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# **Corporate Investment Efficiency Under Beta Uncertainty**

School of Accounting and Finance  
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**ABSTRACT:**

Discounted cash flow analysis is the dominant approach to corporate capital budgeting, and the cost of equity that enters the discount rate is most commonly estimated with the Capital Asset Pricing Model. Within that framework, the risk-free rate and the market risk premium are shared by firms operating in the same environment, while the beta coefficient is firm-specific and must be estimated from historical returns. Beta is therefore the main channel through which estimation error enters the cost of equity, and imprecise estimates may distort the discount rates used to evaluate investment opportunities. While the consequences of cost-of-equity imprecision for investment have been documented for North American firms, little is known about whether the relationship holds in Europe, where capital allocation relies more heavily on bank-based intermediation and where market signals are assumed to play a smaller role.

This thesis examines whether the precision of firm-level beta estimates is associated with corporate investment efficiency among large, publicly listed European firms. The study draws on asset pricing theory, capital structure theory, agency theory, and Tobin's Q-theory of investment to motivate the mechanism linking estimation precision to capital allocation. Investment efficiency is captured by Abnormal Investment, defined as the absolute residual from a model of capital investment on Tobin's Q, operating cash flow, asset growth, and lagged investment. Cost-of-equity precision is captured by Beta Precision, defined as the negative of the standard error of beta from a market model regression. The data are drawn from the component firms of a broad European equity index over a period spanning more than two decades, and the relationship is estimated using ordinary least squares, quantile, and directional specifications, supported by an extensive set of robustness tests.

More precise beta estimates are found to be associated with significantly lower abnormal investment, and the result survives the inclusion of industry, year, and firm fixed effects, alternative risk models and estimation windows, firm-size partitions, and governance controls. The disciplining effect is concentrated in restraining overinvestment rather than in correcting underinvestment, and it is proportionally stronger than has been reported for North American firms. In contrast to the North American evidence, market-based growth signals appear unrelated to European investment. The findings indicate that cost-of-equity precision operates in Europe primarily as an internal capital-allocation discipline rather than through external market pressure, and that the quality of beta estimation is an economically meaningful input to corporate investment decisions rather than a purely technical detail.

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**KEYWORDS:** corporate investment efficiency, cost of equity, beta precision, CAPM, estimation uncertainty, agency costs, European financial markets

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**VAASAN YLIOPISTO****School of Accounting and Finance**

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**TIIVISTELMÄ:**

Diskontatun kassavirran analyysi on yritysten investointilaskennan vallitseva menetelmä, ja sen diskonttauskoron keskeisin osatekijä, oman pääoman kustannus, arvioidaan yleisimmin Capital Asset Pricing -mallilla. Tässä viitekehyksessä riskitön korko ja markkinariskipreemio ovat yhteisiä samassa ympäristössä toimiville yrityksille, kun taas beta-kerroin on yrityskohtainen ja se on estimoitava historiallisista tuotoista. Beta on siten keskeisin kanava, jonka kautta estimointivirhe siirtyy oman pääoman kustannukseen, ja epätarkat estimaatit voivat vääristää investointimahdollisuuksien arvioinnissa käytettyjä diskonttauskorkoja. Vaikka oman pääoman kustannuksen epätarkkuuden vaikutukset investointeihin on dokumentoitu pohjoisamerikkalaisilla yrityksillä, on epäselvää, päteekö yhteys Euroopassa, jossa pääoman allokointi nojaa vahvemmin pankkivälitteiseen rahoitukseen ja jossa markkinasignaalien oletetaan olevan vähäisemmässä roolissa.

Tämä tutkielma tarkastelee, onko yrityskohtaisten beta-estimaattien tarkkuus yhteydessä yritysten investointitehokkuuteen suurissa, julkisesti noteeratuissa eurooppalaisissa yrityksissä. Tutkimus pohjautuu arvopaperien hinnoitteluteoriaan, pääomarakenneteoriaan, agenttiteoriaan sekä Tobinin Q-investointiteoriaan, joiden avulla perustellaan estimointitarkkuuden ja pääoman allokoinnin välinen mekanismi. Investointitehokkuutta mitataan epänormaalilla investoinnilla, joka määritellään jäännöstermin itseisarvona mallista, jossa investointeja selitetään Tobinin Q:lla, liiketoiminnan rahavirralla, taseen kasvulla ja edellisen kauden investoinneilla. Oman pääoman kustannuksen tarkkuutta mitataan betan estimointitarkkuudella, joka määritellään markkinamalliregression beta-kerroimen keskivirheen vastalukuna. Aineisto koostuu laajan eurooppalaisen osakeindeksin yrityksistä yli kahden vuosikymmenen ajalta, ja yhteyttä estimoidaan pienimmän neliösumman, kvantiili- ja suuntaeritellyillä malleilla, joita täydennetään kattavilla robustisuustesteillä.

Tarkempien beta-estimaattien havaitaan olevan yhteydessä merkitsevästi pienempään epänormaaliin investointiin, ja tulos säilyy toimiala-, vuosi- ja yrityskohtaisten kiinteiden vaikutusten, vaihtoehtoisten riskimallien ja estimointi-ikkunoiden, kokoluokittelun sekä hallinnointitapaa kuvaavien kontrollimuuttujien lisäämisen jälkeen. Kurinpitovaikutus keskittyy yli-investoinnin hillitsemiseen pikemmin kuin ali-investoinnin korjaamiseen, ja se on suhteellisesti voimakkaampi kuin pohjoisamerikkalaisilla yrityksillä on raportoitu. Toisin kuin pohjoisamerikkalaisessa aineistossa, markkina-perusteiset kasvusignaalit eivät näytä olevan yhteydessä eurooppalaisten yritysten investointeihin. Tulokset osoittavat, että oman pääoman kustannuksen tarkkuus toimii Euroopassa ensisijaisesti sisäisenä pääoman allokoinnin kurinpitomekanismina eikä ulkoisen markkinapaineen kautta, ja että beta-estimoinnin laatu on taloudellisesti merkittävä tekijä yritysten investointipäätöksissä eikä pelkkä tekninen yksityiskohta.

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**AVAINSANAT:** investointitehokkuus, oman pääoman kustannus, betan estimointitarkkuus, CAPM, estimointiepävarmuus, agenttikustannukset, eurooppalaiset rahoitusmarkkinat

## Contents

1	Introduction	8
1.1	The Purpose of the Study	9
1.2	Limitations and Assumptions	12
1.3	Structure of the Study	13
2	Theoretical Framework	14
2.1	Asset Pricing Models	14
2.1.1	The Capital Asset Pricing Model (CAPM)	14
2.1.2	Fama-French 3 Factor Model	15
2.2	Cost of Capital	16
2.3	Theory of Agency	18
2.4	Tobin's Q-Theory of Investment	19
2.5	Efficient Market Hypothesis	21
2.6	Market-based and Bank-based Financial Systems	22
3	Literature Review	24
3.1	Capital Budgeting Methodology in Practice	24
3.2	The CAPM and Cost of Equity Estimation	28
3.3	Corporate Investment Efficiency	32
3.3.1	Cost of Equity Precision and Investment Efficiency	35
4	Methodology and Data	39
4.1	Empirical Methods	39
4.1.1	Variable Construction and Investment Efficiency Model	39
4.1.2	Beta Precision	40
4.1.3	Main Regression Specification	41
4.2	Data and Descriptive Statistics	42
5	Empirical Research Results	50
5.1	Abnormal Investment and Beta Precision	50
5.2	Quantile Regression on Investment	53

5.3	Over- and Underinvestment	57
5.4	Robustness Tests	59
5.4.1	Alternative Models and Estimation Windows	59
5.4.2	Beta Precision and Firm Size	63
5.4.3	Controlling for Governance and Agency	66
6	Conclusions	70
6.1	Practical Implications and Suggestions for Future Research	72
	References	75
	Appendix	80

## Figures

Figure 1. Beta Precision – Investment Mechanism	12
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## Tables

Table 1. Descriptive Statistics	44
Table 2. Variable Correlation Matrix	46
Table 3. Top and Bottom 5 Firms Ranked by Beta SE	47
Table 4. Beta SE per Sample Nation	49
Table 5. Abnormal Investment on Beta Precision	51
Table 6. Quantile Regression on Investment	55
Table 7. Residual Investment on Beta Precision	58
Table 8. Alternative Risk Models	60
Table 9. Alternative Estimation Windows	61
Table 10. Abnormal Investment and Size	64
Table 11. Residual Investment and Size	65
Table 12. Governance Control	69

## Abbreviations

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<b>Abbreviation</b>	<b>Definition</b>
CAPM	Capital Asset Pricing Model
CEE	Central and Eastern Europe
CEO	Chief Executive Officer
DCF	Discounted Cash-Flow
EMH	Efficient Market Hypothesis
EPS	Earnings per Share
FD	Financial Development
HML	High Minus Low
IRR	Internal Rate of Return
M&A	Mergers and Acquisitions
OLS	Ordinary Least Squares
NPV	Net Present Value
SE	Standard Error
SMB	Small Minus Big
WACC	Weighted Average Cost of Capital
3FM	Fama-French Three-Factor Model

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## 1 Introduction

The majority of firms rely on discounted cash flow (DCF) methods to evaluate capital investment decisions (Graham & Harvey, 2001; Brounen et al., 2004; Hartwig, 2012; Andor et al., 2015; Graham, 2022). DCF methodology requires managers to estimate the future cash flows generated by the investment and an appropriate discount rate to calculate the present value of these cash flows. This thesis focuses on the uncertainty related to assessing the appropriate discount rate in the capital investment decision process.

Cost of equity capital is the primary input in the discount rate. Graham and Harvey (2001) document that firms that use DCF methods in capital budgeting rely on the Capital Asset Pricing Model (CAPM) to estimate cost of equity. In the CAPM framework, managers need to settle on the correct risk-free rate, market risk premia, and the firm's individual risk exposure to the market. Firms with precise cost of equity estimates are more likely to use a rate closer to the true cost of capital. By contrast, poor estimation precision can adjust discount rates up or down, which could lead to over- or underestimation of potential investment opportunities. If uncertainty adjusts cost of equity estimates upwards, firms are more likely to pass on value-increasing opportunities. Conversely, underestimated cost of equity could drive overinvestment.

However, in the CAPM framework, risk-free rate and market risk premium are common to firms operating in the same environment. Market risk exposure — beta — remains individual for each firm, which enables firm-to-firm variation within the same environment. The statistical precision of estimated beta differs between firms, enabling firm-to-firm variation in beta estimates, which potentially distorts cost-of-equity estimates used in discount rates. Cost-of-equity estimates are more accurate if the estimated beta has a low standard error and thus a narrow confidence interval. This precision in beta should enable managers to evaluate investment opportunities with a cost of capital that is closer to the firm's actual cost of capital. Increased accuracy of discount rates based on more precise cost of equity estimates could lead to more efficient capital budgeting.

## 1.1 The Purpose of the Study

The purpose of this thesis is to examine whether the accuracy of CAPM beta estimates is associated with more efficient firm investment. This thesis aims to examine this relationship in general and to assess whether it applies to both over- and underinvestment, or whether it is more concentrated on one side. This thesis follows prior definitions from Biggerstaff et al. (2025), measuring the relative precision of a firm's cost-of-equity estimate with the standard error of beta estimates from a market-model regression. This metric is referred to as Beta Precision, and the negative of this variable is used to measure firms' cost-of-equity precision. Higher values of Beta Precision imply a narrower confidence interval around the estimated beta, suggesting that the estimated beta coefficient is closer to its true value. Firm investment is expected to follow firms' growth opportunities, which are proxied by Tobin's Q. Following prior efficiency literature, firms' investment efficiency is measured as Abnormal Investment, which is the absolute value of the residual from a regression of capital investment on Tobin's Q, cash flow, prior growth of assets and prior investment. Larger values of Abnormal Investment refer to a larger deviation from efficient investment, implying lower investment efficiency. The signed value of Abnormal Investment shows the direction of inefficiency, as negative values imply underinvestment, and positive values overinvestment (Richardson, 2006; Goodman et al., 2014). Using this framework, this thesis examines whether higher values of Beta Precision are associated with lower values of Abnormal Investment, and whether Beta Precision constrains overinvestment more than underinvestment. Figure 1 summarises this mechanism, tracing the path from beta estimation precision through the cost of equity and the project discount rate to investment efficiency.

Cost-of-equity estimates are imprecise. For example, results from Fama and French (1997) suggest that industry cost-of-equity estimates are uncertain. More than 3 % yearly standard errors for industry betas are common, which implies that the estimation error is even more pronounced for individual firms (Fama & French, 1997). Pástor and Stambaugh (1999) find comparable results and emphasise how factor premiums are the largest source of error in firms' cost-of-equity estimates, with betas remaining an equally important source of uncertainty. Imprecise cost-of-equity estimates might be an issue, especially for firms using a DCF

approach, because inaccurate estimates could cause managers to pursue bad projects, and miss opportunities with good ones.

Moreover, survey evidence does suggest that firms use DCF methods to make capital budgeting decisions, and CAPM is the most used approach to estimate cost of equity. For example, Graham and Harvey (2001) suggest that 75 % of firms always or almost always rely on DCF methodology in capital budgeting, and cost of equity is always or almost always estimated with CAPM in 74 % of their sample firms. The relationship is similar in Europe but not as pronounced, where according to Brounen et al. (2004), large European firms favour DCF analyses in capital budgeting, and on average, around 45 % of these use CAPM. The median debt-to-market value of equity in this thesis' sample is 0,24. Imprecise cost of equity is therefore likely to influence the project discount rate precision, and prior empirical evidence suggests real economic effects for this relationship. For example, Dessaint et al. (2021) find that CAPM-derived firm acquisition valuations are associated with valuation errors ranging from 12 % to 33 % of the true firm value.

