602	0,1757	0,1708	0,1798
Breush-Pagan test	80,569 [0,0000]	430,82 [0,0000]	348,62 [0,0000]	140,41 [0,0000]
Hausman test	42,435 [0,0000]	19,482 [0,0006]	22,411 [0,0001]	16,585 [0,0023]

(*) indicates that the estimated coefficient is not statistically significant.
(1) sub-period of 2000-2001
(2) sub-period of 2002-2006
(3) sub-period of 2000-2004
(4) sub-period of 2005-2006
Numbers in brackets are p-values for tests performed.

If we establish a comparison among the outcomes from both sets of sub-periods, we realize that these differ also in magnitude but not in sign. The year of 2005 seems to represent a break in time, so that these findings support H_3.

We may conclude that, by the time that the IAS were adopted, a fundamental change appears to have occurred in the evaluation of firms at their real options level, which is aligned with recent empirical evidence that report significant effects of the use of IAS on european stock markets (e.g. Floros, 2008; Miihkinen, 2008; Callao *et al.*, 2009). Our results imply that this change was characterized by a negative impact over the ratio of real options within firms.

Table 5-11 provides a summary on the results for research hypotheses H_2 and H_3.

5.3 FIRMS' REAL OPTIONS IN THE HIGH-TECH AND R&D BASED INDUSTRIES

As reviewed in prior sections, companies in high-tech and R&D based activities are commonly referred to as "growth stocks" and are believed to detain a higher proportion of the real options' component of those firms' market value.

At this stage, we intend to provide some empirical evidence on whether a clear difference may be found between the markets' perception of real options existence on the abovementioned industries and on the rest of the economic activities.

For the purpose, the model to be tested is the one expressed on equation [4.11]. This is a model based on the original model from [4.1], with the addition of an industry differentiating dummy variable (du_{gs}). This dummy assumes the value of 1 for companies from the Technology industry as a whole (ICB code 9000) and for companies from the Healthcare industry, more particularly on the sector of Pharmaceuticals and Biotechnology (ICB code 4000/4570) often characterising by high levels of R&D. On all other cases, du_{gs} assumes the value of 0. On Table 5-6 we report empirical results for the testing of research hypothesis H_4.

Table 5-6 – Results for H_4 for both aggregated and disaggregated analysis

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \beta_7 du_{gs} + \mu_{it}$$

Coefficient	Euronext full sample	Euronext Paris	Euronext Amsterdam	Euronext Brussels	Euronext Lisbon
Constant	0,5805	0,6785	-0,1376 *	-2,4642	-1,4415 *
ASSI	0,3677	0,3724	0,6564	0,3806	1,5097
FLEV	-0,7027	-0,5156	2,7403	-3,4990	-4,2749
SIZE	-0,1499	-0,0865 *	-0,5951	0,0675 *	-0,6233
RATIO	-0,7806	-0,9576	0,0966 *	-0,1607 *	-0,8391
du_{gs}	0,8030	0,9118	0,7904	1,7657	0,1252 *
N	482	329	69	53	31
Adjusted R^2	0,2011	0,1846	0,1935	0,20899	0,19187
Breush-Pagan test	628,74 [0,0000]	553,55 [0,0000]	102,14 [0,0000]	21,815 [0,0000]	5,866 [0,0154]
Hausman test	19,800 [0,0005]	31,616 [0,0000]	12,594 [0,0134]	21,160 [0,0002]	19,122 [0,0007]

(*) indicates that the estimated coefficient is not statistically significant at a maximum of 10% significance level.
du_{gs} is a dummy variable for the influence of industry over the estimate of real options market value, that assumes the value of 1 for the technology industry, as a whole, and for the pharmaceuticals and biotechnology sector from the healthcare industry, in particular. For the remaining industries it assumes the value of 0.
Numbers in brackets are p-values for tests performed.

The same previous methodology was followed when different panel regressions were used and the standard tests performed, in order to assure the efficiency and consistency of the estimates. All tests led, once again, to the GLS estimation method for the REM model, so that only correspondent outcomes are provided.

In general, our results are in accordance with initial expectations and with some prior studies, where authors' argumented in favour of the fact that high-tech and R&D based activities have a higher proportion real options on their total market value than other industries.

All regressions reveal a positive sign for the coefficient of the dummy variable du_{gs}, indicating that belonging to high-tech and R&D based industries has a strong positive impact on the estimate of the real options market value. In other words, we may say that investors (or the market) recognise that these specific industries are in a favourable position to create, manage and optimally exercise real options, especially the type of growth options (Smit, 2000; Al-Horani *et al*., 2003; Alonso *et al*., 2006; Adam and Goyal, 2007). With these empirical outcomes we find support for the research hypothesis H_4.

For the regression conducted over the full sample of 482 companies we observe that the sign of the remaining explanatory variables' coefficients of the model remains unchanged when compared to the original form, being all of them statistically significant. Nonetheless, the adjusted R^2 has increased, which may be explained by the effective explanatory power of the additional variable (du_{gs}) over the estimate of the market value of real options (*ROV*).

Furthermore, it is found that the industry dummy, being positive and statistically significant, suggests that the real options reflected in the market value of firms belonging to these particular industries are not firm-owned exclusively, but rather shared with the rest of the industry, not corroborating some prior findings in this matter (e.g. Alonso *et al.*, 2005).

Empirical results for a disaggregated analysis by individual Euronext stock markets show that H_4 still stands as, in all cases, a positive sign is obtained for the dummy coefficient.

Even though, there are some particular findings that are worth to be mentioned. Firstly, the only Euronext market where the dummy for technological and R&D based industries reveals no statistical significance is the Portuguese one. This is also the market where the less impact of this variable is felt over ROV. Secondly, Euronext Brussels is where belonging to these industries has more positive impact on the dependent variable. In fact, this impact is twice as much as the overall impact computed for the full sample. Thirdly, the explanatory power of the model increases in the whole set of regressions, providing even stronger evidence that the perception of the real options value by the market is not independent of the activity developed by quoted firms.

To strengthen our findings, we performed an additional analysis where the full sample was divided into two separate panels: panel A is composed by companies belonging to the Technological industry and to the Phamaceutical and Biotechnogical sector of the Healthcare industry, on a total of 54 companies; panel B includes all other companies of the initial sample, with a total of 428 companies.

To re-test research hypothesis H_4, we performed regressions over both panels A and B, not considering the dummy variable du_{gs}. The idea is, again, to see if significant differences exist in the estimated coefficients.

The results of these new regressions (Table 5-7) allow us to corroborate prior conclusions, mainly because coefficients differ in magnitude (but not in sign) from the estimation of Panel A to the estimation of Panel B, showing a relevant difference between the way that the market recognises the value of real options within firms specifically belonging to high tech and R&D based industries and all other firms.

Table 5-7 – Results for H_4 when different industries are analysed separately

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \mu_{it}$$

Coefficient	**Euronext stock markets**	
	Panel A	**Panel B**
Constant	1,3552	0,6202
ASSI	0,5098 *	0,2865
FLEV	-0,8689	-0,6656
SIZE	-0,3778 *	-0,1247
RATIO	-0,1683 *	-0,8453
N	54	428
Adjusted R^2	0,1538	0,1767
Breush-Pagan test	143,81 [0,0000]	417,59 [0,0000]
Hausman test	4,164 [0,0384]	19,314 [0,0007]

(*) indicates that the estimated coefficient is not statistically significant.
Panel A has a total of 54 companies, belonging to both the Technology industry (ICBcode 9000) and the Pharmaceuticals and Biotechnology sector of Healthcare industry (ICB code 4000/4570), and present in all four Euronext stock markets
Panel B has a total of 428 companies, belonging to all industries not considered on Panel A, and present in all four Euronext stock markets.
Numbers in brackets are p-values for tests performed.

However, it is possible to study the empirical evidence provided on Table 5-7 in more detail.

One may account for the fact that three out of four of the explanatory variables of the model are non-significant for Panel A. This fact, considered together with the relative high value for the autonomous variation on the dependent variable (coefficient for the *constant*) and the relatively smaller explanatory power of the model (adjusted R^2) may indicate that, for this set of companies, the proportion of the market value accounted for by real options is quite inherent to their nature, and investors do not need other indicators of the firms' ability to detain real options than the knowledge that firms belong to those specific economic activities.

We may then conclude that, as expected from results of prior studies, there is a positive influence of the industry factor on the market value of real options detained by high-tech and R&D based companies (a summary of results for H_4 is presented on Table 5-11).

5.4 ADJUSTMENT DYNAMICS OF THE REAL OPTIONS VALUE ESTIMATES

To address the problem of the dynamic nature of the economic relations we still explore the possibility to include in our study the adjustment behaviour of the dependent variable over time.

Working under the assumption that investors, aiming at maximising their returns, invest on the basis of future positive expectations, we estimate a new model expressed on equation [4.12]. The difference to the original estimation rests on the introduction of the one period lagged dependent variable, ROV_{it-1}, in order to understand if and how does the market value of real options at one moment affects the estimate of the real options value of the next period.

As stated on section 4.3.4, when describing the methodology to test research hypothesis H_5, the usual methods for panel data estimation are not suitable to dynamic models. This is mainly due to the endogeneity problem that arises from the correlation among the new lagged variable and the error term. In order to obtain unbiased, consistent and efficient estimators, we must use the GMM model (Baltagi, 1995; Marques, 2000).

By default, Gretl applies the Arellano-Bond estimation method, which has the same implicit logic as GMM. In practice, the dynamic model is estimated in first differences and with instrumental variables, two of the methods that are normally used to eliminate time series autocorrelation and endogeneity problems (Marques, 2000).

Estimates for the coefficients of the model are presented on table 5-8, for both the full sample and the disaggregated analysis by market.

Results for these regressions show that there is a strong and positive relation between the market value of real options of firms in one period (ROV_{it-1}) and the market value of real options of firms in the subsequent period (ROV_{it}). In other words, it may be concluded that when the market recognises the value of existing real options in one period, this will affect the proportion of the market value of firms corresponding to their real options in the near future. Investors are then considered to be not indifferent to the past performance of firms in what concerns to their capacity do create, maintain and optimally exercise options over time.

Table 5-8 – Results for H_5 for both aggregated and disaggregated analysis

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZE_{it} + \beta_4 RATIO + \beta_8 ROV_{it-1} + \mu_{it}$$

Coefficient	Euronext full sample	Euronext Paris	Euronext Amsterdam	Euronext Brussels	Euronext Lisbon
Constant	-0,0192	0,0078	-0,1820	-0,3349 *	-0,3378
ASSI	0,0766	0,0257 *	0,0860 *	0,2081	-0,8649
FLEV	-0,0501	-0,0852	0,1805	-0,0055	-1,8667
SIZE	0,0546	0,0704	0,0376	0,0701 *	-0,0635 *
RATIO	-0,2732	-0,2775	-0,2289 *	-0,1811	-0,5019 *
ROV_{t-1}	0,4748	0,5528	0,4084	0,2370	-0,0079 *
N	482	329	69	53	31
Adjusted R^2	0,2136	0,2013	0,1935	0,2090	0,1919
Sargan test	48,98 [0,0000]	30,52 [0,0065]	35,39 [0,0013]	22,882 [0,0422]	65,403 [0,0000]
Wald test	81,212 [0,0005]	61,650 [0,0000]	22,245 [0,0005]	10,352 [0,0658]	10,504 [0,0622]

(*) indicates that the estimated coefficient is not statistically significant at a maximum of 10% significance level.
ROV_{t-1} is the one period lagged dependent variable, now included in the model as an explanatory variable in order to adress adjustment dynamnmics of ROV.
Numbers in brackets are p-values for tests performed.

