The impact of growth options on systematic risk: The case of European firms

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ABSTRACT: This paper focuses on an analysis of the relation between systematic risk and growth opportunities from the real options perspective. Assuming the risk of current and future businesses to be independent from ownership (i.e. from whichever firm invests in them), we deduce that the systematic risk of a firm's equity depends on the weight of growth options on its market value. We test this hypothesis by analysing a sample of 958 European firms over the period 2001-2005. Our findings bear out the impact of growth options on systematic risk and are robust to different splits of the sample into risk groups, thus providing new insights to interpret the findings to emerge from multifactor market models.

Key words: Real Options, Growth Opportunities, Beta, Systematic Risk, Assets-in-Place.

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I. Introduction

The *Capital Asset Pricing Model* (CAPM) states that expected return on an asset is a linear function of its non-diversifiable risk. This non-diversifiable or systematic risk of an asset is defined as the sensitivity of its return to changes in returns on the market (all risk assets) portfolio and is measured from the so-called beta coefficient. Despite the robustness of CAPM principles, empirical evidence to emerge over the last forty years calls into question the model's explanatory power.

After the beta having been discarded and subsequently retrieved, the empirical diagnosis seems clear: although average stock return is linked lineally and positively to its beta, one area of variability remains unaccounted for by the beta, and is related to other factors such as firm size or its equity book to market ratio (Reinganum, 1981; Fama and French, 1992; Kothari *et al*., 1995). What is not evident are the reasons which account for outcomes contrary to the CAPM, which might be due to problems measuring the expected return and the systematic risk, biases in the sample selection, temporary parameter instability, the multidimensional nature of risk or merely the inaccuracy of the initial suppositions.

A convincing alternative to the CAPM should provide empirical results not undermined by any disadvantages in its theoretical basis as well as simplicity of its implications. It might meanwhile be worth analyzing the nature and dynamics of beta and its determinants. Regarding this issue a number of proposals, including the ground-breaking work of Hamada (1972) and Galai and Masulis (1976), linked the firm's equity beta with factors such as the level of financial leverage, debt maturity, income volatility, cyclicality, operating leverage, dividends or non-optional growth, amongst others (Beaver *et al*., 1970; Beaver and Manegold, 1975; Brenner and Smidt, 1978; Bowman, 1979; Gahlon and Gentry, 1982; Mandelker and Ghon, 1984; Arcas, 1991).

More recently, Myers and Turnbull (1977); Chung and Charoenwong (1991); Jacquier *et al.* (2001); and Bernardo *et al*. (2007) assessed the impact of growth options on the systematic risk of a firm's stock and the effect which exercising them, and subsequent conversion to assets-in-place, has on the changes recorded in the beta over time. Similarly, Berk, Green and Naik (1999) and Carlson *et al*. (2004) illustrated that the impact of size and book to market ratio on the dynamic relation between return and risk might be due to continuous and imperceptible changes in a firm's current business and its future growth options.

Underlying all these latter models is the basic precept of the real options approach, by which the firm's market value reflects the value of its assets-in-place plus the value of the decisions yet to be taken, but for which the firm is in an advantageous position to make (its growth options). Empirical evidence found in papers such as Kester (1984 and 1986); Paddock, Siegel and Smith (1988); Quigg (1993); Al-Horani, Pope and Stark (2003); Adam and Goyal (2006) and Andrés *et al*. (2006) bear out the effective market valuation of growth opportunities in various sectors and countries.

Our work draws on this valuation hypothesis to analyse the factors determining systematic risk. In the same way as the risk of a derivative is greater than the risk of its underlying asset, the real options approach states that a firm's growth options evidence a greater level of risk than its underlying business. Hence, a firm's level of risk not only depends on the relative weight of its assets-in-place and growth options in the total value of the firm, as any changes in this distribution may also impact changes in the risk and return of its stock price.

Deducing the linear decomposition of a stock's beta based on the weight of the growth options and financial leverage, as posited in previous works (Chung and Charoenwong, 1991; García and Herrero, 2001; Bernardo *et al*., 2007), requires the risk of assets in place and growth options to be independent from whichever firm invests in them. Recognising this requirement has significant methodological consequences for empirically verifying the impact of real options on systematic risk. Firstly, it assumes the existence of risk classes, each of which covers all firms whose current businesses and growth options present similar risk levels. Secondly, it implies specific variable definitions to measure growth option value weight and financial leverage.

To test our hypothesis on a firm's beta decomposition we apply ordinary Least Squares (OLS) regression to a panel of 4,790 observations, for 958 non-financial firms in the EU-15 member states over the period 2001-2005. Our results confirm the explanatory power of financial leverage on the variability of systematic risk. As evidenced in previous literature, the estimated stock beta depends positively and significantly on financial leverage. However, our analysis bears out the importance of the relative weight of the growth options in accounting for changes in systematic risk. When distinguishing between different kinds of risk, our results reveal that the impact of growth options on stock betas may be even greater than the influence of financial leverage. The main consequence of this finding is that changes in a firm's stock beta are closely linked to the rebalancing of the weight of its growth opportunities and assets-in-place.

Our paper makes a twofold contribution. First, we posit a simple model from which to infer the assumptions required by the dependency relation linking a firm's equity risk to the value of its growth options. Second, we empirically test the weight of growth options in market values of European firms and by provide fresh evidence regarding the impact of this value on stock risk.[1] The relevance of furthering our understanding of the link between return and risk goes beyond the limits of financial investment, since it has a direct impact on the majority of firms' investment strategies. This is reflected in studies analysing capital budgeting practices, where the beta plays a key role, both in valuations as well as in decisions taken. Previous works such as those of Myers and Turnbull (1977); Dandbolt *et al.* (2002); Hirst *et al.* (2008) and Bernardo *et al.* (2007), have already alerted to the impact which growth options have on a firm's capital cost and, indirectly, on its capital budgeting decisions.

The remainder of the paper is organised as follows. Section II deals with the theoretical fundamentals and posits the hypotheses. Section III sums up the characteristics of the empirical analysis: sample, variables and econometric models. Section IV provides and analyses the results obtained in the estimation of the models. Section V discusses the main conclusions of the work.