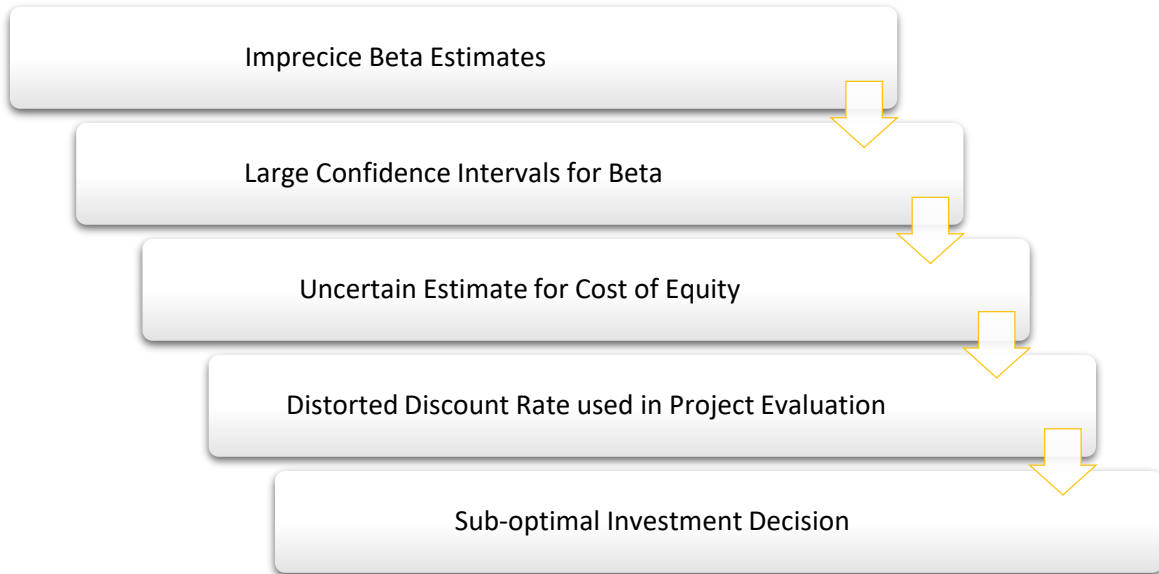
Prior empirical evidence is concentrated in North American samples. However, survey results suggest minor variation with capital budgeting methods between U.S. and large publicly traded European firms (Brounen et al., 2004; Hartwig, 2012; Andor et al., 2015). Regional differences between U.S. and Europe in market dynamics and financial systems could suggest differences in how firms' investment reacts to imprecise cost-of-equity estimates. In a market-oriented financial system — such as those of the U.S. and U.K. — corporations finance their investments through corporate bonds or equity issuance conducted through an “arm's length” transaction directly in the market. In bank-based systems, corporate investments are financed primarily by financial institutions acting as intermediaries, and this market dynamic is more common in the European region (Levine, 2002). However, CAPM is built on assumptions such as frictionless markets and information efficiency which are suitable for a market-oriented system. Bank-based systems violate many of CAPM's assumptions, but CAPM is still commonly used within them. This creates an environment where CAPM inputs might be derived from market information that is less efficient due to the

differences in dynamics. This could mean that the impact of imprecise cost of equity on investment efficiency could be more pronounced or less visible in Europe. However, the literature lacks research related to this relationship from the European region. This thesis aims to bridge this gap in the literature by providing empirical evidence with a sample of publicly traded European firms. This thesis assumes that the documented relationship in North America continues to hold in Europe (Biggerstaff et al., 2025). However, differences in results may reveal important distinctions that could explain how differences in the market and financial environment influence the outcomes of using these standardized approaches, which are more suitable for a market-driven information environment. The key relationship between more precise estimation inputs and investment efficiency, however, should display comparable results between regions. Based on the above, this thesis has two hypotheses. The first concerns the general relationship between cost-of-equity precision and investment efficiency, while the second concerns its direction. The hypotheses of the thesis are as follows:

H1: Higher Beta Precision is associated with greater investment efficiency.

H2: Higher Beta Precision constrains overinvestment more strongly than it corrects underinvestment.

This thesis contributes to the extensive literature examining corporate investment efficiency and numerous factors associated with it (Jensen, 1986; Richardson, 2006; Biddle & Hilary, 2006; McNichols & Stubben, 2008; Goodman et al., 2014; Dessaint et al., 2021; Biggerstaff et al., 2025). Additionally, this thesis contributes to existing research on cost-of-equity uncertainty (Fama & French, 1997; Pástor & Stambaugh, 1999) and the best practices for applying these methods in capital budgeting (Levi & Welch, 2017; Da et al., 2012). The results presented in this thesis provide further evidence on the estimation imprecision of cost of equity, and how the use of these models can affect real investment outcomes. They also provide further evidence on whether inputs in commonly used capital budgeting methods can contain valuable information that affects the outcomes of crucial firm decisions.



**Figure 1.** Beta Precision – Investment Mechanism

## 1.2 Limitations and Assumptions

This thesis contains some assumptions and limitations that should be acknowledged. First, the way managers apply capital-budgeting techniques in practice is inferred solely from prior survey literature, and therefore these practices should not be viewed as absolute facts. For example, there is no guarantee that managers who reported using DCF analysis and the CAPM — both of which can be categorized as sophisticated capital-budgeting tools — are actually applying them consistently in their investment decision-making. Consequently, the results of this thesis assume that surveyed managers truthfully report how they operate in practice. Even if managers are truthful, however, it is impossible to determine the specific decision-making horizons under which they operate. That said, the results of this thesis depend on assumptions regarding timing, particularly concerning the estimation window used in cost-of-equity calculations. Although this thesis addresses this issue by conducting additional tests using alternative estimation windows and risk models, the behaviour of different managers and their investment decisions cannot be generalized to any single estimation window or model specification.

Moreover, the efficient-investment model employed may not be the most appropriate fit for a European sample, as cross-country differences may favour some models over others. For instance, the model assumes that firms invest in accordance with their growth opportunities, but this may be an oversimplification of what is associated with actual European investment behaviour.

### **1.3 Structure of the Study**

The structure of the thesis is as follows: The first chapter introduces the subject and presents the thesis hypotheses. The second chapter covers the relevant theoretical background. The third chapter reviews related literature. The fourth chapter explains the methodology used in the empirical research and describes the sample data. The fifth chapter presents the empirical research results. Finally, the sixth chapter concludes and suggests possibilities for future research and practical implications from the results.

## **2 Theoretical Framework**

This chapter develops the theoretical framework for the relationship between cost-of-equity estimation precision and corporate investment efficiency. The chapter integrates asset pricing theory, capital structure theory, agency theory, and investment theory to explain how expected returns are determined, how discount rates are applied in capital budgeting, and why deviations from optimal investment may arise. These theories set up the mechanism through which imprecision in beta estimation can distort corporate investment decisions.

### **2.1 Asset Pricing Models**

Asset-pricing models provide a link between systematic risk and expected returns. These models form the foundation for estimating a firm's cost of equity. In corporate practice, the Capital Asset Pricing Model (CAPM) and multifactor models are commonly used to determine the required rate of return for equity in capital budgeting (Graham & Harvey, 2001; Brounen et al., 2004; Hartwig, 2012; Andor et al., 2015; Graham, 2022). In the corporate investment context, understanding how these models transform expected risk-return relationships into project-specific discount rates is central to the theoretical framework.

#### **2.1.1 The Capital Asset Pricing Model (CAPM)**

Markowitz (1952) introduces the mean-variance framework, demonstrating that investors should consider expected returns and variance (risk). Building on the mean-variance framework, Markowitz introduces the efficient portfolio and efficient frontier, which make it possible to determine the best possible return for a given level of risk. The analysis shows that diversification across imperfectly correlated assets reduces firm-specific variance. This distinction between diversifiable and non-diversifiable risk forms the foundation for later asset pricing models. Building on Markowitz's (1952) mean-variance framework, Sharpe (1964),

Lintner (1965), and Mossin (1966) prove that only systematic risk is priced in equilibrium, deriving the CAPM. The Capital Asset Pricing Model is defined as follows.

$$E(r_i) = r_f + \beta_i[E(r_m - r_f)]$$

Where  $E(r_i)$  is the expected return on asset  $i$ ,  $r_f$  is the risk-free rate of return,  $\beta_i$  is the beta coefficient, measuring asset  $i$ 's sensitivity to the expected return of the market portfolio,  $E(r_m)$ .

The CAPM suggests that expected returns are dependent solely on systematic risk, measured by beta, and that expected returns are assumed to vary linearly with beta. In corporate finance and more specifically in the capital-budgeting context, CAPM is used to estimate firms' cost of equity, which together with cost of debt forms cost of capital, which is commonly used as the discount rate in project evaluation. Although the CAPM remains widely used, its empirical limitations have motivated alternative multifactor models, the most notable being the Fama-French three-factor model.

### **2.1.2 Fama-French 3 Factor Model**

Building on Sharpe (1964), Lintner (1965), and Mossin (1966), Fama and French (1993) argue that CAPM is not sufficient to explain cross-sectional asset returns, because it only accounts for market risk, disregarding important asset-pricing phenomena. They propose a three-factor model that adds two factors alongside the market factor: size (SMB) and value (HML). The size factor reflects the empirical tendency of small-cap stocks to earn higher returns than large-cap stocks, while the value factor reflects the outperformance of high book-to-market firms relative to low book-to-market firms. These factors represent additional sources of systematic risk not captured by the market beta alone. Fama and French (1993) show that the three-factor model (3FM) provides greater explanatory power for cross-sectional asset returns than the single-factor CAPM. The 3FM is defined as follows.

$$E(r_i) = r_f + \beta_i[E(r_m - r_f)] + \beta_{SMB}SMB + \beta_{HML}HML$$

Where  $E(r_i)$  is the expected return on asset  $i$ ,  $r_f$  is the risk-free rate of return,  $\beta_i$  is the beta coefficient, measuring asset  $i$ 's sensitivity to the expected return of the market portfolio,  $E(r_m)$ ,  $SMB$  absorbs the small minus big effect, and  $HML$  the high book-to-market value minus low book-to-market value effect.

Although multi-factor models may improve explanatory power in asset-pricing tests, the single-beta CAPM remains the most commonly used model in capital budgeting (Graham & Harvey, 2001; Graham, 2022). Even when additional factors are used, each factor loading is estimated from historical return data and is therefore subject to estimation error. Imprecision in these estimates translates directly into uncertainty in cost-of-equity calculations.

## 2.2 Cost of Capital

Investment decisions are fundamentally linked to the firm's cost of capital. In capital budgeting, firms that use DCF methodology discount future cash flows using a rate that reflects the risk of the project, its cost of capital. The theoretical foundation for this discount rate originates from Modigliani and Miller's (1958) capital structure framework and subsequent developments in asset-pricing theory. Modigliani and Miller (1958) develop the capital-structure irrelevance theorem. The theory states that in perfect capital markets (markets without tax, transaction, or bankruptcy costs, where investors can borrow and lend at the risk-free rate and all information is symmetric) the value of a firm is independent of its financing mix of debt and equity. Investment decisions should therefore be based solely on whether a project increases firm value, not on how the project is financed. In this context, a manager who accepts all net present value (NPV) positive investments, discounted with the firm's cost of capital, increases firm value.

Modigliani and Miller (1958) demonstrate this using an economic model and an arbitrage argument: if two identical firms have the same assets and cash flows but different capital

structures, investors can sell the “expensive” leveraged firm and buy the “cheap” unleveraged firm, then borrow personally at the risk-free rate to replicate the leveraged firm’s risk-return profile. Because investors can always recreate or undo leverage on their own, price differences cannot persist. Arbitrage therefore forces the total value of the firm to depend only on the assets it owns. The required rate of return on assets is defined as follows.

$$r_A = \frac{E}{V}r_E + \frac{D}{V}r_D$$

Where  $E$  is the value of equity,  $D$  is the total value of debt,  $V$  is the total value of debt and equity,  $r_E$  is the required rate of return for equity, and  $r_D$  is the cost of debt financing.

The capital structure irrelevance theorem indicates that only investment choices create value and the method of financing does not matter. The framework states that the weighted average cost of capital (WACC) remains constant for different mixes of debt and equity. Although leverage increases the cost of equity due to higher financial risk, the WACC remains unchanged in the no-tax Modigliani-Miller framework. In this setting, only systematic risk — captured by the asset beta — determines the appropriate discount rate. Extending their earlier work, Modigliani and Miller (1963) incorporate taxes into the cost-of-capital equation. Because interest payments on debt are tax-deductible, leveraged firms benefit from a tax shield, which lowers the after tax WACC. Building on the original arbitrage logic, Modigliani and Miller (1963) show that the value of a leveraged firm equals the value of an unleveraged firm plus the present value of the tax savings from interest deductions. The Weighted Average Cost of Capital with taxes is defined as follows.

$$WACC = \frac{E}{V}r_E + \frac{D}{V}r_D(1 - Tc)$$

Where  $E$  is the value of equity,  $D$  is the total value of debt,  $V$  is the total value of debt and equity,  $r_E$  is the required rate of return for equity, and  $r_D$  is the cost of debt financing, and  $Tc$  is the corporate tax rate.

The interest tax shield introduces a possibility of an optimal capital structure. The cost of capital continues to guide investment decisions, but the discount rate now depends on leverage because tax shield reduces WACC. Consequently, capital structure becomes relevant, as changes in debt and equity proportions affect firms' discount rates. However, firms are commonly weighted more towards equity than debt (Graham & Harvey, 2001; Graham, 2022; Brounen et al., 2004). When the proportion is high, the share of equity  $\frac{E}{V}r_E$  contributes more to cost of capital, emphasising how imprecise cost of equity can distort the discount rates used. Investment decisions are made by corporate managers whose incentives may not fully align with those of shareholders. Therefore, even when project discount rates are theoretically well defined, agency frictions may still lead firms to deviate from optimal investment behaviour.

### 2.3 Theory of Agency

Agency theory provides a framework for understanding conflicts between firm owners (principals) and firm managers (agents) (Jensen & Meckling, 1976). According to agency theory, agents act on behalf of principals and represent their best interests. Agency issues arise when the interests of agents and principals diverge, as both parties seek to maximise their own utility. Principals pursue their interests through the maximisation of the firm's stock value, while agents may prioritise their personal benefits instead. The misalignment between these parties is known as the principal-agent problem. Firms face agency costs when agents prioritise their own self-interest over the interests of principals.

Jensen (1986) argues that agency problems arise when firms generate excess internal funds. When firms have more cash than there are profitable investment opportunities, managers may allocate funds to NPV-negative projects rather than distribute excess cash to shareholders. Therefore, the manager is incentivised to overinvest to expand the firm, increase control, or reduce personal employment risk. Myers and Majluf (1984) approach the agency

problem through information asymmetry between managers and outside investors. Firm management possesses superior information regarding the value of the firm and its projects. When the firm needs external financing, issuing equity may signal overvaluation, leading to adverse selection. As a result, firms prefer to finance investments internally rather than rely on external financing (Myers & Majluf, 1984). In practice, this means financing investment first with internal cash flow, then with debt, and issuing equity only as a last resort. This hierarchy is known as the pecking-order theory of capital.

Under the pecking-order theory, information asymmetry raises the cost of external financing, since newly issued equity tends to be undervalued by the market, and debt adds financial obligations. Firms that lack internal funding may therefore forgo positive-NPV projects rather than raise costly external capital, which results as underinvestment. Excess internal funds may lead to overinvestment (Jensen, 1986), while financing frictions and asymmetric information may lead to underinvestment (Myers & Majluf, 1984). Therefore, agency conflicts represent a systematic mechanism that encourages inefficient investment.

However, the absolute investment opportunity set firm managers evaluate remains unobservable to an outsider. Due to this, empirical research suggests that firms' investment efficiency can be evaluated by measuring how firms' investment behaviour is related to its growth opportunities. The most commonly used proxy for growth opportunities is Tobin's Q, introduced by Tobin (1969).