The effective adjustment dynamics are consolidated with the results from the Wald test, a special F-test performed to check the joint significance of the dynamic model. By rejecting the null hypothesis that states that all variables' coefficients in the model are equal to zero, this test shows that the model is globally statistically significant. This is true for the full sample, but also for the subsamples of the disaggregated analysis, even though the p-value for the Euronext Lisbon is higher than 5% (but less than 10%).

Also worth to be mentioned is the positive result for the Sargan test, normally used to detect endogeneity problems. The Sargan test executed to our model rejects the null hypothesis (in all cases), accepting the alternative one for the inexistence of endogeneity of the variables.

Although H_5 is supported by evidence, there are some particular details that should be highlighted. In the first place, one may notice that all coefficients have reduced their impact over the dependent variable when compared to the ones from the original model. On the contrary, the lagged variable is now the one whose behaviour affects more the market value of real options within firms. All proxies seem to lose their earlier relevance for investors, who tend to attribute more value to the perception of ongoing real options. Nevertheless, the adjusted R^2 has increased in all estimations, confirming the maintenance of the explanatory power of the model.

When comparing this estimation to the preceding ones, we may observe that the sign of the coefficients remain unchanged and, with it, the expected relation between the proxies of the real options and the estimate of their value. The exception goes to the variable *SIZE*, which consistently shows a positive sign of the coefficient (except for the Portuguese market) changing our findings in what concerns the research hypothesis H_{1c}. In fact, in the present case, the positive sign supports this hypothesis, revealing that, under a dynamic analysis, larger firms are believed to detain more experience, knowledge and financial capacity to create and fund their options, as predicted by some authors (e.g. Berk *et al.*, 1999; Carson, 2005; Alonso *et al.*, 2006).

The fact that these findings are contrary to our former results may be explained by the fact that, with the introduction of the lagged variable in the model, its statistical significance and its overall impact over *ROV*, the proxy of *size* is no longer interpreted as the consequence of a growth process, where options are progressively substituted by assets-in-place that then cease to exist, but rather as the possibility to maintain successive real options alive.

Focusing on the results for the individual stock markets, it may be observed that Euronext Paris is where the highest impact of the lagged variable over *ROV* is felt. On the contrary, for Euronext Lisbon this impact is negative and not significant. Furthermore, with a joint significance bellow the standard significance level, three out of four variables with no statistical significance, and several coefficients revealing an opposite sign when compared with previous estimations (Table 5-8), we conclude that no support is found for H_5 in the Portuguese case. This is the only market where investors do not recognise the value of real options embedded in firms when considering the previous existence of option market value.

Our concluding remarks on research hypothesis H_5 are summarized on Table 5-11.

5.5 Robustness Analysis

On a final stage of the study, we address the robustness of our results by checking empirical findings against a number of specifications.

An important part of the robustness analysis was firstly performed when some of the hypotheses being studied were tested in several different ways. This was the case of hypotheses H_2, H_3 and H_4, where all additional regressions ended up supporting initial findings and the research hypotheses themselves. These confirmatory estimations were essentially conducted over sub-samples for different periods of time or different sets of companies, according to the issue in question.

Secondly, the robustness of results was analysed against a different measure for the variable *SIZE*, as it is the only proxy for real options where the nature of its relation with the dependent variable (*ROV*) changes from the static to the dynamic model (first negative and then positive, respectively). We re-estimate the models [4.1] and [4.12] computing the variable *SIZE* as the logarithm of market capitalization of firms (*SIZEM*). Results are provided on Table 5-9.

Data on market capitalization was not available for more than 242 companies from the initial sample of 482. However, this sub-sample is still representative from Euronext, as it is composed by firms from all Euronext markets and several industries.

The new results confirm those of the original estimations. On one hand, when substituting the variable *SIZE* by *SIZEM* on the static model [4.1], all coefficients maintain their sign and statistical significance, with special reference to the negative relation between *SIZEM* and *ROV*. More, the model is still globally significant and its explanatory power is not significantly affected. Thus, research hypothesis H_1 still stands.

On the other hand, when considering the dynamic model [4.12] with the one period lagged variable and the new way of computing the variable *size*, we still find support for H_5, with

ROV_{t-1} showing a strong positive impact on the dependent variable. Additionally, all other coefficients' sign remain unchanged, particularly the one related to *SIZEM* that, as before with *SIZE*, is positively related with *ROV*.

Table 5-9 - Results for robustness analysis when re-estimating with SIZEM

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZEM_{it} + \beta_4 RATIO + \mu_{it} \quad \textbf{(1)}$$

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZEM_{it} + \beta_4 RATIO + \beta_8 ROV_{it-1} + \mu_{it} \quad \textbf{(2)}$$

Coefficient	**Euronext stock markets**	
	static model (1)	**dynamic model (2)**
Constant	1,3538	-0,1018 *
ASSI	0,5667	0,2118
FLEV	-0,5111	-0,0127
SIZEM	-0,4980	0,0132
RATIO	-0,6004	-0,1268
ROV_{t-1}	---	0,3916
N	242	242
Adjusted R^2	0,1800	0,2089
Breush-Pagan test	364,50 [0,0000]	---
Hausman test	74,560 [0,0000]	---
Sargan test	---	80,499 [0,0000]
Wald test	---	28,048 [0,0000]

(*) indicates that the estimated coefficient is not statistically significant.
Numbers in brackets are p-values for tests performed.

Thirdly, on the robustness analysis we also substitute the variable *RATIO*, representing the *ratio of book value of assets to total market value of firm*, with another market variable, the *earnings per share* (EPS), frequently used as a proxy for real options within firms (Chung and Charoenwong, 1991; Carson, 2005; Hutchinson and Gul, 2006; Adam and Goyal, 2007). As mentioned in section 3.3.2, a larger *EPS* ratio is expected to lead to a larger proportion of equity value attributable to earnings generated from assets-in-place relative to growth opportunities, so that a negative relation among *ROV* and *EPS* is to be expected.

To perform this study we had to abdicate from some companies in our sample as, once again, *EPS* was not available for the full sample of 482 companies. Thus, robustness analysis is, at this stage, conducted over a sub-sample of 388 companies from the Euronext stock markets and representative of the several industries.

Table 5-10 provides the results from the analysis. Broadly speaking, results are consistent with the earlier findings for the full panel, both in static and dynamic models, with special reference to the variable representing the *size* of companies. Also in both regressions, it is confirmed the expected negative relation between the *EPS* variable and the proportion of market value of firms accounted for by real options.

Even though, it is interesting to realize that the impact of *EPS* over *ROV* is smaller than the one felt with the variable *RATIO*, and that the adjusted R^2 has also decreased in the case where *EPS* is used. This corroborates Adam and Goyal's (2007) findings when referring that, although *earnings-price ratios* are related to investment opportunities, they do not contain information that is not already contained in the ratio *of book value of assets to total market value of firm.*

Table 5-10 - Results for robustness analysis when re-estimating with EPS

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZEM_{it} + \beta_4 EPS + \mu_{it} \quad \textbf{(3)}$$

$$ROV_{it} = \alpha + \beta_1 ASSI_{it} + \beta_2 FLEV_{it} + \beta_3 SIZEM_{it} + \beta_4 EPS + \beta_8 ROV_{it-1} + \mu_{it} \quad \textbf{(4)}$$

Coefficient	**Euronext stock markets**	
	static model	**dynamic model**
Constant	0,7433	-0,0472 *
ASSI	0,1159 *	0,0086 *
FLEV	-0,4813	-0,0292
SIZE	-0,3038	0,0269
EPS	-0,0271	-0,0106
ROV_{t-1}	---	0,4742
N	388	388
Adjusted R^2	0,1612	0,1921
Breush-Pagan test	700,43 [0,0000]	---
Hausman test	11,227 [0,0241]	---
Sargan test	---	43,502 [0,0001]
Wald test	---	56,637 [0,0000]

(*) indicates that the estimated coefficient is not statistically significant.
Numbers in brackets are p-values for tests performed.

According to these outcomes, we may once again conclude that research hypothesis H_1 and H_5 are supported by evidence, even when *earnings per share* are used instead of the *book-to-market assets ratio*.

Our empirical results are summarized on Table 5-11. Overall, the methodology used in the present study allows obtaining empirical evidence that the market recognises the value of real options within firms. Investors are not only able to identify some specific features of firms that enable them to create, maintain and optimally exercise their options, as they also attribute value to this capacity and to the real options themselves which, in turn, is incorporated on the firms' market value.

Table 5-11 – Summary results for research hypotheses

Research hypothesis	Supported / Not supported		Interpretation
H 1	**Full sample**	Supported	Proxies for real options are strongly related with an estimate of the proportion of market value of firms accounted for by real options. The market perceives and values real options within firms based on information from their financial statements.
	Euronext Paris	Supported	
	Euronext Amsterdam	Supported	
	Euronext Brussels	Supported	
	Euronext Lisbon	Supported	
H 1a	**Full sample**	Supported	*Asset irreversibility* is generally positively related to the proportion of the firms' market value concerned to their real options. Irreversibility augments real options' value by raising the probability to postpone investments (deffering the optimal moment for exercising the option).
	Euronext Paris	Supported	
	Euronext Amsterdam	Supported	
	Euronext Brussels	Not supported	
	Euronext Lisbon	Supported	
H 1b	**Full sample**	Supported	*Financial leverage* is generally negatively related to the proportion of the firms' market value concerned to their real options. The higher this debt ratio, the higher the probability of under investment (less value of real options) resulting from agency conflicts and financial constraints.
	Euronext Paris	Supported	
	Euronext Amsterdam	Not supported	
	Euronext Brussels	Supported	
	Euronext Lisbon	Supported	
H 1c	**Full sample**	Not supported	*Size* is generally negatively related to the proportion of the firms' market value accounted for by real options. Size is interpreted as a consequence of the growth process of firms, characterised by a progressive substitution of growth options by assets-in-place.
	Euronext Paris	Not supported	
	Euronext Amsterdam	Not supported	
	Euronext Brussels	Not supported*	
	Euronext Lisbon	Not supported	
H 1d	**Full sample**	Supported	The *ratio of the book value of assets to the total market value* is negatively related to the proportion of the firms' market value concerned to their real options. Augmenting the proportion of assets as a result of investing means that growth options cease to exist.
	Euronext Paris	Supported	
	Euronext Amsterdam	Supported*	
	Euronext Brussels	Supported	
	Euronext Lisbon	Supported*	
H 2	**Full sample**	Supported	The *introduction of the Euro* on the Eurozone has a significant (negative) impact on the estimate of the market value of real options within firms. Investors tend to attribute more relative value to the assets already in place when financial statments of different european companies start to be expressed on the same currency.
	Euronext Paris	Supported	
	Euronext Amsterdam	Supported	
	Euronext Brussels	Supported	
	Euronext Lisbon	Supported	
H 3	**Full sample**	Supported	The *application of the IAS* as a significant (negative) impact on the proportion of the market value of firms accounted for by real options. Harmonised accountancy rules increase investors' trust on financial information, where real options are not directly reported, thus increasing the relative market value of assets in place.
	Euronext Paris	Supported	
	Euronext Amsterdam	Supported	
	Euronext Brussels	Supported	
	Euronext Lisbon	Supported	
H 4	**Full sample**	Supported	Belonging to *high-tech and R&D based industries* has a strong positive impact on the estimate of the real options value. Investors expect these companies to have more capacity to create, manage and optimally exercise real options.
	Euronext Paris	Supported	
	Euronext Amsterdam	Supported	
	Euronext Brussels	Supported	
	Euronext Lisbon	Supported*	
H 5	**Full sample**	Supported	The value of real options in one period as a significant and positive influence over the estimate of real options' value in the subsequent period. Investors consider past performance of firms in what concerns their capacity to create and exercise real options over time.
	Euronext Paris	Supported	
	Euronext Amsterdam	Supported	
	Euronext Brussels	Supported	
	Euronext Lisbon	Not supported	

(*) indicates that the estimated coefficient is not statistically significant at a maximum of 10% significance level.