II. Basis of the link between systematic risk and growth options

The real options approach states that a firm's asset portfolio comprises two differing components: assets-in-place, and real options (Myers, 1977 and 1984). Assets-in-place refers to allocation of resources which a firm has already undertaken and not abandoned. The value of this component emerges from the cash-flows which are expected to be generated over time. Yet, a firm's market value is determined not only

[1] Our paper has a number of similarities with Chung and Charoenwong (1991) and, particularly, Bernardo et al. (2007), as it posits the linear decomposition of a firm's beta into its assets-in-place beta and its growth options beta, and demonstrates that the latter is greater than the former. However, our analysis differs in at least two important issues, apart from the sample. First, we do not use the market-to-book ratio to proxy the ratio of the value of assets-in-place to the total value of the firm. Rather, we estimate it as the present value of the perpetuity of cash flows which is expected to be generated by assets-in-place, and the beta of the latter, which is proxied by the accounting beta. Second, Bernardo *et al*. (2007) consider the beta of assets-in-place to be constant within an industry, but do not use this hypothesis to approximate assets-in-place value. By contrast, we use the assumption of invariable betas of assets-in-place within an industry both to estimate the weight of a growth option value and to test the model.

by the expected cash-flow of a specific allocation of resources, but by the resources themselves and, therefore, the cash-flows as generated by any other allocation the firm might make. The rights to decide over various allocations of resources and capabilities have value in so far as exercising them will impact the firm's future cash-flows.

Should this concept of value prove certain, the hypothesis of efficient markets predicts that a firm's total market value should reflect what emerges from its real options portfolio. Kester (1984) provided early evidence of the relevance of assets other than assets-in-place when accounting for the market value of a sample of large US firms. This was an indirect estimation that paved the way for subsequent works such as Danbolt *et al.* (2002), Ramezani (2003) or Andrés *et al*. (2006), who confirmed the relevance of real growth options in the valuations which investors make of company stocks.[2]

If growth options influence a firm's market value, it would seem logical to assume that return and risk also reflect the nature of the firm's assets as well as changes therein over time. In fact, of these two components of a firm's market value, the one which theoretically evidences greatest volatility is growth options. Further, the real option approach has demonstrated that these growth options increase in value when the risk of the underlying business increases (Trigeorgis, 1988; Dixit and Pindyck, 1995; Herath and Park, 1999). It would therefore not seem reasonable to attempt to explain the intensity and variations in risk in a firm and its stocks without taking due account of the relative weight of its growth options and their subsequent conversion to assets-in-place.

This view might help understand part of the accumulated empirical evidence contrary to the CAPM and the role played by various factors other than the beta when explaining

[2] This evidence is furthered with that drawn from specific resources, such as offshore petroleum reserves (Paddock, Siegel and Smith, 1988; and Adam and Goyal, 2006) and building land (Quigg, 1993).

stock returns. These other explanatory factors, such as size of "*book to market*" ratio, might, in fact, be approximating the weight of the growth options on the firm's market value and changes therein due to the subsequent and discretional implementation thereof.

Myers and Turnbull (1977) provided early evidence of the impact of a firm's growth options on the systematic risk of its stocks and Jacquier *et al.* (2001) showed that growth options entail higher beta coefficients than investments in place. Chung and Charoenwong (1991) and García and Herrero (2001), pointed out that firms displaying the greatest potential for growth are those with the highest betas. Finally, works such as Adam and Goyal (2006) or Andrés *et al*. (2006) provide empirical evidence linking the variables *book to market* and size to the estimated value of growth options.

By directly applying the definition of the beta of a portfolio to the real option decomposition of a firm's market value, we may infer that a firm's beta is the weighted average of the beta of its assets-in-place and its growth options, each of the weights being equal to the stake each of the two components holds in the total market value. In analytical terms:

$$\beta_{U_i} = \beta_{AIP_i} \cdot \frac{V_{AIP_i}}{V_i} + \beta_{GO_i} \cdot \frac{V_{GO_i}}{V_i} \qquad (1)$$

where β_{U_i} and V_i represent, respectively, the beta and the total value of the firm i; β_{AIP_i} and V_{AIP_i} measure, respectively, the beta and the value of its assets-in-place; and β_{GO_i} and V_{GO_i} measure, respectively, the systematic risk and the value of its growth options.

Since $\frac{V_{AIP_i}}{V_i} + \frac{V_{GO_i}}{V_i} = 1$, equation (1) may also be formulated as follows:

$$\beta_{U_i} = \beta_{AIP_i} + \left(\beta_{GO_i} - \beta_{AIP_i}\right) \cdot \frac{V_{GO_i}}{V_i} \tag{2}$$

Expression (2) relates the firm's beta to the value weight of its growth options on the total value of its assets, the systematic risk of its assets-in-place and the systematic risk of its growth options. Determining the kind of functional relation (linear, quadratic, exponential…) and the sign of the influence requires more detailed analysis.

Firstly, it is clear that when the value of the growth options is zero ($\frac{V_{GO_i}}{V_i} = 0$), the firm's beta coincides with the beta of its assets-in-place ($\beta_{U_i} = \beta_{AIP_i}$). In other words, the minimum value of the firm's systematic risk is equal to the systematic risk of its assets-in-place. For the remaining cases, the impact of the weight of the growth options depends on the sign of the difference between the beta of these opportunities and that of its current business ($\beta_{GO_i} - \beta_{AIP_i}$).

It is easy to demonstrate that the volatility of an option is always greater than that of its underlying, which is usually extended to indicate that an option's systematic risk is greater than that corresponding to its underlying asset (Myers and Turnbull, 1977; Chung and Charoenwong, 1991; Berk *et al*., 2004; Carlson *et al*., 2004). As a result, for the difference of the betas to be positive ($\beta_{GO_i} - \beta_{AIP_i} > 0$), it is sufficient for growth options to be based on future business whose systematic risk is equal to or greater than that of existing business. This would not hold if the future business risk on which the growth options are based were appreciably lower than current business. Yet, this is unlikely to occur, since this increased risk for future business is one of the main reasons why the firm would defer the investment option and not turn the opportunity into actual business.

Further, the nature of the function linking the firm's beta to the weight of its growth options in turn depends on the link between the difference of the betas ($\beta_{GO_i} - \beta_{AIP_i}$) and the relative weight of the options ($\frac{V_{GO_i}}{V_i}$). If the risk of the growth options and of the existing business were independent from the amount of resources allocated by the firm to each type of asset, the functional relation of the firm's beta, defined in equation (2), would be linear and increasing in the weight of the investment options.