## **2.4 Tobin's Q-Theory of Investment**

Corporate investments should aim to increase firm value. According to Modigliani and Miller (1958), the value of an investment should exceed the firm's cost of capital in order to do so. While firms evaluate their investment opportunities, equity markets simultaneously evaluate these firms by reflecting expectations of future profitability into stock prices. Tobin's Q, first introduced by Tobin (1969), provides a way to link market expectations to corporate investment decisions. Tobin's Q is the ratio of the market value of a firm to the

replacement cost of its assets. Thus, the ratio measures how much investors are willing to pay for the firm relative to the cost of replacing its existing assets. Q-ratio greater than one suggests that the firm has profitable growth opportunities, as the market values the firm's assets more highly than the cost of replacing its assets. Q-ratio above one implies that expanding the firm, for example via investment in new plant, property, or equipment, is expected to increase firm value. Conversely, Q-ratio under one implies that additional investment is unlikely to increase value, as the market does not anticipate future growth. Hayashi (1982) shows that under specific economic assumptions, a firm's observable average Q reflects the marginal value of capital, which governs optimal investment decisions. This result enables Tobin's Q to be used in empirical research. The Q ratio for a firm  $i$  is calculated as follows.

$$\text{Tobin's } Q_i = \frac{MVE_i + TD_i}{TA_i}$$

Where  $MVE_i$  is the market value of equity for firm  $i$ ,  $TD_i$  is the total value of current and long-term debt for firm  $i$ , and  $TA_i$  represents the value of total assets for firm  $i$ .

In empirical research, investment efficiency is typically evaluated by examining how closely actual investments align with the level predicted by its Q-ratio and other fundamentals. If a firm's investments follow its Q, the theory considers it to be aligned with value maximisation. Deviations from Q-predicted investment can therefore be used to indicate over- or underinvestment in relation to available growth opportunities. However, while the theory predicts that firm investment should increase according to market valuation, equity markets may at times be driven by speculation or noise, which reflects investor sentiment rather than true future profitability expectations. Despite its limitations, Tobin's Q remains a consistent proxy of growth opportunities in investment-efficiency literature. How good a proxy Tobin's Q is depends in part on the quality of market information. The extent to which market prices reflect fundamental information feeds through to efficiency estimates via Tobin's Q, or other proxies that are based on price information. This connection between

market valuation and corporate investment decisions is grounded in the Efficient Market Hypothesis.

## 2.5 Efficient Market Hypothesis

Financial markets aggregate information, and firms observe financial market data that guides investment decisions. The Efficient Market Hypothesis (EMH), developed by Eugene Fama (1970), provides a theoretical foundation for interpreting how much information prices actually reflect. EMH assumes that the degree to which asset prices reflect information can be divided into three forms of market efficiency: strong-, semi-strong-, and weak market efficiency.

Under strong efficiency, markets reflect all information (both public and private) and assets always trade at their true value. As a result, it is impossible to earn abnormal returns by identifying mispriced securities or through market timing. Semi-strong efficiency implies that all publicly available information, such as financial statements, macroeconomic data, and news, is reflected in stock prices, while private information remains unpriced. In such markets, investors may still earn returns based on private or insider information, but public information alone does not offer opportunities for abnormal excess returns. Weak efficiency assumes that all past price information is incorporated into current prices, and only new, unpredictable information affects asset values.

In the context of corporate investments, the semi-strong form of efficiency is the most relevant. Under semi-strong efficiency, stock prices reflect publicly available information about firms' growth opportunities and risks, making market-based measures — such as Tobin's Q — informative indicators. However, market efficiency does not imply perfect pricing. Prices may deviate from fundamental values due to noise, behavioural biases, or limits to arbitrage, all of which should be considered when using market-based information for investment decisions. The relationship between market efficiency and investment behaviour remains important, as differences in market structure and information environments

influence the reliability of inputs which are based on market information and used in project discount rates. This suggests that regional variation in market efficiency could influence how pronounced the effect of market-implied inputs is in discount-rate estimation.

## **2.6 Market-based and Bank-based Financial Systems**

The degree to which market prices reflect fundamental information is not equal across economies. It is strongly influenced by the structure of the financial system in which firms operate. Prior literature distinguishes between market-based and bank-based financial systems (Levine, 2002). In market-based systems, such as those of the United States and the United Kingdom, firms raise a large share of external finance directly from capital markets through arm's-length issuance of equity and debt, and securities prices serve as a primary mechanism for allocating capital and disciplining managers. In bank-based systems — more common in continental Europe — financing is intermediated mainly by banks and other institutions that build relationships with firms and monitor them privately, so that publicly observable market prices play a comparatively smaller allocative role (Levine, 2002).

This distinction matters because the inputs used in standardised cost-of-equity and investment models are themselves market-based. The CAPM assumes frictionless markets and information efficiency that correspond most closely to a market-oriented environment (Sharpe, 1964; Fama, 1970), and proxies such as Tobin's Q derive their informational content from the same market prices (Tobin, 1969; Hayashi, 1982). Where market signals are more central to financing and governance, the precision of these inputs is more likely to feed through to investment decisions. Where financing and monitoring occur mainly through intermediaries, the same signals may carry less weight in corporate capital allocation. Because financial systems vary by region, it can be theoretically expected that the relationship between estimation precision and investment efficiency differs across institutional environments.

However, the evidence does not establish that one structure is naturally superior. Levine (2002) finds that overall financial development and the quality of the legal and contracting environment are more robustly associated with economic outcomes than the bank-based versus market-based classification itself. For the purposes of this thesis, the distinction is therefore treated as descriptive rather than defining. The difference motivates examining whether a relationship documented in the market-based United States carries over to the more intermediated European setting.

### **3 Literature Review**

This literature review combines literature from three areas. The first section contains relevant survey literature from the U.S. and Europe. The aim is to disclose what firm characteristics define preferred capital budgeting methods for firms and whether there are regional differences. The second section considers literature related to cost-of-equity estimation precision, and some suggestions for best practice in capital budgeting. The third segment reviews literature related to investment efficiency, mainly focusing on the measurement methodology of efficiency and on the variables related to it. The aim of this literature review is to identify firm characteristics that determine what capital budgeting methods are used, especially methods that discount future cash flows. This section also aims to describe and discuss the common approach to investment efficiency evaluation, and to justify the use of a residual-based efficiency model in this thesis. The literature review begins with a section dedicated to capital-budgeting methodology in practice, followed by a section discussing problems with cost-of-equity estimation. The final segment considers corporate investment-efficiency literature.

#### **3.1 Capital Budgeting Methodology in Practice**

This section reviews the survey evidence on the main methodology used in capital budgeting. The aim is to discuss common firm characteristics that determine what capital budgeting methods are used in practice, and whether there have been changes through time. The section then turns to how firms determine and process discount rates. Both aims matter for this thesis, as its argument applies specifically to firms that discount cash flows using a CAPM-based cost of equity.

Certain firm characteristics are associated with the methods used in project evaluation. Therefore, it is important to discuss the firm characteristics that lead firms to prefer one method over another, as this thesis focuses on firms that analyse projects using DCF approaches. Another important avenue is to distinguish regional differences and changes in

thinking over the years. In capital budgeting, the chosen method can produce fundamentally different accept or reject decisions for investments. The standard logic in finance argues that in a perfect market environment in the absence of constraints, firms should pursue projects with a positive net present value (NPV) in order to increase firm value (Modigliani & Miller, 1958). Therefore, in an unconstrained rational setting, the investment hurdle rate should be set equal to the cost of capital, and projects with an estimated internal rate of return (IRR) that exceeds this hurdle rate should be pursued. The literature identifies a polarity in how firms approach this in practice, dividing approaches into sophisticated and unsophisticated (Graham & Harvey, 2001). Sophisticated methods such as NPV and IRR explicitly account for the time value of money, risk, and the opportunity cost of capital. Simpler methods such as the payback period, accounting return or other rules of thumb often ignore these important aspects. Therefore, the method selection itself can influence whether firms allocate their capital efficiently.

Prior survey literature suggests consistent heterogeneity in corporate finance practices regarding how firms evaluate projects. Graham and Harvey (2001) survey Fortune 500 companies in North America and find NPV and IRR to be the most popular approaches. A similar survey by Brounen et al. (2004) finds the simple payback period rule to be the most common technique in Western Europe. More recently, Hartwig (2012) and Andor et al. (2015) find that sophisticated approaches have become more popular in Northern Europe, and that simpler methods remain most popular in the Central and Eastern European (CEE) region. Findings suggest that sophisticated capital budgeting methods are more prevalent in North America than in Europe. One explanation for the deviation could be that the governance environment in North America places greater emphasis on shareholder-value maximisation. A more market-oriented financial system might also encourage the use of methods that incorporate more market information as inputs (Levine, 2002). Differences in corporate culture are likely more pronounced between European countries, and this could create variation within the region, as sophisticated methods are more common in western and northern European countries.

Graham (2022) revisits his 2001 survey with a more recent one and finds no major changes in preferred methods in the U.S., which suggests that DCF approaches have become standardised tools in North America. Certain firm characteristics, however, seem to unite methodology between Europe and North America. Survey results suggest that in Europe, DCF approaches are most common among large publicly traded firms with highly educated management (Brounen et al., 2004). Additionally, size seems to dictate capital budgeting methodology (Graham & Harvey, 2001; Brounen et al., 2004). This could be due to differences in salaries between large and small firms, which could attract a highly educated workforce that favours textbook methodology. Preferring DCF methodology over a simple payback criterion does not automatically mean better investment decisions, but it does account for the time value of money, which should guide decision-making to some degree. The inputs in methods that do account for this are quite dependent on market information and the forecasting ability of managers. The regional differences in information environments could influence the outcomes, as these methods are heavily dependent on market information. This becomes pronounced when managers are estimating inputs for their cost of capital.

Survey results suggest that managers who use DCF methodology vary in how they determine discount rates (Graham & Harvey, 2001; Brounen et al., 2004). The main interest for this thesis comes from the differences in how cost of equity capital is determined. Survey evidence finds that CAPM is the most popular method used to estimate a firm's cost of equity. Graham and Harvey (2001) find that in North America, 74 % of firms always or almost always rely on CAPM's outputs. Among firms that use CAPM, large firms with highly educated CEOs, low leverage, or small management ownership are significantly more likely to use it (Graham & Harvey, 2001). The European evidence suggests a similar approach to cost-of-equity estimation. CAPM is on average the most commonly used method in the UK, the Netherlands, Germany, and France. In these countries, CAPM is most commonly used in large firms with relatively high proportions of foreign sales, and the same relationship holds for more advanced multifactor models with additional risk loadings (Brounen et al., 2004). In addition to firm size, culture seems to affect method preferences as well. Andor et al. (2015) find that Central and Eastern European firms' capital budgeting practices are

influenced by factors such as multinational culture, firm objectives and goal-setting preferences, and even the presence of a code of ethics.

This thesis focuses on European firms that estimate cost of equity using asset pricing tools such as CAPM and multifactor models. The literature suggests these firms can be characterised as large, multinational firms that are governed towards shareholder value creation. Even though the majority of European firms differ from North American firms in general with their approach to capital budgeting, focusing on publicly listed large European firms could reveal whether the precision of inputs in commonly used cost-of-equity estimates affects investment outcomes, as firms like these are likely to use these methods as their best practices (Brounen et al., 2004; Hartwig, 2012; Andor et al., 2015). Examining these firms in a primarily bank-based European setting also offers a different test from the existing market-based North American evidence (Levine, 2002).

Contrary to common corporate finance theory, survey results suggest that firms use firm-wide discount rates for all investment opportunities. Theory suggests that discount rates should be adjusted according to the risk profile of the project. Graham and Harvey (2001) find that 60 % of firms always or almost always use a company-wide discount rate in North America. European firms act similarly. Three quarters of surveyed firms report using a company-wide rate for all investment projects (Brounen et al., 2004). Incorporating a single rate for all investment projects increases the risk of missing NPV-positive opportunities and pursuing NPV-negative ones. Similarly to overall methodology, the approach to discount rates differs with firm characteristics. Large public firms with highly educated management report adjusting their discount rates accordingly (Graham & Harvey, 2001; Brounen et al., 2004; Andor et al., 2015). Because a single rate is applied across every project rather than tailored to each, any imprecision in the cost-of-equity input is not confined to one decision but carries through to the firm's entire investment programme. This emphasises the consequences of estimation error, and is precisely the channel this thesis examines.

However, the survey evidence should be interpreted with caution. Ensuring that managers act in line with their reported answers is impossible, so the results should be interpreted as an assumption about reality. For example, there could be internal thresholds for specific methods that vary between firms. Firms might also use completely different inputs in CAPM formulas, such as different proxies for market returns, peer betas, industry betas or others. The survey answers also represent the opinion of a single manager, which might not reflect how the whole firm behaves. In large, multinational corporations, the decision-making process might vary, as these decisions might be decentralised between internal firm functions. An answer implying the use of sophisticated textbook methods might represent something that is stated in the firm's internal protocol, rather than actual practice.

Surveying capital budgeting methods, however, remains the best available source of information, and for the purpose of this thesis, these results can be used to determine the main characteristics associated with specific methods, and how the attitude towards best practices has evolved through time. These results guide the sample focus, and therefore build the framework for the hypothesis that this thesis tests. They establish the firms for which the mechanism is relevant — those that use DCF, estimate the cost of equity with CAPM, and apply a single firm-wide rate — so that the firm-specific input, beta, and its precision become the channel linking estimation quality to investment efficiency. If firms behave accordingly, precision in cost of equity estimates should yield more accurate project discount rates and increase investment efficiency.

### **3.2 The CAPM and Cost of Equity Estimation**

CAPM and related asset pricing models are the most widely used methods for estimating the cost of equity (Graham & Harvey, 2001; Brounen et al., 2004; Hartwig, 2012; Andor et al., 2015; Graham, 2022). However, prior empirical evidence suggests that CAPM is not reliable for producing accurate estimates. Since these estimates feed directly into the discount rates firms apply, their reliability is central to this thesis. For example, Fama and French (1997) examine how precise cost of equity estimates are for industries estimated

with CAPM and the Fama-French three-factor model. Using monthly returns for 48 U.S. industries from 1963 to 1994, they find that cost of equity estimates are distressingly imprecise, as yearly standard errors of 3 % are common, suggesting that firm-specific estimates must be even less precise. Another similar study, by Pástor and Stambaugh (1999), examines the uncertainty of factor-based asset-pricing models, moving the prior analysis from Fama and French (1997) to individual firm-level estimates. They focus on three sources of uncertainty: uncertainty about the model's inputs, about whether the model misprices a given stock, and about which model should be used. The examined models are the CAPM, the Fama-French three-factor model, and the Connor-Korajczyk three-factor model (Connor & Korajczyk, 1986; Pástor & Stambaugh, 1999). The authors use a Bayesian framework, which assumes that the model may misprice the stock by some unknown amount, rather than treating the model as completely wrong or completely right. The model's mispricing term is represented by alpha, which is zero if the model is assumed to be completely right. If the decision-maker is sceptical, alpha may be non-zero. Consistent with Fama and French (1997), the results suggest that cost of equity estimates remain highly uncertain even when a pricing model is assumed to be correct. For individual firms, the posterior standard deviation of the expected excess return is typically at least 3 % for CAPM and 4 % for the 3FM per year. Factor premiums remain the largest source of uncertainty, but beta uncertainty is nearly as important for individual firms (Pástor & Stambaugh, 1999). Because beta is firm-specific while the other inputs are largely shared across firms in the same environment, this firm-level beta uncertainty is the channel this thesis examines.