The findings presented in this section also provide strong evidence that certain corporate characteristics such as *asset irreversibility*, *financial leverage*, *size* and *market to book ratios* are effective proxies for real options, corroborating some prior studies in this particular area of knowledge.

We have realized as well that belonging to technology and R&D based industries positively influences the perception that the market has on the capacity of firms to detain real options, when compared to other industries.

An important aspect of this work is the introduction on the analysis of adjustment dynamics that had not been yet considered in similar studies. In this case, by introducing the one period lagged dependent variable as an explanatory variable of the model, we are able to see how the estimate of market value of real options may influence investors' perception of real options value on subsequent periods.

Finally, it was still possible to confirm the predictions that the introduction of the common currency in the Eurozone, along with the use of IAS by quoted firms, had an effective impact on the estimate of the real options market value. In both cases, we concluded on a negative influence of these events on the proportion of the market value of firms related to real options, mainly due to a valorisation of the component of assets-in-place.

6. Conclusions

The shortcomings of discounted cash-flows valuation methods that have been put forward by both academics and managers are one of the main reasons for the consideration of the real options reasoning in determining firms' value, among other applications.

In spite of the limitations of the real options approach presented in this work, there has been a growing acceptance of the view that firms' total market value is the sum of the value of their assets-in-place and the value of their real options. The ability to create, nurture and optimally exercise a valuable portfolio of real options is considered as important for maximising enterprise value and shareholders' wealth as resources with immediate and measurable payoffs.

Under this perspective, if the market efficiency hypothesis stands, stock prices should reflect available information regarding the real options held by firms.

To understand if the market effectively recognises the existence and value of real options within firms, we review relevant theoretical and empirical literature, and then study the relation between information contained in variables found as representative of real options, and an estimate of the real options market value given by the proportion of firms' market value not explained by assets-in-place.

We test a balanced panel of 482 non-financial companies listed on Euronext stock markets during the period of 2000 through 2006, and conclude that investors do attribute value to the real options embedded in firms when deciding to commit resources.

Results are generally consistent with predictions, as we find that the market value of real options is significantly and positively related with the variable of *asset irreversibility*, and negatively related with the variables of *financial leverage*, *size* and the *ratio of book value of assets to total market value of firms*. Although a positive relationship among the estimate of real options' value and *size* was expected, we suggest that this variable may be seen as the consequence of the growing process of firms, where real options are progressively substituted by assets-in-place, thus reducing the proportion of firms' market value accounted for by their real options.

A few exceptions are found on a disaggregated analysis by Euronext individual stock markets, where we find asset irreversibility negatively related with the estimate of real options on Euronext Brussels, and financial leverage positively related with that estimate for Euronext Amsterdam.

We extend the analysis and examine the impact of the introduction of the Euro and the IAS over the markets' perception of real options value, on 2002 and 2005 respectively, and conclude on a negative impact of both events. These results are in accordance with some empirical evidence that accounts for a growing trust of investors on publicly financial information. Real options are still not directly reported, but assets-in-place are believed to be more correctly evidenced, contributing to a relative higher value of this component of firms' market value when compared to the proportion of their real options.

We find additional evidence that the markets' perception of real options value is also positively influenced by the fact that companies belong to technological and R&D based industries, a situation where all other variables lose their relative importance.

A final contribution of our study is the fact that we also investigate adjustment dynamics of real options' value through time. We conclude that the market value of real options is significantly and positively related with the perception of real options' value within firms on the preceding period. In this case, the variable *size* has no longer a negative coefficient, indicating that although some real options may have been substituted by assets-in-place, not all real options cease to exist as firms grow. Even though, on a disaggregated analysis, we find no support for this fact on Euronext Lisbon.

Provided results are robust, even after controlling for alternative measures of size and the market's ratio, and additional regressions over different panels and periods of time.

Despite the results are according with expectations of real options reasoning, and capital markets believed to be efficient due to the efficiency of most individual stocks (Markovitch *et al.*, 2005), we understand that the assumption of the market efficiency hypothesis puts aside the high probability of some information asymmetry, which may become an important limitation to the investors' perception of real options only based on firms' publicly financial information.

Hence, while evidence has been provided about the market's valuation of real options and some of its explanatory variables, future research would gain by extending the model by including a different or more accurate estimation of the dependent variable, always keeping in mind that real options are generally unobservable to external investors.

Additionally, research may progress by including more or alternative measures of investors' expectations of firms' ability to acquire and explore their options, or broaden the samples of companies or the period of analysis, namely by including the impact of the recent financial crisis. Future work may also consider comparative studies, in order to understand how cultural factors may influence investors' expectations on real options value within firms.

APPENDIX A – OPTION PRICING METHODS

A.1) Wiener process or Brownian motion

A Wiener process or Brownian motion is a specific type of Markov process. The Markov process is a stochastic process where the probability distribution for all future values depends only on its current value, being unaffected by past values or any current information (Dixit and Pindyck, 1994).

Stock prices and gross project values are usually assumed to follow a stochastic Markov process as public information is quickly incorporated in the current price of the stock and the past pattern of prices fail to have forecasting value (called the *weak form* of market efficiency).

When a variable *z(t)* follows a Wiener process, then changes in z (Δz) must satisfy two properties (Dixit and Pindyck, 1994; Linde *et al*., 2000):

1) Δz over small time periods are independent, meaning that the process can be viewed as the continuous limit of discrete random walk.
2) Δz are normally distributed, with mean $E(\Delta z) = 0$, and variance that follows a linear increase with the time interval so that $var(\Delta z) = \Delta t$ (the variance of the change in a Wiener process grows linearly with time horizon). The relationship between Δz and Δt is then given by $\Delta z = \varepsilon_t \sqrt{\Delta t}$, where ε_t follows a standard normal distribution $(\varepsilon_t \sim N(0,1))$.

In continuous time, the variance will go to infinity ($\Delta t \to 0$), and the increment of a standard Wiener process becomes $dz = \varepsilon_t \sqrt{dt}$, with $E(dz) = 0$ and $var(dz) = dt$.

Although stocks prices seem to satisfy the first property, price changes do not follow a normal distribution, but are closer to a lognormal distribution, otherwise negative prices would be observed. Thus, it can be assumed that the natural logarithm of prices follows a Wiener process.

Stock prices also usually have a non-zero drift and volatility other than 1; so a more generalised Wiener process (a Brownian motion with drift) would be more appropriated (Linde *et al*., 2000). This generalization has the following form

$$ds = \propto (s,t)dt + \sigma(s,t)dz$$

where *dz* is the increment of a standard Wiener process with mean *0* and variance *dt*, and where $\alpha(s,t)$and $\sigma(s,t)$are the drift and the variance of the coefficients expressed as a function of the current state and time. The continuous time stochastic process s is called *Ito's process*[39] with mean $E(ds) = \alpha(s,t)dt$ and variance $var(ds) = \sigma^2(s,t)dt$.

A special case is the Geometric Brownian motion with drift, also known as the standard diffusion Wiener process, and widely used to model stock price behaviour, where $\alpha(s,t) = \alpha s$ and $\sigma^2(s,t) = \sigma^2 s^2$ with α and σ constant. Thus, we can have

$$ds = \alpha s dt + \sigma s dz \quad \text{or} \quad ds/s = \alpha dt + \sigma dz$$

where α is the instantaneous expected return on the stock, σ is the constant instantaneous deviation of the stock returns and *dz* is the differential of a standard Wiener process. $E(ds) = \propto sdt$ and $var(ds) = \sigma^2 s^2 dt$, so that the expected stock price drift as a proportion of the current stock price is assumed constant. Having a constant instantaneous expected stock return α, the expected increase in the stock price within a small time interval Δt is $\alpha s \Delta t$ (Dixit and Pindyck, 1994, Trigeorgis, 1996; Linde *et al.*, 2000).

We can also represent the discrete time version of the model, which comes

$$\frac{\Delta s}{s} = \alpha \Delta t + \sigma \varepsilon \sqrt{\Delta t}$$

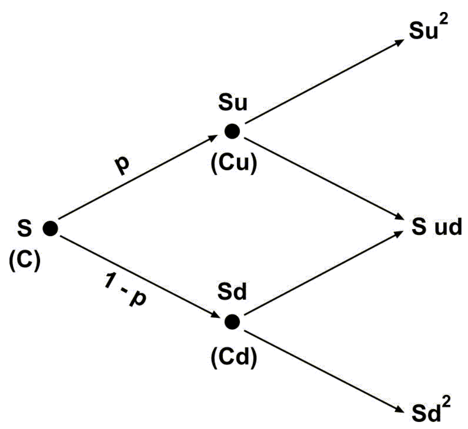
where Δs is the change in the stock price in a small time interval (Δt), ε is a random sample from standardised normal distribution, α is the expected stock return per unit of time, and σ is the volatility of stock price.

[39] For a detailed explanation, see Dixit and Pindyck (1994), chapter 3.

A.2) Binomial Model (BM)

In the BM the time to maturity of the option is divided into *n* discrete intervals, allowing taking into consideration option values before the maturity date of the option[40]. At each of these intervals, the stock price is assumed to have only two possible movements that are either up or down compared to the initial price. The general formulation of a stock price process is shown bellow (Fig.A-1 and Table A-1).

Figure A-1- General formulation for binomial price path (two-step tree)



In the figure, *S* is the asset's value at time *t*; in the next period (t_1) the price may move up to *Su* with probability of *p*, or down to *Sd* with probability *1-p*. The proportional increase when the price moves upwards is *u-1*, and when it moves downwards the proportional decrease is *1-d*. Thus, *u* and *d* correspond to the upward or downward move of the asset's value, respectively. If the asset's price moves to *Su* the payoff from the option will be *Cu* and if it moves to *Sd* then the payoff will be *Cd*.

Source: Damodaran, 2001; pp.10

The model is originally based on the idea of the *replicating portfolio* under uncertainty (Dixit and Pindyck, 1994; Trigeorgis, 1996; Linde *et al.*, 2000; Damodaran, 2001; Copeland and Antikarov, 2002; Ferreira, 2005).

To extract the value of an option one can create a portfolio buying a particular number of units of the underlying asset (which can be a common stock) and borrow against them, at the risk-free rate *r*, an amount *B* that exactly replicates the future returns of the option, i.e., that is able to create the same cash-flows as the option being valued. The principles of arbitrage apply here, and to avoid risk-free arbitrage profit opportunities, the value of the option must be equal to the value of the replicating portfolio. Satisfied this condition, it is possible to value the option by determining the cost of the equivalent synthetic option (the replicating portfolio).