Treating the betas of the assets-in-place and the growth opportunities as independent or exogenous variables depends on how the elements in equation (1) are defined. Taking these betas as exogenous implies applying the same criteria used to calculate the beta of a portfolio based on the weighted average of the exogenous betas of the financial assets of which it is composed. In the case of firms, defining the betas as exogenous does not require firms to maintain the same exposure to risk. On the contrary, it implies that the risk inherent in each asset is independent from the firm assuming it, each firm's exposure to risk being proportional to the investment effort required in each of the assets.

The exogeneity of these betas allows us to divide the universe of firms into risk classes similar to those defined by Modigliani and Miller, each of which is characterised by the same systematic risk of its assets-in-place and growth options.[3] In this case, equation (2) adopts the functional form of the following line with a positive slope:

$$\beta_{U_i} = a_k + b_k \cdot \frac{V_{GO_i}}{V_i} \qquad \forall i \in k \tag{3}$$

where a_k represents the beta of the assets-in-place of risk type k and which, by definition, is equal for all firms belonging to risk class k; and b_k reflects the difference, equally constant in this group of firms, between the beta of the current business and the beta of the growth opportunities.

The linear and positive relation between systematic risk and the weight of growth options has already been reported in the literature (Chung and Charoenwong, 1991 and García and Herrero, 2001). Yet, these studies do not delve deeply into the suppositions on which this functional form is based, nor do they address the need to reference the link to the firm's kind of business risk. The exception is the paper of Bernardo *et al.* (2007), which assumes the beta of assets-in-place to be the same for all firms in the same industry at any point in time.

To determine the relation in terms of the systematic stock risk, equivalent to that reported in previous literature, we need only formulate firm systematic risk in terms of the beta of its stock and debt (Fernández, 2004), in other words:

$$\beta_{\mathrm{U_i}} = \beta_{\mathrm{E_i}} \cdot \frac{\mathrm{E_i}}{\mathrm{V_i}} + \beta_{\mathrm{D_i}} \cdot \frac{\mathrm{D_i} \cdot (1-\mathrm{t})}{\mathrm{V_i}} \tag{4}$$

[3] Given the close dependency between a firm's investment options and its actual business, it seems by no means far-fetched to assume that the investment options risk of firms engaged in business with the same risk should also concur.

where β_{Ei} and E_i represent, respectively, systematic risk and the market value of the firm's shares i, β_{Di} and D_i reflect, respectively, the systematic risk and the debt value; and t is the tax rate.

Assuming the systematic risk of the debt to be zero and replacing equation (4) in equation (1) we obtain:

$$\beta_{E_i} \cdot \frac{E_i}{V_i} = \beta_{AIP_i} \cdot \frac{V_{AIP_i}}{V_i} + \beta_{GO_i} \cdot \frac{V_{OC_i}}{V_i} \tag{5}$$

Rearranging and bearing in mind that $V_{AIP_i} = E_i + D_i - V_{GO_i}$, we have:

$$\beta_{E_i} = \beta_{AIP_i} \cdot \frac{V_i}{E_i} + \left(\beta_{GO_i} - \beta_{AIP_i}\right) \cdot \frac{V_{GO_i}}{E_i} \tag{6}$$

which for firms belonging to the same risk class k, becomes the following equation:

$$\beta_{E_i} = a_k \cdot \frac{V_i}{E_i} + b_k \cdot \frac{V_{GO_i}}{E_i} \qquad \forall i \in k \tag{7}$$

where a_k and b_k once again reflect the same information on the risk of the assets-in-place and growth options as in equation (3); the first quotient is a measure of the financial leverage and the second is a proxy of the relative weight of the real options in the firm's value.[4]

Equation (7) may be expressed in the form of an empirically verifiable hypothesis in the following terms: *Within a single risk class, the systematic risk of a firm's stock depends lineally and positively on the weight of the value of its growth options, measured on the*

[4] Including this measure of debt harks back to the proposals of Hamada (1972) and Galai and Masulis (1976), who posited an explanation of systematic stock risk based on a firm's financial leverage.

market capitalisation value, and likewise depends on the level of leverage, proxied by the ratio of the total value of the firm to the market capitalisation value.

III Sample, variables and econometric model

III.1 Sample.

The sample used to test our hypothesis comprises all European non-financial firms listed on a stock exchange of an EU-15 member state, as provided by *Thomson One Banker* database. We excluded from the list of firms those which did not provide data required to estimate the variables in the study. Specifically, we removed those firms whose accounting and market information prevented estimating variables for three or more consecutive years within the period 2001-2005; as well as those which showed a negative profit for the period being analysed.[5]

After filtering, the sample comprised a total of 958 firms with 4,790 observations. Table 1 shows the distribution of the firms in the sample across industries, based on their 2-digit SIC code, and countries of origin.

Table 1: Number of firms in the sample by industry and country

This table shows the distribution of the number of firms in the sample by country of origin and business sector. The columns reflect the eight industries into which the sample is classified, in line with the following classification. (1): Agriculture, Mining and Other sectors; (2): Home and Office Products; (3): Other manufacturers; (4): Transport and Telecommunications; (5): Wholesale and Retail; (6): Professional and other services.

	(1)	(2)	(3)	(4)	(5)	(6)	Total	%
Austria	1	5	9	4	0	0	19	1.98
Belgium	3	6	6	3	5	0	23	2.40
Denmark	1	8	5	5	4	7	30	3.13
Finland	3	7	8	3	4	3	28	2.92
France	10	31	44	11	31	14	141	14.71
Germany	9	33	54	14	23	12	145	15.14
Greece	10	14	12	5	12	3	56	5.85
Ireland	3	4	1	1	4	0	13	1.36
Italia	5	11	18	10	0	3	47	4.91

[5] This is a common requirement in studies which demand an estimation of the value of growth options from the difference between the market value of the firm and the value of its assets-in-place. Using it introduces a bias in selection which is obvious and is caused by excluding those firms whose market value is determined solely by their growth options.