In a more recent study, Nagel et al. (2007) examine whether including more risk factors improves the precision of cost of equity estimates. The practical assumption is that incorporating more risk factors into asset pricing models should provide better estimates. The authors test this by comparing multiple asset pricing models against a simple model, where cost of equity equals the risk-free rate plus the historical market risk premium, effectively assuming that beta equals one for each firm. They examine out-of-sample forecast errors for individual firms and portfolios in a sample consisting of U.S. non-financial stocks from 1953 to 1996, and find that adding risk factors does not improve cost of equity forecasting

accuracy. For individual firms, the "more sophisticated" models with additional risk factors typically increase forecast error relative to the simple LMS model benchmark. This suggests that either the models used are misspecified or estimation error in factor loadings and premia is so large that it outweighs any theoretical benefit gained from the added factors (Nagel et al., 2007). Consistent with Fama and French (1997) and Pástor and Stambaugh (1999), the results suggest that cost of equity estimates based on historical returns are extremely uncertain. This reinforces the concern about using a noisy cost of equity estimate in capital budgeting, and about whether this translates into misinvestment.

Despite CAPM's poor performance as an asset pricing model, some research suggests it should not be disregarded in the capital budgeting context. Da et al. (2012) argue that a firm's stock is not a clean claim on only its assets in place. It is also a claim on real options to expand, abandon, modify, delay or start new projects. This means that stock returns might violate the CAPM, even if the expected returns of the underlying projects satisfy the CAPM. Da et al. (2012) examine this with a theoretical and empirical approach, first through simulations and then with a test on U.S. stock data from 1970 to 2008, estimating betas using the prior 60 months of returns. Real options are unobservable to an outside observer and are thus proxied by the book-to-market ratio, idiosyncratic volatility, and return on assets. The effect of these real option proxies is removed from stock returns and betas, and the residuals are interpreted as option-adjusted returns and option-adjusted betas. The option-adjusted variables are run in a Fama-MacBeth cross-sectional regression to compare the accuracy of raw and option-implied variables. Results suggest that CAPM adjusted for real options yields more accurate estimates and performs better, meaning the CAPM relationship becomes much closer to what theory predicts. This evidence suggests that, despite its flaws as an asset pricing model, CAPM can still be a valid method for corporate management, especially as managers possess superior access to information regarding investment opportunities.

Incorporating real options into common corporate budgeting practice might be a secondary solution to its uncertainty issue, and even too complex for the majority of firms to adopt. A

parallel strand therefore asks how firms can instead reduce beta imprecision in practice. Levi and Welch (2017) address this issue directly, investigating how firms should estimate the inputs used in cost of capital models, especially beta, since it is unique to each firm. The authors study this using data from CRSP and Compustat and examine how well different beta estimators predict future beta. Findings suggest that CAPM betas should be shrunk in order to increase their predictive precision. The best predictive precision is achieved with Vasicek-shrunk betas estimated with one to four years of daily returns, and then shrunk again by approximately 20–30 %. Results emphasise that betas for projects with longer time horizons should be shrunk even more. Additionally, daily return betas dominate monthly return betas, contrary to the common textbook advice of using three to five years of monthly data. Moreover, the results suggest that industry betas are poor substitutes for firm betas, consistent with Fama and French (1997) and Pástor and Stambaugh's (1999) predictions. Results from Levi and Welch reinforce that beta estimation error is real and economically meaningful. Beta shrinkage is not a common practice taught in business schools, and if firm betas require aggressive shrinkage to retain their predictive accuracy, it suggests that betas used in cost of equity estimates might distort investments.

Prior literature shows that the use of CAPM-derived cost of equity estimates is surrounded by measurement and implementation problems. Fama and French (1997) and Pástor and Stambaugh (1999) document that cost of equity estimates are highly imprecise. Adding additional risk factors does not necessarily mean better results either, especially for individual firms, because estimation error in factor loadings and risk premia can outweigh the theoretical benefits of richer models (Nagel et al., 2007). However, empirical failures of CAPM in stock return tests do not invalidate its use in capital budgeting for estimating project-level cost of capital, because equity returns also reflect embedded real options (Da et al., 2012). Additionally, Levi and Welch (2017) conclude that beta estimates are noisy, time-varying, and sensitive to estimation choices, which implies that standard textbook approaches can produce unreliable inputs for project discount rates. Taken together, these findings suggest that beta precision alone should not be interpreted as a perfect proxy for cost of equity precision, but rather as a measure of the reliability of a commonly used

market-based input in capital budgeting, and it is in this sense that this thesis adopts it as its measure of cost of equity precision.

### **3.3 Corporate Investment Efficiency**

This section of the literature review considers prior empirical research on corporate investment efficiency. The aim of this section is to discuss and validate how investment efficiency is measured, and what factors prior literature has identified as being associated with it. The section then proceeds to discuss prior research that directly links errors in cost-of-equity estimates to investment efficiency, and what remains to be studied.

This branch of literature is centred on residual-based model approaches to measuring what is considered efficient investment. The methodology used in this thesis is highly influenced by this branch of literature, especially by Richardson (2006). Richardson (2006) studies whether firms with excess internally generated cash flow are prone to overinvestment, meaning whether they spend beyond what is needed to maintain existing assets and to fund expected positive-NPV projects. The paper uses a large U.S. sample of 58 053 firm-year observations from 1988 to 2002, excluding financial firms. Firm total investment is decomposed into maintenance investment and new investment. Total investment includes capital expenditures, research and development, and acquisitions, less the income arising from sales of plant, property, and equipment. Maintenance investment is proxied by depreciation and amortisation. The remaining new investment is then split into expected investment and abnormal investment. Expected investment is estimated with an investment expectation model that controls for growth opportunities, leverage, cash, firm age, firm size, prior stock returns and prior investment, with year and industry fixed effects. The residual from this model represents the deviation from efficient investment, defined as abnormal investment. Richardson (2006) estimates how much cash the firm is left with after funding normal operations and expected good investments, and tests whether that excess cash is associated with unusually high investment. The results suggest that overinvestment concentrates among firms with positive free cash flow, consistent with Jensen's (1986) free

cash flow hypothesis and broader agency theory. For firms with positive cash flow, the average firm overinvests approximately 20 % of its free cash flow.

The methodology used in Richardson's (2006) expected investment model provides a clean justification for interpreting investment inefficiency as deviations from the efficiency model, where positive residuals indicate overinvestment and negative residuals underinvestment. Biddle and Hilary (2006) examine the relationship between higher financial reporting quality and efficient investment using a similar residual-based under- and overinvestment definition. Using a U.S. sample from 1993 to 2005 containing 34 791 firm-year observations and excluding financial firms, the authors find that higher reporting quality is associated with lower under- and overinvestment. Additionally, firms with higher reporting quality deviate less from predicted investment levels. Biddle and Hilary (2006) extend Richardson's (2006) approach, in which inefficiency is measured as a deviation from predicted investment. Their results suggest that information quality is linked to investment efficiency.

McNichols and Stubben (2008) examine whether earnings management affects firms' real investment decisions. They examine whether firms that manipulate reported earnings make sub-optimal investment decisions, especially when income-increasing misreporting leads firms to overinvest. The authors investigate this using three main samples: firms investigated by the SEC for accounting irregularities, firms sued by shareholders for improper accounting, and firms that restated their financial statements. Their findings suggest that firms that manipulate their earnings are prone to overinvestment during the misreporting period. The overinvestment declines or disappears after the misreporting period, which suggests that it is likely due to intentionally distorted accounting information. Similarly to Biddle and Hilary (2006), information quality steers firms' investment decisions towards the sub-optimal, consistent with broader agency theory and information asymmetry (Jensen & Meckling, 1976; Jensen, 1986; Myers & Majluf, 1984). Inflated earnings could weaken the monitoring of firms, because stakeholders receive an overly positive picture of the firm's state. This weaker monitoring might incentivise overinvestment. These findings support the idea that information quality matters for real corporate investment decisions. McNichols

and Stubben (2008) suggest that accounting misstatements can distort firm investment by creating exaggerated growth expectations.

Moreover, Goodman et al. (2014) examine whether managers' externally issued earnings forecasts reveal something about the quality of their investment decisions. The key argument is that capital budgeting requires managers to forecast project payoffs, but these internally made project forecasts are unobservable to outsiders. Because of this, the authors argue that more accurate earnings forecasting ability, which is observable to outsiders, can be used as a signal of broader managerial ability. Managers who forecast future earnings well are more likely to forecast project payoffs accurately, and thus make better investment decisions. This relationship is examined through the efficiency of firm acquisitions and capital expenditures. Forecasting quality is measured by its accuracy, defined as the absolute difference between forecasted earnings-per-share (EPS) and actual EPS, scaled by stock price and then multiplied by negative one, so that higher values represent better forecasting quality. Results suggest that better management forecasting ability leads to better investment decisions, as higher-ability firms report higher post-acquisition returns and operating performance. Moreover, firms with more accurate management forecasts deviate less from expected investment, meaning more efficient investing.

Results from these studies suggest that information quality is an important factor that mitigates inefficiencies in capital budgeting. In general, the literature relies heavily on the model-implied measure of investment efficiency, which is not flawless, mainly because the true investment opportunity set cannot be observed by an outsider. Richardson (2006) acknowledges this, stating that the model can suffer from measurement errors. Deviation from prediction could reflect omitted growth opportunities not captured by Tobin's Q or other similar proxies. The residual-based measurement is indeed imperfect. It assumes that expected investment can be approximated using observable firm characteristics, even though the true investment opportunity set remains unobservable. Therefore, the residual remains susceptible to criticism. Despite this, the approach remains the most suitable empirical proxy for investment efficiency in a large-sample setting. Modelling expected

investment and focusing on deviations from that benchmark provides a theoretically grounded and literature-consistent way to capture investment behaviour that can be defined as abnormal (Richardson, 2006; Biddle & Hilary, 2006; McNichols & Stubben, 2008; Goodman et al., 2014). The information inputs examined in this literature — financial reporting quality, earnings management, and management forecasting ability — are largely accounting-based. This thesis extends the same logic to a market-based input, the precision of the cost of equity, and the following section reviews the research that links it directly to investment efficiency.

### **3.3.1 Cost of Equity Precision and Investment Efficiency**

More recent literature directly investigates the relationship between CAPM-derived cost of equity estimates and sub-optimal capital budgeting decisions. Dessaint et al. (2021) examine whether using the CAPM in acquisition valuations creates real errors. The argument is built on the empirical evidence suggesting that the true security market line is flatter than the CAPM predicts. This means that low-beta assets earn higher returns, and high-beta assets earn lower returns, than the CAPM implies. Managers who use CAPM-derived discount rates to value acquisitions could therefore end up with distorted valuations. Using M&A transaction data consisting of bids for private targets by U.S. public bidders from 1977 to 2015, Dessaint et al. (2021) find that bidders receive worse market reactions when they acquire low-beta targets and better reactions when they acquire high-beta targets. This is consistent with the assumption that CAPM users overvalue low-beta targets, and therefore the market reacts negatively. The valuation error is on average 23 % of the total deal value (Dessaint et al., 2021).

The findings from Dessaint et al. (2021) are consistent with the survey evidence showing that firms commonly use CAPM to estimate cost of equity (Graham & Harvey, 2001). The empirical evidence also confirms that the security market line is flatter than the CAPM implies. This is consistent with the idea that the use of CAPM can distort valuation and investment decisions. More precisely, errors in cost-of-capital inputs can translate into real

investment valuation errors. Dessaint et al. (2021) suggest that biased or empirically flawed cost-of-equity estimates can distort acquisition valuations. This implies that more precise estimates should mitigate the distortion. Moreover, the economic magnitude of their results (12 % to 33 % of deal value) motivates further examination of the real cost of imprecise beta estimates.

More closely related to the research presented in this thesis, Biggerstaff et al. (2025) investigate the relationship between imprecision in cost-of-equity estimates and investment efficiency. Firms commonly use DCF methodology in capital budgeting, and many estimate the cost of equity using CAPM. CAPM requires estimates for the market return and for the risk-free rate. A firm's individual exposure to the excess return is captured by beta, which is firm-specific. Therefore, firms with more precise beta estimates should invest closer to their expected investment levels, as more precise betas yield more precise cost-of-equity estimates when using the CAPM (Biggerstaff et al., 2025). The authors use U.S. firm-year data ranging from 1965 to 2015. Their main sample consists of 147 000 firm-year observations with over 14 000 unique firms. The precision of beta is defined using the standard error of the beta coefficient from a market-model regression. Similarly to Goodman et al. (2014), the standard error is multiplied by negative one so that higher values represent more precise beta estimates. Abnormal Investment, which is derived from a residual-based investment model (Richardson, 2006; Biddle & Hilary, 2006; Goodman et al., 2014), is then regressed on the precision of beta. Consistent with their assumption, the evidence suggests that more precise cost-of-equity estimates mitigate Abnormal Investment, as these firms deviate less from expected investment. As a measure, Beta Precision is validated with a test against analyst-implied cost of equity. The results suggest that firms with more precise beta estimates have lower dispersion across analysts' implied cost of equity estimates. This supports the idea that Beta Precision is not just a statistical artefact of a regression model, and suggests that it captures real difficulty in cost of equity estimation (Biggerstaff et al., 2025). Further robustness tests strengthen the result. A quantile regression on raw investment levels is used to test whether Beta Precision depends on the residual-based investment measure commonly used in the efficiency literature. The results suggest that Beta Precision

is not model-dependent and does not simply reduce general investment levels. Rather, it compresses investment in the high and low quantiles. This is consistent with the hypothesis that noisy discount rates can cause both under- and overinvestment. Additionally, the signed test of Beta Precision (Residual Investment) suggests that it does not predict the direction of investment, rather, it predicts less deviation from expected investment. Further tests suggest that Beta Precision interacts with firm conditions as well, and is therefore not a universal average effect. Firms with low investment capacity are less likely to overinvest due to a shortage of resources, and the results show that Beta Precision reduces underinvestment for these firms. Moreover, firms with high CEO tenure are likely to overinvest due to agency issues such as empire-building behaviour, and for these firms the results show that Beta Precision reduces overinvestment. Family-controlled firms are also tested, as they might rely less on market-based cost of capital estimates. The results support this, as the main relationship between Abnormal Investment and Beta Precision is weaker for family-controlled firms. Tests related to governance, incentives, and monitoring also suggest that Beta Precision is not proxying for poor management or high agency costs (Biggerstaff et al., 2025).

Taken together, the evidence in this section supports investigating investment efficiency by examining deviations from expected investment levels (Richardson, 2006; Biddle & Hilary, 2006; Goodman et al., 2014), and shows why cost of equity precision is a relevant determinant of those deviations (Dessaint et al., 2021; Biggerstaff et al., 2025). The residual-based model remains imperfect, as it cannot observe the true investment opportunity set firms face. However, it remains the most suitable model proxy for a large sample because it is theoretically grounded and capable of capturing both under- and overinvestment (Tobin, 1969; Hayashi, 1982; Goodman et al., 2014; Biggerstaff et al., 2025). Prior literature suggests a clear mechanism through which poor information inputs can distort capital budgeting decisions, while better information quality enables firms to allocate capital closer to efficient levels. Dessaint et al. (2021) and Biggerstaff et al. (2025) move this discussion directly to the cost-of-equity channel, providing empirical evidence that CAPM-related estimation errors have real consequences for valuation and investment outcomes. The main

implication for the rest of this thesis is that Beta Precision should not be treated as a purely statistical property of a market model regression. Instead, Beta Precision represents a potential source of variation affecting the quality of capital budgeting decisions. This motivates the empirical analysis of cost-of-equity precision and Abnormal Investment among European firms, to detect whether regional and institutional differences are associated with the documented relationship. Because the existing evidence comes almost entirely from the market-based U.S. setting, whether the same relationship holds in Europe's more bank-based financial systems remains an open question (Levine, 2002), and it is this gap that this thesis addresses.