[40] This feature is particularly important when valuing American type options that, by opposition to European options, can be exercised at any time prior to maturity.

In a multi-period binomial process, the valuation has to proceed iteratively, starting with the last time period and moving backwards until the current point in time. The portfolios replicating the option are created and valued at each step, providing the values for the option in that time period. The final output of the model is a statement of the value of the option in terms of the replicating portfolio (as in A.2.1).

Another possibility is to determine the value of an option under the *risk neutrality assumption*. While the idea of the replicating portfolio locks-in future cash-flows and relies on the arbitrage free hypothesis, risk neutral valuation, instead of first taking the expectation and then adjusting for risk, adjusts the probabilities of future outcomes in the first place (such as they incorporate the effects of risk), and then take the expectation under those different probabilities.

An important feature of this method is the fact that it is independent of risk attitudes or considerations of capital market equilibrium (Trigeorgis 1995 and 1996, Ferreira 2005).

Table A-1 - Option valuation logic with the binomial model

Valuation Logic	Description
Replicating portfolio	Proceeding with this logic, constructing a portfolio consisting of Δ units of the underlying asset at its current price *S*, financed by borrowing an amount of *B* at the risk-free rate, the value of the option will be $$C \approx \Delta \cdot S - B \quad \text{[A.2.1]}$$ Assuming Δ as the number of units of the underlying asset that are (hypothetically) bought, *Cu* as the value of the option if the asset price is *Su*, and *Cd* the value of the option if the asset price is *Sd*, the value of the portfolio will be $(S_u \cdot \Delta - C_u)$ in the case of an upward movement of the asset's price, and $(S_d \cdot \Delta - C_d)$ if that movement is downwards. Since we want Δ to be such that the portfolio is riskless, then the two possible outcomes should be equal, meaning that $$S_u \cdot \Delta - C_u = S_d \cdot \Delta - C_d \quad \text{[A.2.2]}$$ Thus, Δ comes, $$\Delta = \frac{C_u - C_d}{S_u - S_d}. \quad \text{[A.2.3]}$$

<table>
<tr><th>Valuation Logic</th><th>Description</th></tr>
<tr><td>Risk neutrality probability</td><td>Being the variables p and 1-p the probability that the price of the asset will have an upward or downward movement respectively (as in fig.2-5), the expected payoff from the option is
$$p \cdot C_u + (1-p) \cdot C_d \quad [A.2.4]$$
and the value of the option today is its expected future value discounted at the risk-free rate, where we get
$$C \approx e^{-rT}\left[p \cdot C_u + (1-p) \cdot C_d\right] \quad [A.2.5]$$
where
$$p = \frac{e^{eT} - d}{u - d}. \quad [A.2.6]$$
Since p is the probability that the price will move up, then the expected price of the asset at time t, $E(S_t)$, is
$$E(S_t) = p \cdot S_u + (1-p) \cdot S_d \quad [A.2.7]$$
or
$$E(S_t) = p \cdot S \cdot (u-d) + S_d \quad [A.2.8]$$
Substituting p for the expression from equation (2.11) it is possible to obtain:
$$E(S_t) = S \cdot e^{rT}. \quad [A.2.9]$$
This final expression states that the price of the asset grows at the risk-free rate. Thus, when setting the probability equal to p we are assuming that the return on the asset equals the risk-free rate, assuming investors to be risk-neutral, following the principle of the risk-neutral valuation ().</td></tr>
</table>

Source: Trigeorgis, 1996; Linde *et al.*, 2000 and Ferreira, 2005

The relevance of the BM is that it is able to, in a simple manner, provide insights into the determinants of option value, which is not determined by the expected price of the asset, but by its current price that reflects expectations about the future.

However, as a possible disadvantage is the fact that it requires a large number of inputs in terms of the expected future prices at each node of the binomial tree (Damodaran, 2001).

A.3) Black-Scholes Model (B-S)

The Black-Scholes formula is a continuous-time model and is represented by a mathematical expression that depends, exclusively, on observable variables: the underlying asset current value (S), the exercise price of the option (X), the time to expiration or to maturity (t), the risk-free interest rate corresponding to the life of the option (r), and the volatility of the asset represented by the variance in its value (σ^2).

Relying on the same basic assumptions of the BM, we still need to consider that the options being valued are (dividend-protected) European options, and that the prices of the underlying asset, although following a Wiener process, are log-normally distributed as prices cannot be negative because of the limited liability of stockholders (Table A-2).

Table A-2 - The B-S model

Under the B-S model, the value of a call option[41] can be obtained by the expression: $$C = S \cdot N(d_1) - X \cdot e^{-rt} \cdot N(d_2) \qquad [2.10]$$ where, $$d_1 = \frac{\ln\left(\frac{S}{X}\right) + \left(r + \frac{\sigma^2}{2}\right) \cdot t}{\sigma \cdot \sqrt{t}} \qquad [2.11]$$ $$d_2 = d_1 - \sigma \cdot \sqrt{t} \qquad [2.12]$$	To calculate the value of an option using the B-S formulation we first need to determine the variables d_1 and d_2; only then it is possible to estimate the normal distributions $N(d_1)$ and $N(d_2)$, that correspond to those standardised normal variables. Using the continuous time version, we need to calculate the present value of the exercise price. Altogether, these inputs are substituted in the B-S model.
The principle of the replicating portfolio used in the binomial valuation is also present here. In fact, embedded in the B-S model is the replicating portfolio itself (Damodaran, 2001; Copeland and Antikarov, 2002): The value of the call option (C) is given by: $$C = \underbrace{S \cdot N(d_1)}_{\text{Buy } N(d_1) \text{ shares}} \; \underbrace{- X \cdot e^{-rt} \cdot N(d_2)}_{\text{Borrow this amount}}$$	Under this perspective, $N(d_1)$ is the number of shares that are needed to create the replicating portfolio (the option Δ). $N(d_2)$ is the probability that the option will be exercised (i.e., will be in-the-money at the expiration, or S>X) in a risk-neutral context, so that $X.N(d_2)$ represents the strike price times the probability that the strike price will be paid.

Source: Damodaran, 2001a and Ferreira, 2005

[41] The value of an European put option can be obtained in the same manner, or by using the put-call parity which states that $C + Xe^{-rt} = P + S$, i.e. the value of a put with a certain exercise price and exercise date can be deducted from de value of a call with the same exercise price and date (Ferreira, 2005).

The idea behind B-S approach is the construction of a portfolio comprising options and the underlying asset with the same source of uncertainty which, in order to avoid arbitrage opportunities, should be riskless and, therefore earn the return on a risk-free security. If the portfolio has the right proportion of short options and a long position in the underlying asset, for very small changes in the asset's price, the gains on one side are offset by the losses on the other side. B-S is then a model where the valuation of options follows a risk-neutral assumption (Trigeorgis, 1996; Linde *et al*., 2000; Copeland and Antikarov, 2002).

However, this B-S model suffers from the limitations of not taking into account the payment of dividends and the possibility of early exercise. Adjustments to the initial formulation can be made to provide partial correction to the option value (Table A-3).

Table A-3 - The B-S model with dividends

Considering the payment of dividends, as it reduces the stock price, the call option will become less valuable as dividend payments increase (and puts more valuable). It is possible to use an alternative formulation to the original B-S model: $$C = S \cdot e^{-yt} \cdot N(d_1) - K \cdot e^{-rt} \cdot N(d_2) \quad [2.13]$$ with *y* representing the dividend yield (dividends/current value of the asset) assumed to remain unchanged during the life of the option, and where $$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r - y + \frac{\sigma^2}{2}\right) \cdot t}{\sigma\sqrt{t}} \quad [2.14]$$ $$d_2 = d_1 - \sigma\sqrt{t} \quad [2.15]$$	This adjustment has a double effect. On one hand, to take into account the expected drop in the value of the option, the value of the asset is discounted back to the present at the dividend yield. On the other hand, the interest rate is offset by the dividend yield reflecting a lower carrying cost from holding the stock

Source: Damodaran, 2001a

Also important to realise is that American options should be worth at least as much (but most of times more) as a European option because of the early exercise option. One possible way to deal with this issue is to use the unadjusted B-S formula and look at its result as a floor estimate of the true value of the option. A second alternative is to value the option to each potential exercise date, implying a complication on the analytical procedures to apply the model. Thirdly, we can use a modified continuous-time version of the BM to consider the possibility of early exercise (Trigeorgis, 1996; Damodaran, 2001a).

APPENDIX B - EURONEXT INDICES BASED ON ICB CLASSIFICATION[42]

B.1) List of Indices (Industry Codes)

Industry code	Names	Mnemonic code	ISIN code	Index
0001	AEX OIL & GAS	NLOG	QS0011016472	Amsterdam AllShares Index (AAX)
1000	AEX BASIC MATERIALS	NLBM	QS0011016480	
2000	AEX INDUSTRIALS	NLIN	QS0011016506	
3000	AEX CONSUMER GOODS	NLCG	QS0011016530	
4000	AEX HEALTH CARE	NLHC	QS0011016555	
5000	AEX CONSUMER SERVICES	NLCS	QS0011016563	
6000	AEX TELECOMMUNICATIONS	NLTEL	QS0011016589	
8000	AEX FINANCIALS	NLFIN	QS0011016605	
9000	AEX TECHONOLOGY	NLTEC	QS0011016613	
1000	BEL BASIC MATERIALS	BEBM	QS0011016696	Brussels AllShares Indices (BAS)
2000	BEL INDUSTRIALS	BEIN	QS0011016738	
3000	BEL CONSUMER GOODS	BECG	QS0011016761	
4000	BEL HEALTH CARE	BEHC	QS0011016795	
5000	BEL CONSUMER SERVICES	BECS	QS0011016829	
6000	BEL TELECOMMUNICATIONS	BETEL	QS0011016860	
7000	BEL UTILITIES	BEUT	QS0011019005	
8000	BEL FINANCIALS	BEFIN	QS0011016902	
9000	BEL TECHONOLOGY	BETEC	QS0011016936	
0001	PSI OIL & GAS	PTOG	QS0011016502	PSI General Index
1000	PSI BASIC MATERIALS	PTBM	QS0011016514	
2000	PSI INDUSTRIALS	PTIN	QS0011016522	
3000	PSI CONSUMER GOODS	PTCG	QS0011016571	
5000	PSI CONSUMER SERVICES	PTCS	QS0011016597	
6000	PSI TELECOMMUNICATIONS	PTTEL	QS0011016621	
7000	PSI UTILITIES	PTUT	QS0011016647	
8000	PSI FINANCIALS	PTFIN	QS0011016662	
9000	PSI TECHONOLOGY	PTTEC	QS0011016688	
0001	CAC OIL & GAS	FROG	QS0011017603	SBF 250 Index
1000	CAC BASIC MATERIALS	FRBM	QS0011017637	
2000	CAC INDUSTRIALS	FRIN	QS0011017652	
3000	CAC CONSUMER GOODS	FRCG	QS0011017686	
4000	CAC HEALTH CARE	FRHC	QS0011017702	
5000	CAC CONSUMER SERVICES	FRCS	QS0011017736	
6000	CAC TELECOMMUNICATIONS	FRTEL	QS0011017769	
7000	CAC UTILITIES	FRUT	QS0011017785	
8000	CAC FINANCIALS	FRFIN	QS0011017801	
9000	CAC TECHONOLOGY	FRTEC	QS0011017827	

[42] Information withdrawn from http://www.euronext.com.