Luxemburg	1	1	0	2	0	0	4	0.42
Netherlands	7	16	7	3	7	7	47	4.91
Portugal	1	5	2	3	3	0	14	1.46
Spain	6	6	11	7	3	6	39	4.07
Sweden	4	11	19	2	8	4	48	5.01
UK	36	59	72	30	58	49	304	31.73
Total	100	217	268	103	162	108	958	
%	10.44	22.65	27.97	10.75	16.91	11.27		

III.2 Variables

To test our hypothesis regarding beta decomposition we have to approximate the values attributable to the firm, its equity and its growth opportunities, the beta of assets-in-place, and the risk classes into which the sample is divided.

The growth options value of firm i (V_{GO_i}) is obtained from the difference of the total market value of firm i (V_i) and the market value of its assets-in-place (V_{AIP_i}):

$$V_{GO_i} = V_i - V_{AIP_i}$$

A firm's market value is calculated as the market value of equity (E_i) less the book value of equity (BVE_i) plus the book value of assets (BVA_i). Therefore:

$$V_i = E_i - BVE_i + BVA_i$$

The value of assets-in-place for firm i (V_{AIP_i}) is determined from the present value of current earnings before interest expense and after income taxes. Linking the cash-flow generated by a firm's assets-in-place to this specific measure of its income is coherent with a policy of reinvestment in maintaining current assets, and therefore with an annual flow of investments equal to annual accounting depreciation, while preserving the levels linked to current assets and debt (Fernández, 2004). In analytical terms:

$$V_{AIP_i} = \frac{NI_i + r_i \cdot D_i \cdot (1-t)}{K_{AIP_k}}$$

where NI_i is the net income of firm i, and $r_i \cdot D_i \cdot (1-t)$ represents its after tax interest expenses. The discount rate K_{AIP_k} is the median of K_{AIP_i} for all firms in risk class k. K_{AIP_i} is estimated from a proxy of the beta of assets-in-place, obtained by estimating the following regression:

$$ROA_i = c_i + \beta_{AIP_i} \cdot ROA_M + e_i$$

That is:

$$\beta_{AIP_i} = \frac{\text{cov}(ROA_i, ROA_M)}{\text{var}(ROA_M)}$$

where ROA_i is the ratio of earnings before interest and after tax in the current year to the book value of the firm in the previous period:

$$ROA_i = \frac{BN_i + r_i \cdot D_i \cdot (1-t)}{BVA_i}$$

and ROA_M is the market equivalent of ROA_i which is calculated as

$$ROA_M = \sum_{i=1}^{n} \frac{ROE_i}{n}$$

n being the number of firms in the sample.[6] The series used to estimate $\text{cov}(ROA_i, ROA_M)$ and $\text{var}(ROA_M)$ are built using the 12 most recent annual values. For robustness analysis, we test our model with another proxy for the beta of assets-in-

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[6] Similarly, Chung and Charoenwong (1991), and García and Herrero (2001) estimate the beta of equity associated with assets-in-place by using the return on equity (ROE).

place, which derives from accounting beta as defined by Damodaran (2002). That is, accounting beta of firm i is obtained by regressing the 12 most recent annual changes in its profits against corresponding changes in profits for all firms in the sample.

The stock beta is estimated using the traditional market model, with monthly stock returns recorded over the last five years. Hence,

$$\beta_{E_i} = \frac{\operatorname{cov}\left(R_{E_i}, R_M\right)}{\operatorname{var}\left(R_M\right)}$$

where $R_{E_{i,t}} = \frac{P_{i,t} - P_{i,t-1} + DPS_{i,t}}{P_{i,t-1}}$, and $R_{M,t} = \sum_{i=1}^{n} \frac{R_{i,t}}{n}$, $P_{i,t}$ being the stock price for firm i, and $DPS_{i,t}$ the dividend per share paid by firm i in $(t-1, t)$.

Finally, we sorted the sample into risk classes. To do this, we classify each firm into six main industries as per SIC code. We defined dummy variables (D1, D2, D3, D4 and D5) to identify the firm's group of origin.

Table 2 shows the statistics for the main variables used for estimating equation (7), namely, equity beta, beta of assets-in-place, growth option's weight value, financial leverage and equity market value.

The mean and the median of the equity beta for the sample are close to the unit, as expected. The standard deviation is 59.17% with a range of -0.82 to 3.05. Even more dispersed is the distribution of the beta of assets-in-place. With a mean and a median of 0.83 and 0.26 respectively, its values range from -151.63 to 422.26, showing a standard deviation of 12.39.

Table 2: Summary statistics

This table presents the descriptive statistics for our sample. We have a total of 4,790 observations for a sample of 958 companies for the period 2001-05. All data are obtained in US$ from Thomson One Banker database. The variables are defined as follows. β_{E_i} measures the systematic risk of equity and is estimated on a monthly basis using returns of the previous five years. The market portfolio M is estimated using all the firms in the sample. β_{AIP} measures the systematic risk of assets-in-place and is calculated from returns on assets over the last 12 years. Return on assets is defined as the ratio of earnings before interest and after tax in the current year to the book value of the firm in the previous period. V_{GO}/E is a measure of the weight of the value of growth options on the market value of equity. The value of growth options is calculated from the difference between the firm's market value and the value of its assets-in-place. The value of assets-in-place is estimated from the present value of the current earnings before interest and after tax in perpetuity. The discount rate to be used for determining the value of assets-in-place is obtained as the median of $K_{AIP\,i}$ for all firms belonging to the same industry. $K_{AIP\,i}$ is obtained from CAPM and β_{AIP}. The risk free rate is estimated from returns in US Treasury Bonds and the risk premium is considered stable and equal to 4.23% as estimated by Fama and French (2002). V/E is a measure of the financial leverage. The firm's market value is calculated as the market value of equity (E) less the book value of equity (BVE) plus the book value of assets (BVA). Also included are the statistics for the equity market value: E.

Variable	Mean	Median	Std dev.	Minimum	Maximum
β_E	0.98607	0.91916	0.59169	-0.82972	3.04848
β_{AIP}	0.83316	0.26251	12.39127	-151.63220	422.26510
V_{GO}/E	0.42320	0	2.67777	0	109.11110
V/E	2.29171	1.75123	2.13206	1.00040	34.82944
E (US$ million)	3 856.2959	324.301	13 779.301	0.9075	209 366.608

With regard to the estimated weight of the growth options, our data support the evidence reported in previous literature in terms of its relevance: 42.32% of the equity market value corresponds, on average, to future possibilities.[7] Nevertheless, the zero value recorded in the median of this variable shows that it is an asymmetric relevance, reached despite the fact that over half the firms lack growth options of any significant value. The high level of dispersion in the beta of assets-in-place is reflected in the standard deviation of the weight of the growth options.