## 4 Methodology and Data

This section describes the methodology and sample data used in the empirical analysis. The first part defines the main dependent and independent variables and describes the construction of the empirical models. The second part presents the data sources, sample construction, and descriptive statistics.

### 4.1 Empirical Methods

This segment describes the variable and model construction used in the empirical tests. The first part describes how the main dependent variable, Abnormal Investment, is defined, followed by the definition of Beta Precision. The final part describes the main regression model of Abnormal Investment on Beta Precision.

#### 4.1.1 Variable Construction and Investment Efficiency Model

This thesis follows previous literature (Richardson, 2006; Biddle & Hilary, 2006; Goodman et al., 2014; Biggerstaff et al., 2025) and defines investment efficiency as the relationship between investment and growth opportunities, measured with Tobin's Q (Tobin, 1969; Hayashi, 1982). Following Richardson (2006) and more directly the specification of Biggerstaff et al. (2025), the expected level of investment for firm  $i$  in year  $t$  is defined as follows.

$$Investment_{i,t} = c + \beta_1 TobinsQ_{i,t-1} + \beta_2 CFO_{i,t}/Avg.Assets_{i,t} + \beta_3 AssetGrowth_{i,t-1} + \beta_4 Investment_{i,t-1} + \varepsilon_{i,t}$$

Where  $Investment_{i,t}$  is capital expenditure for firm  $i$  scaled by its average assets in year  $t$ .  $TobinsQ_{i,t-1}$  is the beginning-of-year value of Tobin's Q for firm  $i$ .  $CFO_{i,t}/Avg.Assets_{i,t}$

is cash flow from operations scaled by average assets for firm  $i$  in year  $t$ .  $AssetGrowth_{i,t-1}$  is the growth rate of assets from year  $t - 2$  to year  $t - 1$  for firm  $i$ .

Investment is measured as capital expenditures scaled by average total assets. Tobin's Q captures firms' growth opportunities, while operating cash flow scaled by assets controls for internal financing capacity (Myers & Majluf, 1984). Prior asset growth captures persistent growth dynamics, and prior investment controls for investment momentum (Richardson, 2006). The regression is estimated separately for each industry-year to isolate model-implied investment within comparable firms facing similar environments, following Biggerstaff et al. (2025). Abnormal Investment is measured using the absolute value of the regression residuals (Goodman et al., 2014; Biggerstaff et al., 2025), representing the deviation from model-implied efficiency — that is, the gap between a firm's actual investment and the level predicted by its growth opportunities and fundamentals. Larger values indicate greater misalignment between actual and expected investment. The signed value of Abnormal Investment indicates the direction of inefficiency, where positive values indicate overinvestment and negative values indicate underinvestment (Richardson, 2006; Goodman et al., 2014). The signed value of Abnormal Investment is defined as Residual Investment in the empirical tests. Abnormal Investment is defined as follows.

$$Abnormal\ investment_{i,t} = |\varepsilon_{i,t}|$$

#### 4.1.2 Beta Precision

The main independent variable, Beta Precision, follows Biggerstaff et al. (2025) and measures the precision of firm-level beta estimates. Beta is estimated using a market model regression. The market model regression is defined as follows.

$$R_{i,t} = c + \beta_{i,t}R_{m,t} + \varepsilon_{i,t}$$

Where monthly returns for firm  $i$  over the 36 months preceding year  $t$  are regressed on market returns, proxied by the STOXX 600, following the estimation approach of Biggerstaff et al. (2025). Beta Precision is defined as the negative of the standard error of the beta estimate, following Biggerstaff et al. (2025). As in Goodman et al. (2014), the standard error is multiplied by minus one so that higher values represent more precise estimates. Beta Precision is defined as follows.

$$Beta\ Precision_{i,t} = -SE(\beta_{i,t})$$

Where higher values of Beta Precision indicate more precise beta estimates (narrower confidence intervals). Because beta enters the CAPM linearly, a less precisely estimated beta translates directly into a less precise cost-of-equity estimate. The empirical expectation is that firms with more precise beta estimates face less cost-of-equity uncertainty and therefore invest more closely to model-implied efficiency.

#### 4.1.3 Main Regression Specification

To test whether Beta Precision explains deviations from efficient investment, the following ordinary least squares (OLS) model is estimated, following Biggerstaff et al. (2025). The definition is as follows:

$$\begin{aligned} Abnormal\ Investment_{i,t} = & c + \beta_1 Beta\ Precision_{i,t-1} + \beta_2 Ln(Assets)_{i,t-1} + \\ & \beta_3 Tobin's\ Q_{i,t-1} + \beta_4 CFO_{i,t}/Avg.\ Assets_{i,t} + \beta_5 Asset\ Growth_{i,t-1} + \beta_6 Beta_{i,t-1} + \\ & \beta_7 Investment_{i,t-1} + \varepsilon_{i,t} \end{aligned}$$

The model controls for firm size, as larger firms could have more sophisticated systems or managers who allow them to invest more efficiently (Graham & Harvey, 2001; Graham, 2022; Brounen et al., 2004). Firm growth expectations are controlled with Tobin's Q and Asset Growth (Tobin, 1969; Hayashi, 1982). This distinguishes between firms that invest only to maintain or replace existing assets and firms that invest in new projects. In addition,

the model controls for cash flow scaled by assets, since internal funds can finance investment (Myers & Majluf, 1984). The estimated beta is included to control for differences in systematic risk across firms, isolating estimation precision from the level of systematic risk (Fama & French, 1997; Pástor & Stambaugh, 1999), and prior-year investment is included to account for persistence in corporate investment behaviour (Richardson, 2006). Industry, year, and firm fixed effects are included in the specifications. Standard errors are clustered at the firm level to address serial correlation and heteroskedasticity. In further analysis, Abnormal Investment is replaced with Residual Investment to assess whether the effect of Beta Precision differs between over- and underinvesting firms.

## **4.2 Data and Descriptive Statistics**

Large public firms are more likely to incorporate sophisticated methods to evaluate potential investment opportunities (Graham & Harvey, 2001; Graham, 2022; Brounen et al., 2004; Hartwig, 2012; Andor et al., 2015). This motivates a focus on large publicly traded firms in Europe to test the relationship. Therefore, the sample data are gathered from firms listed in the STOXX 600 index from 1997 to 2024. All accounting, ESG and stock data are retrieved from Refinitiv (LSEG).

The measurement of Abnormal Investment depends on industry classifications, because a firm's investment behaviour is measured against the investment behaviour of its industry. In this thesis, the industry classifications follow Refinitiv's (LSEG) methodology, which assigns firms to one of six sectors: industrials, utilities, transportation, banks/savings and loans, insurance, and other financial services. Each firm is also assigned a country code based on the location of its primary business operations. The original panel data consisted of 14 523 firm-year observations. The sample was adjusted to exclude firms allocated to financial or financial-like industries, as well as firms with a country code outside the European region. Financial sectors were excluded mainly due to their different relationship with capital expenditure and differences in business operations. Non-European firms were

excluded to maintain a clean regional sample, as the focal point is regional comparison. After these adjustments, the remaining panel data comprised 10 712 firm-year observations.

Following Biggerstaff et al. (2025), this thesis uses a threshold approach to firm-year observations in variable construction, requiring a minimum of 15 firm-year observations for each industry-year sample in the construction of Abnormal Investment. This led to further adjustments to firms' sector allocation. Therefore, Refinitiv's industry allocation was readjusted into four main sectors. The four adjusted sectors, used in all regression analyses and in variable construction, are consumer goods and services, industrials, utilities, and other. In addition, the data includes a small number of firms with exceptionally large values in key financial variables, resulting in highly skewed distributions with extreme tails. Such outliers can distort OLS estimation and undermine statistical inference. To address this, variables with extreme values are winsorised at the 1st and 99th percentiles. Winsorisation reduces the influence of extreme tails while preserving the underlying cross-sectional variation. Winsorised variables are marked with an asterisk. The sample summary statistics are presented in Table 1.

**Table 1.** Descriptive Statistics

Descriptive Statistics						
	Mean	Std. Dev.	P25	Median	P75	Observations
Tobin's Q *	1,70	1,55	0,82	1,19	1,93	10 173
Ln(Assets)	15,48	1,76	14,43	15,55	16,69	10 706
Residual Investment *	-0,00	0,02	-0,01	-0,00	0,01	9 389
Abnormal Investment *	0,01	0,01	0,00	0,01	0,01	9 389
Investment *	0,05	0,04	0,02	0,04	0,06	10 243
CFO/Avg.Assets *	0,10	0,07	0,06	0,09	0,14	10 148
Beta Precision	-0,31	0,14	-0,35	-0,27	-0,22	8 433
Beta	1,05	0,59	0,64	0,99	1,39	8 433
Debt/MVE*	0,42	0,54	0,1	0,24	0,51	10173
Asset Growth *	0,10	0,23	-0,01	0,05	0,15	10 266

Variables winsorised at the 1st and 99th percentiles are marked with an asterisk (\*).

During the sample period (1997–2024), the mean European firm has an investment ratio of 5,0 %. The sample average for Abnormal Investment is 1 % of average assets, which implies that, in practice, the average European firm misinvests 52 830 € per year. The negative mean of Residual Investment indicates that the average inefficiency manifests as underinvestment. The average Beta in the sample is 1,05, and the average Beta Precision is –0,31. This implies that, at a 95 % confidence interval, the true beta for the average firm lies roughly between 0,44 and 1,66. Combined with an average debt-to-market-equity ratio of 0,42, this wide range of plausible "true" beta values illustrates how imprecision in cost-of-equity estimates can carry through to discount rates and potentially distort investment evaluation.

European firms show differences in characteristics compared with the North American sample of Biggerstaff et al. (2025). In general, the average European firm has a lower investment ratio and a lower ratio of Abnormal Investment. The average European firm also has a more precise beta estimate. Additionally, the average cash-flow-to-average-assets ratio is higher

in Europe, which suggests a higher capacity to finance investments internally, or a more mature set of firms. Another potential reason for the difference could be regional differences in access to financing. A more institutionally oriented European financial system could create constraints on external financing and incentivise firms to generate higher internal funds (Levine, 2002).

Table 2 presents the correlation coefficients for the main variables used in analyses throughout the thesis. The table suggests no high correlations between the independent variables, which implies that the variables are unlikely to suffer from severe multicollinearity. The correlation coefficients between Beta Precision and Investment, Residual Investment, and Abnormal Investment are all negative and statistically significant, consistent with the thesis hypothesis. The strong, significant, positive coefficient between firm size and Beta Precision (0,32) is consistent with the view that large publicly traded firms tend to have more liquid and actively traded shares, broader analyst and investor coverage, and thus more informative stock prices. Because of this, the return series in market model regressions likely contain less idiosyncratic noise, which yields beta estimates with lower standard errors, consistent with the information efficiency arguments from Fama (1970). In addition to higher-quality stock price information, the association could be driven by the fact that larger firms have broader investment opportunity sets and stronger internal analytical capabilities, which could enhance decision-making quality (Graham & Harvey, 2001; Brounen et al., 2004). The negative and significant coefficient between size and Abnormal Investment (-0,16) supports this assumption. High-beta firms are likely to have more volatile stock returns and thus weaker covariance stability, which could explain the negative and significant correlation between Beta and Beta Precision (-0,34). In addition, the positive and significant correlation of Investment and Abnormal Investment with Cash Flow suggests that excess internal funds incentivise firms to invest, thereby encouraging inefficient capital allocation, consistent with Jensen (1986) and Myers and Majluf (1984).

**Table 2.** Variable Correlation Matrix

Correlation Matrix									
	Tobin's Q *	Ln(Assets)	Residual Invest- ment *	Abnormal Invest- ment *	Investment *	CFO/ Avg.Assets *	Beta Precision	Beta	Asset Growth *
Tobin's Q *	1,00 (-----)								
Ln(Assets)	-0,37*** (-36,54)	1,00 (-----)							
Residual Investment *	0,00 (-0,24)	0,00 (0,43)	1,00 (-----)						
Abnormal Investment *	0,04*** (3,65)	-0,16*** (-14,89)	0,22*** (21,11)	1,00 (-----)					
Investment *	0,01 (0,69)	0,01 (1,08)	0,48*** (50,06)	0,51*** (54,00)	1,00 (-----)				
CFO/Avg.Assets *	0,55*** (59,65)	-0,23*** (-22,02)	0,00 (0,31)	0,15*** (13,51)	0,27*** (26,01)	1,00 (-----)			
Beta Precision	-0,07*** (-6,50)	0,32*** (30,51)	-0,04*** (-3,70)	-0,16*** (-14,76)	-0,07*** (-6,77)	0,03** (2,88)	1,00 (-----)		
Beta	-0,12*** (-10,69)	0,02* (1,99)	-0,01 (-1,21)	0,00 (0,06)	-0,09*** (-8,37)	-0,12*** (-11,34)	-0,34*** (-33,43)	1,00 (-----)	
Asset Growth *	0,14*** (12,90)	-0,10*** (-9,03)	0,03** (2,82)	0,10*** (9,10)	0,08*** (6,92)	0,10*** (8,83)	-0,09*** (-8,67)	-0,01 (-1,02)	1,00 (-----)

Variables winsorised at the 1st and 99th percentiles are marked with an asterisk (\*). T-statistics are reported in parentheses. Statistical significance is denoted as follows: \* p < 0,05, \*\* p < 0,01, \*\*\* p < 0,001.

Table 3 presents the top 5 most and least precise firms ranked by the standard error of beta in January 2015. It illustrates a point-in-time view of sample firms operating in the same macroeconomic market environment. Therefore, the large differences in the standard error of beta suggest that firms face different estimation environments under the same market conditions. From the sample data, Nestlé has the most precisely estimated beta coefficient, while Frontline PLC has the least precisely estimated beta coefficient. At a 95 % confidence interval, the true beta coefficient for Nestlé is between 0,15 and 0,80, and for Frontline PLC between -3,34 and 3,45. Even with the most precise beta estimate, the resulting cost-of-equity estimate can still vary depending on the beta coefficient used.