Sector code	Names	Mnemonic code	ISIN code	Index
0530	AEX Oil & Gas Producers	NLOGP	QS0011016705	Amsterdam AllShares Index
0570	AEX Oil Equipment Services & Distribution	NLOESD	QS0011016755	
2350	AEX Construction & Materials	NLCM	QS0011016803	
2730	AEX Electronic & Electrical Equipment	NLEEE	QS0011016894	
2750	AEX Industrial Engineering	NLIE	QS0011016928	
2770	AEX Industrial Transportation	NLINT	QS0011016951	
2790	AEX Support Services	NLSS	QS0011016985	
3570	AEX Food Producers	NLFPR	QS0011017041	
3720	AEX Household goods	NLHG	QS0011017058	
4570	AEX Pharmaceuticals & Biotechnology	NLPB	QS0011017165	
5330	AEX Food & Drug Retailers	NLFDR	QS0011017181	
5550	AEX Media	NLMED	QS0011017223	
8350	AEX Banks	NLB	QS0011017389	
8730	AEX Real Estate	NLRE	QS0011017454	
8770	AEX General Financial	NLGF	QS0011017488	
9530	AEX Software & Computer Services	NLSCS	QS0011017553	
9570	AEX Technology Hardware & Equipment	NLTHF	QS0011016613	
1350	BEL Chemicals	BECH	QS0011017249	Brussels AllShares Indices
2350	BEL Construction & Materials	BECM	QS0011017371	
2720	BEL General Industrials	BEGI	QS0011017421	
2750	BEL Industrial Engineering	BEIE	QS0011017512	
3530	BEL Beverages	BEBEV	QS0011017678	
3570	BEL Food Producers	BEFPR	QS0011017728	
4570	BEL Pharmaceuticals & Biotechnology	BEPB	QS0011018015	
5550	BEL Media	BEMED	QS0011018122	
5750	BEL Travel & Leisure	BETL	QS0011018148	
8350	BEL Banks	BEB	QS0011018353	
8730	BEL Real Estate	BERE	QS0011018387	
8770	BEL General Financials	BEGF	QS0011018411	
9530	BEL Software & Computer Services	BESCS	QS0011018486	
9570	BEL Technology Hardware & Equipment	BETHF	QS0011018510	
0530	CAC Oil & Gas Producers	FROGP	QS0011017843	SBF 250 Index
1350	CAC Chemicals	FRCH	QS0011017903	
1730	CAC Forestry & Paper	FRFP	QS0011017951	
1750	CAC Industrial Metals & Mining	FRIMM	QS0011017969	
2350	CAC Construction & Materials	FRCM	QS0011017991	
2710	CAC Aerospace & Defense	FRAD	QS0011018007	
2720	CAC General Industries	FRGI	QS0011018012	
2730	CAC Electronical & Electrical Equipment	FREEE	QS0011018072	
2750	CAC Industrial Engineering	FRIE	QS0011018106	
2770	CAC Industrial Transportation	FRINT	QS0011018130	
2790	CAC Support Services	FRSS	QS0011018163	
3350	CAC Automobile & Parts	FRAP	QS0011018197	
3530	CAC Beverages	FRBEV	QS0011018205	
3570	CAC Food Producers	FRFPR	QS0011018221	
3720	CAC Household Goods	FRHG	QS0011018247	
3740	CAC Leisure Goods	FRLEG	QS0011018254	
3760	CAC Personal Goods	FRPG	QS0011018270	
4530	CAC Health Care Equipment & Services	FRHES	QS0011018296	
4570	CAC Pharmaceuticals & Biotechnology	FRPB	QS0011018312	
5330	CAC Food & Drug Retailers	FRFDR	QS0011017819	
5370	CAC General Retailers	FRGR	QS0011017835	
5550	CAC Media	FRMED	QS0011017868	
5750	CAC Travel & Leisure	FRTL	QS0011017884	
6530	CAC Fixed Line Telecommunications	FRFLT	QS0011017900	
7570	CAC Gas, Water & Multiutilities	FRGWM	QS0011017983	
8350	CAC Banks	FRB	QS0011018023	
8530	CAC Nonlife Insurance	FRNI	QS0011018031	
8730	CAC Real Estate	FRRE	QS0011018098	
8770	CAC General Financial	FRGF	QS0011018114	
9530	CAC Software & Computer Services	FRSCS	QS0011018239	
9570	CAC Technology Hardware & Equipment	FRTHF	QS0011018262	

B.2) Characteristics of Indices

	Amsterdam	Brussels	Lisbon	Paris
Indices	26	23	8	37
Industry	9	9	8	10
Sector	17	14	0	27
Weighting	Market Capitalisation	Market Capitalisation	Market Capitalisation	Market Capitalisation
Capping	No	No	No	No
Indexes	Price			Price
	Gross Total Return		Gross Total Return	
		Net Total Return		Net Total Return
Frequency of Calculation	End of Day	End of Day	End of Day	Opening and Closing
Base on 30/11/05	1000	1000	1000	1000

APPENDIX C – STATISTICAL TESTS

C.1) Test F (for Fixed Effects Model vs Pooled Model)

The F test can be used to choose among the *pooled model* and the *fixed effects model* in panel data analysis, i.e, between the homogeneity among individuals and a constant heterogeneity. The hypotheses to be tested are:

$H_0: a_1 = a_2 = \cdots = a_{35} = 0$ (homogeneity, *pooled model*)

$H_A: a_1 \neq a_2 \neq \cdots \neq a_{35} \neq 0$ (constant heterogeneity, *fixed effects model*)

The ratio used for the test is

$$F_{estatístico} = \frac{\frac{(R_{fe}^2 - R_{pool}^2)}{(N-1)}}{\frac{(1-R_{fe}^2)}{(TN-N-k)}} \sim F_{(N-1, TN-N-k)}$$

with R_{fe}^2 the coefficient of determination from the regression of the *fixed effects model*, R_{pool}^2 the coefficient of determination from the regression of the *pooled model*, T the number of periods, N the number of individuals (firms) and k the number of explanatory variables of the model.

The null hypothesis is rejected if $F_{estatístico} > F_{(N-1,TN-N-k)}$ and, thus, the pooled model. The heterogeneity among individuals is then admitted and the fixed effects model is more appropriate.

C.2) Breusch-Pagan Test

To decide whether the *pooled model* or the *random effects model* offers the most efficient estimators, a Breusch-Pagan test can be applied.

As the *random effects model* assumes that heterogeneity among individuals is random due to their specific characteristics, the test considers the following hypotheses referred to the individual term of error:

$H_0: \sigma_v^2 = 0$ (no individual heterogeneity, *pooled model*)

$H_A: \sigma_v^2 > 0$ (individual heterogeneity, *random effects model*)

This is an LM test given by the following statistic:

$$LM = \frac{NT}{2(T-1)}\left[\frac{\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\widehat{w}_{it}\right)^2}{\sum_{i=1}^{N}\sum_{t=1}^{T}\widehat{w}_{it}^{\,2}} - 1\right] \sim \chi_1$$

where *N* and *T* are the number of individuals and the number of periods, respectively, and $\widehat{w}_{it}$ is the estimator of $w_{it} = v_i + u_{it}$, being the $v_i$the non-observable individual random effect and u_{it} the term of error.

The *pooled model* is rejected (H_0) in favour of the *random effects model* (H_A) if LM > χ_1.

C.3) Hausman Test

The Hausman test is a formal test that can help us to choose between the *fixed effects model* and the *random effects model*. Symbolically, the null hypothesis to be tested is:

$H_0: cov(a_i, X_{it}) = 0$ (*random effects model*)

$H_A: cov(a_i, X_{it}) \neq 0$ (*fixed effects model*)

Under the assumption that no correlation exists among the error term and the explanatory variables, one the *random effects model* is applied, the *fixed effects model* estimators are consistent but not efficient, while the GLS estimators are efficient. For the alternative hypothesis, GLS estimators lose their consistency, so the *fixed effects model* is more appropriate.

The Hausman test rejects the null hypothesis if $H > \chi_i^2$, with the statistic H given by the expression

$$H = (\hat{b}_{fe} - \hat{b}_{re})'\left[var(\hat{b}_{fe}) - var(\hat{b}_{re})\right]^{-1} = (\hat{b}_{fe} - \hat{b}_{re}) \sim \chi_k^2$$

where $\hat{b}_{fe}$ the vector of the *fixed effects model* estimators, $\hat{b}_{re}$ the vector of the *random effects model* estimators, $var(\hat{b}_{fe})$ is covariance matrices of the $\hat{b}_{fe}$ estimators, and $var(\hat{b}_{re})$ the covariance matrices of the $\hat{b}_{re}$ estimators.

APPENDIX D – OUTPUTS FROM GRETL

D.1) GLS regression for H_1, H_{1a}, H_{1b}, H_{1c}, H_{1d} (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 3374 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,750752	0,147040	5,106	3,48e-07 ***
assi	0,340200	0,235179	1,447	0,09481 *
flev	-0,686666	0,0999212	6,872	7,51e-012 ***
size	-0,172731	0,0550198	-3,139	0,0017 ***
ratio	-0,797548	0,0958162	-8,324	1,22e-016 ***

Média var. dependente	0,510310
D.P. var. dependente	2,050623
Soma resíd. quadrados	13218,47
E.P. da regressão	1,980504
Log. da verosimilhança	-7091,124
Critério de Akaike	14192,25
Critério de Schwarz	14222,87
Critério de Hannan-Quinn	14203,20

'Por dentro' da variância = 2,87131
'Por entre' a variância = 1,44303
teta utilizado para quasi-desmediação = 0,466845

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 686,617
com valor p = 2,43154e-151

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 20,9236
com valor p = 0,000327905

R^2 ajustado (calculado) = 0,17461

D.2) GLS regression for H_1, H_{1a}, H_{1b}, H_{1c}, H_{1d} (Euronext Paris)

Estimativas Efeitos-aleatórios (GLS) usando 2303 observações
Incluídas 329 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,817729	0,158374	5,163	2,63e-07 ***
assi	0,397937	0,287052	1,386	0,08658 *
flev	-0,507966	0,0970478	5,234	1,81e-07 ***
size	-0,115208	0,0643237	-1,791	0,0734 *
ratio	-0,958474	0,107048	-8,954	6,93e-019 ***

Média var. dependente	0,573886
D.P. var. dependente	1,926799
Soma resíd. quadrados	7975,591
E.P. da regressão	1,862567
Log. da verosimilhança	-4698,178
Critério de Akaike	9406,356
Critério de Schwarz	9435,065
Critério de Hannan-Quinn	9416,822

'Por dentro' da variância = 2,37652
'Por entre' a variância = 1,38161
teta utilizado para quasi-desmediação = 0,504288

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 608,924
com valor p = 1,91758e-134

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 31,8445
com valor p = 2,05828e-006

R^2 ajustado (calculado) = 0,16224

D.3) GLS regression for H_1, H_{1a}, H_{1b}, H_{1c}, H_{1d} (Euronext Amsterdam)