III.3 Econometric model

Verifying the hypothesis posited in section II requires previously pinpointing the risk groups into which the universe of firms is divided, in each of which the statistical significance of the coefficients of the weight of the growth options and the financial

[7] This value might have been even higher, if firms showing current negative earnings before interests and after taxes had not been excluded. This reflects the fact that investors value future growth potential.

leverage will be analysed. In other words, in each risk class k the coefficients a_k and b_k in equation (7) are constants to be estimated:

$$\beta_{E_i} = a_k \cdot \frac{V_i}{E_i} + b_k \cdot \frac{V_{GO_i}}{E_i} \qquad \forall i \in k \tag{7}$$

which should verify that $a_k < b_k$ and $0 < b_k$, in so far as a_k and b_k are respectively proxies for β_{AIP_i} and $\left(\beta_{GO_i} - \beta_{AIP_i}\right)$ in risk class k.

To make this contrast operative, we define as many dummies ($D_i; i = 1,2,...$) as risk groups are defined to divide the sample. Since coefficients a_k and b_k are different in each type of risk, the model to be verified introduces the dummy variables by multiplying both explanatory variables. Assuming for instances 6 different risk classes,[8] the first model to be verified (M1) involves the following expression:

$$\begin{aligned}\beta_{E_i} &= a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GO_i}}{E_i} + a_1 \cdot D_1 \cdot \frac{V_i}{E_i} + a_2 \cdot D_2 \cdot \frac{V_i}{E_i} + a_3 \cdot D_3 \cdot \frac{V_i}{E_i} \\ &+ a_4 \cdot D_4 \cdot \frac{V_i}{E_i} + a_5 \cdot D_5 \cdot \frac{V_i}{E_i} + b_1 \cdot D_1 \cdot \frac{V_{GO_i}}{E_i} + b_2 \cdot D_2 \cdot \frac{V_{GO_i}}{E_i} + b_3 \cdot D_3 \cdot \frac{V_{GO_i}}{E_i} + \\ &+ b_4 \cdot D_4 \cdot \frac{V_{GO_i}}{E_i} + b_5 \cdot D_5 \cdot \frac{V_{GO_i}}{E_i} + \varepsilon_i\end{aligned} \qquad \text{[M1]}$$

The second and third models (M2 and M3) to be estimated are built including risk class dummies for each of the explanatory variables separately. Expressed analytically:

$$\begin{aligned}\beta_{E_i} &= a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GOC_i}}{E_i} + a_1 \cdot D_1 \cdot \frac{V_i}{E_i} + a_2 \cdot D_2 \cdot \frac{V_i}{E_i} + a_3 \cdot D_3 \cdot \frac{V_i}{E_i} \\ &+ a_4 \cdot D_4 \cdot \frac{V_i}{E_i} + a_5 \cdot D_5 \cdot \frac{V_i}{E_i} + \varepsilon_i\end{aligned} \qquad \text{[M2]}$$

[8] Logically, the model excludes one of the dummy variables (D_6) so as to avoid linear combination of the regressors.

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GO_i}}{E_i} + b_1 \cdot D_1 \cdot \frac{V_{GO_i}}{E_i} + b_2 \cdot D_2 \cdot \frac{V_{GO_i}}{E_i} + b_3 \cdot D_3 \cdot \frac{V_{GO_i}}{E_i} + + b_4 \cdot D_4 \cdot \frac{V_{GO_i}}{E_i} + b_5 \cdot D_5 \cdot \frac{V_{GO_i}}{E_i} + \varepsilon_i \quad \text{[M3]}$$

These two models are interpreted in the following manner. According to the second model (M2), sensitivity of a firm's systematic risk of equity to changes in financial leverage depends on the risk class k it belongs to. In other words, the classes of risk differ in the systematic risk of assets-in-place (a_k coefficient in equation (7)), but not in the difference between the risk of growth options and assets in place (b_k coefficient). In the third model (M3) differences in sensitivity per risk class occur in relation to the weight of growth options value. In other words the classes of risk differ in the distance between the risk of growth options and the risk of assets-in-place (b_k coefficient in equation (7)).

Finally, we verified the posited hypothesis for a very specific case of the general case, which is that assuming the existence of a single class of risk. This verification is stated formally in the fourth model (M4):

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GO_i}}{E_i} + \varepsilon_i \quad \text{[M4]}$$

The approach used to estimate the four models is ordinary least squares (OLS).

IV. Results

Table 3 presents OLS estimation results of models 1 to 4, which relate a firm's systematic risk of equity (β_{E_i}) on its financial leverage (V/E) and the relative weight of its growth options (V_{GO}/E). Coefficient estimations in Model 4 indicate that equity betas depend positively and significantly on financial leverage, and are independent of the relative value of growth options. Assuming that both the beta of assets-in-place and the beta of growth options are constant for all firms in the sample, as required by Model 4, this result implies that the beta of assets-in-place is approximately 0.235, but does not differ significantly from the beta of growth options (the difference is around 0.003). This value of the beta of assets-in-place is consistent with the median value of the accounting beta in the sample (0.265) used to approximate the decomposition of each firm’s market value.

This result is confirmed in the estimation of Model 2. The implicit assumption in this model is that the beta of assets-in-place and the beta of growth options are invariable in the same risk class and the whole sample respectively. Estimation results reveal that equity betas depend positively and significantly on financial leverage in all but one of the six industries considered. Again, the coefficient of the relative weight of growth options does not significantly differ from zero, indicating that this variable is not a determinant factor of systematic risk of equity under these model assumptions. An interpretation of the coefficient of independent variables in the Model 2 result reveals that betas of assets-in-place are significantly different from zero in all industries, but do not differ from respective growth option betas.