**Table 3.** Top and Bottom 5 Firms Ranked by Beta SE

Top 5 Most Precise (lowest Beta SE)				
Firm	Beta	Beta SE	95 CI Low	95 CI High
Nestlé S.A.	0,48	0,17	0,15	0,80
L'Air Liquide S.A.	0,68	0,17	0,33	1,02
Lindt & Sprüngli AG	0,28	0,18	-0,08	0,64
Snam S.p.A.	0,68	0,19	0,31	1,06
Compass Group PLC	0,59	0,19	0,21	0,97
Bottom 5 Least Precise (highest Beta SE)				
Firm	Beta	Beta SE	95 CI Low	95 CI High
Frontline PLC	0,06	1,73	-3,34	3,45
Ocado Group PLC	1,41	1,23	-1,00	3,82
Vestas Wind Systems A/S	2,44	1,16	0,17	4,70
Bavarian Nordic A/S	0,39	0,92	-1,41	2,20
Nokia Oyj	2,43	0,91	0,64	4,22

Values represent a snapshot in time from the overall sample. Table values are from January 2015.

Table 4 presents how Beta SE is distributed across sample countries, alongside each country's average score on the IMF Financial Development Index. There is no large variation across the European region, though some differences emerge. Countries with higher financial development tend to display lower standard errors of beta. The least financially

developed markets in the sample, Poland and Cyprus, also exhibit the least precise beta estimates, whereas the most developed markets, such as Switzerland and the United Kingdom, are among the most precise. This is consistent with the view that deeper, larger, and more liquid markets generate smoother price discovery, more stable covariance estimates, and less noisy return series, and therefore more reliable beta estimates. The pattern is not monotonic, however. Luxembourg, for example, combines a high financial development score with a relatively high standard error, partly reflecting its small number of sample firms. The association should therefore be read as a descriptive, country-level regularity rather than a firm-level test, which the main regressions address directly.

**Table 4.** Beta SE per Sample Nation

Beta SE per Nation							
Country	Mean	Std. Dev.	P25	Median	P75	Count	Mean FD
Austria	0,305	0,077	0,253	0,290	0,342	116	0,627
Belgium	0,265	0,075	0,218	0,259	0,316	133	0,644
Cyprus	0,686	0,330	0,506	0,585	0,790	23	0,546
Denmark	0,378	0,170	0,256	0,331	0,449	410	0,677
Faroe Islands	0,385	0,093	0,326	0,373	0,426	11	N/A
Finland	0,312	0,108	0,238	0,283	0,354	337	0,587
France	0,276	0,134	0,194	0,248	0,313	1 123	0,748
Germany	0,314	0,142	0,222	0,287	0,369	1 025	0,739
Ireland	0,296	0,101	0,224	0,280	0,353	157	0,717
Italy	0,280	0,117	0,197	0,256	0,344	391	0,743
Luxembourg	0,438	0,197	0,301	0,365	0,512	76	0,729
Netherlands	0,304	0,139	0,209	0,272	0,350	473	0,780
Norway	0,389	0,229	0,248	0,329	0,459	230	0,660
Poland	0,485	0,217	0,350	0,427	0,577	89	0,406
Portugal	0,265	0,077	0,210	0,262	0,307	63	0,687
Spain	0,259	0,086	0,201	0,245	0,299	352	0,836
Sweden	0,316	0,125	0,235	0,280	0,362	777	0,749
Switzerland	0,269	0,114	0,195	0,243	0,310	835	0,947
United Kingdom	0,304	0,136	0,215	0,272	0,359	1 812	0,877

Beta SE is the standard error of the market-model beta. Mean FD is the country's average score on the IMF Financial Development Index, measuring the depth, access and efficiency of financial institutions and markets, ranging from 0 to 1, with higher values indicating greater financial development. Due to data availability, the FD average is computed over 1997 – 2020, whereas the remaining columns cover the full 1997 – 2024 sample period. The index is not available for the Faroe Islands (N/A).

## 5 Empirical Research Results

This chapter presents results from the empirical tests. The main relationship between Abnormal Investment and Beta Precision is tested first. This is followed by a quantile regression on investment. The third section divides the sample into over- and underinvesting subsamples to test one-sidedness. The final section incorporates additional robustness tests, using alternative estimation windows and model specifications, controls for agency issues, and tests whether the relationship is more or less dependent on firm size.

### 5.1 Abnormal Investment and Beta Precision

The main analysis of this thesis examines whether increased precision in cost of equity estimates mitigates over- or underinvesting firm behaviour. The analysis is conducted via OLS regression, where the dependent variable (Abnormal Investment) represents the absolute value of the error term from the efficient-investment model. Higher values of Abnormal Investment imply a larger deviation from efficiency. The key variable of interest is Beta Precision, where higher values imply more precise cost-of-equity estimates. The relationship between Abnormal Investment and Beta Precision is tested using four different specifications. The first specification tests the model without any fixed effects to establish a baseline for the relationship. The second specification adds year- and industry fixed effects to the model. Industry fixed effects are included to control for differences between industries in investment behaviour. Year fixed effects control for macroeconomic and market-wide conditions that affect all firms simultaneously, thereby reducing the possibility that the relationship is being driven by economic shocks or trends through time. The third specification adds estimated beta as a control variable. This separates the effect of Beta Precision from the effect of the beta estimate itself. Including Beta as a control variable isolates the independent relationship of Beta Precision with Abnormal Investment beyond systematic risk. The fourth and final specification adds firm fixed effects to control for firm-specific characteristics. Including firm fixed effects makes it possible to compare firms against themselves over time rather than against other firms. Standard errors are clustered at the firm level to

account for serial correlation and heteroskedasticity within firms over time in each specification. Results from the main analysis are presented in Table 5.

**Table 5.** Abnormal Investment on Beta Precision

Variables	Abnormal Investment $t$			
	(1)	(2)	(3)	(4)
Beta Precision $t-1$	-0,007*** (-5,361)	-0,009*** (-5,351)	-0,008*** (-4,494)	-0,004* (-2,277)
Ln(Assets) $t-1$	-0,001*** (-9,485)	-0,001*** (-7,368)	-0,001*** (-7,383)	-0,001*** (-3,372)
Tobin's Q $t-1$	-0,000 (-1,684)	-0,000 (-0,393)	-0,000 (-0,373)	0,000 (0,526)
CFO/Avg.Assets $t$	0,003 (1,122)	0,003 (0,978)	0,003 (0,995)	0,008* (2,404)
Asset Growth $t-1$	0,000 (-0,022)	0,000 (-0,504)	0,000 (-0,483)	0,000 (0,025)
Investment $t-1$	0,152*** (23,277)	0,146*** (20,878)	0,146*** (20,872)	0,124*** (11,292)
Beta $t-1$			0,000 (0,635)	0,000 (1,226)
Industry FE	No	Yes	Yes	No
Year FE	No	Yes	Yes	Yes
Firm FE	No	No	No	Yes
Clustered Standard Errors	Firm	Firm	Firm	Firm
Observations	8 366	8 366	8 366	8 366
R-Squared	0,257	0,269	0,270	0,358

Standard errors are clustered at the firm level. Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ .

The analysis shows a consistent, negative and statistically significant relationship between Beta Precision and Abnormal Investment across all four model specifications. The results are consistent with the thesis hypothesis, suggesting that more precise cost-of-equity estimates are associated with higher investment efficiency. The relationship remains negative and significant in specifications that include industry, firm, and year fixed effects, which implies that it is not driven by any particular type of firm, macroeconomic cycle, or industry structure within the sample. Fama and French (1997) and Pástor and Stambaugh (1999)

argue that estimate uncertainty — rather than the risk level itself — drives mispricing and distortions. This is tested by including Beta as a control variable to strip the risk level out of Beta Precision. Consistent with Fama and French (1997) and Pástor and Stambaugh (1999), Beta Precision remains negative and significant after controlling for Beta. The results indicate that the level of Beta (high or low) is irrelevant for investment efficiency. Instead, the key mechanism is the precision of the beta estimate. Including firm and year fixed effects (the fourth specification) decreases the magnitude of the Beta Precision coefficient from  $-0,007$  to  $-0,004$ , implying that unobserved and static firm characteristics absorb some of the variance. The main driver of Abnormal Investment, however, seems to be past investment and investment momentum. Firms locked into capital expenditure momentum consistently generate the largest deviations from model-implied efficiency.

The small and insignificant coefficients on growth opportunities (Tobin's Q), internal financing (Cash Flow) and prior asset growth suggest that their effects are fully absorbed in the first-stage regression, during the construction of Abnormal Investment. The first-stage regression already absorbs the expected, economically rational level of investment defined by industry peers. The findings are economically meaningful. The average investment rate for the sample firms is 5,0 % of assets, and the average Abnormal Investment is approximately 1,0 % of assets. Using the third model specification as a reference, where the coefficient on Beta Precision is  $-0,008$ , a one-standard-deviation increase in Beta Precision would decrease Abnormal Investment by approximately 11,2 % of the sample mean. Even under the most demanding fourth specification, which includes firm fixed effects, the coefficient of  $-0,004$  implies a within-firm reduction in Abnormal Investment of roughly 5,6 % of the sample mean for a one-standard-deviation increase in Beta Precision. The rise in  $R^2$  from 0,257 to 0,358 once firm fixed effects are added indicates substantial firm-level heterogeneity, but the relationship survives this within-firm comparison, which is the most conservative test of the hypothesis.

In addition, the results are consistent with prior research (Dessaint et al., 2021; Biggerstaff et al., 2025) but reveal some distinct structural differences in how corporate environments

process market signals. In Europe, the coefficient on Tobin's Q is near zero and statistically insignificant, and turns negative in every specification except the one with firm fixed effects. In North America, however, Tobin's Q remains positive and highly statistically significant (Biggerstaff et al., 2025). This could reflect regional differences between the U.S. market-based economy and Europe's bank-based economy (Levine, 2002). Managers in North America are more sensitive to equity-market sentiment and are pressured to expand in line with market expectations. In Europe, capital allocation is more governed by steadier long-term bank and stakeholder relationships, which could be reflected in the low, non-significant coefficient on Tobin's Q (Levine, 2002). Internal financing capacity (Cash Flow) is a highly significant driver of Abnormal Investment in North America as well, whereas in Europe it is only weakly significant in the fourth specification. However, the major difference in sample size between the European sample tested in this thesis and the US sample is likely associated with differences in the significance of the coefficients. A common mitigating factor of inefficiency across regions is size, consistent with survey evidence and the assumption that information quality and the inputs used in cost of equity estimates increase with firm size (Graham & Harvey, 2001; Brounen et al., 2004; Goodman et al., 2014). The comparison suggests that Beta Precision has a stronger proportional effect on investment efficiency in Europe. Comparing the same model specification (the third model, with industry and year fixed effects), a one-standard-deviation increase in Beta Precision decreases Abnormal Investment in North America by 4,5 % (Biggerstaff et al., 2025), versus 11,2 % in Europe.

## 5.2 Quantile Regression on Investment

The OLS regression of Abnormal Investment on Beta Precision is dependent on the model of efficient investment, as the main dependent variable is derived from the investment efficiency model. To test this model dependency, the relationship between firm investment and Beta Precision is tested using a quantile regression approach. Quantile regression measures how the effect of an independent variable differs across the distribution of the dependent variable. Introduced by Koenker and Bassett (1978), quantile regression extends

classical linear regression by estimating conditional quantiles of the dependent variable, which allows covariate effects to vary across the distribution rather than being restricted to the conditional mean as in the OLS framework. In addition to addressing model dependency, the quantile regression approach makes it possible to identify whether the effect of Beta Precision is more pronounced in high or low quantiles of investment. The quantile regression analysis also includes some additional variables. For example, the natural logarithm of cash flow from operations is added as an alternative variable to control for investment behaviour associated with excess funds (Myers & Majluf, 1984). The standard deviation of cash flow is included to capture investment behaviour associated with unstable internal operations (Jensen, 1986). Each quantile regression includes industry fixed effects. Results from the quantile regression on Investment are presented in Table 6.

Results from the quantile regression on investment imply that Beta Precision is not restricted to the efficiency model. The coefficient on Beta Precision is negative and statistically significant in all but the lowest investment quantile. This suggests that more precise cost-of-equity estimates restrict investment, and the effect is emphasised when investment is high. The coefficient grows almost monotonically across the distribution, from  $-0,007$  at the bottom to  $-0,072$  at the top — roughly a tenfold increase in magnitude — indicating that the restraining effect is concentrated precisely where the risk of overinvestment is greatest. With respect to the level of investment, the effect is therefore one-sided. Beta Precision restrains investment rather than encouraging it, and becomes stronger in higher investment quantiles. The coefficient on Cash Flow is positive and statistically significant in each quantile, consistent with Jensen's (1986) theory on overinvestment and excess cash flow.

**Table 6.** Quantile Regression on Investment

Quantile Regression									
Variable	Investment $t$								
	Tau = 0,1	Tau = 0,2	Tau = 0,3	Tau = 0,4	Tau = 0,5	Tau = 0,6	Tau = 0,7	Tau = 0,8	Tau = 0,9
Beta Precision $t$	-0,001 (-0,717)	-0,008*** (-3,705)	-0,007** (-2,988)	-0,012*** (-4,656)	-0,021*** (-6,735)	-0,030*** (-8,450)	-0,039*** (-9,111)	-0,054*** (-12,296)	-0,072*** (-10,667)
Ln(Assets) $t$	-0,004*** (-8,240)	-0,007*** (-13,437)	-0,010*** (-16,828)	-0,012*** (-19,556)	-0,014*** (-19,344)	-0,016*** (-19,112)	-0,019*** (-18,390)	-0,023*** (-21,883)	-0,027*** (-16,941)
Tobin's Q $t$	-0,001*** (-4,329)	-0,002*** (-6,960)	-0,002*** (-7,345)	-0,002*** (-7,503)	-0,002*** (-6,976)	-0,002*** (-6,259)	-0,002*** (-5,453)	-0,003*** (-7,741)	-0,004*** (-6,278)
Ln(Cash Flow) $t$	0,006*** (13,604)	0,008*** (18,328)	0,010*** (20,610)	0,011*** (22,039)	0,013*** (20,069)	0,013*** (18,964)	0,015*** (17,095)	0,017*** (19,028)	0,018*** (13,331)
Asset Growth $t$	0,000 (0,279)	0,001 (0,425)	0,003 (1,755)	0,004** (2,881)	0,007*** (3,823)	0,011*** (5,048)	0,016*** (6,080)	0,027*** (10,068)	0,055*** (13,647)
STD Dev Cash Flow $t$	0,000 (-0,881)	0,000 (-0,381)	0,000 (0,877)	0,001* (2,408)	0,002*** (3,348)	0,002*** (3,771)	0,004*** (5,141)	0,005*** (7,034)	0,008*** (7,163)
Beta $t$	-0,001** (-2,899)	-0,002*** (-4,070)	-0,002*** (-4,032)	-0,002*** (-4,271)	-0,002** (-3,077)	-0,002* (-2,269)	-0,002* (-2,242)	-0,002* (-2,224)	-0,004* (-2,394)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7 729	7 729	7 729	7 729	7 729	7 729	7 729	7 729	7 729

Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ .

In contrast to the main analysis, where Tobin's Q is mechanically absorbed in the first-stage efficiency model and therefore appears insignificant, the quantile regression is estimated on raw investment levels, so the coefficient on Tobin's Q reflects a genuine relationship rather than an artefact of construction. The negative coefficient on Tobin's Q in each quantile implies that investment in Europe does not react positively to market growth opportunities. If anything, higher-Q firms invest slightly less, consistent with mature, high-valuation European firms whose value reflects intangibles and future rents rather than current capital expenditure. Instead, firm investment is heavily influenced by internally generated cash flows, an influence that becomes more pronounced in higher investment quantiles. At the upper quantiles, Asset Growth and the volatility of cash flow also load positively and significantly, indicating that the most aggressive investors are driven by realised growth and unstable internal cash flows rather than by market-based growth signals — precisely the firms for which an imprecise discount rate is most likely to translate into overinvestment.

Beta Precision has almost no impact on Investment when Investment is low, implying that clearer estimates do not affect the investment behaviour of firms that are not investing heavily in the first place. Beta Precision becomes progressively more powerful at higher investment levels. This means that higher-quality information prevents firms from overexpanding or making other inefficient investment choices. The results also differ between regions. Biggerstaff et al. (2025) find in their quantile regression analysis on investment that Beta Precision works in both directions: encouraging investment in low quantiles (preventing underinvestment) and restricting it in high quantiles (preventing overinvestment). The comparison suggests that the effect is more pronounced in North America. The Beta Precision coefficient on Investment in the highest investing quantile is twice as powerful in the U.S. This reinforces prior implications that market structure differences affect the relationship. U.S. corporate capital expenditure is more sensitive, reactive, and volatile to market signals than that of European firms (Levine, 2002). Investment also seems to react differently to firm size across regions. Biggerstaff et al. (2025) find that larger firms invest more than smaller firms when investment is high, implying that size reduces both overinvestment

and underinvestment. In Europe, the negative coefficient on size in each investment quantile suggests that size restrains investment even in the lowest investment quantiles.

### 5.3 Over- and Underinvestment

The quantile regression results on Investment suggest that Beta Precision appears to restrict mainly overinvestment in Europe. To examine this more directly, this section divides the sample into over- and underinvesting firms using the signed value of Abnormal Investment (Residual Investment), where positive residuals represent overinvestment and negative residuals underinvestment. The analysis is a simple OLS regression with three specifications. The first specification runs the regression for the whole sample. The second specification restricts the sample to underinvesting firms, and the third to overinvesting firms. Results from the analysis are presented in Table 7.

Results suggest that Beta Precision can mitigate both under- and overinvestment, but the effect is more pronounced in the overinvesting sample. This suggests that the primary effect of higher cost of equity precision is restraining firms from overinvesting in Europe. The coefficient on Beta Precision suggests that the effect is almost three times as powerful in the overinvesting sample. In the underinvesting subsample, the coefficient on Beta Precision is positive and significant (0,004), meaning that more precise estimates raise investment towards the expected level, while in the overinvesting subsample it is negative (-0,011), pulling investment back down. Beta Precision therefore moves firms towards model-implied efficiency from both sides, even though the economically dominant effect is the restraint of overinvestment. In economic terms, a one-standard-deviation increase in Beta Precision corresponds to roughly 8 100 € less overinvestment per year for the average firm. This reconciles the one-sided result on investment levels in Section 5.2 with a two-sided effect on efficiency. Low and high investment levels do not map cleanly onto under- and overinvestment, because each firm's expected investment depends on its own fundamentals. Prior investment momentum seems to be the most influential driver in both samples. Under- or overinvesting firms in the prior year tend to continue investing accordingly in the future.

Firm size shows the same symmetric pattern, reducing both underinvestment (0,001) and overinvestment (-0,001) and reinforcing the survey-based view that larger firms allocate capital more efficiently (Graham & Harvey, 2001; Brounen et al., 2004). The very low  $R^2$  of the pooled specification (0,005) reflects the fact that positive and negative deviations largely offset one another in the full sample. Explanatory power rises sharply once the sample is split (0,325 for underinvestors and 0,234 for overinvestors), confirming that the structure lies in the direction of inefficiency rather than in its overall level.

**Table 7.** Residual Investment on Beta Precision

Variables	Residual Investment $t$		
	(Total)	(Under)	(Over)
Beta Precision $t-1$	-0,007** (-3,094)	0,004** (3,131)	-0,011*** (-4,150)
Ln(Assets) $t-1$	0,000 (1,571)	0,001*** (5,806)	-0,001*** (-6,819)
Tobin's Q $t-1$	-0,000 (-0,277)	-0,000 (-0,518)	-0,000 (-0,897)
CFO/Avg.Assets $t$	0,000 (0,089)	-0,003 (-1,099)	0,006 (1,123)
Asset Growth $t-1$	-0,001 (-0,924)	0,000 (0,064)	-0,001 (-1,133)
Investment $t-1$	0,015 (1,762)	-0,120*** (-18,405)	0,143*** (14,064)
Beta $t-1$	-0,001** (-2,806)	-0,001** (-2,760)	0,000 (-0,812)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	No	No	No
Clustered Standard Errors	Firm	Firm	Firm
Observations	8 366	4 697	3 669
R-Squared	0,005	0,325	0,234

Standard errors are clustered at the firm level. Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ .

## **5.4 Robustness Tests**

Corporate managers use varying approaches to cost-of-equity estimation that are not accounted for in the prior models. For example, the specific estimation window or applied risk model might vary depending on the manager's choice. Firm investment inefficiency might also be a product of poor corporate governance, rather than imprecise cost of equity estimates. Additionally, as firm size is linked to firms' investment behaviour, Beta Precision might be conditional on firm size. This section examines whether the prior findings are affected by these factors.

### **5.4.1 Alternative Models and Estimation Windows**

Prior analyses in this thesis rely on a beta estimate from a market-model regression using a 36-month return window. Therefore, this section includes alternative estimation windows of 24, 48, and 60 months to estimate beta and Beta Precision. Additionally, this section estimates betas using the textbook definitions of CAPM and the Fama-French three-factor model, as survey results suggest these are the most popular estimation methods used in practice (Graham & Harvey, 2001; Graham, 2022; Brounen et al., 2004). Beta Precision is defined using both of these risk models with a 36-month estimation window. Abnormal Investment is then regressed on both CAPM and Fama-French 3FM Beta Precision, including different combinations of industry, year, and firm fixed effects. Results from the alternative risk model test and the estimation-window test are presented in Tables 8 and 9.

**Table 8.** Alternative Risk Models

Variables	Abnormal Investment $t$			
	(3FM 36)		(CAPM 36)	
3FM Beta Precision $t-1$	-0,003*** (-4,229)	-0,002** (-2,597)		
CAPM Beta Precision $t-1$			-0,008*** (-4,391)	-0,004* (-2,249)
Ln(Assets) $t-1$	-0,001*** (-7,789)	-0,001** (-3,193)	-0,001*** (-7,378)	-0,001*** (-3,378)
Tobin's Q $t-1$	0,000 (-0,201)	0,000 (0,572)	0,000 (-0,380)	0,000 (0,526)
CFO/Avg.Assets $t$	0,002 (0,727)	0,008* (2,389)	0,003 (1,002)	0,008* (2,404)
Asset Growth $t-1$	0,000 (-0,413)	0,000 (-0,063)	0,000 (-0,470)	0,000 (0,030)
Investment $t-1$	0,147*** (20,910)	0,124*** (11,311)	0,146*** (20,873)	0,124*** (11,291)
3FM Beta $t-1$	0,000 (0,252)	0,000 (-0,299)		
CAPM Beta $t-1$			0,000 (0,638)	0,000 (1,234)
Industry FE	Yes	No	Yes	No
Year FE	Yes	Yes	Yes	Yes
Firm FE	No	Yes	No	Yes
Clustered Standard Errors	Firm	Firm	Firm	Firm
Observations	8 366	8 366	8 366	8 366
R-Squared	0,267	0,358	0,269	0,358

Standard errors are clustered at the firm level. Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ .

**Table 9.** Alternative Estimation Windows

Variables	Abnormal Investment $t$					
	(24)		(48)		(60)	
24 Beta Precision $t-1$	-0,006*** (-4,432)	-0,003** (-3,053)				
48 Beta Precision $t-1$			-0,010*** (-3,445)	-0,004* (-1,985)		
60 Beta Precision $t-1$					-0,012*** (-3,351)	-0,005* (-2,188)
Ln(Assets) $t-1$	-0,001*** (-7,526)	-0,001*** (-3,596)	-0,001*** (-6,880)	-0,001* (-2,523)	-0,001*** (-6,433)	-0,001* (-2,009)
Tobin's Q $t-1$	0,000 (0,295)	0,000 (1,131)	0,000 (-0,614)	0,000 (0,009)	0,000 (-0,750)	0,000 (-0,170)
CFO/Avg.Assets $t$	0,002 (0,686)	0,006 (1,676)	0,003 (1,113)	0,009** (2,779)	0,003 (0,938)	0,008* (2,579)
Asset Growth $t-1$	0,000 (-0,221)	0,000 (0,385)	0,000 (-0,275)	0,000 (0,377)	0,000 (-0,250)	0,000 (0,563)
Investment $t-1$	0,146*** (21,448)	0,122*** (11,765)	0,142*** (18,984)	0,117*** (9,860)	0,141*** (18,827)	0,115*** (9,926)
24 Beta $t-1$	0,000 (0,549)	0,000 (0,763)				
48 Beta $t-1$			0,000 (0,732)	0,001 (1,643)		
60 Beta $t-1$					0,000 (-0,280)	0,000 (0,301)
Industry FE	Yes	No	Yes	No	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Firm FE	No	Yes	No	Yes	No	Yes
Clustered Standard Errors	Firm	Firm	Firm	Firm	Firm	Firm
Observations	8 772	8 772	7 965	7 965	7 568	7 568
R-Squared	0,276	0,357	0,255	0,352	0,250	0,352

Standard errors are clustered at the firm level. Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ .

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The coefficient on Beta Precision remains negative and significant in both specifications, suggesting that the relationship is not restricted to the market-model regression used in prior analyses. The Fama-French three-factor model returns a lower coefficient on Beta Precision, which could reflect how the SMB and HML factors absorb unexplained variance from the underlying asset returns, mitigating the overall model noise and thereby decreasing the standard error of market beta. Using additional risk factors might therefore capture a purer and less noisy cost-of-equity estimate (Fama & French, 1993). Moreover, the analysis using different estimation windows for beta suggests that the results are not restricted to a specific estimation window either. Beta Precision remains negative and significant in each specification. The results show a stronger coefficient on Beta Precision in specifications that use longer estimation windows. This could imply that the extended estimation window averages out short-term market noise, which leads to a structurally purer proxy for market risk. The results are consistent with Levi and Welch (2017), who find that estimation precision increases with extended estimation windows. Both results are consistent with Biggerstaff et al. (2025), which implies no significant differences between the regions.

#### **5.4.2 Beta Precision and Firm Size**

Prior results may be conditional on firm size. For example, smaller firms might invest more aggressively to expand, while more mature firms' investment behaviour could be more aligned with maintaining their existing assets in place. Moreover, larger publicly listed firms are subject to higher trading volumes and analyst coverage, which could increase the information efficiency of stock prices (Fama, 1970) and therefore yield more statistically accurate beta estimates. For these reasons, the relationship between Abnormal Investment and Beta Precision could vary with firm size. To test size dependency, Beta Precision is tested on firms divided into size quartiles based on total assets in a given year. The effect is tested on Abnormal Investment first, and then on sub-samples divided into under- and overinvesting firms. Each quartile is re-adjusted yearly to account for changes in assets. The quartiles are ranked from 1 to 4, where 1 represents the smallest quartile and 4 the largest. Each

specification includes industry and year fixed effects. The results from the size dependency test are presented in Tables 10 and 11.

**Table 10.** Abnormal Investment and Size

Variables	Abnormal Investment $t$			
	Q1	Q2	Q3	Q4
Beta Precision $t-1$	-0,006* (-2,163)	-0,011*** (-3,391)	-0,008* (-2,248)	-0,008*** (-3,464)
Ln(Assets) $t-1$	-0,001 (-1,974)	-0,001 (-0,954)	-0,002** (-2,827)	-0,001*** (-4,140)
Tobin's Q $t-1$	0,000 (0,517)	0,000 (-1,830)	0,000 (0,164)	0,001 (1,656)
CFO/Avg.Assets $t$	0,002 (0,558)	0,010 (1,811)	0,002 (0,198)	-0,010 (-1,198)
Asset Growth $t-1$	0,000 (-0,347)	-0,001 (-1,138)	-0,001 (-1,038)	0,002 (1,409)
Investment $t-1$	0,149*** (10,169)	0,143*** (12,867)	0,146*** (9,160)	0,143*** (10,064)
Beta $t-1$	0,000 (0,371)	-0,001 (-0,989)	0,001 (1,191)	0,000 (0,843)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No
Clustered Standard Errors	Firm	Firm	Firm	Firm
Observations	1 950	2 014	2 083	2 229
R-Squared	0,273	0,318	0,247	0,262

Standard errors are clustered at the firm level. Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ . Size quartiles range from Q1 (small) to Q4 (large) and are re-allocated each year to account for natural firm growth.

**Table 11.** Residual Investment and Size

Variables	Residual Investment $t$							
	(Q1)	(Over Investment) (Q2)	(Q3)	(Q4)	(Q1)	(Under Investment) (Q2)	(Q3)	(Q4)
Beta Precision $t_{-1}$	-0,009*	-0,013***	-0,008	-0,009**	0,003	0,004	0,007*	0,006*
	(-2,126)	(-3,861)	(-1,345)	(-2,863)	(1,194)	(1,415)	(2,601)	(2,241)
Ln(Assets) $t_{-1}$	-0,002	-0,002	-0,003*	-0,002**	0,001	0,000	0,001	0,001**
	(-1,911)	(-1,306)	(-2,468)	(-3,038)	(1,631)	(-0,123)	(1,180)	(3,184)
Tobin's Q $t_{-1}$	0,000	-0,001*	0,000	0,000	0,000	0,000	0,000	-0,001*
	(0,372)	(-2,051)	(-0,419)	(-0,150)	(0,112)	(0,587)	(-0,881)	(-2,312)
CFO/Avg.Assets $t$	0,000	0,009	0,010	0,006	-0,005	-0,011	0,001	0,018**
	(-0,021)	(0,954)	(0,637)	(0,513)	(-1,342)	(-1,852)	(0,115)	(2,703)
Asset Growth $t_{-1}$	-0,002	-0,002	-0,002	0,002	-0,001	0,001	0,001	0,000
	(-0,904)	(-1,330)	(-0,931)	(1,384)	(-0,701)	(0,526)	(0,795)	(-0,010)
Investment $t_{-1}$	0,143***	0,160***	0,127***	0,122***	-0,126***	-0,112***	-0,121***	-0,129***
	(6,725)	(8,181)	(5,642)	(7,878)	(-10,224)	(-8,294)	(-9,851)	(-11,766)
Beta $t_{-1}$	-0,002	-0,002	0,002	0,001	-0,002**	-0,001	0,000	-0,001
	(-1,860)	(-1,751)	(1,341)	(0,764)	(-3,160)	(-1,104)	(0,150)	(-1,358)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No	No	No
Clustered Standard Errors	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
Observations	826	933	901	1 009	1 124	1 171	1 182	1 220
R-Squared	0,250	0,352	0,201	0,216	0,359	0,317	0,331	0,323

Standard errors are clustered at the firm level. Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ . Size quartiles range from Q1 (small) to Q4 (large) and are re-adjusted yearly.