Estimativas Efeitos-aleatórios (GLS) usando 483 observações
Incluídas 69 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,207174	0,524260	0,3952	0,6929
assi	0,530278	0,697593	0,7602	0,0947 *
flev	2,68462	0,545233	4,924	1,17e-06 ***
size	-0,623205	0,178331	-3,495	0,0005 ***
ratio	-0,0391155	0,377424	0,1036	0,9175

Média var. dependente	0,537931
D.P. var. dependente	2,423829
Soma resíd. quadrados	2632,484
E.P. da regressão	2,344311
Log. da verosimilhança	-1094,851
Critério de Akaike	2199,702
Critério de Schwarz	2220,602
Critério de Hannan-Quinn	2207,915

'Por dentro' da variância = 3,8009
'Por entre' a variância = 2,12837
teta utilizado para quasi-desmediação = 0,494908

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 107,038
com valor p = 4,36821e-025

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 14,0439
com valor p = 0,0071562

R^2 ajustado (calculado) = 0,17845

D.4) GLS regression for H_1, H_{1a}, H_{1b}, H_{1c}, H_{1d} (Euronext Brussels)

Estimativas Efeitos-aleatórios (GLS) usando 371 observações
Incluídas 53 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	-1,03868	0,814637	-1,275	0,2031
assi	-0,223374	0,680469	-0,3283	0,0742 *
flev	-2,75117	0,776533	3,543	0,0004 ***
size	-0,0186789	0,186932	-0,09992	0,9205
ratio	-0,493520	0,286105	-1,725	0,0854 *

Média var. dependente	0,208644
D.P. var. dependente	2,266051
Soma resíd. quadrados	1812,741
E.P. da regressão	2,222464
Log. da verosimilhança	-820,7021
Critério de Akaike	1651,404
Critério de Schwarz	1670,985
Critério de Hannan-Quinn	1659,181

'Por dentro' da variância = 3,83711
'Por entre' a variância = 1,33326
teta utilizado para quasi-desmediação = 0,358798

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 22,2008
com valor p = 2,45568e-006

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 28,828
com valor p = 8,47232e-006

R^2 ajustado (calculado) = 0,19888

D.5) GLS regression for H_1, H_{1a}, H_{1b}, H_{1c}, H_{1d} (Euronext Lisbon)

Estimativas Efeitos-aleatórios (GLS) usando 217 observações
Incluídas 31 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	-1,31189	1,10063	-1,192	0,2346
assi	1,41991	0,912184	1,557	0,09211 *
flev	-4,25007	0,826906	5,140	6,24e-07 ***
size	-0,635104	0,239473	-2,652	0,0086 ***
ratio	-0,854354	0,491401	-1,739	0,0836 *

Média var. dependente	0,289865
D.P. var. dependente	1,985711
Soma resíd. quadrados	683,1391
E.P. da regressão	1,790873
Log. da verosimilhança	-432,3376
Critério de Akaike	874,6752
Critério de Schwarz	891,5747
Critério de Hannan-Quinn	881,5019

'Por dentro' da variância = 2,6239
'Por entre' a variância = 0,782557
teta utilizado para quasi-desmediação = 0,307903

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 5,84336
com valor p = 0,0156359

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 19,2732
com valor p = 0,000694514

R^2 ajustado (calculado) = 0,18767

D.6) GLS regression for H_2 and H_3 with 2 dummies (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 3374 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,940844	0,152535	6,168	7,74e-010 ***
assi	0,409172	0,235021	1,741	0,0818 *
flev	-0,654082	0,0994825	6,575	5,62e-011 ***
size	-0,137774	0,0553298	-2,490	0,0128 **
ratio	-0,856761	0,0960750	-8,918	7,65e-019 ***
du02	-0,187591	0,0700202	-2,679	0,0074 ***
du05	-0,368056	0,0705971	-5,213	1,97e-07 ***

Média var. dependente	0,510310
D.P. var. dependente	2,050623
Soma resíd. quadrados	13091,15
E.P. da regressão	1,971528
Log. da verosimilhança	-7074,796
Critério de Akaike	14163,59
Critério de Schwarz	14206,46
Critério de Hannan-Quinn	14178,92

'Por dentro' da variância = 2,8006
'Por entre' a variância = 1,44303
teta utilizado para quasi-desmediação = 0,47345

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 713,497
com valor p = 3,47255e-157

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(6) = 41,7057
com valor p = 2,10192e-007

R^2 ajustado (calculado) = 0,18901

D.7) GLS regression for H_2 and H_3 with 2 dummies (Euronext Paris)

Estimativas Efeitos-aleatórios (GLS) usando 2303 observações
Incluídas 329 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,919622	0,163888	5,611	2,25e-08 ***
assi	0,452660	0,286889	1,578	0,08147 *
flev	-0,488256	0,0968178	5,043	4,94e-07 ***
size	-0,0823039	0,0647115	-1,272	0,2036
ratio	-0,995476	0,107160	-9,290	3,48e-020 ***
du02	-0,0986314	0,0776761	-1,270	0,2043
du_05	-0,301800	0,0782869	-3,855	0,0001 ***

Média var. dependente	0,573886
D.P. var. dependente	1,926799
Soma resíd. quadrados	7937,900
E.P. da regressão	1,858970
Log. da verosimilhança	-4692,723
Critério de Akaike	9399,446
Critério de Schwarz	9439,640
Critério de Hannan-Quinn	9414,100

'Por dentro' da variância = 2,33913
'Por entre' a variância = 1,38161
teta utilizado para quasi-desmediação = 0,508204

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 623,026
com valor p = 1,64316e-137

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(6) = 41,2298
com valor p = 2,609e-007

R^2 ajustado (calculado) = 0,17200

D.8) GLS regression for H_2 and H_3 with 2 dummies (Euronext Amsterdam)

Estimativas Efeitos-aleatórios (GLS) usando 483 observações
Incluídas 69 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,608288	0,544678	1,117	0,2646
assi	0,640721	0,694816	0,9221	0,0357 *
flev	2,50690	0,546013	4,591	5,65e-06 ***
size	-0,592269	0,179475	-3,300	0,0010 ***
ratio	-0,0949903	0,383173	-0,2479	0,8043
du02	-0,329206	0,215647	-1,527	0,1275
du_05	-0,402399	0,220582	-1,824	0,0687 *

Média var. dependente	0,537931
D.P. var. dependente	2,423829
Soma resíd. quadrados	2583,049
E.P. da regressão	2,327058
Log. da verosimilhança	-1090,273
Critério de Akaike	2194,545
Critério de Schwarz	2223,805
Critério de Hannan-Quinn	2206,044

'Por dentro' da variância = 3,75201
'Por entre' a variância = 2,12837
teta utilizado para quasi-desmediação = 0,498167

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 111,132
com valor p = 5,53595e-026

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(6) = 11,8782
com valor p = 0,0447413

R^2 ajustado (calculado) = 0,19234

D.9) GLS regression for H_2 and H_3 with 2 dummies (Euronext Brussels)

Estimativas Efeitos-aleatórios (GLS) usando 371 observações
Incluídas 53 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	-0,229398	0,835908	-0,2744	0,7839
assi	-0,154629	0,673457	-0,2296	0,0818 *
flev	-2,20876	0,782113	2,824	0,0050 ***
size	0,0131145	0,185593	0,07066	0,9437
ratio	-0,597378	0,284398	-2,100	0,0364 **
du02	-0,384636	0,248120	-1,550	0,0220
du05	-0,741394	0,253291	-2,927	0,0036 ***

Média var. dependente	0,208644
D.P. var. dependente	2,266051
Soma resíd. quadrados	1729,792
E.P. da regressão	2,176960
Log. da verosimilhança	-812,0135
Critério de Akaike	1638,027
Critério de Schwarz	1665,440
Critério de Hannan-Quinn	1648,915

'Por dentro' da variância = 3,72586
'Por entre' a variância = 1,33326
teta utilizado para quasi-desmediação = 0,368161

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 24,8127
com valor p = 6,31809e-007

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(6) = 22,7036
com valor p = 0,000902081

R^2 ajustado = 0,20646

D.10) GLS regression for H_2 and H_3 with 2 dummies (Euronext Lisbon)

Estimativas Efeitos-aleatórios (GLS) usando 217 observações
Incluídas 31 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	-0,957428	1,10398	-0,8672	0,3868
assi	1,41582	0,910186	1,556	0,01213 *
flev	-4,61115	0,827684	5,571	7,70e-08 ***
size	-0,598184	0,239441	-2,498	0,0132 **
ratio	-1,07928	0,505067	-2,137	0,0338 **
du02	-0,698514	0,272067	-2,567	0,0109 **
du05	-0,101810	0,277734	-0,3666	0,7143

Média var. dependente	0,289865
D.P. var. dependente	1,985711
Soma resíd. quadrados	659,8322
E.P. da regressão	1,768380
Log. da verosimilhança	-428,5712
Critério de Akaike	871,1425
Critério de Schwarz	894,8018
Critério de Hannan-Quinn	880,6998

'Por dentro' da variância = 2,54407
'Por entre' a variância = 0,782557
teta utilizado para quasi-desmediação = 0,318513

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 6,96274
com valor p = 0,00832247

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(6) = 18,3887
com valor p = 0,00533083

R^2 ajustado (calculado) = 0,19745

D.11) GLS regression for H_2 and H_3 with dummy du_{02} (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 3374 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,958289	0,152498	6,284	3,72e-010 ***
assi	0,382421	0,235063	1,627	0,09039 *
flev	-0,688453	0,0995884	6,913	5,65e-012 ***
size	-0,162600	0,0550639	-2,953	0,0032 ***
ratio	-0,815839	0,0957932	-8,517	2,44e-017 ***
du02	-0,332460	0,0645728	-5,149	2,77e-07 ***

Média var. dependente	0,510310
D.P. var. dependente	2,050623
Soma resíd. quadrados	13152,46
E.P. da regressão	1,975846
Log. da verosimilhança	-7082,679
Critério de Akaike	14177,36
Critério de Schwarz	14214,10
Critério de Hannan-Quinn	14190,50

'Por dentro' da variância = 2,84007
'Por entre' a variância = 1,44303
teta utilizado para quasi-desmediação = 0,469753

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 699,882
com valor p = 3,17219e-154

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(5) = 27,1824
com valor p = 5,25615e-005

R^2 ajustado (calculado) = 0,18213

D.12) GLS regression for H_2 and H_3 with dummy du_{05} (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 3374 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,839048	0,147695	5,681	1,45e-08 ***
assi	0,394138	0,235022	1,677	0,0936 *
flev	-0,646198	0,0995212	6,493	9,65e-011 ***
size	-0,137697	0,0553274	-2,489	0,0129 **
ratio	-0,856169	0,0960949	-8,910	8,21e-019 ***
du05	-0,443131	0,0648607	-6,832	9,89e-012 ***

Média var. dependente	0,510310
D.P. var. dependente	2,050623
Soma resíd. quadrados	13108,96
E.P. da regressão	1,972575
Log. da verosimilhança	-7077,090
Critério de Akaike	14166,18
Critério de Schwarz	14202,92
Critério de Hannan-Quinn	14179,32

'Por dentro' da variância = 2,80801
'Por entre' a variância = 1,44303
teta utilizado para quasi-desmediação = 0,472754

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 709,814
com valor p = 2,19544e-156

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(5) = 40,2284
com valor p = 1,34305e-007