Estimation results for Models 1 and 3 reveal that systematic risk of equity significantly depends not only on financial leverage but also on growth option values, when growth options betas are felt to differ between industries. Assuming that both assets-in-place betas and growth option betas are invariable for all firms in the same risk class (Model 1), we find that financial leverage positively and significantly affects systematic risk in all industries. By contrast, the effect of growth option value varies amongst industries. The relative weight of growth options has a positive and significant impact in the cases of Agriculture, mining and other sectors ($V_{GO}/E + D1*V_{GO}/E$); Home and office products ($V_{GO}/E + D2*V_{GO}/E$), and Other manufacturers ($V_{GO}/E + D3*V_{GO}/E$). It has a negative and significant impact in the case of Transport and telecommunications ($V_{GO}/E + D4*V_{GO}/E$) and Professional and other services (V_{GO}/E); and finally, does not affect Wholesale and retail ($V_{GO}/E + D5*V_{GO}/E$). This finding evidences that the beta of assets-in-place is positive for all six industries considered, but also that it is below the beta of growth options in only half of the industries.

Table 3: OLS regressions of systematic risk of equity on financial leverage and the relative weight of growth options

	[M1]	[M2]	[M3]	[M4]
V_{GO}/E	-0.01520 (-2.43**)	-0.00546 (-1.14)	-0.02902 (-4.54***)	0.00282 (0.59)
V/E	0.14570 (20.13***)	0.14356 (19.85***)	0.22980 (55.45***)	0.23474 (56.06***)
V/E + D1*V/E	0.20945 (18.25***)	0.22610 (19.96***)		
V/E + D2*V/E	0.27593 (26.00***)	0.28174 (26.91***)		
V/E + D3*V/E	0.28843 (36.15***)	0.29110 (36.50***)		
V/E + D4*V/E	0.21636 (19.89***)	0.21177 (19.95***)		
V/E + D5*V/E	0.44849 (22.35***)	0.46159 (27.04***)		
V_{GO} /E + D1* V_{GO} /E	0.47790 (7.19***)		0.45441 (6.74***)	
V_{GO} /E + D2* V_{GO} /E	0.14484 (2.62***)		0.19339 (3.44***)	
V_{GO} /E + D3* V_{GO} /E	0.04438 (2.37**)		0.06166 (3.21***)	
V_{GO} /E + D4* V_{GO} /E	-0.02160 (-2.04**)		-0.02522 (-2.38***)	
V_{GO} /E + D5* V_{GO} /E	0.00837 (0.68)		0.08615 (8.24***)	
F-value	345.66	573.83	510.25	1650.92
R-square	0.4657	0.4575	0.4285	0.4092

Notes:

[1] This table presents results from OLS regressions of a firm's systematic risk of equity (β_{E_i}) on its financial leverage (V_i/E_i) and the relative weight of growth options in its market value (V_{GO_i}/E_i). Columns [1] to [4] respectively show estimation results for models [1] to [4]:

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GO_i}}{E_i} + a_1 \cdot D_1 \cdot \frac{V_i}{E_i} + a_2 \cdot D_2 \cdot \frac{V_i}{E_i} + a_3 \cdot D_3 \cdot \frac{V_i}{E_i} + a_4 \cdot D_4 \cdot \frac{V_i}{E_i} + a_5 \cdot D_5 \cdot \frac{V_i}{E_i} + b_1 \cdot D_1 \cdot \frac{V_{GO_i}}{E_i} + b_2 \cdot D_2 \cdot \frac{V_{GO_i}}{E_i} + b_3 \cdot D_3 \cdot \frac{V_{GO_i}}{E_i} + b_4 \cdot D_4 \cdot \frac{V_{GO_i}}{E_i} + b_5 \cdot D_5 \cdot \frac{V_{GO_i}}{E_i} + \varepsilon_i \quad [1]$$

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GOC_i}}{E_i} + a_1 \cdot D_1 \cdot \frac{V_i}{E_i} + a_2 \cdot D_2 \cdot \frac{V_i}{E_i} + a_3 \cdot D_3 \cdot \frac{V_i}{E_i} + a_4 \cdot D_4 \cdot \frac{V_i}{E_i} + a_5 \cdot D_5 \cdot \frac{V_i}{E_i} + \varepsilon_i \quad [2]$$

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GO_i}}{E_i} + b_1 \cdot D_1 \cdot \frac{V_{GO_i}}{E_i} + b_2 \cdot D_2 \cdot \frac{V_{GO_i}}{E_i} + b_3 \cdot D_3 \cdot \frac{V_{GO_i}}{E_i} + b_4 \cdot D_4 \cdot \frac{V_{GO_i}}{E_i} + b_5 \cdot D_5 \cdot \frac{V_{GO_i}}{E_i} + \varepsilon_i \quad [3]$$

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{OC_i}}{E_i} + \varepsilon_i \quad [4]$$

[2] D_1, D_2, D_3, D_4, D_5 are industry dummies which classify firms in the sample in the six industries defined in Table 1.
[3] β_E, V_{GO}/E and V/E are defined as in Table 2.

[4] *t*-statistics in parentheses; ***denotes significance at the 1% level; **, at 5%; and * at 10%.

A similar conclusion is reached from estimation of Model 3, where the implicit assumption is that the beta of assets-in-place and the beta of growth options are invariable in the whole sample and the same risk class respectively. In this case, all coefficients are shown to be statistically significant. Financial leverage positively impacts systematic risk of equity in the whole sample. However, growth option weight affects systematic risk positively in four of the six industries and negatively in the other two risk classes. Again, this means that the beta of assets-in-place is above zero for the whole sample, below the beta of growth options in four of the six industries, and above the beta of growth options in two industries.

To check robustness, we re-estimated Models 1 to 4 by modifying the proxy of the accounting beta to be used in the estimation of the weight of growth option value. Rather than using the beta of returns on assets, we employed correlation in annual changes in profits (Damodaran, 2002). Estimation results are shown in Table 4. No changes are detected with regard to our previous results other than the coefficient of the independent variable of growth option value in Model 4. According to this result, it should be considered that the weight of the growth option negatively and significantly impacts the systematic risk of equity and that the beta of assets-in-place is above the beta of growth options.