The evidence suggests, however, that there is no clear size dependency, as Beta Precision remains negative in each quartile. The effect is strongest in the second quartile, and firm size becomes an increasingly significant mitigating factor for Abnormal Investment in the largest size quartiles. The additional tests restricted to over- and underinvesting sub-samples are consistent with prior findings, concentrating the effect on overinvestment. The effect remains strongest in the second overinvesting size quartile as well.

The concentration of the effect in the second quartile may reflect a transition zone in which firms are sufficiently large and sophisticated to rely on DCF methodology, yet lack the analyst coverage and market liquidity that would otherwise compress estimation error. This could be the reason why Beta Precision has the most discriminatory power in the second size quartile. The increasing significance of the size factor suggests that size itself proxies for information quality. However, Beta Precision remains a distinct and relevant channel across the full distribution. The asymmetric pattern across the overinvestment and underinvestment sub-samples — with Beta Precision becoming significant primarily in the largest quartiles for underinvestors, while overinvestment concentrates the effect in the smaller quartiles — is consistent with the view that smaller firms' underinvestment is driven by financing frictions unrelated to discount rate precision (Myers & Majluf, 1984). For larger firms, a more precise cost of equity reduces the likelihood of misclassifying investment opportunities, helping to avoid NPV-negative projects. In the context of the market-based versus bank-based system distinction (Levine, 2002), smaller European firms are more likely to rely on negotiated bank financing rather than CAPM-derived hurdle rates, which may explain the relatively weaker Beta Precision channel among Q1 underinvestors.

#### **5.4.3 Controlling for Governance and Agency**

Firms may deviate from the efficient investment benchmark due to poor governance or misaligned managerial incentives (Jensen & Meckling, 1976; Jensen, 1986). A key concern is that poorly governed firms may exhibit both higher abnormal investment and noisier beta

estimates simultaneously — for instance, due to weaker disclosure practices or lower analyst coverage — which could create a spurious correlation between Beta Precision and Abnormal Investment. Prior research links the quality of a firm's information environment to both investment efficiency (Biddle & Hilary, 2006; McNichols & Stubben, 2008) and the informativeness of its stock prices (Fama, 1970), so it is important to separate this channel from discount-rate precision. Biggerstaff et al. (2025) raise and test the same concern directly. To test whether the documented relationship is driven by poor governance rather than discount-rate precision, additional control variables are included in the main model. The firm's overall governance score is included to examine whether a higher governance score attenuates the relationship between Beta Precision and Abnormal Investment. Board size is also included as a control variable.

Prior governance research offers competing predictions. Smaller boards are associated with stronger oversight and higher firm value (Yermack, 1996; Eisenberg et al., 1998), whereas larger boards may provide broader expertise but can also slow decision-making and create coordination problems (Jensen, 1993). This leaves the net effect on investment discipline unclear. Board independence is also included to control for managerial oversight and investment discipline. Independent boards are less subject to managerial influence and are therefore better positioned to monitor managers (Fama, 1980; Fama & Jensen, 1983) and to challenge empire-building behaviour or other self-serving capital allocation decisions (Jensen, 1986). All specifications include industry and year fixed effects. The first specification controls for the prior year's governance score. The second controls for the prior year's board size and independence. The third includes all prior control variables. The results are presented in Table 12.

The results suggest that Abnormal Investment is not merely proxying for poor governance or misaligned firm incentives. The coefficients on Governance Score, Board Size, and Board Independence all remain insignificant, and the coefficient on Beta Precision remains negative and significant in each specification. This indicates that Beta Precision does not proxy for the firm's governance environment. The insignificance of the governance controls is

consistent with the interpretation that the Beta Precision effect captures information quality rather than reflecting a governance deficit. Governance mechanisms may reduce managerial discretion, but they do not correct measurement errors in the cost of capital. Governance quality and discount-rate precision therefore represent distinct and separate channels through which investment quality is shaped. This is consistent with Biggerstaff et al. (2025), whose findings suggest that the Beta Precision effect operates independently of the governance environment. It is worth noting that European firms exhibit considerable cross-country variation in governance quality — for instance, between Scandinavian and Eastern European firms — and the governance score control partly absorbs this variation, further strengthening the robustness of the main result.

**Table 12.** Governance Control

Variables	Abnormal Investment $t$		
	(1)	(2)	(3)
Beta Precision $t_{-1}$	-0,009*** (-4,062)	-0,010*** (-4,399)	-0,010*** (-4,416)
Ln(Assets) $t_{-1}$	-0,001*** (-5,427)	-0,001*** (-4,057)	-0,001*** (-3,720)
Tobin's Q $t_{-1}$	-0,000 (-1,423)	-0,000 (-1,020)	-0,000 (-1,037)
CFO/Avg.Assets $t$	0,003 (1,132)	0,003 (0,887)	0,003 (0,885)
Asset Growth $t_{-1}$	-0,000 (-0,623)	-0,001 (-1,425)	-0,001 (-1,457)
Investment $t_{-1}$	0,142*** (17,368)	0,142*** (15,958)	0,142*** (15,938)
Beta $t_{-1}$	-0,000 (-0,378)	-0,000 (-0,620)	-0,000 (-0,608)
Governance Score $t_{-1}$	-0,000 (-1,423)		-0,000 (-0,980)
Board Size $t_{-1}$		-0,000 (-0,373)	-0,000 (-0,372)
Board Independence $t_{-1}$		-0,000 (-1,150)	-0,000 (-0,794)
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	No	No	No
Clustered Standard Errors	Firm	Firm	Firm
Observations	6814	6047	6047
R-Squared	0,250	0,260	0,260

Standard errors are clustered at the firm level. Statistical significance is denoted as follows: \*  $p < 0,05$ , \*\*  $p < 0,01$ , \*\*\*  $p < 0,001$ .

## 6 Conclusions

This thesis examines whether the precision of firm-level beta estimates is associated with corporate investment efficiency among publicly listed European firms in the STOXX 600 index from 1997 to 2024. Drawing on capital budgeting theory, asset pricing, and investment efficiency literature, the central hypothesis is that firms with more precise beta estimates — and therefore more reliable cost of equity estimates — invest closer to model-implied optimal levels. Beta Precision is measured as the negative of the standard error of beta from a market-model regression on 36 months of preceding returns, following Biggerstaff et al. (2025). Investment efficiency is measured as Abnormal Investment, the absolute value of the residual from a regression of capital investment on Tobin's Q, cash flow, prior asset growth, and prior investment.

The main results provide consistent and statistically significant support for H1. The relationship between Beta Precision and Abnormal Investment is negative across all four model specifications in the main analysis, including those that control for industry, year, and firm fixed effects. This implies that more precise beta estimates are associated with lower deviations from efficient investment, and that the relationship is not driven by any particular firm type, macroeconomic cycle, or industry structure. The finding that the Beta Precision coefficient remains significant after controlling for the level of beta itself is consistent with Fama and French (1997) and Pástor and Stambaugh (1999), who argue that rather than the level of systematic risk, estimation uncertainty is the primary source of cost-of-equity imprecision. The economic magnitude of the effect is meaningful. A one-standard-deviation increase in Beta Precision is associated with an approximately 11,2 % reduction in Abnormal Investment relative to the sample mean, which is notably larger than the equivalent estimate of 4,5 % reported for the North American sample by Biggerstaff et al. (2025).

The quantile regression analysis on raw investment levels confirms that the result is not an artefact of the residual-based efficiency model. Because this specification is estimated on raw investment rather than the efficiency residual, Tobin's Q is no longer mechanically absorbed by the first-stage model, and its coefficient is negative and significant across all

quantiles — indicating that European investment does not respond positively to market-implied growth opportunities. Beta Precision is negative and significant across all but the lowest investment quantile, and its magnitude increases along with investment levels. This pattern implies that more precise cost-of-equity estimates primarily constrain firms from overinvesting, with the strongest disciplining effect occurring at the highest investment quantiles. This finding is consistent with the view that noisy discount rates are more likely to cause overinvestment than to cause underinvestment in the European context. A comparison with Biggerstaff et al. (2025) reveals a regional asymmetry. In North America, Beta Precision operates in both directions, reducing both overinvestment and underinvestment, whereas in Europe the effect is concentrated mostly on the overinvestment side. This may reflect the different roles that equity market signals play in guiding corporate investment decisions across financial systems, reinforced by the negative role of Tobin's Q.

The directional analysis using the signed Residual Investment confirms the overinvestment concentration in support of H2. The coefficient on Beta Precision is nearly three times larger in the overinvesting sub-sample than in the underinvesting one. Investment momentum is the dominant predictor in both sub-samples, which suggests that firms locked into prior capital expenditure patterns persistently deviate from efficient investment levels regardless of discount-rate precision. This further implies that Beta Precision operates as a corrective mechanism at the point of investment decisions, not as a long-run structural characteristic that can override constant behavioural tendencies.

The robustness tests collectively strengthen the main finding. The relationship between Beta Precision and Abnormal Investment holds across alternative risk model specifications, including CAPM-derived and Fama-French three-factor model betas, and across estimation windows of 24, 48, and 60 months. Longer estimation windows produce stronger Beta Precision coefficients, consistent with Levi and Welch (2017), who find that extended windows average out short-term noise and improve the predictive accuracy of beta estimates. The finding that the Fama-French three-factor model produces a smaller Beta Precision coefficient than the single-factor CAPM is consistent with the additional risk factors partially

absorbing unexplained variance in asset returns, thereby mechanically reducing the standard error of the market beta. No size dependency is found either. Beta Precision remains negative and significant across all four firm size quartiles, though the effect peaks in the second quartile and firm size becomes an increasingly significant mitigating factor in the largest quartiles. Governance controls — including a governance score, board size, and board independence — do not weaken the Beta Precision coefficient, confirming that the documented relationship captures information quality rather than a proxy for poor managerial oversight.

Taken together, the results extend the prior North American evidence from Biggerstaff et al. (2025) to the European context, demonstrating that the mechanism linking Beta Precision to investment efficiency remains robust across regional institutional environments. At the same time, several structural differences emerge between regions. The near-zero and insignificant coefficient on Tobin's Q in the European sample, in contrast to its positive and significant role in North America, suggests that European corporate investment is less sensitive to equity market signals and more governed by steady, relationship-based bank financing. This is consistent with the theoretical distinction between market-oriented and bank-based financial systems (Levine, 2002), and implies that the channel through which Beta Precision operates in Europe is not primarily mediated by market pressure, but rather by the internal cost of capital calculations that managers apply in project evaluation. The larger proportional effect of Beta Precision on investment efficiency in Europe relative to North America may reflect the fact that, in the absence of strong market discipline, accurate cost of equity estimates represent a more critical internal governance mechanism for capital allocation decisions.

## **6.1 Practical Implications and Suggestions for Future Research**

The results of this thesis carry several practical implications for corporate managers, financial practitioners, and academics. The primary implication is that the precision of beta estimates used in cost-of-equity calculations is not merely a statistical property of market

model regressions. It has measurable consequences for corporate investment outcomes. Managers who rely on noisy beta estimates when constructing project discount rates are more likely to deviate from optimal investment levels, particularly by overinvesting. This suggests that firms should treat beta estimation methodology as a real input quality problem, not a technical detail to be handled by default textbook approaches.

Levi and Welch (2017) report that cost of equity estimation precision increases meaningfully when using higher frequency return data and mechanically shrunk betas. Specifically, they find that Vasicek-shrunk betas estimated from one to four years of daily returns outperform conventional monthly return estimates in predicting future beta, and that industry betas are poor substitutes for firm-specific estimates. This has direct implications for practitioners. Firms that currently rely on the standard textbook approach of three to five years of monthly return data may be systematically understating the noise in their beta estimates. Future research could examine whether the relationship between Beta Precision and Abnormal Investment is altered when using daily return data or Vasicek-shrunk betas. If such approaches yield stronger effects, this will provide additional motivation for practitioners to adopt higher-frequency estimation methods or incorporate beta shrinkage into their standard cost-of-capital routines.

A complementary perspective is offered by Da et al. (2012), who argue that CAPM-based cost of equity estimates from historical stock returns are contaminated by embedded real options, referring to the value of a firm's options to expand, delay, abandon, or modify projects. Because stock returns reflect both the value of assets in place and the value of these real options, beta estimates from stock data can be systematically biased when applied to project discount rates. Da et al. (2012) show that removing real option effects from stock returns produces option-adjusted betas that align more closely with theoretical CAPM predictions. For practitioners, this implies that standard beta estimates may be inappropriate inputs for capital budgeting even when estimated with high precision. Future research could integrate the real option adjustment of Da et al. (2012) with the Beta Precision

framework used in this thesis, examining whether option-adjusted beta precision yields stronger or qualitatively different investment efficiency results.

Câmara et al. (2009) propose an alternative approach to cost of equity estimation that is more forward looking than historical return-based methods. Using information embedded in current stock and stock option prices, their option-implied cost of equity aligns more closely with market expectations over the investment horizon, allows duration-matching between the discount rate and the project, and tracks investor sentiment more accurately than Fama-French estimates. Their findings indicate that option-implied costs of equity are more stable and produce more reasonable estimates than historical methods. Future research could examine whether option-implied cost-of-equity estimates are associated with even greater investment efficiency than the market model based Beta Precision used in this thesis. Such a study would also be informative about whether the mechanism identified operates through reduced estimation uncertainty specifically, or more broadly through the quality of forward-looking information available to managers.

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## Appendix

Variable or Concept	Definition
Abnormal Investment	The absolute value of a residual from a regression of investment on Tobin's Q, cash flow, asset growth rate and prior investment
Residual Investment	Signed value of Abnormal Investment. Positive values represent overinvestment, and negative values underinvestment.
Beta Precision	Negative of the standard error of Beta from a market model regression on 36 months of preceding returns
Capital Expenditures	Represent the funds used to acquire fixed assets other than those associated with acquisitions. It includes but is not restricted to: Additions to property, plant and equipment, Investments in machinery and equipment
Cash Flow from Operations (CFO)	Represent the net cash receipts and disbursements resulting from the operations of the company. It is the sum of Funds from Operations, Funds From/Used for Other Operating Activities and Extraordinary Items.
Market Returns	Monthly returns of the STOXX 600 Index
Beta	Estimated Beta coefficient from a market model regression.
Total Debt (TD)	Represents all interest bearing and capitalized lease obligations. It is the sum of long and short term debt.
Total Assets (TA)	Represent the sum of total current assets, long term receivables, investment in unconsolidated subsidiaries, other investments, net property plant and equipment and other assets.

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Risk-Free rate (Rf)	Monthly yield of the 10-Year German Bund
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Market Value of Equity (MVE)	Market Price-Year End * Common Shares Outstanding
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Investment	Capital Expenditures / Average Assets
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Asset Growth(-1)	$TA_{t-1}/TA_{t-2}-1$
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Average Assets	$(TA_t+TA_{t-1})/2$
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Tobin's Q	$(MVE+ TD) / TA$
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