R^2 ajustado (calculado) = 0,18422

D.13) GLS regression for H_2 for sub-period pre 2002 (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 964 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 2
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p	
const	0,555722	0,205722	2,701	0,0070	***
assi	0,206817	0,283190	0,7303	0,4654	
flev	-0,930680	0,242663	3,835	0,0001	***
size	-0,140346	0,0626201	-2,241	0,0252	**
ratio	-0,347734	0,111228	-3,126	0,0018	***

Média var. dependente	0,743095
D.P. var. dependente	1,557664
Soma resíd. quadrados	2255,073
E.P. da regressão	1,532656
Log. da verosimilhança	-1777,483
Critério de Akaike	3564,965
Critério de Schwarz	3589,321
Critério de Hannan-Quinn	3574,238

'Por dentro' da variância = 1,27395
'Por entre' a variância = 1,65523
teta utilizado para quasi-desmediação = 0,379656

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 80,5692
com valor p = 2,80695e-019

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 42,4347
com valor p = 1,35555e-008

R^2 ajustado (calculado) = 0,16019

D.14) GLS regression for H_2 for sub-period pos 2002 (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 2410 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 5
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,845589	0,175146	4,828	1,47e-06 ***
assi	0,173365	0,287118	0,6038	0,09460 *
flev	-0,621856	0,111211	5,592	2,50e-08 ***
size	-0,169524	0,0657124	-2,580	0,0099 ***
ratio	-0,949916	0,117346	-8,095	9,00e-016 ***

Média var. dependente	0,417197
D.P. var. dependente	2,210768
Soma resíd. quadrados	10807,17
E.P. da regressão	2,119377
Log. da verosimilhança	-5227,845
Critério de Akaike	10465,69
Critério de Schwarz	10494,63
Critério de Hannan-Quinn	10476,21

'Por dentro' da variância = 3,11147
'Por entre' a variância = 1,98423
teta utilizado para quasi-desmediação = 0,439983

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 430,823
com valor p = 1,07565e-095

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 19,4815
com valor p = 0,000631958

R^2 ajustado (calculado) = 0,17573

D.15) GLS regression for H_3 for sub-period pre 2005 (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 2410 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 5
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	1,00316	0,159766	6,279	4,03e-010 ***
assi	0,250263	0,268743	0,9312	0,09518 *
flev	-0,417133	0,109778	3,800	0,0001 ***
size	-0,164193	0,0602645	-2,725	0,0065 ***
ratio	-0,680613	0,104703	-6,500	9,71e-011 ***

Média var. dependente	0,639274
D.P. var. dependente	2,042748
Soma resíd. quadrados	9558,276
E.P. da regressão	1,993159
Log. da verosimilhança	-5079,867
Critério de Akaike	10169,73
Critério de Schwarz	10198,67
Critério de Hannan-Quinn	10180,26

'Por dentro' da variância = 2,86478
'Por entre' a variância = 1,65769
teta utilizado para quasi-desmediação = 0,412094

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 348,619
com valor p = 8,47128e-078

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 22,4114
com valor p = 0,000165958

R^2 ajustado (calculado) = 0,17080

D.16) GLS regression for H_3 for sub-period pos 2005 (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 964 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 2
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	-0,0330019	0,241641	-0,1366	0,8914
assi	0,377258	0,347977	1,084	0,09786 *
flev	-1,93330	0,254451	7,598	7,14e-014 ***
size	-0,200807	0,0801321	-2,506	0,0124 **
ratio	-1,25265	0,154660	-8,099	1,67e-015 ***

Média var. dependente	0,187903
D.P. var. dependente	2,035776
Soma resíd. quadrados	3348,443
E.P. da regressão	1,867608
Log. da verosimilhança	-1968,024
Critério de Akaike	3946,047
Critério de Schwarz	3970,403
Critério de Hannan-Quinn	3955,320

'Por dentro' da variância = 1,55386
'Por entre' a variância = 2,69716
teta utilizado para quasi-desmediação = 0,463293

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 140,407
com valor p = 2,1693e-032

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 16,5852
com valor p = 0,00232655

R^2 ajustado (calculado) = 0,17984

D.17) GLS regression for H_4 (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 3374 observações
Incluídas 482 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,580467	0,149573	3,881	0,0001 ***
assi	0,367666	0,232255	1,583	0,09935 *
flev	-0,702662	0,0995267	7,060	2,01e-012 ***
size	-0,149929	0,0542941	-2,761	0,0058 ***
ratio	-0,780601	0,0945388	-8,257	2,12e-016 ***
dugs	0,802987	0,172223	4,662	3,25e-06 ***

Média var. dependente	0,510310
D.P. var. dependente	2,050623
Soma resíd. quadrados	13010,61
E.P. da regressão	1,965162
Log. da verosimilhança	-7064,385
Critério de Akaike	14140,77
Critério de Schwarz	14177,51
Critério de Hannan-Quinn	14153,91

'Por dentro' da variância = 2,87131
'Por entre' a variância = 1,38649
teta utilizado para quasi-desmediação = 0,456084

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 628,737
com valor p = 9,41034e-139

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 19,7996
com valor p = 0,000547005

R^2 ajustado (calculado) = 0,20112

D.18) GLS regression for H_4 (Euronext Paris)

Estimativas Efeitos-aleatórios (GLS) usando 2303 observações
Incluídas 329 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,678507	0,159136	4,264	2,09e-05 ***
assi	0,372380	0,282990	1,316	0,09883 *
flev	-0,515605	0,0966157	5,337	1,04e-07 ***
size	-0,0865039	0,0634650	-1,363	0,1730
ratio	-0,957618	0,105495	-9,077	2,33e-019 ***
dugs	0,911844	0,219569	4,153	3,40e-05 ***

Média var. dependente	0,573886
D.P. var. dependente	1,926799
Soma resíd. quadrados	7812,904
E.P. da regressão	1,843874
Log. da verosimilhança	-4674,447
Critério de Akaike	9360,893
Critério de Schwarz	9395,345
Critério de Hannan-Quinn	9373,453

'Por dentro' da variância = 2,37652
'Por entre' a variância = 1,31789
teta utilizado para quasi-desmediação = 0,492446

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 553,549
com valor p = 2,12799e-122

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 31,6156
com valor p = 2,29226e-006

R^2 ajustado (calculado) = 0,18455

D.19) GLS regression for H_4 (Euronext Amsterdam)

Estimativas Efeitos-aleatórios (GLS) usando 483 observações
Incluídas 69 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	-0,137612	0,558514	-0,2464	0,8055
assi	0,656426	0,698578	0,9397	0,09479 *
flev	2,74026	0,544887	5,029	6,99e-07 ***
size	-0,595067	0,178037	-3,342	0,0009 ***
ratio	0,0965878	0,377344	0,2560	0,7981
dugs	0,790445	0,450588	1,754	0,0800 *

Média var. dependente	0,537931
D.P. var. dependente	2,423829
Soma resíd. quadrados	2595,467
E.P. da regressão	2,330203
Log. da verosimilhança	-1091,431
Critério de Akaike	2194,862
Critério de Schwarz	2219,942
Critério de Hannan-Quinn	2204,717

'Por dentro' da variância = 3,8009
'Por entre' a variância = 2,10787
teta utilizado para quasi-desmediação = 0,492458

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 102,139
com valor p = 5,17566e-024

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 12,5935
com valor p = 0,0134424

R^2 ajustado (calculado) = 0,19349

D.20) GLS regression for H_4 (Euronext Brussels)

Estimativas Efeitos-aleatórios (GLS) usando 371 observações
Incluídas 53 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p	
const	-2,46418	0,939654	-2,622	0,0091	***
assi	0,380634	0,701812	0,5424	0,05879	*
flev	-3,49898	0,808792	4,326	1,96e-05	***
size	0,0674563	0,186464	0,3618	0,7177	
ratio	-0,160735	0,303998	-0,5287	0,5973	
dugs	1,76568	0,595715	2,964	0,0032	***

Média var. dependente	0,208644
D.P. var. dependente	2,266051
Soma resíd. quadrados	1764,279
E.P. da regressão	2,195549
Log. da verosimilhança	-815,6754
Critério de Akaike	1643,351
Critério de Schwarz	1666,848
Critério de Hannan-Quinn	1652,683

'Por dentro' da variância = 3,83711
'Por entre' a variância = 1,31844
teta utilizado para quasi-desmediação = 0,355204

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 21,8153
com valor p = 3,00193e-006

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 21,1596
com valor p = 0,000294407

R^2 ajustado (calculado) = 0,20899

D.21) GLS regression for H_4 (Euronext Lisbon)

Estimativas Efeitos-aleatórios (GLS) usando 217 observações
Incluídas 31 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	-1,44146	1,19337	-1,208	0,2284
assi	1,50970	0,937708	1,610	0,09089 *
flev	-4,27488	0,835385	5,117	6,96e-07 ***
size	-0,623283	0,259953	-2,398	0,0174 **
ratio	-0,839130	0,497939	-1,685	0,0934 *
dugs	0,125219	0,624070	0,2006	0,8412

Média var. dependente	0,289865
D.P. var. dependente	1,985711
Soma resíd. quadrados	683,9186
E.P. da regressão	1,796116
Log. da verosimilhança	-432,4613
Critério de Akaike	876,9226
Critério de Schwarz	897,2020
Critério de Hannan-Quinn	885,1147

'Por dentro' da variância = 2,6239
'Por entre' a variância = 0,813501
teta utilizado para quasi-desmediação = 0,321194

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 5,86566
com valor p = 0,0154391

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 19,122
com valor p = 0,000743714

R^2 ajustado (calculado) = 0,19187

D.22) GLS regression for H_4 with Panel A (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 378 observações
Incluídas 54 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p	
const	1,35516	0,643300	2,107	0,0358	**
assi	0,509832	0,889745	0,5730	0,5670	
flev	-0,868894	0,368399	2,359	0,0189	**
size	-0,377813	0,285460	-1,324	0,1865	
ratio	-0,168310	0,430110	-0,3913	0,6958	

Média var. dependente	1,326270
D.P. var. dependente	2,602242
Soma resíd. quadrados	2451,974
E.P. da regressão	2,560485
Log. da verosimilhança	-889,7424
Critério de Akaike	1789,485
Critério de Schwarz	1809,159
Critério de Hannan-Quinn	1797,293

'Por dentro' da variância = 4,10736
'Por entre' a variância = 3,15032
teta utilizado para quasi-desmediação = 0,568427

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 143,812
com valor p = 3,90658e-033

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 4,16418
com valor p = 0,0384242

R^2 ajustado (calculado) = 0,15378

D.23) GLS regression for H_4 with Panel B (full sample)

Estimativas Efeitos-aleatórios (GLS) usando 2996 observações
Incluídas 428 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
const	0,620158	0,143174	4,331	1,53e-05 ***
assi	0,286503	0,230736	1,242	0,09144 *
flev	-0,665643	0,101457	6,561	6,28e-011 ***
size	-0,124669	0,0523271	-2,383	0,0173 **
ratio	-0,845250	0,0921576	-9,172	8,43e-020 ***

Média var. dependente	0,407362
D.P. var. dependente	1,946472
Soma resíd. quadrados	10475,64
E.P. da regressão	1,871154
Log. da verosimilhança	-6126,298
Critério de Akaike	12262,60
Critério de Schwarz	12292,62
Critério de Hannan-Quinn	12273,40