Table 4: OLS regressions of systematic risk of equity on financial leverage and the relative weight of growth options. Damodoran's estimation of accounting beta

	[1]	[2]	[3]	[4]
V_{GO}/E	-0.00731 (-1.78*)	-0.00082 (-0.24)	-0.01777 (4.24***)	-0.00761 (-2.12**)
V/E	0.14518 (20.02***)	0.14268 (19.60***)	0.22988 (55.07***)	0.23709 (56.67***)
V/E + D1*V/E	0.19597 (16.67***)	0.22599 (19.94***)		
V/E + D2*V/E	0.26631 (24.31***)	0.28162 (26.88***)		
V/E + D3*V/E	0.28519 (35.53***)	0.29090 (36.44***)		
V/E + D4*V/E	0.21838 (19.87***)	0.21060 (19.77***)		
V/E + D5*V/E	0.45318 (26.93***)	0.45652 (27.73***)		
V_{GO} /E + D1* V_{GO} /E	0.29196 (8.39***)		0.26150 (7.55***)	
V_{GO} /E + D2* V_{GO} /E	0.13786 (4.26***)		0.17291 (5.40***)	
V_{GO} /E + D3* V_{GO} /E	0.05119 (3.75***)		0.06876 (4.91***)	
V_{GO} /E + D4* V_{GO} /E	-0.01754 (-2.31**)		-0.02008 (-2.67***)	
V_{GO} /E + D5* V_{GO} /E	0.02745 (0.769		0.14854 (4.09***)	
F-value	351.34	573.50	507.90	1654.43
R-square	0.4698	0.4574	0.4274	0.4097

Notes:

1 This table presents results from OLS regressions of a firm's systematic risk of equity (β_{E_i}) on its financial leverage (V_i/E_i) and the relative weight of growth options in its market value (V_{GO_i}/E_i). Columns [1] to [4] respectively show estimation results for models [1] to [4]:

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GO_i}}{E_i} + a_1 \cdot D_1 \cdot \frac{V_i}{E_i} + a_2 \cdot D_2 \cdot \frac{V_i}{E_i} + a_3 \cdot D_3 \cdot \frac{V_i}{E_i} + a_4 \cdot D_4 \cdot \frac{V_i}{E_i} + a_5 \cdot D_5 \cdot \frac{V_i}{E_i} + b_1 \cdot D_1 \cdot \frac{V_{GO_i}}{E_i} + \quad [1]$$

$$+ b_2 \cdot D_2 \cdot \frac{V_{GO_i}}{E_i} + b_3 \cdot D_3 \cdot \frac{V_{GO_i}}{E_i} + b_4 \cdot D_4 \cdot \frac{V_{GO_i}}{E_i} + b_5 \cdot D_5 \cdot \frac{V_{GO_i}}{E_i} + \varepsilon_i$$

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GOC_i}}{E_i} + a_1 \cdot D_1 \cdot \frac{V_i}{E_i} + a_2 \cdot D_2 \cdot \frac{V_i}{E_i} + a_3 \cdot D_3 \cdot \frac{V_i}{E_i} + a_4 \cdot D_4 \cdot \frac{V_i}{E_i} + a_5 \cdot D_5 \cdot \frac{V_i}{E_i} + \varepsilon_i \quad [2]$$

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{GO_i}}{E_i} + b_1 \cdot D_1 \cdot \frac{V_{GO_i}}{E_i} + b_2 \cdot D_2 \cdot \frac{V_{GO_i}}{E_i} + b_3 \cdot D_3 \cdot \frac{V_{GO_i}}{E_i} + b_4 \cdot D_4 \cdot \frac{V_{GO_i}}{E_i} + b_5 \cdot D_5 \cdot \frac{V_{GO_i}}{E_i} + \varepsilon_i \quad [3]$$

$$\beta_{E_i} = a_0 \frac{V_i}{E_i} + b_0 \frac{V_{OC_i}}{E_i} + \varepsilon_i \quad [4]$$

2 D_1, D_2, D_3, D_4, D_5 are industry dummies which classify firms in the sample in the six industries defined in Table 1.

3 β_E, V_{GO}/E and V/E are defined as in Table 2. The only exception is approximation of the discount rate K_{AIP_k} to estimate the present value of assets-in-place and growth options. K_{AIP_k} is the median of K_{AIP_i} for all firms in risk class *k*, and K_{AIP_i} is obtained by regressing the 12 most recent annual changes in firm *i* profits against changes in profits for all firms in the sample.

4 *t*-statistics in parentheses; ***denotes significance at the 1% level; **, at 5%; and * at 10%.

V. Conclusions

The real options approach states that the firm's market value reflects both the value of its assets-in-place and the value of its growth options. Previous empirical research supports the effective market valuation of growth opportunities in various sectors and countries. If a firm's market value depends on the growth options it holds it seems logical to expect that its equity risk will also depend on this variable. Following this reasoning, some authors have proposed a linear decomposition of a stock's beta based on the weight of the growth options and financial leverage. This paper has shown that linear decomposition requires the risk of assets in place and growth options to be independent from the firm which invests in them. We have assumed the existence of risk classes, each of which comprises all firms whose assets-in-place and growth options present similar risk levels. This assumption allows us to posit that a firm's systematic risk of equity positively and linearly depends on both its financial leverage and the weight value of its growth option.

We have tested this model on a panel of 958 non-financial firms in the EU-15 member states over the period 2001-2005. Our results confirm the explanatory power of both financial leverage and growth options on the variability of systematic risk. More importantly, we have found that the effect of the relative weight of growth options depends on the existence of the aforementioned risk classes of invariable betas. Our results also confirm the beta of assets-in-place to be positively and significantly different from zero for all the industries considered. However, we have found that the sign and significance of the difference between the growth option beta and the beta of assets-in-place again depend on the industry to which the firm belongs.

These findings indicate that when estimating a firm's cost of capital it may prove helpful to consider the existence of risk classes, each defined by a particular binomial of the betas of assets-in-place and growth options. One consequence of our findings is that changes in a firm's stock beta might be explained by a simple rebalancing of the weight of its growth opportunities and assets-in-place.

Our simple proposal of six industries bears out the importance of the relative weight of growth options in accounting for changes in systematic risk. Further analysis should study in depth the estimation results of alternative firm classifications and risk class approximations.

VII. References

ADAM, T. and V.K. GOYAL (2006): "The Investment Opportunity Set and its Proxy Variables: Theory and Evidence", Working Document*, Social Science Research Network Electronic Paper Collection*.

AL-HORANI, A., P.F. POPE and A.W. STARK (2003): "Research and Development Activity and Expected Returns in the United Kingdom", *European Finance Review*, Vol. 7 (1), pp. 27-46.

ANDRES, P., V. AZOFRA and G. DE LA FUENTE (2006): "The Real Options Component of Firm Market Value: The Case of Technological Corporation", *Journal of Business Finance & Accounting,* Vol. 33 (1 and 2), pp. 133-49.