'Por dentro' da variância = 2,7209
'Por entre' a variância = 1,15425
teta utilizado para quasi-desmediação = 0,419692

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 417,59
com valor p = 8,16715e-093

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 19,3143
com valor p = 0,000681701

R^2 ajustado (calculado) = 0,17670

D.24) GMM regression for H_5 (full sample)

Estimativas Arellano-Bond de uma fase usando 2410 observações
Incluídas 482 unidades de secção-cruzada
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
Drov(-1)	0,474751	0,0656166	7,235	4,65e-013 ***
const	-0,0191882	0,0790893	-0,2426	0,08083 *
assi	0,0766493	0,142186	0,5391	0,05898 *
flev	-0,0500924	0,129557	-0,3866	0,06990 *
size	0,0546249	0,0281366	1,941	0,0522 *
ratio	-0,273172	0,0962716	-2,838	0,0045 ***

Soma resíd. quadrados 17760,57 E.P. da regressão 2,718074

Testar erros AR(1): z = -6,93665 [0,0000]
Testar erros AR(2): z = 0,047584 [0,9620]
Teste de Sargan para a sobre-identificação: Qui-quadrado(14) = 48,9803 [0,0000]
Teste de Wald (conjunto): Qui-quadrado(5) = 81,2124 [0,0000]

Teste da normalidade dos resíduos -
Hipótese nula: o erro tem distribuição Normal
Estatística de teste: Qui-quadrado(2) = 4251,68
com valor p = 0

R^2 ajustado = 0,21356

D.25) GMM regression for H_5 (Euronext Paris)

Estimativas Arellano-Bond de uma fase usando 1645 observações
Incluídas 329 unidades de secção-cruzada
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
Drov(-1)	0,552772	0,0883279	6,258	3,89e-010 ***
const	0,00781330	0,0838492	0,09318	0,09258 *
assi	0,0257092	0,149798	0,1716	0,8637
flev	-0,0852238	0,137808	-0,6184	0,05363 *
size	0,0704295	0,0301361	2,337	0,0194 **
ratio	-0,277523	0,109073	-2,544	0,0109 **

Soma resíd. quadrados 10453,48 E.P. da regressão 2,525463

Testar erros AR(1): z = -5,00464 [0,0000]
Testar erros AR(2): z = 0,228012 [0,8196]
Teste de Sargan para a sobre-identificação: Qui-quadrado(14) = 30,5177 [0,0065]
Teste de Wald (conjunto): Qui-quadrado(5) = 61,6502 [0,0000]

Teste da normalidade dos resíduos -
Hipótese nula: o erro tem distribuição Normal
Estatística de teste: Qui-quadrado(2) = 2762,91
com valor p = 0

R^2 ajustado = 0,20125

D.26) GMM regression for H_5 (Euronext Amsterdam)

Estimativas Arellano-Bond de uma fase usando 345 observações
Incluídas 69 unidades de secção-cruzada
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
Drov(-1)	0,408355	0,157025	2,601	0,0093 ***
const	-0,181968	0,269009	-0,6764	0,4988
assi	0,0860383	0,294525	0,2921	0,07702 *
flev	0,180471	0,751492	0,2401	0,08102 *
size	0,0375900	0,107207	0,3506	0,07259 *
ratio	-0,338874	0,211999	-1,598	0,1099

Soma resíd. quadrados 3249,240 E.P. da regressão 3,095929

Testar erros AR(1): z = -3,37715 [0,0007]
Testar erros AR(2): z = 1,16407 [0,2444]
Teste de Sargan para a sobre-identificação: Qui-quadrado(14) = 35,3928 [0,0013]
Teste de Wald (conjunto): Qui-quadrado(5) = 22,2454 [0,0005]

Teste da normalidade dos resíduos -
Hipótese nula: o erro tem distribuição Normal
Estatística de teste: Qui-quadrado(2) = 455,718
com valor p = 1,10151e-099

R^2 ajustado = 0,19678

D.27) GMM regression for H_5 (Euronext Brussels)

Estimativas Arellano-Bond de uma fase usando 265 observações
Incluídas 53 unidades de secção-cruzada
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
Drov(-1)	0,236951	0,0839308	2,823	0,0048 ***
const	-0,334944	0,618558	-0,5415	0,5882
assi	0,208050	0,590063	0,3526	0,07244 *
flev	-0,00548782	0,585102	-0,009379	0,09925 *
size	0,0700538	0,120138	0,5831	0,5598
ratio	-0,181101	0,230526	-0,7856	0,04321 **

Soma resíd. quadrados 2229,736 E.P. da regressão 2,934113

Testar erros AR(1): z = -2,86504 [0,0042]
Testar erros AR(2): z = -0,329199 [0,7420]
Teste de Sargan para a sobre-identificação: Qui-quadrado(14) = 22,8822 [0,0422]
Teste de Wald (conjunto): Qui-quadrado(5) = 10,3524 [0,0658]

Teste da normalidade dos resíduos -
Hipótese nula: o erro tem distribuição Normal
Estatística de teste: Qui-quadrado(2) = 395,108
com valor p = 1,59734e-086

R^2 ajustado = 0,21989

D.28) GMM regression for H_5 (Euronext Lisbon)

Estimativas Arellano-Bond de uma fase usando 155 observações
Incluídas 31 unidades de secção-cruzada
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
Drov(-1)	-0,00785354	0,0706539	-0,1112	0,9115
const	-0,337777	0,609268	-0,5544	0,05793 *
assi	-0,864924	0,993924	-0,8702	0,03842 **
flev	-1,86674	0,876384	2,130	0,0332 **
size	-0,0635349	0,0746793	-0,8508	0,3949
ratio	-0,501878	0,487330	-1,030	0,3031

Soma resíd. quadrados 1056,478 E.P. da regressão 2,662791

Testar erros AR(1): z = -2,15298 [0,0313]
Testar erros AR(2): z = -1,06844 [0,2853]
Teste de Sargan para a sobre-identificação: Qui-quadrado(14) = 65,4034 [0,0000]
Teste de Wald (conjunto): Qui-quadrado(5) = 10,5036 [0,0622]

Teste da normalidade dos resíduos -
Hipótese nula: o erro tem distribuição Normal
Estatística de teste: Qui-quadrado(2) = 140,748
com valor p = 2,73565e-031

R^2 ajustado = 0,19670

D.29) GLS regression for robustness analysis with variable SIZEM (static model)

Estimativas Efeitos-aleatórios (GLS) usando 1686 observações
Incluídas 241 unidades de secção-cruzada
Comprimento da série temporal: mínimo 6, máximo 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p	
const	1,35383	0,289380	4,678	3,12e-06	***
assi	0,566702	0,327314	1,731	0,0836	*
flev	-0,511129	0,127539	4,008	6,40e-05	***
sizem	-0,498016	0,0784980	-6,344	2,87e-010	***
ratio	-0,600408	0,159941	-3,754	0,0002	***

Média var. dependente	0,269795
D.P. var. dependente	1,980032
Soma resíd. quadrados	6293,037
E.P. da regressão	1,934270
Log. da verosimilhança	-3502,633
Critério de Akaike	7015,266
Critério de Schwarz	7042,416
Critério de Hannan-Quinn	7025,321

'Por dentro' da variância = 2,55449
'Por entre' a variância = 1,38968

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 364,5
com valor p = 2,94904e-081

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 74,5602
com valor p = 2,4685e-015

R^2 ajustado = 0,18003

D.30) GMM regression for robustness analysis with variable SIZEM (dynamic model)

Estimativas Arellano-Bond de uma fase usando 1205 observações
Incluídas 241 unidades de secção-cruzada
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
Drov(-1)	0,391632	0,104375	3,752	0,0002 ***
const	-0,101770	0,126488	-0,8046	0,4211
assi	0,211792	0,221744	0,9551	0,03395 **
flev	-0,0126719	0,0730746	-0,1734	0,08623 *
sizem	0,0131735	0,0457805	0,2878	0,07735 *
ratio	-0,126789	0,109751	-1,155	0,02480 **

Soma resíd. quadrados 7947,586 E.P. da regressão 2,574590

Testar erros AR(1): z = -5,35615 [0,0000]
Testar erros AR(2): z = -0,933025 [0,3508]
Teste de Sargan para a sobre-identificação: Qui-quadrado(14) = 80,4985 [0,0000]
Teste de Wald (conjunto): Qui-quadrado(5) = 28,0483 [0,0000]

Teste da normalidade dos resíduos -
Hipótese nula: o erro tem distribuição Normal
Estatística de teste: Qui-quadrado(2) = 2455,12
com valor p = 0

R^2 ajustado = 0,20886

D.31) GLS regression for robustness analysis with variable EPS (static model)

Estimativas Efeitos-aleatórios (GLS) usando 2716 observações
Incluídas 388 unidades de secção-cruzada
Comprimento da série temporal = 7
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p	
const	0,743255	0,155245	4,788	1,78e-06	***
assi	0,115935	0,248839	0,4659	0,6413	
flev	-0,481349	0,0943293	5,103	3,58e-07	***
size	-0,303795	0,0569289	-5,336	1,03e-07	***
eps	-0,0270653	0,00297898	-9,085	1,94e-019	***

Média var. dependente	0,393142
D.P. var. dependente	1,890248
Soma resíd. quadrados	8949,954
E.P. da regressão	1,816626
Log. da verosimilhança	-5473,236
Critério de Akaike	10956,47
Critério de Schwarz	10986,01
Critério de Hannan-Quinn	10967,15

'Por dentro' da variância = 2,31501
'Por entre' a variância = 1,31078
teta utilizado para quasi-desmediação = 0,4977

Teste de Breusch-Pagan -
Hipótese nula: Variância do erro de unidade-específica = 0
Estatística de teste assimptótica: Qui-quadrado(1) = 700,431
com valor p = 2,41003e-154

Teste de Hausman -
Hipótese nula: As estimativas GLS são consistentes
Estatística de teste assimptótica: Qui-quadrado(4) = 11,2274
com valor p = 0,0241238

R^2 ajustado = 0,16120

D.32) GMM regression for robustness analysis with variable EPS (dynamic model)

Modelo 2: Estimativas Arellano-Bond de uma fase usando 1940 observações
Incluídas 388 unidades de secção-cruzada
Variável dependente: rov

	coeficiente	erro padrão	rácio-t	valor p
Drov(-1)	0,474230	0,0790013	6,003	1,94e-09 ***
const	-0,0472167	0,0793696	-0,5949	0,5519
assi	0,00861243	0,122109	-0,07053	0,9438
flev	-0,0291578	0,130557	-0,2233	0,08233 *
size	0,0268669	0,0197257	1,362	0,01732 **
eps	-0,0105804	0,00610692	-1,733	0,0832 *

Soma resíd. quadrados 11649,89 E.P. da regressão 2,454329

Testar erros AR(1): z = -5,31418 [0,0000]
Testar erros AR(2): z = 0,368037 [0,7128]
Teste de Sargan para a sobre-identificação: Qui-quadrado(14) = 43,5021 [0,0001]
Teste de Wald (conjunto): Qui-quadrado(5) = 56,6372 [0,0000]

Teste da normalidade dos resíduos -
Hipótese nula: o erro tem distribuição Normal
Estatística de teste: Qui-quadrado(2) = 3312,74
com valor p = 0

R^2 ajustado = 0,19207

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