ARCAS, M. (1991): "Estudio de la Asociación entre el Riesgo Sistemático del Mercado y Determinadas Variables Contables", *Revista Española de Financiación y Contabilidad,* Vol. 20 (66), pp. 127-50.

BEAVER, W., P. KETTLER, and M. SCHOLES (1970): "The Association Between Market Determined and Accounting Determined Risk Measures", *Accounting Review*, Vol. 45 (4), pp. 654-82.

BEAVER, W., and J. MANEGOLD (1975): "The Association Between Market – Determined and Accounting – Determined Measures of Systematic Risk: Some Further Evidence", *Journal of Financial and Quantitative Analysis,* Vol. 10 (2), pp. 231-84.

BERK, J., R. GREEN and V. NAIK (1999): "Optimal Investment, Growth Options and Security Returns", *Journal of Finance,* Vol. 54 (5), pp. 1553-607.

BERK, J., R. GREEN and V. NAIK (2004): "Valuation and Return Dynamics of New Ventures", *Review of Financial Studies,* Vol. 17, pp. 1-35.

BERNARDO, A., B. CHOWDHRY and A. GOYAL (2007): "Growth Options, Beta, and the Cost of Capital", *Financial Management*, Vol. 36 (2), pp. 5-17.

BOWMAN, R. (1979): "The Theoretical Relationship between Systematic Risk and Financial (Accounting) Variables", *Journal of Finance,* Vol. 34 (3), pp. 617-30.

BRENNER, M. and S. SMIDT (1978): "Asset Characteristics and Systematic Risk", *Financial Management,* Vol. 7 (4), pp. 33-9.

CARLSON, M., A. FISHER and R. GIAMMARINO (2003): "Corporate Investment and Asset Price Dynamics: Implications for the Cross-Section of Returns", *Journal of Finance*, Vol. 59, pp. 2577-603.

CHUNG, K. and C. CHAROENWONG (1991): "Investment Options, Assets in Place, and the Risk of Stocks", *Financial Management,* Autumn, 21-33.

DAMODARAN, A. (2002): *Investment Valuation: Tools and Techniques for Determining the Value of Any Asset*, New York: John Wiley & Sons.

DANBOLT, J., I. HIRST, and E. JONES (2002): "Measuring Growth Opportunities", *Applied Financial Economics,* Vol. 12, pp. 203 -12.

DIXIT, A. and R. PINDICK (1995): "The Options Approach to Capital Investment", *Harvard Business Review,* May-June, pp. 105-15.

FAMA, E. and K. FRENCH (1992): "The Cross – Section of expected Stock Returns", *Journal of Finance,* Vol. 47 (2), pp. 427-65.

FERNÁNDEZ, P. (2004): *"The value of tax shields is NOT equal to the present value of tax shields"*, *Journal of Financial Economics,* Vol. 73, pp. 145-65.

GAHLON, J. and J. GENTRY (1982): "On the Relationship between Systematic Risk and the Degrees of Operating and Financial Leverage", *Financial Management,* Vol. 11 (2), pp. 15-23.

GALAI, D. and R. MASULIS (1976): "The Option Pricing Model and the Risk Factor of Stock", *Journal of Financial Economics*, Vol. 3, pp. 53-81.

GARCÍA, C. and M. HERRERO (2001): "Efectos de las Opciones de Crecimiento de una Empresa en su Riesgo Sistemático: Evidencia para el Caso Español", Vol. 30, (109), pp. 765-94.

HAMADA, R. (1972): "The Effect of the Firm's Capital Structure on the Systematic Risk of Common Stock", *Journal of Finance*, Vol. 27 (2), pp. 435-58.

HERATH, H. and C. PARK (1999): "Economic Analysis of R&D Projects: An Options Approach", *Engineering Economist,* Vol. 44 (1), pp. 1-35.

HIRST, I.R.C., J. DANBOLT and E. JONES (2008): "Required rates of return for corporate investment appraisal in the presence of growth opportunities", *European Financial Management*, 14 (5), pp. 989-1006

JACQUIER, E., S. TITMAN and A. YALCIN (2001): "Growth Opportunities and Assets in Place: Implications for Equity Betas", Working Document*, Social Science Research Network Electronic Paper Collection.*

KESTER, W. (1984): "Today's options for tomorrow growth", *Harvard Business Review,* Vol. 62 (2), pp. 153-60.

KESTER, W. (1986): "Capital and Ownership Structure: A Comparison of United States and Japanese Manufacturing Corporations", *Financial Management,* Vol. 15 (1), pp. 5-16.

KOTHARI, SOAN and SHANKIN (1995): "Another Look at the Cross-Section of Expected Stock Returns", *Journal of Finance,* Vol.50 (1), pp. 185-224.

MANDELKER, G. and S. GHON RHEE (1984): "The Impact of the Degrees of Operating and Financial Leverage on Systematic Risk of Common Stock", *Journal of Financial and Quantitative Analysis,* Vol. 19 (1), pp. 45-57.

MYERS, S. (1977): "Determinants of Corporate Borrowing", *Journal of Financial Economics*, Vol. 5, pp. 147-75.

MYERS, S. (1984): "Finance Theory and Financial Strategy", *Interfaces,* Vol. 14 (1), pp. 126-37.

MYERS, S. and M. TURNBULL (1977): "Capital Budgeting and the Capital Asset Pricing Model: Good News and Bad News", *Journal of Finance,* Vol. 32 (2), pp. 321-36.

PADDOCK, J., D. SIEGEL and J. SMITH (1988): "Option Valuation of Claims of Real Assets: The Case of Offshore Petroleum Leases", *Quarterly Journal of Economics,* Vol. 102 (3), pp. 479-508.

QUIGG, L. (1993): "Empirical Testing of Real Option Pricing Models", *Journal of Finance,* Vol. 48 (2), pp. 621-40.

RAMEZANI, C. (2003): "Real Options, Corporate Performance, and Shareholder Value Creation", *7th Annual International Conference on Real Options: Theory Meets Practice,* Washington, DC, July.

REINGANUM (1981): "A New Empirical Perspective on the CAPM", *Journal of Financial and Quantitative Analysis,* Vol. 14 (4), pp. 439-62.

TRIGEORGIS, L (1988): "A Conceptual Options Framework for Capital Budgeting". *Advances in Futures and Options Research,* Vol.3, pp. 145-67.